TO: Northern Territory Department of Mines - for period ending November 11, 1977

by: Neil Fraser
Minerals Department
ESSO AUSTRALIA LTD.
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INTRODUCTION

The Razorback Exploration Licence (EL 1323) is located in the Macdonnell Ranges approximately 130km west of Alice Springs (Figure 1). The EL covers an area of 1096 sq. km and was granted to Esso Exploration and Production Inc. on November 11, 1976.

During the past year exploration for uranium has been carried out in Proterozoic metamorphic rocks within the E.L. Two airborne radiometric surveys were flown and ground follow-up of all anomalies was completed. Visible secondary uranium mineralization was located at a number of localities. However, geochemical and petrological studies have indicated that the mineralization has little economic significance. It has subsequently been decided to relinquish the entire E.L.

REGIONAL GEOLOGY

The basement rocks within the E.L. are part of the Arunta Block which is a complex of igneous, sedimentary and metamorphic rocks outcropping throughout most of the southern part of the Northern Territory. The Block extends for about 1000km east-west and 400km north-south and forms a basement to several shallow-marine sedimentary basins of Adelaidean to Palaeozoic age. The block consists essentially of Lower Proterozoic or older Archean sedimentary and volcanic rocks which were completely deformed, metamorphosed and intruded by granite early in the Carpentarian. An episode of migmatization occurred in the southern part of the block in the Adelaidean.

Epicontinental sands of the Heavitree Quartzite were deposited unconformably over the basement in the Adelaidean and sedimentation continued with minor breaks, into the Upper Palaeozoic. Widespread thrust-faulting and associated retrogressive metamorphism occurred late in the Palaeozoic.

Several thrust nappes, involving the Arunta basement and Adelaidean sediments of the Amadous Basin to the south formed along the southern margin of the Block during the Late Palaeozoic tectonism.

Within the E.L. the basement rocks consist of granulites to the north, and amphibolite facies migmatite, anatetic granite and metasedimentary rocks to the south. A very complex structural and metamorphic history is evident here and R.F. Loxton Hunting and Associates were engaged to prepare a 1:83,000 scale photogeological study of the area. The aim of this study was to delineate the major basement rock types and geological structures, and to determine the sequence of structural events that occurred in the area. A copy of this report (Appendix 1) and the photogeological interpretation map (Plate 1) are included.

AIRBORNE RADIOMETRIC SURVEYS

Two airborne radiometric surveys were completed and a total of 2713 line km, were flown. The first survey was flown in 1976 using a Bell 206B Jetranger helicopter. 713 line km were flown over the more rugged areas of the E.L. with a line spacing of 300m. A second survey was flown in 1977 using a Cessna 172 aeroplane with a Robertson STOL conversion. 2000 line km were flown over the less rugged positions of the E.L. using a line spacing of 200m.
Both surveys used identical instrumentation which comprised an Exploranium DGRS-1002 analogue differential gamma-ray spectrometer, a 452 cu.in. cylindrical crystal detector and a Mars 6 channel chart recorder. A radar altimeter and tracking camera were also employed. The aircraft attempted to maintain a mean terrain clearance of 60m and an average ground speed of 60 knots. Data recovery was performed manually and the flight paths were recovered by plotting on 1:25,000 scale photomosaics.

A total of 41 anomalies were selected for ground follow up. The locations of the anomalies is shown on Plate 1. Ground checking was accomplished by relocating the anomalies with the helicopter borne spectrometer system and then carrying out a ground survey using a Geometrics GR-410 spectrometer. Samples for geochemical analysis were collected from many anomalies.

Anomalies R1, R2, R9, MZ25 and MZ27, lie over small domed granitic bodies which intrude migmatite and other granitic rocks. The granitic domes have a maximum diameter of 200 metres and form topographic highs. They are coarsely porphyritic with large feldspar phenocrysts and have a high biotite and opaque mineral content. They are unfoliated, exhibit no fracturing and veining, and have a homogeneous coarse grained ground mass. They have sharp intrusive contacts but do not contain fragments of the intruded rocks. The intruded migmatites and granitic rocks are generally non porphyritic, medium grained, have a lower biotite and opaque mineral content, and have a fine grained ground mass. They are often foliated and lineated.

Auutinite is present along exfoliation surfaces on parts of the granitic domes. Assays of rock chip samples have given values of up to 2280 ppm U\textsubscript{3}O\textsubscript{8} and 800ppm ThO\textsubscript{2}. The complete assay results are given in Appendix 2.

Samples from these anomalies were submitted to A.W.G. Whittle and Associates and Central Mineralogical Services Pty. Ltd., for petrological examination. Their reports attribute the radioactivity and secondary uranium mineralization of these rocks to the presence of monazite, zircon, crytoltite and allanite. These reports are included as Appendix 3.

Anomaly R13 is located at the base of the Bitter Springs Formation. It appears to represent small concentrations of uranium scavanged by secondary iron oxides at the surface. The iron oxides have been derived from the weathering of thin iron rich shale units within the dolomites. Assay values are given in Appendix 2.

The remaining 35 anomalies were assessed to be due mainly to thorium. Most of these anomalies were located within dykes or bodies of granitic composition which intrude migmatite or metasediments. These granitic rocks frequently contained high concentrations of monazite and zircon. Some anomalies could be attributed to concentrations of these minerals in creek beds. Assay results are given in Appendix 2.

**CONCLUDING COMMENTS**

Overall, the Razorback EL was found to have a very high level of regional background radioactivity. However, most of this was shown to be due to potassium from biotite and potash feldspar rich rocks, and thorium from accessory minerals. The nature and extent of uranium mineralization encountered was considered to warrant no further detailed investigation.
APPENDIX 1

REPORT ON THE PHOTOGEOLOGICAL STUDY OF THE RAZORBACK AREA
NORTHERN TERRITORY

Undertaken on behalf of

ESSO AUSTRALIA LTD.

December 1976

R.F. Loxton, Hunting and Associates
P.O. Box 25
Barker Centre
Canberra, A.C.T. 2603

GA.28A/76
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## SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

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SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

1. Photogeological reconnaissance of about 2500 sq. km in the Hermannsburg region, Central Australia, using black and white panchromatic aerial photographs on a scale of 1:83,000 has led to the subdivision of the basement rocks into a number of lithostructural domains.

2. The northwestern part of the area consists of granulite facies rocks, which support a strong west-trending gravity anomaly and a high plateau of very erratic magnetic activity.

3. A major west-trending zone of intensely deformed rocks, referred to as the Redbank Zone, broadly separates the granulite facies rocks in the north from amphibolite facies rocks in the south. It is considered that this zone of deformation originated before the migmatization and exerted a strong structural control on basement and cover rocks during the later Alice Springs orogeny.

