GEOLOGY OF THE RUM JUNGLE DISTRICT (NORTHERN TERRITORY) WITH PARTICULAR REFERENCE TO THE ORIGIN OF THE URANIUM OREBODIES

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PART I

Discussion of Ore Genesis, Conclusions and Recommendations
ABSTRACT

Uranium minerals and base metals are thought to have been deposited independently. The uranium minerals are thought to be syngenic and stratigraphically controlled. The distribution of the ore bodies does not appear to be controlled by structure. The principle of prospecting the "limestone contact" is further verified.

It is thought that the base metal mineralisation is probably hydrothermal and may well be structurally controlled.

The sequence of events in the Hundred of Goyder is summarised.

1. ORE ENVIRONMENT

In studying an orebody an attempt should be made to establish the present ore environment, i.e. the total conditions in which the ore now occurs. This work is descriptive and is limited only by time and facilities available. An attempt to determine the origin of an orebody is an attempt to interpret the ore environment, and to do this it is necessary to be able to single out those factors which are essentially related to the ore genesis.

In the Hundred of Goyder a number of uranium ore bodies and prospects exist. They are all very similar in ore mineralogy and environment as far as can be ascertained. It therefore seems reasonable to assume a common origin and also to assume that the common factors in the ore environments include the factors which are significant in determining the ore genesis. (Batchelor laterites is not considered. The writer knows very little about this prospect but it appears atypical and could well be an example of redistribution of ore minerals).

It can be reasoned that the validity of the above argument is undermined to some extent by the fact that prospecting has been based, for much of the time, on the principle of searching for ore in areas where certain factors of the ore environment were thought to be repeated. Thus it is possible that the apparent stratigraphical control is a function of the prospecting programme, rather than actual distribution of mineralisation. However, in the opinion of the writer this is not so, since the evidence for stratigraphical control seems to have been good before stratigraphical control was adopted as the guiding principle in prospecting.

The significance of establishing an ore environment is twofold. Firstly, it is a necessary step in solving the problem of ore genesis. Secondly, knowledge of an ore environment can be of value in prospecting even before its significance is understood.

2. COMMON FACTORS OF THE URANIUM ORE ENVIRONMENTS IN THE HUNDRED OF GOYDER

The factors common to the uranium mineral, or ore environment in the mines and prospects under consideration are as follows:

(1) The ore in each case occurs in rocks of the Golden Dyke Formation.
(2) The host rocks are pyritic.
(3) Dolomitic marble or dolomite rich rocks occur close to the mineralisation.
(4) Uranium occurs as pitchblende at depth but is altered to secondary minerals, particularly phosphates, near the surface.
(5) All deposits occur in intensely deformed rocks in which cleavage and schistosity have largely obscured original bedding.

(6) Where the mode of occurrence is known the uranium minerals occur on the foliation $S_1$ and in joints.

3. **DEDUCTIONS BASED ON MODE OF OCCURRENCE AND COMMON FACTORS OF ORE ENVIRONMENT**

(a) **Stratigraphical control**

The fact that the known mineralisation occurs in rocks of the Golden Dyke Formation suggests a stratigraphical or lithological control. It does not always occur in the same rock type, but may occur in black slate or green schist. This is consistent with a stratigraphical control but does not appear to be consistent with a lithological control. If the control is lithological it would be expected that the mineralisation would occur consistently in the one rock type.

(b) **Structural control**

Where the ore occurrence is known in detail the uranium minerals occur on $S_1$ as a thin smear. $S_1$ is not an open break in the rock but a foliation defined by mineral orientation. Therefore if the ore minerals were introduced into the rock after deformation there is no reason why they should occur on the foliation. Joints would provide far easier access. Thus it appears that the pitchblende is either pre or syn-tectonic with respect to $F_1$.

If the ore is pre-tectonic and behaved passively during the folding the role of deformation in its localization is somewhat different to what it would be if the ore was syn-tectonic. In the first case the distribution of the ore within the orebody will be related to the deformation, but this will only be a modifying factor and its regional distribution will be related to some pre-deformational factor. In the second case the regional distribution of the ore will, in all probability, be related to the deformation. The difference between the two is the difference between a deformed coal seam and a syn-tectonically emplaced hydrothermal deposit.

The effects of $F_1$ deformation on ore distribution are recognisable in R.J.C.S., but there is insufficient evidence to determine on structural grounds whether the ore is pre-tectonic or syn-tectonic.

The fact that the uranium minerals also occur in joints which are thought to have post dated $S_1$, indicates that there has been remobilisation of the ore in post $S_1$ times.

(c) **Alteration of pitchblende to secondary minerals**

The significance of the secondary phosphate minerals in R.J.C.S. is discussed in Section II. The presence of pitchblende at depth, in the relatively unweathered rock, and secondary minerals in the oxidised zone, however, is not peculiar to R.J.C.S. The proportions of primary and secondary minerals vary but the pattern of occurrence is always the same. The pattern is consistent with an orebody that is being altered to secondary minerals but not with an ore body that owes its origin to supergene activity.
4. ORE GENESIS

There are a number of ways in which the ore could have been introduced and they are discussed below.

The possibility of the ore bodies being a product of supergene activity has been considered in Rum Junglo. However, in the opinion of the writer it can be overruled for the following reasons.

(1) There is evidence as stated above to suggest that ore pre-dates the deformation.

(2) At present the ground water is evidently leaching the ore and reprecipitating it as secondary minerals. Therefore, the pitchblende was presumably deposited under somewhat different circumstances to those existing at present.

(3) It would not explain stratigraphical control. It is possible that stratigraphical control is only apparent and that the real control is lithological. Adler (1963) has put forward an explanation of the association of uranium with rocks containing organic remains. He describes "sandstone type" deposits which are rich in organic material, and suggests that they have been precipitated from ground water by the action of $\text{H}_2\text{S}$, produced by bacterial decay of organic material. Rum Junglo could possibly be described as a metamorphosed sandstone type deposit and the uranium occurs in carbon rich rocks but the carbon does not occur as organic material and it seems unlikely that the model postulated by Adler could have functioned in post metamorphic times. "Pre-metamorphism there may have been organic material in the model could possibly have been applicable, though it must be remembered that the rocks involved are thought to be Proterozoic."

Alteration of pyrite has been suggested as a source of $\text{H}_2\text{S}$ and thereby the controlling factor in the deposition of the uranium. However, pyrite is by no means restricted to the narrow horizon to which the uranium is thought to be restricted.

Roberts (1960) claims that "the mechanism involved in the emplacement of the ore has been essentially a hydrothermal one". He does not, however, offer much evidence to support this statement, which is based only on the presence of two generations of andalusite in the embayment, and on S/Se ratios, which he himself indicates are suspect.

There is no obvious source for the required hydrothermal solutions now that the granite is thought to pre-date the sediments. Nor are there any obvious gangue minerals, associated with the pitchblende, to suggest a hydrothermal origin. Also, the stratigraphical control again has to be explained. In view of this, the writer does not consider the case for a hydrothermal origin very strong.

A syngenetic origin seems more compatible with the facts. The association of uranium with black shales is common, and is known in present day sediments in such areas as the Baltic Sea (Swanson 1961).

As stated above the distribution of the ore does not seem to be related to the distribution of pyrite. However, it has been stated by Swanson (1961) that the significance of pyrite in black shales, is that it indicates the presence, durin- sedimentation, of $\text{H}_2\text{S}$, and this makes the precipitation of uranium possible.
The amount of uranium deposited, however, depends on:

1. Whether H₂S is confined to the sediment or is present in the overlying water.

2. The supply of uranium to the water.

In the case of Rum Jungle the significant fact appears to be that the ore occurs in pyritic sediments. Not all of the pyrite is necessarily syngenetic but since much of it pre-dates the F₁ deformation, it seems reasonable to assume that much of it is. The type of rock that the uranium occurs in is therefore compatible with a syngenetic origin.

If the uranium minerals were syngenetic their presence on S₁ and their sheared nature are explicable. Also, in view of the tectonic and metamorphic history the remobilisation of the ore is no more than would be expected, and finally the stratigraphical control is compatible with a syngenetic origin.

The occurrence of base metal ore at White's and Mount Burton is difficult to explain. All the evidence suggests that the base metal mineralisation is more recent than the pitchblende, but it seems a great coincidence that the two should be associated in two cases. However, no explanation can be offered.

5. CONCLUSIONS

In the opinion of the writer, the available evidence weighs in favour of a syngenetic origin for the uranium prospects studied. During folding the ore probably behaved passively and although it is probably structurally controlled to some extent, on the scale of individual mines, the writer does not consider that deformation has played a big part in the localisation of the ore. It is thought probable that the base metal mineralisation is structurally controlled and this could be a valuable tool in prospecting.

The sequence of events can now be summarised as follows.

1. Basement complex of Archaean intrusives, gneisses and sediments (banded ironstone) was subjected to erosion.

2. Sediments resembling those of "unstable shelf areas" (Krumbein and Sloss 1951) were deposited in Lower Proterozoic sea. The sediments were derived from the near-by Archaean, so that pebbles in the arkoses of the Bostons Formation can still be identified with rock types from the "Rum Jungle Granite".

A thorium rich mineral was deposited in the Crater Formation in the E.B.C., presumably as a placer deposit. Later, in a time when the rocks were mostly finer grained elastics and were rich in carbonaceous material, possibly of organic origin, euxinic conditions prevailed and pyrite and uranium were deposited.

Sedimentation continued but there is no record, in the area studied, after the deposition of the Burroli Creek Formation.

3. Then followed three and possibly four generations of deformation. When they occurred is known only in a relative sense. However, they were responsible for folding the basement into dome and basin structures which explains the present disposition of the "Rum Jungle Granite" and probably the "Waterhouse Granite" also.
At least one of the deformations (F1) was accompanied by regional metamorphism to green schist facies and the final movement resulted in a repetition of the same conditions locally.

(4) At some stage, possibly during the final deformation, the base metal minerals were injected, accompanied by a quartz-tourmaline rich gangue. The quartz-tourmaline veins which invade the granite and sediments probably belong to the same period of hydrothermal activity.

(5) A suite of basic rocks was intruded in post tectonic times.

(6) Erosion reduced the land surface to its present form and exposed the up-domed basement rocks of the "Rum Jungle Granite". In areas where ground water was free to circulate, as between the "dry season" and "wet season" water tables, solution of the uranium minerals began and secondary minerals were deposited.

6. RECOMMENDATIONS

On the basis of the above conclusions the only available geological guide to prospecting is the fact that the uranium ore appears to be stratigraphically controlled. Geophysical techniques can help to outline the disposition of a given horizon as has been shown by work on the "conducting horizon". However, geophysical techniques appear to be inadequate in detecting uranium ore. The only direct technique available is radiometric work and it failed to locate the main orebody at both White's and Rum Jungle Creek South. This means that if the secondary minerals are missing (they weren't very abundant at R.J.C.S.) an orebody may not give an anomaly. For this reason there is the possibility that anywhere near the base of the Golden Dyke Formation (i.e. near the contact with the Coomalie Dolomite), uranium ore may occur. However, the following areas have been singled out as particularly noteworthy in that they are associated with anomalies, are in keeping with the postulated theory of ore genesis and recapture the "ore environment".

(a) **Limestone Contact West of R.J.C.S.**

R.J.C.S. is thought to be on the north eastern limb of a major syncline between the Rum Jungle and Waterhouse granites. It is possible that the Golden Dyke Formation occurs in contact with the limestone on the western limb of the syncline. If so, it would appear to be a potentially good area for the following reasons:-

1. Its stratigraphic position.
2. Like R.J.C.S. is is on the edge of an anomalous area.
3. It is close to known ore bodies.
4. Its environment is probably very much like that of R.J.C.S.

It is suggested that preliminary costeaning be carried out and then drilling can be considered if results are favourable.

(b) **Area 44**

This area is suggested for drilling because:-

1. It is an area where the Golden Dyke Formation is believed to overlie the Coomalie Dolomite.
2. There is a reasonable radiometric anomaly.
(c) West of the Finnis River

To the west of the Finnis River and just north of the Finnis, west of Mount Ritch, there are a number of reasonable anomalies. The writer is of the opinion that much of this area may be underlain by Golden Dyke Formation and some attempt should be made to check the cause of the anomalies. Geological mapping could possibly throw some light on the subject but would be greatly hindered by lack of outcrop over most of the area. Alternatively a few drill holes on one or two of the anomalies might prove that the Golden Dyke Formation and Conglomerate Dolomite underlies much of the area between the Finnis and the Burrull Creek Formation. If this proved to be so, more drilling would probably be worthwhile. On the other hand, if the Golden Dyke Formation was not intersected the situation would have to be reconsidered.

(d) Rum Jungle Granite

Many of the first order anomalies in the Hundred of Goyder occur in the Rum Jungle Granite. No work has yet been done on these anomalies. The writer is of the opinion that a representative number of these anomalies should be examined with a view to finding the cause of the anomalies. Such a project may or may not require drilling. What would constitute a representative number of anomalies would depend on the consistency of the results.

(e) Copper Lamination

The possibility of structural control of the copper mineralisation should be checked. If the Intermediate prospect is mined there could be ample scope for such work, otherwise there will probably be insufficient information to draw conclusions. The possibility of a tie up with the quartz tourmaline veins or the chalcopyrite bearing quartzes and calcite veins in the granite should also be checked.

(f) Semi-opaque Minerals

The nature of the semi-opaque minerals observed in schists from the Rum Jungle Copper Prospect (cf. R.J. O.F. under Part III) should be checked. They may prove an economical by-product if the copper is mined.

(g) Regional Mapping

If any further geological or geophysical work is to be carried out in the Hundred of Goyder, in the opinion of the writer it should be accompanied by regional mapping. The existing regional map was compiled as a reconnaissance map and as such is good but it is an inadequate basis for more critical work. Outcrop is not good but critical mapping paying attention to minor structures could produce a good, factual regional map. Such a project would probably require three seasons in the field and laboratory work, also, since there are many problems involved (e.g. the H.O.R.).

It could possibly be best carried out by a University student working on a similar basis to J. Hodgson in Broken Hill. A student who needed only be in Rum Jungle during the dry season would have better access to literature, laboratory facilities and more opportunity of discussion with experts in the various relevant fields of study.
PART II

Rum Jungle Creek South
ABSTRACT

The R.J.C.S. orebody occurs in a pyritic, quartz-mica schist adjacent to black slate and dolomite marble, both of which are pyritic. These rocks have been subjected to three phases of deformation, the first of which appears to control the distribution of the ore. The first deformation is accompanied by metamorphism to green schist facies and there has been a return to the same conditions during the third deformation. Finally, parts of the orebody have been leached and uranium phosphates have been precipitated in the weathered zone.

1. INTRODUCTION

Rum Jungle Creek South (R.J.C.S.) is situated approximately four miles south-south-west of Rum Jungle. The orebody is tabular in shape, being 750 feet long, 150 feet wide and 130 feet thick, and is 100 feet below the surface. (Spratt 1963) Despite its size and ore grade no radiometric anomaly occurred directly over the orebody. The nearest was a 3 x background anomaly, the south-eastern edge of which corresponds approximately with the north-western edge of the open cut.

The ore occurs in steeply dipping schists of the Golden Dyke Formation and the long axis of the orebody is parallel to the strike of the prominent schistosity. The structure of the Golden Dyke in the mine area was studied in detail and an attempt made to relate the mineralisation to it.