4. The central part of the area consists of a migmatite complex which displays all stages in the conversion of an older series of gneiss and schist to highly migmatized rocks and ultimately to homophanous rocks of plutonic appearance. The pre-migmatite structural history is thus largely obliterated by the migmatization. A dolerite dyke-swarm about 50 km long transects the foliation of the migmatites and connects with the Redbank Zone. Some evidence of structural reactivation along the dykes was found.

5. The southeastern part of the area consists essentially of non-migmatitic gneiss and schist with rare amphibolitic layers, which are considered to be a map-scale paleosome. A sedimentary origin is thought likely, because of the common occurrence of alternating pelitic and quartzo-feldspathic horizons. This area, referred to as the Chewings Range Zone, has been affected by two periods of brittle deformation, along north-trending fractures displaced by west-trending shears.
6. The tectono-thermal history of the basement rocks is divided, on the basis of Rb/Sr isotopic dating and observations during mapping, into two main events, in addition to the Alice Springs Orogeny, which produced mild retrograde metamorphic effects, and reactivated the Redbank Zone.

7. The earlier event, referred to as the Arunta Orogeny, at the close of the Lower Proterozoic (1620 ± 70 m.y.), produced the metamorphism to granulite facies in the northwest and to amphibolite facies in the south of the Redbank Zone, which was probably initiated at this time.

8. The second main event, during the Middle Proterozoic (1076 ± 90 m.y.), involved the formation of a large migmatitic massif south of the Redbank Zone. Basic intrusive bodies were emplaced, and are possibly coeval with the west- and north-trending dolerite dykes which cut the migmatites and the Redbank Zone, and are truncated by the unconformity at the base of the Amadeus Basin.

9. The southern part of the area consists of weakly metamorphosed sediments, which form the base of the Amadeus Basin, and postdate the migmatization. Two major Upper Proterozoic formations, known as the Heavitree Quartzite and Bitter Springs Formation have been differentiated for structural purposes. A nappe emplacement with Southward translation obscures much of the unconformity with the basement rocks.

10. The tectono-thermal history of the cover rocks culminated during the Devonian-Carboniferous Alice Springs Orogeny, when reactivated basement thrust faults penetrated through the cover rocks, without reaching the surface, to drive wedges of basement rocks within the overlying Bitter Springs Formation. A period of brittle deformation along a northerly trend predates the deposition of the Bitter Springs Formation.
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FORMAN, D.J. and SHAW R.D. (1973)
Deformation of the Crust and Mantle in Central Australia.


Tectonophysics, 33, pp.15-32.


LIST OF AERIAL PHOTOGRAPHS USED

(Black and White RC9 photographs on the scale of 1:83,000)

Source: Department of National Resources/Commonwealth Photography

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APPENDIX II

NOMENCLATURE USED

Blastomylonite  Term used in a general sense for rocks in which neoformation or recrystallization (by migmatization or otherwise) have partly masked the purely cataclastic effects. Equivalent terms used in the literature are augen schist, mylonite gneiss and flaser rock.

Granulite  Refers to the high-grade metamorphism of a group of fine-grained gneissic rocks, containing quartz-feldspar-garnet or pyroxene and little mica. Two subfacies have been recognised (Turner and Verhoogen, 1960)

- the hornblende-garnet-(biotite) subfacies
- the pyroxene-granulite facies, with no hornblende or mica.

A distinctive fabric is developed with segregation banding of light "acid" layers alternating with dark "basic" bands.

Homphanous  Structure of migmatite, which constitutes the last stage of migmatisation. The term describes the homogeneous nature and massive plutonic appearance of these rocks.

Migmatite  Composite rock containing two or more petrographically different rocks. One is in a metamorphic stage and the other is generally of plutonic appearance (pegmatitic, granitic, aplitic).
11. The economic uranium potential of areas containing late-stage granite differentiates is considered favourable if suitable structural and chemical traps can be defined. Some anomalies in the present Esso radiometric survey appear to be associated with lineaments; it is possible that vein-type uranium occurrences are the cause of these anomalies.

12. Recommendations are that certain areas be covered by ground traversing with petrographic follow-up; that some areas be photogeologically mapped in detail using colour photography on a scale of 1:25,000; and that a radiometric contour map be produced to augment and help interpret the photogeological mapping.
I.  INTRODUCTION

On behalf of Esso Australia Limited a photogeological reconnaissance of an area approximately 130 km west of Alice Springs, Northern Territory, was carried out during October-November 1976, by Mr M.M. Coupard, of R.F. Loxton, Hunting and Associates, Canberra.

The study-area, referred to as the Razorback area, covers some 2,500 sq. km and includes the central part of the Hermannsburg 1:250,000 geological sheet (SF 53-13). Figure 1 shows the location of the study-area.

The area has a semi-desert climate with spinifex as the prevailing vegetation. Eucalypts grow along the major creeks.

Four physiographic regions extend across the study-area as follows, from north to south:-

- the flat sand-covered Burt Plain (+ 600 m ASL) accommodates isolated high hills (Mt Chapple, Redbank Hill)

- a hilly region (760-900 m ASL) is developed over basement rocks, with isolated high peaks (Mt Zeil 1510 m)

- a west-northwest trending belt of ranges and hills, known as the Chewings and Heavitree Ranges, forms a prominent physiographic feature in the landscape

- the parallel strike ridges and valleys of the MacDonnell Ranges bound the area to the south.

The main drainage in the study-area forms the headwaters of the Finke River, via three major tributaries, the Davenport, the Ormiston and Ellery Creeks, which form watergaps where they cut through the Heavitree and Chewings Ranges.
Fig 1. Location Diagram
To date, the overall area has been comprehensively mapped by the Bureau of Mineral Resources, on a scale of 1:100,000. Several parts of the area, including the Ormiston Gorge, have been mapped by the Bureau in some detail, on scales ranging approximately from 1:45,000 to 1:10,000.

A three and a half day field trip was undertaken at the end of the initial annotation phase, using a helicopter. A total of 81 localities of particular interest were visited.

The results of the photogeological mapping are incorporated in five photoscale map sheets on the approximate scale of 1:83,000, which represent the most important outcome of the study. This report describes the various units and structural features that are relevant to the general understanding of the area, but it is presented merely to supplement the map sheets.

It must be emphasised that the outcome of the study of this complicated area would have been more definite had there been more time allotted to field checking.
II. AIMS OF THE PROJECT

The aims of the project are essentially structurally oriented and can be summarised as follows:

- to map and assess all geological structures, including lineaments and structures in the basement in relation to the overview afforded by the RC9 photographs.

- to determine the sequence of structural events that occurred in the area.

- to assess the economic potential of the area with emphasis on uranium, and also to provide some guidelines for further exploration.
III. PROCEDURE

A total of 68 black and white photographs on the scale of 1:85,000 were interpreted using a Zeiss stereoscope with a $1 \frac{1}{2} x$ and 6x magnification.