2. LITHOLOGICAL UNITS

Two main lithological units are exposed in R.J.C.S.; they are the black slate and the green schist. Other units occur in drill core and limited exposure in the open cut. The characteristics of the rock types (Appendix) are summarised below:

(a) Black Slate
The black slate is a fine grained rock consisting essentially of quartz, very fine grained opaque minerals and mica. The opaque minerals cannot be identified with any certainty but probably include carbon in some form (carbon is known to be present in the rock - it is apparent in hand specimens and is recorded in chemical analyses) and iron minerals. The micas are usually chlorite and muscovite and occasionally biotite. Pyrite is an abundant accessory mineral, both in veins and disseminated through the rock. Zircon or Sphene is a less common accessory and rutile and tourmaline occur locally. Dolomite (determined by X-ray Diffraction by The Australian Mineralogical Development Laboratories - A.M.D.L) is fairly common in some specimens.

In most specimens two s-surfaces are immediately recognisable. Lenticular and hook-shaped patches of comparatively coarse grained quartz and pyrite occur in bands. The long axis of individual patches is inclined to the trace of a band of such aggregates. The bands define the earliest recognisable s-surface and may represent bedding. For convenience this s-surface is labelled S1. The long axes of the aggregates, which are interpreted as tectonic fish, (McIntyre 1951) are parallel to another s-surface which they therefore partially define. This s-surface is labelled S2, and is further defined by preferred dimensional orientation of quartz and dolomite when present, or by preferred orientation of micas and "stream" of fine grained opaques. Both S1 and S2 are recognisable in hand specimens.

(b) Green Schist
The green schist consists essentially of quartz and mica. The micas in order of abundance are chlorite, sericite and biotite, the latter only occurring in a few of the specimens collected.
"Streams" of very fine grained opaque minerals occur but are less common than in the black slate. Accessory minerals include zircon, tourmaline, sphene and rutile. The rock has a lenticular fabric on all scales and may be more accurately described as a phyllonite (Turner and Verhoogen 1960, p. 454). Lensos of quartz-rich rock, sometimes identical to the black slate occur in a micaceous matrix. Such lenses are equally prominent in this section and on a much larger scale on all exposed faces. The orientation of the lenses and the preferred orientation of the minerals define a foliation that is parallel to S, in the black slate and is also labelled S.

Occasionally tectonic laths appear to define an earlier c-surface as in the black slate, but this is rare and not above suspicion.

(e) **Gray Slate**

The grey slate is so named because of its appearance in hand specimen. It is, in fact, a fine grained, foliated marble with the composition of a calcitic dolomite (Pettifohn 1956). The foliation is defined by the preferred dimensional orientation of the carbonate crystals and the scattered quartz crystals, and by streams of very fine grained opaque minerals. Recrystallisation of carbonate is occurring in some specimens. Veins of coarse grained carbonate crystals with embayed margins are quite common and sometimes contain lenticular areas of polygonal quartz. Some veins appear to pre-date the foliation while others appear to be later. Zircon or sphene and calcite occur as accessory minerals and large euhedral and skeletal crystals of pyrite are not uncommon. Extensive hematite staining occurs in some specimens.

(d) **Limestone**

The so-called limestone is really a coarse-grained dolomitic marble and is known only in diamond drill holes. It consists of coarse interlocking crystals of dolomite which show slight preferred dimensional orientation. There are veins of carbonate and quartz with pyrite. Pyrite is locally oxidised.

(e) **Lower Green Schist**

The green schist described above lies above the black slate. There is another green schistose rock underlying the black slate. It resembles the green schist generally but locally differs considerably. In some specimens the foliation is less well developed and in what appear to be recrystallised specimens, is completely lacking.

Some specimens contain abundant carbonates both scattered through the rock and in veins. Zircon or sphene and ilmenite occur as accessory minerals and locally zircon is abundant and occurs in small aggregates.

(f) **Distribution**

The distribution of the main body of black slate is shown in Fig. 5a. The area to the west of the black slate within the open-cut is occupied by the green schist with lenses of black slate. The lenses of black slate are particularly common along the western edge of the open-cut. The grey slate occurs below the black slate in diamond drill core. Its distribution is patchy and it was not recognised at the surface on the east wall. A patch of grey slate does outcrop on the road in the north-west corner of the open-cut. The lower green schist occurs in drill core below the black slate. Its relationship to the grey slate is variable (i.e. it may be above or below). It outcrops on the east wall of the open-cut. The limestone was only recorded in deep drill holes. The eastern edge of the open-cut may just outcrop onto the hematite quartz breccia (H.Q.B.) of Castlecrag Hill. However, it is not possible to ascertain whether or not the H.Q.B. is in situ in this locality.

3. **STRUCTURAL ANALYSIS**

The contact between the black slate and the green schist generally dips westwards but is complex. Fig. 10 shows a portion of the contact as it can
be seen on the north wall and Fig. 1b as it could be seen in sub area 1; (Fig. 5).

No attempt is made to draw plans or sections to represent the contact accurately because with no knowledge other than outcrop mapping it has not been possible to reconcile the mapping of the upper levels with the geology mapped on the lower levels by D. Berkman and examined also by the writer. Also, interpolation of the contact between mapped surfaces is not justifiable in view of the complexity of the structure.

As stated above there are two s-surfaces recognizable in the black slate and the green schist. In the black slate one is folded and is referred to as a; the other, S, is parallel to the axial plane of the folds.

In the green schist the same situation occurs but S is ill-defined and restricted to micaceous lenses which may themselves define isoclinal folds.

(a) Geometry of S
S is a surface defined by compositional banding and records the earliest recognizable generation of folds, \( F_1 \). Figs. 1a and b, 2a - e, and 3 show typical \( F_1 \) folds. There is some variation between the style of \( F_1 \) folds as defined by the contact (Fig. 1a and b) and the folds defined by S within the green schist (Fig. 2a - e) and the black slate (Fig. 3). This is probably due to the difference in compositional homogeneity. There is considerable variation in green schist but the black slate is very nearly homogeneous on the scale of the microscopic folds. Microfolds in the black slate closely resemble the folds in the green schist but on a microscopic scale the black slate is heterogeneous.

A fold in the black slate was measured in the manner described by Ramsay (1962) and shown to be exclusively according to the slip fold model (Fig. 3). Others certainly appear to approximate to the same model and the style of \( F_1 \) folds in the black slate does not vary appreciably.

The \( F_1 \) folds in the green schist are not so common or obvious as in the black slate. It appears that before folding this rock consisted of alternating bands of sediments which varied principally in the proportion of quartz and clay minerals that they contained. The quartz-rich bands are now represented by lenses of micro-quartz slate including black slates and probably owe their discontinuous nature to deformation, having been broken up during folding into fold knobs and lenticular remnants of limbs. They are, in fact, thought to be fish or tectonic inclusions. This explanation of the lenticular nature of the green schist is preferred to the possibility of it being an inherent feature of the rock because, except where they are hook-shaped, the lenses are parallel or sub-parallel to the schistosity plane \( S_1 \). They are inclined to the green schist-black slates contact by as much as 90°; the outline of the lenses or a relict S surface within them may define a fold symmetrical about \( S_1 \) and the lenticular character of the rock is apparent on all scales.

Thus in the green schist S is usually present only as an ill-defined relic having been largely transposed by \( S_1 \), (Turner and Weiss 1963).

A typical fold (Fig. 2a) from the green schist was measured in the manner described by Ramsay (1962). The measurements indicated that the fold was a product of deformation combining movement according to both the flexural slip and the slip fold models. The degree of flattening varies in different layers in the fold and on the different limbs. Variation is between 30° flattening in the quartztic layers and 90° flattening in the schistose layers.
Liniations parallel to the axes \( f_1 \) of the \( F_2 \) folds are quite well developed. They are defined by the intersection of \( S \) and \( S_1 \), by minor folds and in the green schist by the long axes of tectonic fish.

Fig. 6a is a synoptic diagram of \( F_2 \) lineations. The lineations can be seen to form a girdle which is tending to spread along girdles \( W \) and \( X \). The lineations responsible for girdle \( X \) were all measured in sub area 3 (Fig. 5) and one their distribution to the \( F_3 \) generation of folding. They will be discussed below. Girdle \( W \) corresponds to the cyclic representation of the statistical orientation of \( S \), in the areas where the lineations were measured (Fig. 5). Thus in an area homogeneous in respect of the axial plane \( (a, b) \) the fold axis \( f_1 \) varies considerably \( (70^\circ) \) within the \( a, b \) plane. There are three possible explanations. Firstly, the folded surface \( S \) may have been folded about a different axis prior to \( F_2 \). Secondly, the variation in plunges could be inherent in the folding (Namdy, 1962). Finally \( g \) may have been rotated about a later \( B \) axis which is perpendicular to \( a, b \). There is no evidence to favour either of these possibilities.