Annotation of photogeological detail was made directly onto five transparent photo-scale drainage bases that were derived from the enlarged 1:250,000 topographical maps. Inherent inconsistencies of drainage due to high relief and distortion were minimised where possible.

Provisional work-sheet maps were used in the field in conjunction with aerial photographs for both field-checking and navigation purposes. Routine re-annotation followed, and took account of the data gained from the field-checking.

A coloured version of the photogeological work-sheet was prepared for presentation with this report.
IV. REGIONAL GEOLOGY.

Comprehensive reviews of early exploration and geological studies have been given by Marjoribanks (1975) and Forman, Milligan and McCarthy (1967). The regional geology will be only briefly summarised here.

In the broadest sense, the area falls within the Arunta Block (Metallogenic Map of Australia and Papua New Guinea, 1972), which consists of a suite of metamorphic rocks that have undergone at least two major tectonic events at about 1620 ± 70 m.y. and 1076 ± 50 m.y. (Marjoribanks and Black, 1974).

The former event produced the metamorphism to granulite facies in the north and amphibolite facies in the south-east of the area. This event is referred to as the Arunta Orogeny (Forman and Milligan, 1967). The effects of this pre-migmatization event are preserved to the south of the Chewings Range, where quartzo-pelites and possibly quartzo-feldspathic sediments have been converted to schists and gneisses. During this period, a major west-trending thrust-fault zone was initiated and produced the blastomylonites of the Redbank Zone (Marjoribanks, 1975).

At around 1076 ± 59 m.y., migmatization affected the previously formed metamorphic rocks and obscured much of the pre-migmatite structural history, large areas of the older rocks being converted from migmatitic gneisses to structureless granite-like rocks.

The metamorphic rocks of the Arunta Complex are overlain unconformably by sediments which form the Amadeus Basin. The Heavitree Quartzite, a clastic unit, is the basal formation of the Amadeus Basin and its older age limit is provided by the migmatite complex formation. Following the deposition of the Bitter Springs formation; with shale, dolomite and evaporites; the Amadeus Basin deepened and received mostly clastic sediments derived
from the north. The Devonian-Carboniferous Alice Springs Orogeny produced most of the large structures that are visible on the Hermannsburg 1:250,000 geological sheet, namely, the Hts. Razorback and Sonder nappes and the Ormiston folds which consist of thrust slices of basement which were inserted into the unconformably overlying sediments. The nappes, with an estimated southwards arched translation up to 20 km, did not penetrate formations above the Bitter Springs Formation. Their translation eventually stopped, conceivably when equilibrium was reached between the energy required to produce them and the opposing resistance of the thickness of sediments under which the nappes were driven.

On the Hermannsburg 1:250,000 geological sheet, most of the rock types of the Arunta Complex are not differentiated; mapping by Marjoribanks (1975) on a larger scale was in much greater detail, and emphasised the regional importance of structural and stratigraphic relationships within the Arunta Block.
V. PHOTOGEOLOGICAL RESULTS

A. The Nature and Distribution of the Various Lithological Units

The detailed photogeological reconnaissance in the Razorback area has resulted in the differentiation of a number of discrete lithological units, which are discussed in the following paragraphs.

1. Basement Rocks

The nature of the photographs, the obscuring effects of the extensive migmatization, and the lack of marker horizons, place severe restrictions on detailed geological mapping of the metamorphites of the basement.

The basement rocks have been subdivided empirically into twelve lithological units, which appear on the accompanying photogeological map sheets. However, it was realised after compilation that these units correspond with a series of broader lithostructural units (see Fig. 2) and for descriptive purposes the basement rocks of the study-area are subdivided into four lithostructural domains. These are considered in the following paragraphs from northwest to southeast. The boundaries between the zones are either gradational or obscured by migmatization, hence difficult to locate precisely.

a. The Granulite Facies Rocks - The northwestern and northern parts of the study-area incorporate a zone with rocks having a granulite facies metamorphic assemblage with quartz-pyroxene-minor biotite-garnet-K-feldspar in a granoblastic texture.

A mylonitic texture is inherited from the nearby mylonites of the Redbank Zone, with development of eye-shaped lenses of quartz-feldspar in a granoblastic texture (locality 78). Typical outcrops with a granulitic facies were visited in the field at localities 66, 67, 70,
75 and 78. Here, the rocks have acquired a coarse irregular compositional banding, in which eyes of leucocratic quartz-feldspar material alternate with dark mafic-rich layers. The impression gained from the examination of a few outcrops of granulite facies rocks is that they bear little resemblance to either the migmatites or the schist and gneiss units. The photogeological response of these rocks is very distinct, for example at Mt Zeil where massive outcrops show a pronounced north-dipping foliation on the photographs. At all localities visited, the rock specimens contain much magnetite, which may explain the magnetic plateau shown on the aeromagnetic map (Hermannsburg 1:250,000 No. F53-81).

The contact between these granulite-facies rock outcrops and the adjacent migmatites appears to be a series of fractures, almost certainly of a thrust type, which coincide with the mylonites referred to as the Redbank Zone (Marjoribanks, 1976).

A strong west-trending gravity anomaly is a prominent feature over the granulite facies rocks, and the gradient increase coincides with the Redbank Zone. The latest model (Anfiloff and Shaw, 1974) using upper crustal density differences reproduces the observed gravity pattern.

Numerous gabbroic intrusions occur in the southern part of the granulite facies rocks, although most appear related to the Redbank Zone. A few outcrops of augen gneiss are present (locality 59) within the granulite facies rocks, and are interpreted as a structure of migmatites, rather than a cataclastic deformation. This observation implies that the metamorphism of the granulite facies rocks is older than the migmatization.

No isotopic dating of these rocks has been undertaken, but other similar granulites occurring in the Harts and Reynolds Ranges to the east of the Arunta Complex have yielded isochron ages (Rb/Sr method) of 1600-1800 m.y. (Marjoribanks and Black, 1974).
b. The "Mylonites" of the Redbank Zone - The northern part of the study-area is occupied by a west-northwesterly trending belt, some 2-10 km wide, of mechanically deformed amphibolite-facies metamorphic rocks, which include mainly migmatites, and lesser amounts of gneiss and leucogneiss, schist, quartzite and minor amphibolite layers. Individual marker horizons, such as quartzite or amphibolite bands, are rare and difficult to follow laterally on the air photographs. These are interpreted as "resisters", which opposed the processes of the later migmatization. The photographic response is generally mediocre, with north-dipping narrow bands of alternately dark and lighter tone where migmatization has not obliterated the pre-migmatite rocks.

The textures observed from a few outcrops (localities 58 and 68 - see map) are invariably blasto-mylonitic, with "eyes" of quartz or feldspar. A fine foliation swirls around the "eyes", which have in places been flattened, forming elongated trails. The mylonites of the Redbank Zone have a strong north-dipping fine foliation, and broadly separate the granulite-facies rocks to the north from the amphibolite facies migmatite complex to the south. The latter boundary appears from the photogeological and field evidence to be a gradational one, and coincides with the front of migmatization.

Porphyroblasts of K-feldspar are in places so abundant that K-metasomatism is thought to have been an active process in the zone, before and/or during the time when the cataclastic effects were produced.

The Redbank Zone rocks in their pre-deformational state consisted of felsic gneiss with minor metasedimentary and amphibolitic layers, possibly similar to those of the Chewings Range Zone; this is indicated at locality 55 where migmatization is less intense.

Numerous intrusions of gabbro up to 1 sq. km in area were observed within the blasto-mylonites of the Redbank Zone, (locality 49-52). None of the gabbro occurrences appear to form sill-like outcrops except in the southern part of Redbank Hill, north of the study-area.
c. The Migmatites of the Ormiston Zone - A large part of the study-area is occupied by migmatized rocks, which have yielded in recent isotopic studies an age of 1076 ± 50 m.y. (Marjoribanks and Black, 1974). The migmatites display all stages in the conversion of an older series into granitized rocks.

It was not possible to map individual units of the older series but the latter is sufficiently preserved to show that the migmatites developed from felsic gneiss, containing minor metasedimentary bands. The rocks include felsic gneiss, alternating mafic-felsic layered gneisses, schist and minor amphibolite, and are similar to those of the Chewings Range Zone. (See section d.)

The northern boundary of the migmatites coincides approximately with the mylonites of the Redbank Zone, and the southern boundary is expressed as either a series of thrust faults bringing the migmatite into contact with the Heavitree Quartzite, or a geological contact with a series of gneisses in which incipient stages of migmatization can be observed.

On the accompanying photogeological map sheets, the migmatites have been differentiated into two units, pGM₁ and pGM₂, on the basis of photographic response, in addition to the granite-like rocks. The unit referred as pGM₂ appears generally darker, has a low relief, and lies adjacent to the thrust-fault zone of the Alice Springs Orogeny. It may be equated with a zone of lesser migmatization intensity (relative to pGM₁). Retrogressive metamorphism developed in this unit during the Alice Springs Orogeny, with an epidote-chlorite grade mineral assemblage.

Although most of the migmatite structures, described in Mehnert (1971, p.7-42), have been observed within the Ormiston Zone, only a few occur widely. They belong to the following types:

- the widespread stromatic or layered structure (localities 3 - 35 - 64) appears, commonly, near the contact with the gneissic terrain of the Chewings Range Zone.
- the folded structure (localities 30 - 53 - 57) is usually found farther from the gneissic terrain of the Chewings Range Zone, commonly surrounding or within the more granitized rocks.

- the schlieric and nebulitic structures (localities 29 - 61) are associated with the almost completely granitized rocks.

- the ophthalmitic structure (locality 45)

- the ptygmatic structure (locality 51) is rare within the study-area.

The major granite-like rocks shown on the accompanying photogeological map sheets are intimately associated with migmatites. The dotted shred-shaped boundaries shown on the map sheets represent a gradational contact, behind which highly granitized rocks predominate with schlieric or nebulitic migmatitic structures. Only a few outcrops within these larger bodies could be termed porphyritic, occasionally oriented, leucogranite (localities 29 - 79 - 80 - see map). The grain size of these completely granitized rocks was found, from a few outcrop investigations, to vary considerably.

The Ormiston Pound granite is typical of the progressive transformation that was observed from a felsic gneiss series into migmatitic gneiss and homophanous rocks of plutonic appearance.

The shape of the two major granite-like outcrops, near Mts Razorback and Sonder, suggests a strong west-trending structural control. To the northeast, other bodies were mapped during the photogeological re-annotation, but were not checked in the field.

An important point is the apparent lack of a significantly developed leucocratic phase emplaced within the completely granitized rocks. No definite evidence of intrusive granite has been observed within the study-area, but this should not be considered as a negation of the existence of intrusive granite in the study-area.
At locality 80 is a mass of rock about 100 m across resembling magmatic granite and containing minor pegmatites. Contact with the surrounding anatetic granite is gradational, possibly indicating similar chemical composition for the two rock types. Other bodies of this type of granite were found during ground work at localities 29, 62, 63 and 79, but were not detectable on the photographs; they could be intrusive and not a part of the transformed Chewings Range Zone.

It appears that several processes have been involved in migmatization including anatetic and metasomatic processes. Effects of the latter process have been observed at several localities (58, 22, 45) where feldspathization appears to be a common phenomenon. Anatetic formation of the granite is the more likely process because:

- boundaries are gradational with a progressive migmatization towards the highly granitized core of the migmatitic massifs;

- chemical changes appear minimal, excluding the concept of wide-spread metasomatism for the formation of granite from an original source of quartz feldspar-rich sediments, (for example, graywacke), in the Chewings Range Zone.

A point of interest is the presence of conformable pegmatites, which are mostly in the less migmatized rocks (location 30, eastern part of the Orlston Pound).

A west-trending swarm of dolerite dykes, slightly concave to the north, extends for some 50 km from the "Redbank" ruins in the east to the southern flank of Mt Zeil in the west. The dykes cut the foliation of the migmatites at a low angle. There is evidence of movement along some dykes, possibly coeval with the Alice Springs Orogeny, with retrogressive metamorphism and development of green chlorite schist (locality 62-63).
d. The Gneissic Terrain of the Chewings Range Zone — The southeastern part of the study-area adjacent to the Chewings Range is occupied by a series of west-northwest-trending belts of felsic gneiss, banded mafic-felsic gneiss and schist, and lesser amounts of amphibolite. The photogeological mapping indicates that there is some banded gneiss in the western part of the study-area, but this was not checked in the field. In this terrain, amphibolite facies metamorphism is indicated by a biotite-garnet-(staurolite)-muscovite-quartz mineral assemblage. Isotopic dating (Marjoribanks and Black, 1974) yielded an age of 1620 ± 70 m.y. for the metamorphism, which is a widespread event in the Arunta Block. This gneissic terrain thus predates the migmatization.

Incipient migmatization was found to occur at localities 15 - 16 and 22 with a stromatic structure. Elsewhere, a discrete yet widespread porphyroblastic "augen" structure south of the Chewings Range is in places interpreted as a feldspathisation process (locality 21 - 22) or as blastomylonitic (localities 6 - 7 - 13 - 16). The lack of intense migmatization indicates that this zone can be regarded as a large scale paleosome preserved during migmatization. The impression gained during field checking from a few brief visits to outcrops is that the zone south of the Chewings Range Zone has undergone much mechanical deformation, along west-trending structures.