(b) Geometry of \( S_1 \)

\( S_1 \) is genetically related to the first generation of folds (\( F_1 \)) and is the most prominent foliation in the green schist. Since the open-cut is excavated largely in the green schist it is, along with a north plunging lineation \( (L_1) \) and a system of vertical joints, one of the most prominent visible structural features. It is rotated, within the open-cut, by two sets of folds which are designated \( F_2 \) and \( F_3 \).

i. \( F_2 \) generation of folds

The \( F_2 \) folds are monoclinical and are not very common. Examples of \( F_2 \) folds are illustrated in Fig. 4 and also feature in a minor capacity in Fig. 1a. In all known examples in the open-cut the lower limb of the fold is offset to the west and the axis is horizontal (as in Fig. 7). The rotation of \( S_1 \) in the sub areas represented by Fig. 5b, c, e and g is about \( F_2 \) axes and the distribution of points can be explained by the style of folding observed in the minor folds (Weiss, 1959).

Fig. 7 represents a minor \( F_2 \) fold which could be seen to rotate the axial planes of \( F_2 \) folds. The significance of this exposure is that members of the two fold systems exist together and their relationship is conveniently and clearly demonstrated. \( S_1 \) is seen to be parallel to the axial planes of the \( F_2 \) folds and both are rotated about the new fold axis \( f_2 \). There is therefore no doubt of the existence of two generations of folds and \( F_2 \) must post date \( F_1 \). However, this does not preclude the possibility of the two being related to the same period of deformation. Again the distribution of \( S_1 \) reflects the style of the \( F_2 \) folds.

All the lineations in Fig. 7 plot in a goal which is axial to the \( S_1 \) girdle. This would suggest at first sight that the lineations are related to the \( F_2 \) folds. However, there are two types of lineation recorded. There are minor \( F_2 \) fold axes and lineations apparently due to the intersection of \( S \) and \( S_1 \). Neither of these lineations could conceivably be related to the \( F_2 \) folds. It is evident that \( L_1 \) is axial to the \( F_2 \) fold. Therefore, in this outcrop \( \beta_1 \) and \( \beta_2 \) are coincident.

\( \beta_2 \) also falls within the \( L_1 \) goal in the sub areas 1, 2 and 4 (Fig. 5) and is close to the only two \( L_1 \) lineations recorded to sub area 6 (Fig. 5). There is therefore close coincidence of \( \beta_1 \) and \( \beta_2 \) throughout the area. Fig. 6b shows the distribution of \( \beta_2 \) and it is evident that if the effects of \( F_3 \) are removed, the \( \beta_2 \) axes can be rotated back along a great circle to a common origin (Points \( X \) and \( X' \) in Fig. 6b).
Thus prior to $F_2$, $\beta$ would apparently have plotted as a point maximum coinciding with the highest values in the partial girdle representing $L_1$ (Fig. 6a).

On the scale of the minor folds no penetrative lineations or $s$-surfaces were recognised which could be related to $F_2$. A non-penetrative shear was recorded and the cyclic representation of two such structures is plotted in Fig. 7. They can be seen to contain the axis of the fold and are apparently parallel to the axial plane.

Fig. 6b also represents what is thought to be an $F_2$ fold. In this example the axial plane shear is developed locally to the exclusion of the fold.

ii. $F_3$ generation of folds
The $F_3$ folds like $F_2$ are monoclinal but usually have steeply plunging axes. In all the major examples recorded in the open-cut the limbs strike almost north-south and the south limb is transported westwards relative to the north limb.

Microfolds of this generation had been recognised and the possibility of macro structures about the same deforming axial plane was realised for some time before a macro structure was discovered. Fig. 8 is a drawing of a portion of a thin section, cut perpendicular to the axes of the micro folds, in a piece of chloritic schist from the green schist series. The micro crenulations were only recognised with certainty in the schistose rocks.

In the stereogram in Fig. 6c the micro crenulations are plotted as a lineation ($L_3$). The girdle distribution can be interpreted in two ways.

Firstly, it may represent the movement plane $ab_3$ which produced the crenulations. Each lineation then represents the intersection of $ab_3$ with a previous orientation of $S_1$. Thus the maximum concentration of $L_3$ occurs at a point in the girdle which corresponds to the intersection of $ab_3$ with the most common orientation of $S_1$.

Secondly, the girdle may be the result of a later generation of folds, according to the slip fold model, rotating the $L_3$ lineation about an axis perpendicular to the great circle represented by the girdle. The same movement would also rotate $S_1$ and the maximum distribution of $L_3$ would still correspond to the maximum distribution of $S_1$.

The first possibility is thought to be the correct interpretation for reasons that will be discussed below.

Stereogram, Fig. 6d, represents a minor $F_3$ fold recorded on the 960 foot bench at a point approximately 27930’N 10640’E. The micro folds plot at the axis of the girdle. Sub area 5 (Fig. 5f) is similarly deformed but on a larger scale and like the minor fold its axis plots on the $ab_3$ plane as determined from the plot of $L_3$ (Fig. 6c). The fold is visible in the west wall of sub area 5 and persists upwards into an area of post mine subsidence.

On the opposite wall of the open-cut in sub area 3 there is a similar structure. This sub area is largely in the black slate and the readings of foliation include $S$ and $S_2$. $S$ is folded about an $F_3$ fold axis. If sub area 3 is subdivided into smaller areas in which $S$ and $S_2$ are unaffected by $F_2$ and $F_3$, plots of $\beta S$ then define partial girdles about the axes $3a$, $3b$ and $3c$. 
These axes are plotted on the $/3$ synoptic (Fig. 6b) and fall on or close to the $a_3$ plane as determined from the plot of micro crenulations (Fig. 6c). This area is therefore affected by the $F_3$ deformation and this also explains the partial girdle distribution of $L_1$. $L_1$ has been rotated by $F_2$. In view of the incipient axial plane cleavage, illustrated in Fig. 8, deformation is presumably according to the slip fold model and $L_1$ should therefore be rotated about a great circle. A great circle can in fact be drawn through the $L_1$ lineations (Fig. 6a) and joins them with the main goal of $L_1$ lineations. The great circle is therefore a possible path for the rotation of $L_1$. The lineations were all recorded in one small area of sub area 3 with the exception of the one point isolated from the rest; this point came from a different part of the sub area. It is ignored in drawing the great circle since its point of origin was probably different to that of the others. (The $L_1$ lineations rotated by $F_2$ are not generally rotated from one point but from anywhere within the partial girdle defined by $L_1$ in Fig. 6a).

The presence of two $F_2$ folds, of major size, relative to the area under consideration, on opposite walls of the open-cut and in line along their axial planes strongly suggests the presence of one major $F_2$ fold traversing the open-cut. This may be so, but the fold was not recognised in sub area 4.

(c) Chronological Order of Folding

It has already been proved that $F_2$ and $F_3$ post date $F_1$ since both rotate the axial planes of $F_1$ folds. The chronological order of $F_2$ and $F_3$ can also be determined.

Fig. 6b is a synoptic diagram of the $F_2$ and $F_3$ fold axes as determined from $\gamma S$ and $\gamma S_1$ girdles. Both the $F_2$ and $F_3$ axes statistically define great circles. The great circle through the $\gamma S$ points is drawn to coincide with the $\gamma S_1$ girdle for the micro folds which are not shown on this diagram. If a fold axis is re-folded according to the slip fold model the early fold axes will be rotated around a great circle containing their original orientation and the movement direction (a). The axes of the later folds will form so that their axes lie in a great circle which defines their $\gamma S$ plane. The two girdles will intersect at the point representing the direction of movement (a) (Ramsay 1960). The result of two generations of folding according to the slip fold model will be the same in respect of $S$, $\gamma S$, and $\gamma S_1$ irrespective of the order of folding. Thus in Fig. 6b the point of intersection of the two great circles (a3) is the direction of movement during the later generation of folding, assuming that the later deformation is according to the slip fold model. This assumption is supported by the fact that the lineations plot on great circles rather than small circles (Ramsay 1960). If $F_2$ post dates $F_3$ the great circle containing its axes must be the plane $a_2$. However, this cannot be since the plane would be tangential to the re-folded folds. If $F_3$ is the later generation the great circle containing its axes will be the plane $a_2$. This plane is orientated so that its trace is parallel to the incipient cleavage observed in the thin sections (Fig. 9). Thus it is reasonable to assume that $F_3$ post dates $F_2$.

The $L_1$ lineations recorded in Fig. 6b were measured on an $F_1$ fold. They also, should be rotated from their point of origin about a great circle towards $a_1^1$. A great circle drawn through these points intersects the $a_1$ plane at $a_1^1$. This point is very close to $a_3$ as determined from the plane of rotation of $\gamma S_2$ and therefore confirms the position of $a_3$.

(d) Joints and Minor Faults

Fig. 6c is a synoptic diagram of 103 joint planes from all parts of the open-cut. There are four, axial maxima, W, X, Y and Z.

The W maximum is due to a series of prominent near vertical joints. The joint corresponds closely to the goal of $L_1$ and $B$, and would therefore be close in orientation to the $a_2$ plane of either generation of folds. However, $L_1$ shows considerably more variation in orientation than does $\gamma S_2$ or
the joint planes and the joints are therefore thought to be ac joints related to the second generation of folds. The nature of the fault with two adjacent maxima fits closely the pattern, observed elsewhere, for ac joints.

The shear joints that give rise to maximum X have already been discussed and are also thought to be related to \( F_2 \).

Both of the above planes are potential fault planes. The displacement on the joints which define X has already been mentioned. Minor displacements of the order of inches were also observed on \( ac_2 \) in two places on the black slaty-green schist contact. In both cases the north block was down faulted.

The origin of the maxima represented by Y and Z is not understood.

(a) Other Lineations
A number of readings were taken of the orientation of a lineation on the west wall of the open cut in sub area 1. The readings are plotted in Fig. 6f. The lineations are defined by quartz boudins and small folds with an amplitude of approximately 2° and are traversed by \( F_2 \) micro cleavages. It is not known where they fit into the general sequence of events but they apparently post date \( F_1 \) since they rotate \( S_1 \). No other occurrence was recorded.

4. METAMORPHIC HISTORY

The mineral assemblages in the rocks from R.J.C.S. belong to the green schist facies, (Turner and Verhoogen 1960). The fact that the minerals are, for the most part, aligned parallel to \( S \), indicates that the metamorphism is syntectonic with the first recognisable deformation (\( F_1 \)).

Locally the micas are not very well oriented but this seems to be due to rotation of existing micas by the final deformation \( F_3 \). There is also a second generation of mica which developed locally due to recrystallisation of the micas originally parallel to \( S_1 \). The second generation micas appear to be parallel to the incipient cleavages \( S_2 \). It would therefore appear that during the \( F_3 \) deformation there was a return to the conditions required to produce the mineral assemblages of the green schist facies. In view of the localised distribution of second generation micas it would appear that the necessary conditions were also localised or did not persist for very long.

In the grey slaty the carbonate indicates two periods of crystalisation. The foliation is defined by preferred dimensional orientation of carbonate and there is recrystallisation on a coarser scale which post dates the formation of \( S_1 \), and may also be related to \( F_3 \).

5. SUMMARY OF THE TECTONIC AND METAMORPHIC HISTORY

Three generations of deformation are recognised in the area occupied by R.J.C.S. open cut. The first is intense and principally according to the slip fold model. It results in almost complete transposition of an earlier s-surface in the green schist and more local transposition in the black slate. The foliation produced by the first deformation and the earlier s-surface are then rotated by two generations of monoclinic folds. The structure is summarised diagrammatically by the block diagrams in Fig. 10. It is not intended that this diagram should, in its final stage, (Fig. 10d) represent the actual disposition of lithological units in R.J.C.S. It is intended to summarise the styles of deformation, the interference of the three fold systems and the sequence of events.
The first deformation is accompanied by regional metamorphism resulting in green schist facies. No metamorphic effects were recognised that could be correlated with the second deformation. The third deformation is accompanied by a little recrystallisation of micas but it is insufficient to obscure the earlier foliation.

The general structure of the mine area is difficult to ascertain. Large lenses of black slate are fairly common in the green schist along the western margin of the open-cut, and are accompanied by two lenses of grey slate. There is no means of telling whether or not these two rock types can be correlated with the main mass of black slate and grey slate on the eastern side of the open-cut. The general structure can therefore be equally well interpreted as an overturned, isoclinal syncline with an axial plane dipping westwards or as a westward dipping limb.

6. **ORE OCCURRENCE**

The orebody, the shape of which has already been described, occurs almost exclusively in the green schist. Mineralisation, however, occurs in patches in most of the rocks intersected in drilling at R.J.C.S. The black slate approximately defines the eastern limit of the orebody except in sub area 3 (Fig. 5). In all other directions the boundary is an "assay boundary" and patches of mineralisation occur outside the orebody. Along the strike of S, mineralisation persists for a distance of up to 2 miles, within the same rock type. It persists upwards into the weathered zone and downwards as far as drilling has penetrated. Across strike it does not appear to persist very far. In sub area 3, high grade ore persists several yards into the black slate and appears to occur principally in vein-like areas of what is thought to be talcose material.

From macroscopic examination the ore is thought to occur as black uranium oxide on the joint surfaces and on the schistosity surface S. No microscopic evidence is available yet. Specimens of ore, including the talcose material mentioned above, were sent to the Bureau of Mineral Resources (B.M.R.) for examination early in 1963 but no results have been received to date.

The upper limit of the orebody does not appear to be related to the weathering profile and often ends below it. Two pods of ore occurred in the weathered zone and scattered traces of ore minerals were recorded very close to the surface. The uranium minerals in the weathered zone were phosphates. Black oxide was not recorded. (D. Haldane personal communication).

As the grade of ore falls towards the western and southern extremities of the orebody there is an increase in limonite in the green schist. There has been oxidation of the green schist, locally, at least as deep as the mine. Where the green schist contains ore there is fresh pyrite and very little, if any, limonite. Conversely where the green schist is very limonitic there is little, if any, ore. The simplest explanation appears to be that there has been circulation of ground water along the western and southern sides of the orebody. The circulating water has provided the necessary conditions for oxidation of the pyrite to limonite and also for the leaching of the orebody. Nothing is known of the extent of the ore before leaching, if in fact, leaching has occurred.

7. **RELATIONSHIP OF OREBODY TO STRUCTURE**

The orebody is elongate parallel to the statistical orientation of the long axes of the tectonic fish and the ore minerals occur largely on the S surface (genetically related to the tectonic fish).
Within the or body "pods" of differing grade of ore can be recognised and they also seem to mirror the tectonic-fold in shape and orientation.

On the basis of symmetry, therefore, there is good reason to believe that the distribution of ore is related to the F₁ folds.

The fact that the only significant occurrence of ore in the black slate is where the slate is rotated by an F₃ fold suggests the possibility of control by F₃. However, the fact that an F₂ control is still recognisable indicates that if F₃ has played any part its effects have been very localised.

The presence of mineralisation on F₂ joint planes also indicates local remobilisation.

8. POST-MINE ALTERATION

During the "wet season" encrustations of a yellow radioactive mineral appeared on most exposed ore bearing faces in the open-cut. Chemical tests proved the mineral to be a uranium, magnesium phosphate suggesting that it is salicite. Thus it appears that the rain water percolating through the rock into the open-cut was dissolving the black oxide and reprecipitating it as phosphate.