Some outcrops of augen gneiss, however, have a distinct geomorphological expression with a bouldery nature and rough surfaces (localities 18 - 45). These are interpreted as a migmatitic structure and occur in association with granite-like rocks (locality 19), similar to those in the Ormiston Pound and near Mts Sonder-Razorback. A strong east-west tectonic control, across a zone approximately four kilometres wide, is apparent in the development of these migmatites.

A sedimentary origin of the gneissic terrain is favoured because of the interfoliated occurrence of more pelitic horizons within it. Another concept, suggesting that the felsic gneiss was derived from
either an older granite or a felsic gneiss, upon which the sediments of the Chewings Range Zone were laid unconformably, was suggested but thought unlikely by Marjoribanks (1975).

The Chewings Range Quartzite (Marjoribanks, 1975) is in this report excluded from the gneissic terrain of the Chewings Range Zone on a lithostructural basis. The same belt of quartzitic sediments at Simpsons Gap and Stanley Chasm to the east of the study-area has been recently reviewed and mapped as Heavitree Quartzite (D. Clarke, pers. comm.). An angular unconformity between Heavitree Quartzite and Chewings Range Quartzite was "demonstrated" by Forman and Milligan (1967), who also admitted that structural causes for the unconformity were as likely an explanation.

It is the author’s opinion that the quartzite which forms the high Chewings Range (Mt. Giles - Brinkley Bluff to the east) belongs partly or wholly to the Heavitree Quartzite.

The occurrence of a schist band (locality 40) within the quartzite could well result from purely mechanical deformation during the infolding of the quartzite within the Arunta Complex, similar to those observed at localities 41,22 or 34. The contact between the quartzite of the Chewings Range appears either unconformable (north of Mt. Giles), or conformable (southeast of locality 40) although here a series of north-trending dolerite dykes indicates also a possible structural control.

Most of the quartzite in the Chewings Range is shown on the maps published by the Bureau of Mineral Resources as being intruded by pegmatite and dolerite dykes. The photogeological mapping did not confirm this.

More detailed work at a larger scale should be done to ascertain the relationship, structural or otherwise, between the "two" quartzites.
2. Cover Rocks

a. The Heavitree Quartzite - This unit occurs throughout the southern half of the area and forms prominent ridges and scarps in the present landscape.

The nature of the basal contact in many areas is difficult to interpret, because of the complicated structure due to widespread thrusting. In some areas, particularly north of the Heavitree Range, the contact appears to form an angular unconformity with the Arunta Complex formations.

The Heavitree Quartzite forms the basal unit within the Amadeus Basin and has been divided into three members referred to as Lower, Middle and Upper (Marjoribanks, 1975).

- The Lower Member (0-30m thick) is generally too deformed within the thrust faults and has too many facies variations to allow certain correlation between sections along gorges. It consists usually of arkosic to gritty sandstone-quartzite, with or without conglomerate.

- The Middle Member (+ 220m) forms the greater part of the Heavitree Quartzite and consists of massive quartzite with minor shale partings and pebbly horizons. A characteristic photographic expression is imparted on the RC9 photographs by this Middle Member.

- The Upper Member (+ 80m) consists of a sequence of alternating shale and quartzite, thus imparting a well banded flaggy-type expression on the air-photographs. The Upper Member is well represented north of Ormiston Pound, where the finer sediments have been mildly metamorphosed to phyllite and schist.
Elsewhere, the quartzite members have been converted to sericitic meta-quartzite and schistose quartzite within the nappe complexes.

On the accompanying phogogeological map sheets, the internal members of the Heavitree Quartzite have not been differentiated, although it is possible in some areas, particularly north and northeast of the Ormiston Pound, to recognise two members coinciding with the Lower-Middle and Upper Members. This point was found to be of some importance for the understanding of the structural features associated with the Ormiston Pound Folds.

b. The Bitter Springs Formation - This unit has a low relief and rests conformably on the Heavitree Quartzite. The lower geological contact is considered to be at the lowest dolomite bed.

Rock types include shale, siltstone, dolomite, limestone and some evaporite horizons (Marjoribanks, 1975).

In the vicinity of the nappe complexes, the rocks have been mildly metamorphosed to phyllite and slate.

The presence of salts within this unit and the processes of seepage and evaporation impart a characteristic white tone on the photographs.

The age of this unit is approximately 650-950 m.y., given from stromatolite fossils.

c. The Areyonga and Pertatataka Formations - These formations outcrop in the southeastern part of the area and have been mapped on the photogeological sheets as undifferentiated Proterozoic-Cambrian formations, resting unconformably over the Bitter Springs Formation. The Areyonga formation consists of two members:
- a pale brown calcareous quartz-sandstone

- a sandstone-siltstone with minor conglomerate bands. This lower member is not always present.

The Areyonga Formation is conformably overlain by the Pertatataka Formation, which consists of siltstone, shale and thin limestone and sandstone beds.

d. The Pertaoorrenta Group - The Pertaoorrenta Group, also classed in the mapping as undifferentiated Proterozoic-Cambrian formation, succeeds the Pertatataka Formation conformably. In the study-area it includes in ascending order the Arumbera Sandstone, the Hugh River Shale, the Jay Creek Limestone and the Goyder Formation.

A disconformity is present between the non-fossiliferous Arumbera sandstone and the overlying fossiliferous formations.

e. The Larapinta and Pertnjara Groups - To the south of the area, the MacDonnell Ranges consist of parallel strike ridges and valleys of Cambrian to Carboniferous sediments, composed of the Larapinta and Pertnjara Groups (Quinlan and Forman, 1968), which consist mostly of clastic sediments with lesser amounts of limestone.

f. Surficial Deposits - Flat-lying Tertiary sediments have been mapped but not field-checked as laterite (T1) overlying basement rocks in the southwest of the area, within the Razorback klippe -

- thin beds (maximum thickness 10m) of conglomerate (Csc) form an extensive scree cover surrounding the Heavitree Quartzite escarpment.

- Alluvium and aeolian sand have been mapped as undifferentiated Quaternary (Q). No evidence of the presence of calcrete was found during field checking, although some minor patches probably occur in the centre of the area, north of Teapot Yard.
B. Structural Features

In the foregoing section, a breakdown of the rock units within the study-area has been made on the basis of gross lithostructural features recognisable on the RC9 photographs, resulting in the subdivision of the area into four domains.

The detailed reconnaissance photogeology indicates the existence of at least three separate tectono-thermal events within the study-area. The earliest of these was a period of high-grade metamorphism and deformation, referred to as the Arunta Orogeny by Forman and Milligan (1967), followed by a period of migmatization. The final one was one of strong deformation with the production of related nappe complexes.