Solution of the black uranium oxides occurs equally well in oxidising or reducing conditions and so also does the precipitation of uranium phosphates - a series of minerals which are stable under most natural conditions. The only significant difference therefore between pre- and post-mine conditions appears to be in the degree of ground water circulation. Pre-mine there would probably have been very little circulation of ground water below the level of the "dry season" water table. Soluble oxides could have existed then, in the rock, provided that circulation of ground water was restricted, since pore water would soon become saturated with ions from the soluble oxides. However, the excavation of the mine would greatly increase circulation and once ground water started circulating solution of uranium oxides would occur. Phosphate ions being available, uranium phosphates would be precipitated.

This appears to be the simplest explanation consistent with the facts.
(a) Portion of Black slate/green schist contact on North wall of R.J.C.S. open cut.
(b) Portion of Black slate/green schist contact, sub area I R.J.C.S. open cut. Traced from photograph.
F1 fold styles in the green schist series R.J.C.S. (a) & (e) are traced from photographs.
$F_1$ fold in black slate R.J.C.S. Perfect example of folding according to slip fold model.

**FIG. 3**

$F_2$ fold styles traced from photographs, green schist series, R.J.C.S.

**FIG. 4**
(a) Block diagram of R.J.C.S. showing subdivision into sub areas and distribution of main body of block slate, (shaded). Structural analysis carried out on exposed slopes and within area excavated during writer's stay in Rum Jungle, (dotted and hatchured areas).

(b) to (h) diagrams of foliation planes B lines. R.J.C.S. Sub areas 1, 2, 4, 5 & 6 contours represent distribution of Ti S. Sub areas 3 & 7 contours represent distribution of Ti O.

FIG. 5
(a) $L_1$ synoptic R.J.C.S.

(b) $\beta_2$ & $\beta_3$ synoptic R.J.C.S.

(c) $\beta_3$ microfold synoptic R.J.C.S.

(d) Minor $F_3$ fold from sub area I R.J.C.S.

(e) Joint synoptic R.J.C.S.

(f) Other lineations from sub area I R.J.C.S.

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$> 30\% / 1\%$ area

$20 - 30\% / 1\%$ area

$10 - 20\% / 1\%$ area

$5 - 10\% / 1\%$ area

$1 - 5\% / 1\%$ area
Fig. 7

$F_2$ fold in black slate, sub area I, R.J.C.S.

Fig. 8

$F_3$ microfolds, Thin section from green schist series, R.J.C.S. Field is restricted to a single chlorite crystal.
Fig 9 a is a histogram representing 35 orientations of $S_3$ as measured on thin sections cut perpendicular to $B_3$. 30% of the measurements fall between 35° and 40°. Taking 35° and 40° as the statistical orientation of $S_3$ the plane is represented by its polar projection in Fig.9 b. It is assumed that the plane varies a corresponding amount in the third dimension to the variation in the plane in which the measurements were made. This assumption seems justified in view of the fact that variation in $B_3$ is of the same order. The $aB_3$ plane as determined from Fig.6 c is also plotted in Fig.9 b and as would be expected, if $aB_3$ and $S_3$ are the same plane, its cyclic representation is perpendicular to the polar representation of $S_3$. 

FIG. 9
PART III

Geology of Other Mines and Prospects West
of Rum Jungle Granite
ABSTRACT

The ore is found to occur in pelitic sediments overlying limestone, a fact that has been the guiding factor in prospecting for several years. For the most part the pelites are foliated and all may be classed as tectonites. (Turner and Weiss, 1963)

In all cases the rocks have been subjected to multiple deformation and the resulting structure is complex.

Where the distribution of the uranium minerals is known it is found that pitchblende only occurs below the weathered zone. Near the surface the uranium occurs as secondary minerals - principally phosphates.

In Whites it is found that the uranium pre-dates at least part of the deformation. Elsewhere, its occurrence on the schistosity plane (S) supports an early introduction but there is also evidence of remobilisation.

The base metal mineralisation appears to be post deformation for the most part but there are local complications.

1. WHITE'S OPEN-CUT

The rocks around the periphery of the open-cut, diamond drill core, and boulders removed from the open-cut during excavations, were examined.

(a) Lithology

Thin sections were prepared of specimens representative of the rocks, other than the H.G.B., occurring in White's open-cut. They are all believed to belong to the Golden Dyke Formation with the exception of the Dolomite which is thought to be the Coomalie Dolomite.

Black slate was fairly common in the open-cut, and is well foliated. It is a quartz-sericite slate particularly rich in sericite. Fine grained opaques are common and tourmaline is sometimes present as an accessory mineral. Apatite may also be present. The slate has a strong foliation (S₁) which is folded by at least two generations of microfolds. One set of folds is isoclinal and locally transposes S₁; the other is much more open in style and has an incipient axial plane cleavage. There is also a suggestion locally of an s-surface (S₂) predating S₁.

In parts the black slate is brecciated and fragments are reconstituted by quartz and sulphides.

A number of rocks rich in chlorite and sericite and from their appearance in hand specimen, variously named green slate, green schist and gray slate, were common in White's Open-cut.

They are all micaceous slates or schists containing sericite, and usually chlorite. Carbonate is an important constituent in some examples. Apatite is a common accessory, and sphene or zircon is present in all of the thin sections. Most specimens are well foliated but microbrecciation, which is almost ubiquitous, has destroyed the foliation locally.
The limestone from White's Open-cut is a dolomitic marble. Locally it is well foliated and bands of opaque minerals are isoclinally folded. Elsewhere it is recrystallised into a coarse grained granoblastic marble.

Most of the rocks examined from White's Open-cut show signs of having undergone brecciation, on a macro or micro-scale, after the formation of the foliation S1, and breccia and pug represent a large proportion of the constituent rocks. All except the marble show signs of post S1 deformation in thin sections.

(b) Structural Analysis

No detailed structural analysis was carried out in White's Open-cut at the time of operations. Very little is known therefore other than the fact that the structure was extremely complex. This is unfortunate since it limits the value of records of the ore occurrence. For example, Nathanson and Ward agreed that Embayment ore "was localised on shears through the fold structure". However in hand specimens alone more than one such foliation can often be recognised. A little structural work was carried out by the writer round the periphery of White's Open-cut and several boulders were also examined and yielded a few interesting facts.

(i) Observations in the open-cut

Working round the edge of the open-cut the rocks were found to be well foliated and microfolds proved common. In small areas (areas of exposed face of the order of 150 feet long) the foliation proved in some cases to be rotated about the microfolds. Elsewhere in even smaller areas of the order of only two or three square feet, as many as three generations of microfolds were recognisable. Folding about the three axes is not restricted to microscopic scale and the distribution of the microfolds is therefore meaningless unless some means can be devised of identifying the various generation of microfolds, or they can be studied in fold structures where they are all present and are rotated. The fold described below and represented in Fig. 11 is an example of the latter type of approach.

Unfortunately suitable material for such work was not discovered, in situ, in White's Open-cut nor was a means devised of identifying the various generations of microfold. Fig 12, shows the distribution of microfolds as measured around the periphery. As can be seen the area is heterogeneous in terms of microfolds. It was decided therefore, in view of the apparent complexity of the problem and the lack of suitable material to restrict the study of White's Open-cut to examination of boulders, which might throw some light on the problem.

(ii) Observations on the mine dumps

Fig 13 represents a boulder of black slate. There are two recognisable foliations. One is defined by compositional banding which may represent bedding and is labelled S1. The other is defined by preferred orientation of minerals and is labelled S2. S1 is tightly folded and S2 is parallel to the axial surface of the folds.

Fig. 14 represents a other boulder from White's Open-cut. The rock is again black slate. The earliest surface (S) appears to be defined by preferred orientation of mica as well as by compositional banding. This surface may represent original bedding, in which case the schistosity has developed parallel to it. However, in view of the transposed folding recorded elsewhere in the area (cf. RGE) and the isoclinal folds recorded in Fig. 13 where transposition is beginning to take place, the writer prefers the alternative explanation of regarding S as a foliation
resulting from the transposition of bedding. However, this remains unproven.

S is folded into mesoscopic folds with amplitudes of the order of 2'.
Another foliation, S1, has developed parallel to the axial surface of
these folds and is defined by a weak cleavage. This was presumably the
movement plane, aB1, in the formation of the folds.

A third foliation, S2, is also recognisable and is parallel to the axial
plane of another generation of folds of somewhat greater amplitude. S2 is
defined by a cleavage plane.

The earliest recognisable S surface, whether it be bedding or a transposed
foliation, has therefore been subjected to two generations of folding.

Fig. 11 represents an even more complex example of multiple deformation in
black slate. On a planar area of one limb three sets of lineations were
recognised. They were all defined by microfolds. In the one boulder
mesoscopic folding, about the same axes as the microfolds, was recognisable.
Fig. 11 represents diagrammatically, the structure observed. Movement
on the aB1 and aB2 surfaces is reproduced as accurately as possible.
Movement on aB2 however, has been exaggerated for the sake of clarity.

The first movement, on the aB1 surface, has produced isoclinal folds
recorded by the surface S. S is defined by the common orientation of
minerals (again this suggests the possibility of deformation prior to
movement on aB1). Microfolds have developed on S parallel to the axis
of the main isoclinal fold, but like the other microfold lineations,
are not shown in Fig. 11 for the sake of clarity. Movement on aB2 has
then produced the second set of microfolds and rotated the axes of the
isoclinal folds. Finally movement on aB2 has produced the third set of
microfolds and rotated all earlier structures with the possible exception
of aB2.

Breccia and micro breccia are common rock types in White's Open-cut. In
specimens examined where crenulation folds are recognisable, brecciation
has post dated crenulation. Since the crenulations could be one of three
recognised sets of crenulations this fact does not date the brecciation.
However, it does indicate that it occurred in the latter part of the sequence
of events.

A boulder of typical main shear material was examined. (The writer is
indebted to W.K. Copeman for information regarding the original locality of
this and several other boulders from White's Open-cut). It is a green, very
well foliated schist with intercalations of pink carbonates. The foliation
is not planar but crenulated and the crenulations do not appear to be the
result of one simple movement. If this boulder is typical of the Main
Shear then it would appear that the Main Shear is not a fault but a zone
of movement which is potentionally parallel to the axial surface of a
generation of folds. Further the Main Shear is not the most recent
deforation though it may be related to such. That is to say the foliation
of the 'Shear' is post dated by the crenulations but both may be part of
the same deformation.

(iii) Conclusions

The structure around the periphery of the open-cut and in boulders from
White's is complex. In places bedding may be recognisable, elsewhere it
is apparently transposed. The geometry of the transposed surface itself,
is apparently complex and controlled by at least three different sets of
movement planes. It appears therefore that the rocks of White's Open-cut
have been subjected to at least four generations of movement with breccia-
lation in the later stages.
The detailed structure is therefore very complex. Since the rocks examined were, for the most part, not in situ it is not possible to draw further conclusions.

(c) Ore Occurrence

Both uranium and sulphide ores were mined in White’s Open-cut. On the basis of open-cut mapping the ore body was divided into the following zones: copper-uranium, copper-cobalt, cobalt-nickel and cobalt-lead. (Spratt 1963), Thomas (1956) pointed out that the uranium mineralisation occurred principally in north-south shears while the base metals occurred in east-west shears. He claimed that the east-west shears post dated the north-south and that the sulphide mineralisation post dated the uranium. Unfortunately it is not possible to identify the shears with certainty since they are insufficiently defined. However, it seems possible that his east-west shears are the axial plane foliation of the F3 folding. The latter is the deformation thought to be responsible for the Embayment and is the most recent of the recognised generations of folds.

A mineragraphic investigation of 53 specimens was carried out by Roberts (1960). He recognises two phases of mineralisation. During the first, he claims, pyrite, pitchblende and possibly orosiderite were deposited while during the second, copper-cobalt-lead sulphides were introduced with a quartz-tourmaline gangue. The two phases of mineralisation are said to be separated by a period of movement during which the pitchblende and pyrite were strongly sheared. At the time he wrote, the Rum Jungle Granite was thought to be intruded into the mineralised sediments and Roberts claims that the granite was responsible for the emplacement and was possibly the source of the ore minerals. He points out that this conclusion is not consistent with the age determination results (uraninite 17 x 10^8 years, pitchblende 6.5 x 10^8 years) but claims that these are unreliable anyway. However, it now appears that the “Granite” represents an old land surface precipitating the mineralised sediments and this invalidates Roberts’ conclusions. Nevertheless his work still stands and it can be concluded that the pyrite and pitchblende were deposited in the rock before the completion of its deformational history. The copper-cobalt-lead mineralisation on the other hand post-dates deformation and has the characteristics of an epigenetic deposit.

Roberts claims that the pyrite and pitchblende have been introduced hydrothermally even if they were derived from the sediments. However, he does not substantiate this claim.

Work carried out by the American Atomic Energy Commission (A.E.C.) indicates that uraninite occurs much later in the paragenetic sequence and post-dates the base metal mineralisation. (Hariol Naheet, 1953). However this may well be a case of remobilised uranium.

The examination of boulders from White’s Open-cut supports the theory of two phases of mineralisation. Pyrite in isoclinal folded black slates occurs as saddle roof type bodies. Chalcopyrite however occurs in veins, sometimes parallel to the axial plane of minor folds, and in the quartz cement of brecciated rocks.

The primary uranium ore in White’s Open-cut was pitchblende; in addition secondary minerals were recorded. They occurred in the weathered zone as a capping over the primary ore. (Thomas, 1956) They were mostly phosphatic minerals and included Torbernite, Phosphuranyllite, Autunite, Salinit, Gummit and Johannite. (Spratt, 1963)

(d) Conclusion

The ore minerals are contained in a series of quartz-sericite slates, chloritic schists and brecciated equivalents of both. These rocks have been produced
by intense multiple deformation, accompanied by green schist facies metamorphism, of presumably politic sediments.

Insufficient is known about the structure to relate the mineralisation to it. However, it appears that pyrite and pitchblende, predate at least part of the deformation while the base metal minerals were introduced post deformation.

2. DYSON'S OPEN-CUT

(a) Lithology

Dyson's Open-cut is excavated largely in black slate of the Golden Dyke Formation. Two types of black slate were differentiated in the original mapping and logging of drill core. However, differentiation seems to have been difficult since core logging and mine mapping do not agree. Talcose green schist and H.Q.B. outcrop along one edge of the open-cut and are underlain by limestone. The distribution of the main rock types is illustrated in Fig. 17 which is based on plans and sections accompanying W.N. Thomas' report (Thomas, 1956).

Intercalated with the black slate are lenticular layers of grey, pyritic quartzite. The pyrite in the quartzite and also in the black slate is often coarse grained, (up to \( \frac{1}{4} \)) and euhedral.

In thin section (Appendix) the black slate is more precisely described as a chlorite-muscovite slate and is sufficiently coarse grained to be "banded" between slate and schist.

It is coarser grained than the black slates examined from other areas and contains less quartz. Its structural history seems to have been complex since four lineations are recognisable in the thin section. At least one of the lineations is due to the intersection of a foliation with the observed surface. Sphene occurs as an accessory mineral in the areas of coarse grained mica.

(b) Structural Analysis

Like Whites the structure at Dyson's Open-cut is very complex and there is insufficient accessible outcrop (excluding the H.Q.B. which is not a suitable rock for structural analysis), to form a reasonably detailed picture. A few general observations however were made and are recorded below, along with observations based on the existing plans.