1. The Lower and Middle Proterozoic Metamorphic Events

   a. Lower Proterozoic Event - The oldest metamorphic episode appears to have coincided with the close of the Lower Proterozoic, as indicated by the Rb/Sr radiometric ages published for the rocks in the study-area by Marjoribanks and Black (1974). The ages of 1620 ± 70 m.y. were obtained from specimens of a leucocratic gneiss typical of the pre-migmatite gneiss of the Chewings Range Zone, 2.5 km east-southeast of locality 40. This age is similar to dates around 1700 m.y. obtained from other areas of the Arunta Complex.

   During the course of this tectono-thermal event the basement rocks were metamorphosed to granulate facies in the north and northwest and to amphibolite facies in the east and southeast.

   A major west-trending thrust-fault zone was probably initiated at this time predating the migmatization, with movements responsible for the intense deformation of the rocks seen in the Redbank Zone.

   The juxtaposition of the granulate and amphibolite facies rocks is the likely result of movements during the oldest event, although some evidence of reactivation, including isotopic biotite ages which
indicate re-setting, and narrow zones of retrogressive metamorphism within the Redbank Zone, resulted from the Alice Springs Orogeny.

Within the pre-migmatite sequence of the Chewings Range Zone, Marjoribanks (1975) recognised at least three phases of folding before the Alice Springs Orogeny, although many observations were based on small-scale folding of the quartzite in the Chewings Range and could not be repeated in the adjacent gneiss and schist.

The photogeological mapping and field evidence indicate at least two phases of folding south of the Chewings Range. The earlier phase produced tight isoclinal folding with north-south trending axial planes, and the latter phase refolded the former, resulting in a tight east-west foliation and axial planes obliterating much of the earlier phase. On a large scale, the gneiss and interfoliated metasediments of the Chewings Range Zone appear to form a paleosome within the surrounding migmatitic terrain.

Similar styles of folding were observed from a few brief visits to outcrops within the Redbank Zone. Here, the minor east-west trending folds defined by quartz-rich or quartzo-feldspathic layers are transposed or obliterated by the mylonitic foliation, some of which is folded by north-plunging larger folds.

b. Middle Proterozoic Event - The youngest metamorphic event appears to have coincided with the Middle Proterozoic, as indicated from the Rb/Sr ages of 1080 ± 90 m.y. obtained from specimens of coarse banded migmatite within the migmatitic complex.

During the course of this event, a migmatitic complex was formed in the area south of the Redbank Zone and between Mts Giles and Zeil.

The numerous cores of anatectic granite possibly indicate several centres of migmatization, although some may be intrusive. More detailed work is required to map these structures satisfactorily. Large west-trending folds occur throughout the area, and many are overturned to the north.
c. Brittle Deformation Stage - A stage of brittle deformation is reflected in the many dolerite and pegmatite dykes which occur in the study-area.

To the south of the Redbank Zone, a west-trending swarm (up to two kilometres wide) of dolerite dykes extends eastwards for some fifty kilometres from the Redbank ruins in the east, where they terminate in the mylonitic rocks of the Redbank Zone, to the southern flank of Mt Zeil, where they are truncated by a northeast-trending fault.

The dykes, up to 10 m wide, have chilled margins and cut the foliation of the migmatites at a low angle.

The photogeological evidence indicates that this dyke swarm has undergone much cross-faulting along northeast trends, and in places gentle folding. (e.g. four kilometres west of locality 57).

To the northeast of Mt Razorback, several dykes diverge from the main swarm along wide bends southwards and connect with the Mt Sonder thrust. This pattern possibly results from differential movement across a major northeast-trending fault, whose trace lies to the east of locality 64. The youngest stage of faulting in the vicinity of Mt Razorback was in part a reactivation of pre-existing faulting, was not accompanied by intrusion, and followed the deposition and deformational emplacement of the Heavitree Quartzite. Highly crenulated green chlorite-rich schist (almost a chloritite) was found to occur at localities 62 - 63 with relics of dolerite in the basement rocks. These reactivated faults were found to be of post-Heavitree Quartzite and pre-Bitter Springs Formation age.

In the eastern part of the study-area, several dolerite dyke swarms trend north, but are less well defined than the west-trending swarm previously described. Several individual dykes show an en échelon pattern as a result of transcurrent east-west shears.
No dyke is known to transect the Heavitree Quartzite, although pre-existing north-south trending fractures have been reactivated over a wide area, particularly in the Chewings Range.

It is possible that the many intrusions of gabbro found within the Redbank Zone and the migmatites were emplaced at about the same time as the dolerite dykes. Marjoribanks (1975) reports a sill-like form of the gabbro on the southern flank of Redbank Hill, with a control on intrusion exerted by the north dipping foliation, but it was not checked in the field.

Pegmatite dykes occur in the extreme eastern part of the study-area, along north-northwest and northeast trends. Some pegmatites transect and appear to postdate the dolerite dykes. The photogeological evidence indicates the pegmatites to be coeval with the east-west trending shear structures, in the east of the study-area at least.

Pegmatite dykes were found at locality 53 to transect the folded migmatites and a dolerite dyke.

2. The Alice Springs Orogeny

After the deposition of Heavitree Quartzite and Bitter Springs Formation, the Amadeus Basin deepened and received mostly clastic sediments, in which intraformational unconformities indicate periodic uplifts, culminating in the Alice Springs Orogeny, from 358 to 322 m.y.

This orogeny affected both Proterozoic and Paleozoic rocks as well as the Arunta Complex.

Comprehensive reviews of the geometry of the structures in the cover rocks that resulted from the Alice Springs Orogeny have been given by Marjoribanks (1975 and 1976). The present photogeological work confirmed most of these structures and only a summary will be given.
a. **Structural Features in the Basement Rocks** - Renewed movement probably took place within the Redbank Zone but it is difficult to ascertain and distinguish from earlier deformation. Converging evidence of reactivation is indicated by narrow zones of retrogressive metamorphism, and by the partial resetting of isotopic biotite ages, which demonstrate a rise in geothermal gradient northward across the area.

The major effects of the Alice Springs Orogeny in the basement are restricted to the vicinity of the thrust faults. Isoclinal folding and transposition of an earlier foliation was observed near locality 34. Retrogressive metamorphism with the widespread development of quartz-epidote veining and minor chlorite replacing biotite (locality 32) is probably related to the orogeny.

This parallelism between the structures produced during the Alice Springs Orogeny and the west-trending folds that were produced during the Arunta Orogeny in the Chewings Range Zone, suggests that the latest shear deformation either followed a pre-existing fracture zone or was caused by the reactivation of the west-trending structures produced during the Arunta Orogeny.

b. **Structural Features in the Cover Rocks** - During the Alice Springs Orogeny, the major fold and nappe structures which have been recognised are, from west to east:

- the Razorback klippe.
- the Mts Razorback - Sonder Nappe
- the Ormiston Pound Folds

which three constitute the Ormiston Nappe Complex.

The shallow westerly plunge of these antiformal structures preserves the uppermost structures in the west, and brings the lowermost ones to
surface in the east. The above nappe systems are therefore given in a descending order.

A change in the large-scale style of folding occurs from east to west. The style ranges from open in the east to recumbent in the Ormiston Gorge area. Farther to the west, nappe complexes are developed and include overturned limbs of a nappe preserved as a klippe.

The model of Marjoribanks (1975) for the mechanism of emplacement of the Ormiston Nappe Complex involves major vertical movements, along which thrusts pierced the Heavitree Quartzite along a decollement zone within the Bitter Springs Formation. Allochthonous wedges of basement rocks were driven into and stayed within the latter formation probably because of the minimal frictional drag of the evaporites. Movements of the front of the nappe produced disharmonic folding in the Bitter Springs Formation. Other underlying nappes resulted from the stress within the basement, relieved by thrusts which pierced (to a lesser extent than that of the frontal nappe) the Heavitree Quartzite. An "en échelon" system of nappes would be expected from this model. (See Fig. 3)

The **Razorback** klippe represents a large (25 x 3 km) klippe with Arunta Complex rocks overlying the Heavitree Quartzite, which rests on the Bitter Springs Formation. From the above model, the klippe could be interpreted as the advancing nose of the nappe.

The **Mts. Sonder-Razorback Nappe** has an anticlinal structure, with mostly the upper limb gently dipping to the north, and the lower limb either steep or overturned. North of Mt Sonder, the upper limb is truncated and sheared out by the Mt Sonder thrust, which can be followed westwards to Crawford Creek near Mt Razorback. The thrust dies out eastwards within the Arunta Complex. Numerous smaller thrusts have resulted in the many slices of Heavitree Quartzite observed in the western vicinity of the Redbank Gorge. The axial plane of the structure plunges to the west at approximately 5°. A dome structure is defined at Mt Razorback.
1. Attitude of the basin sediments before the Alice Springs Orogeny.

2. Uplift to the north along reactivated thrusts within the Redbank Zone.


4. Formation of fold-thrust complex of the parautochthon.

Sketch sections illustrating the development of the Ormiston Nappe Complex. Vertical exaggeration 1:5x. Scale approximate.

After Marjoribanks 1975 (fig. 34)
The Ormiston Pound Folds represent the nose of a large west-plunging structure, which extends for at least 45 km in the study area. The northern limb of the structure is the most deformed and includes the Chewings Range. The southern limb is known as the Heavitree Range.

The Chewings Range has undergone at least three phases of folding. The earlier phase produced tight west-trending isoclinal folding with near-horizontal or gently west or east-plunging axes (locality 22). Low grade metamorphism may have accompanied this phase of folding, which produced a synform near Mt Giles.

The second phase of folding produced the sharp 90° swings in strike of the Chewings Range, which defines a large anticline (north) and syncline (south) which plunge to the northeast. These folds refold the earlier isoclinal fold structures. The syncline was named the Eastern Pound Fold by Marjoribanks (1975).

The last recognizable phase of folding trends northwest and produced relatively open and asymmetric folds within the steep or overturned limb facing south. This phase may be a consequence of the second phase, overprinting a crenulation onto the first phase. It possibly created the crenulated schist observed at locality 40.

The Heavitree Range, or southern limb of the large west-trending structure, has undergone at least two phases of folding, similar to those observed in the Chewings Range.

The structural implications of the Ormiston Pound Folds are best understood when the Heavitree Quartzite is divided into its Lower-Middle Member and Upper Member. The folds underlie the Ormiston thrust and are spectacularly exposed in the north flank of Ormiston Gorge. Here the stratigraphic succession is repeated due to thrusting along a decollement which formed at the base of the Upper Member of the Heavitree Quartzite. This thrust broadly parallels the Ormiston thrust. The Ormiston Pound Folds form an asymmetrical recumbent fold with a steeper limb facing south.
The southern limb of the Ormiston Pound Folds exhibits a strong control along west-trending shears. The right-angle swings in strike west of Mt Giles appear also to have been controlled by a shear along the southern boundary of the Chewings Range, with maximum stress exerted along this structure. Ultimately overthrusting resulted in the case of the folds and also in the northern limb.

To which structural model the Ormiston Folds can be related is still a matter of speculation. In both the Chewings and Heavitree Ranges, more detailed work would be required to unravel these structural problems.
VI. ECONOMIC ASPECTS

No significant indications of old mineral prospects were found during field checking. Minor disseminated malachite was noted in the northwest of the study-area, at locality 74, in a "float" of coarse-grained biotite-rich garnet-bearing migmatite.

Concerning uranium mineralization, recent studies of the distribution of uranium in igneous rocks indicate that it concentrates in the late-stage granitic differentiates. The Rossing deposit in South-west Africa provides the best example. Alaskitic granite, leucogranite, graphic granite and K-feldspar pegmatite are likely rocks in which to seek enrichments of uranium, provided that suitable structural and chemical traps are present and that uranium has not been expelled from the host. Most of the above rock types have been observed during field investigation of "floats" in major creeks.

The granitized suite of rocks north of Mts Razorback and Sonder has received some recent attention, where several radiometric anomalies were detected during the course of an airborne survey. The anomalies and their relative strengths are indicated on the accompanying photogeological map sheets. They appear to be associated with the granitized rock and fractures within these rocks.

The two strongest anomalies are at localities 79 and 80. Highest scintillometer readings were obtained from microfractures, generally north-dipping, in a leucogranitic rock, which may not be entirely an anatetic equivalent of the sediments of the Chewings Range Zone. Detailed petrological work and mapping should reveal the origin of the "granite". At locality 80, no direct structural evidence was found to account for the highest scintillometer readings.
The rocks here include several varieties of plutonic appearance, which vary progressively from porphyritic and oriented, to nebulitic. Minor pegmatite differentiates are developed in the eastern part of the outcrop.

Despite the relative paucity of late-stage granite differentiates in this area, other structural traps that could be of significance exist, such as fractures.

The distribution of the anomalies within the granitized rocks appears spatially related, in part at least, to northeast-trending fractures. One of these fractures, located east of Mt Sonder, supports two main anomalies.

The photogeological evidence indicates that this fracture postdates the trace of the Mt Sonder thrust in the basement rocks. Another major lineament, located north of Redbank Gorge, supports two anomalies and appears to form a geological contact between highly granitized rocks and migmatites. These observations could be of some significance relative to vein-type uranium.
VII. RECOMMENDATIONS

Suggestions for further work include the following:

1. A detailed north-northeasterly ground traverse should be made from Stokes Well to Mt Heughlin in order to check banded gneiss, pegmatite in migmatite, and possibly basic granulite in the northeast. This area was only very briefly inspected during field checking.

2. An extension of the spectrometer survey should be carried out in order to cover areas of prospective interest and to provide a relationship between rock types and radioactivity, near Glen Helen homestead, and 90 km to the east-southeast near Ellery Creek. In the latter area, a small west-trending "anomaly" was detected during the course of the BMR survey (1965) and appears to correlate with a zone of numerous pegmatitic bodies. Ten kilometres farther to the southwest, favourable conditions for uranium mineralisation seem to exist where there are granitic rocks and a schist-gneiss sequence; and some north-trending faulting appears to predate the deposition of the Bitter Springs Formation. Colour photography could be useful here in discriminating between the various rock units.

3. Contour maps of the radiometric data should be made.

4. Detailed photogeological mapping using colour photography on a scale of 1:25,000 would definitely improve the existing mapping in the northeast part of the Ormiston Pound, because details of structure and lithology would be clarified.

5. Subtle differences were observed within the more granitized rocks, including K-feldspar rich varieties, and it may be possible that colour photography could assist the differentiation of several phases of granitization by revealing different colour tones in the various phases.
The areas recommended for further study, using colour photography on the scale of 1:25,000, are shown in Fig. 2.
APPENDIX 3

Assay results, Rock Chip Samples, Airborne Radiometric Anomalies

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<th>( ThO_2 ) ppm</th>
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<tr>
<td>MZ 26</td>
<td>23</td>
<td>91</td>
</tr>
<tr>
<td>MZ 27</td>
<td>2280</td>
<td>33</td>
</tr>
</tbody>
</table>
Nappe  A recumbent fold (fold nappe with horizontal axial plane), where the reversed limb has been replaced by a thrust, or the hanging wall of a low angle overthrust (thrust nappe). A considerable distance of travel (several kilometers) is a condition, as well as the large dimensions involved (also several kilometers).

Nappe Complex  Contains two or more nappes piled on to the other.

Nebulitic  Migmatitic structure with ghost-like relics of pre-existing rocks.

Ophthalmitic  Migmatitic structure characterized by augen (ie, feldspar "eyes") of the newly formed minerals or aggregates.

Paleosome  Parent rock from which the migmatite derived

Resister  Rock able to resist any process of granitization, owing to its chemistry or mineral fabric.

Schlieren  Heterogeneous elongated light and dark streaks or masses with blended outlines in migmatites.

Stromatic  Layered migmatitic structure with light and dark bands in the paleosome. There is a complete gradation between the banded gneisses and the stromatic migmatites.

Synform  A synclinal-type megascopic structure with unknown stratigraphical sequence.
Samples A2, A9, H2-25, H3-27.

Anatetic granites with monazite, zircon-cyrtolite, epidote-allanite, apatite and secondary autunite.

Each of these samples of granitic rock displays similar textural and structural characteristics which indicates their common origin. They are virtually non-schistose rocks which contain as prominent porphyroblasts, anhedral and subhedral composite perthite-microcline individuals of several mm grain size. These composite potassic felspars embody smaller subhedra of sodic plagioclase and quartz; and they are contained in a contrastingly finer grained granuloblastic-textured medium which consists of quartz, fine grained felspars, micas, epidote, zircon, sericite, martite, leucoxene, ilmenite, and sparse allanite, cyrtolite, apatite, chlorite and autunite.

The felspar porphyroblasts display minor sericitisation in some areas, but they are otherwise free from alteration. The coarse grained, non-stressed, non-fractured features of these large felspars, contrasts with the granuloblastic-recrystallised texture of the micaceous quartzitic medium which exists amongst them. The conclusion is that the felspars formed in place in the finer medium of an original felspathic-micaceous quartzitic rock by a process which suggests anatexis; i.e. this is not a granitic rock with a stressed-committed fine grained micaceous-quartzitic groundmass as are A1, A2, A3.

The granuloblastic quartzitic medium which is more or less continuous amongst the felspar porphyroblasts, contains muscovite, biotite and felspars which are coarser grained than the quartz, but much finer grained than the felspar porphyroblasts. This medium also contains widespread fine grained epidote, sericite, zircon and many small crystals of cyrtolite. Martite of 0.3 mm maximum size, smaller ilmenites and leucoxene, as well as occasional oxidised fine pyrites were observed from the polished sections of the samples.
The thin films of microcrystalline autunite which are visible on several of the hand specimens, e.g. R2, MZ-27, were found in the thin sections, to be located in the intergranular medium amongst the felspar porphyroblasts. In the case of sample R2, the autunite appears to have developed from the breakdown of small crystals of cyrtolite. In the case of sample MZ-27, the autunite appears to relate to small grains of zoned isotropic allanite which exist in composite intergrowth with epidote within the intergranular areas. These areas in MZ-27 also contain zircons, but only an occasional cyrtolite was observed. Evidence for reactions involving apatite, as suggested in correspondence, was not observed.
CENTRAL MINERALOGICAL SERVICES PTY. LTD.

SAMPLE REPORT (Mineralogy, Petrology, Ore Microscopy)

Job No. CMS 77/1/12 Date Received: 21.1.77
Reference Order No. S 306854
Sample No. 65648, 65649, 65650
Nature of Sample: Hand specimen

DESCRIPTION

SECTION NO 20647, 20648, 20649

a. Hand Specimen:

Grey, coarsely crystalline granitic rocks. K-feldspar stain test positive.

b. Microscopic:

As is often the case with coarsely-crystalline igneous rocks, there is some variation in the distribution of the components, but the three rocks are so similar as to require only one description; separate descriptions would not be justified. They may be classified as gneissic biotite-adamellites, and were subjected to (mainly) dynamic metamorphism after solidification. There is a suggestion of fluxion-orientation, especially in 65648.

The major components are microcline (about 35%), quartz (35%), and oligoclase (25%), with the remaining 5% or so comprised of biotite and others. The oligoclase is sodic and thus the composition of the rock is almost granitic. The microcline forms subhedral, prismatic crystals with a tendency to be porphyritic. The quartz is anhedral, and granulated/recrystallised where traversed by shears. Oligoclase is not as coarse as microcline, and is generally cloudy from partial alteration to sericite and fine zoisite-epidote. Biotite is dark green, nearly opaque in places, and deformed and contorted. It is characterised by many pleochroic haloes and contains fine inclusions.

During or after dynamic metamorphism, secondary, deuteric minerals developed, mainly represented by epidote (partly replacing biotite), minor sericite and chlorite.

Accessory minerals, as determined from thin sections and a heavy mineral fraction (1.5% of rock), include apatite, monazite, magnetite, allanite, and metamict zircon. At least three of these minerals carry some U/Th and are thus primary sources of these elements; in addition, they are sources of P₂O₅ to produce secondary uranyl phosphates. All these accessory minerals are of primary origin.