Compositional banding is well defined due to the presence of lenticular masses of grey quartzite, (Acacia gap quartzite) intercalated with the black slate. For the most part the quartzite is parallel to a prominent foliation (S₁) but locally, where the quartzite is isoclinal folded (Fig 15a & b), it transgresses the foliation. The example in Fig. 15a has been refolded about a second axis. Isoclinal folds are also occasionally recognisable in the black slate. (Fig. 15c) Crenulation folds form a common lineation on the foliation surface (S₁). In one two foot square area of an S₁ surface five distinct sets of differently oriented lineations were recognised. When the edges of the rock perpendicular to S₁ were examined only one set could be traced the others were only recognisable as lineations on S₁. It is not possible to analyse such material except on a microscopic scale. Locally S₁ is completely transposed by a later foliation and an example of such a situation is illustrated in Fig. 16.

Wherever S₁ foliation measurements were possible the strike was close to north-south. This however does not appear to account for the disposition of the lithological units which, according to the maps of the Open-cut, (Thomas, 1956) trend approximately north east-south west. In the geological plans
DIAGRAMMATIC REPRESENTATION OF SEQUENCE OF EVENTS IN EVOLUTION OF STRUCTURE OF R.J.C.S.
Diagrammatic representation of a fold in black slate, from White's Open-cut. Three generations of deformation are recorded.

**FIG. 11**


**FIG. 12**
Fold styles in black slate, White's Open-cut. Traced from photograph.

**FIG. 13**

Multiple deformation. White's Open-cut.

**FIG. 14**
all contacts between different rock types are shown as faults. Fig. 17 is a three dimensional representation of the contacts drawn from the plans and accompanying sections. The shapes of the different units are difficult to explain by simple faulting. However, the disposition of the lithological units and the more intense movement evidently recorded along the contacts, is compatible with large scale transposition of earlier compositional banding. More evidently is illustrated on a macroscopic scale what can be seen in any hand specimen of green schist from R.J.C.S. Both are apparently transposed rocks but transposition is recorded on different scales due to the different scales of compositional homogeneity, in the rock, prior to transposition. If transposition has occurred in Dyson's the new foliation is approximately parallel to the 'Main Shear' in Whites and the 'Giants Reef Fault'.

(c) Ore Occurrence

The uranium ore occurred principally in the black slates but also occurred locally in the green schists of the mudstone sequence (Thomas, 1956). The only sulphide recorded was pyrite which is abundant, as subhedral crystals or druses after subhedral crystals, in both the slate and Acacia Gap quartzite.

The uranium occurred principally as salicite. At depth the rocks were recorded as pyritic and some of the uranium occurred as pitchblende (Spratt, 1963). The significance of this statement would appear to be that at depth where the rocks were less weathered (pyrite still present), there was pitchblende, whereas in the weathered zone the uranium occurred as secondary salicite and sklodowskite. Salicite persisted into the pitchblende zone but no doubt the weathering did also.

The ore is said to have occurred on joints and fractures (Thomas, 1956) but there is no detailed account where, or in what state, the minerals occurred.

3. RUM JUNGLE COPPER PROSPECT

No detailed work was attempted at the Rum Jungle Copper Prospect- (R.J. Cu,P.) since available material is at present restricted to drill core and also, since there are no significant quantities of uranium minerals known there, it does not come within the scope of the present project. However, the writer did examine R.J.Cu,P. core and thin sections of two specimens and the following points of interest arose from this work.

(a) Sulphides

Chalcopyrite as in White's Open-cut occurs primarily in the quartz cement of brecias and as veins of chalcopyrite-often without gangue minerals. However, in some specimens of black slats chalcopyrite and quartz occur in parallel laminae which are tightly and intricately folded. The foliation of the slate is parallel to the axial plane of the folds. Thus, although most of the evidence suggests that the sulphides were introduced into the rocks of the Embayment in post deformation times, the story is apparently not quite so simple.

(b) Heavy minerals

A specimen of sericite-quartz schist from Diamond Drill Hole 63 R.J.Cu,3 was examined in thin section (Appendix) and was found to contain an unusual amount of a semi-opaque mineral thought to be sphene or zircon. The mineral is very fine grained and therefore difficult to identify with a petrological microscope. It represents approximately 25% of the constituent minerals of the rock.
Minor folds, Dyson’s Open-cut.

FIG. 15

Transposition of earlier surfaces, Dyson’s Open-cut.

FIG. 16
Diagrammatic representation of main lithological units in Dyson's Open-cut as recorded in plans and sections accompanying W.N. Thomas's report (1956).

- **Mudstone sequence including H.Q.B.**
- **Pugby black slate.**
- **Grey hematitic black slate.**

**FIG. 17**

Scale of feet
4. MOUNT BURTON

(a) Lithology

At Mount Burton the ore body occurred in pyritic black slates, which were intercalated with pyritic quartzite and overlying limestone. The black slates are thought to belong to the Golden Dyke Formation (Thomas, 1956). In hand specimen the black slates closely resemble the quartz-sericite slates recorded in WIGS, Whites and Dymsons etc. The quartzite is typical of the Acacia Gap Quartzite and is recrystallised locally into what looks like glassy vein quartz with pyrite. A typical example of this is illustrated in Fig. 18c.

(b) Structural Analysis

Many of the lenticular masses of quartzite in the black slate in Mount Burton Open-cut are hook shaped and thereby indicate the origin of the well defined foliation in the slates. The foliation, \( S_1 \), is parallel to the axial planes of the fold hooks and has resulted from the folding and transposition of an earlier \( S \)-surface. The earlier \( S \)-surface may have been original bedding but is now only recognizable in relic form, in the fold hooks defined by some of the quartzite lenses (Fig. 18 a & b) and in very occasional folds defined by an early compositional banding in the black slate (Fig. 18a).

The stereogram Fig. 19a, represents:

1. the geometry of \( S \) as measured around quartzite fold hooks
2. the geometry of the hooks as lineations, and other related lineations.

It represents the earliest recognizable generation of folds in Mount Burton Open-cut. This generation is referred to as \( F_1 \). The foliation parallel to the axial plane of the \( F_1 \) folds is denoted \( S_1 \) and its geometry is represented in Fig. 19b. This stereogram indicates that \( S_1 \) has also been rotated into gentle, low amplitude folds. There has therefore been deformation of the rocks after the formation of \( S_1 \). This fact not only explains the partial girdle distribution of \( S_1 \) but also the tendency for \( L_1 \) (Fig 19a) to spread about a great circle. No foliations or lineations were recognised which could be related to this later deformation.

Essentially therefore the structure of Mount Burton can be described as a gently folded, tectonic foliation dipping generally south westerly at 50\(^\circ\) and containing tectonic fish, defined largely by quartzite relics, which statistically have a plunge of 250\(^\circ\)-45\(^\circ\) (i.e. plunge at 45\(^\circ\) in a west-north-westerly direction). This situation is summarised by the block diagram Fig. 19c. In this diagram \( S_2 \) is shown for the sake of clarity, however no evidence is available for its orientation and any other plane intersecting \( S_1 \) parallel to \( \alpha_3 \) is equally possible.

The above folds were designated \( F_1 \) and \( F_2 \) with axes \( \alpha_1 \) & \( \alpha_3 \) because a direct comparison with folding in other areas seems possible and also because a fold of another generation was recorded. It is a very minor feature and has a horizontal axis. It is represented in Fig. 19 (a). The effects of this fold on \( S_1 \) are also represented in Fig. 19 c. There is no means of telling, from the evidence recorded in Mount Burton Open-cut, whether the fold \( F_2 \) is pre or post \( F_3 \). However, the pattern of folding is so like that recorded elsewhere in the area that it would seem to be a reasonable assumption that the sequence of events is the same. Thus the folds are numbered to indicate the suspected chronological order.

The folding recognised during the excavation of Mount Burton Open-cut (Thomas, 1956) is apparently the folding here designated \( F_2 \) with axes \( \alpha_3 \).
(c) Ore Occurrence

The ore is said to occur (Thomas, 1956), around the closure of what is apparently an F₂ fold. However this in itself does not constitute evidence for a structural control and no further evidence, for or against, is available.

The uranium occurs as torbernite in the weathered zone and as pitchblende at depth. Copper ore occurred in the weathered zone as the secondary minerals, malachite, chalocite and native copper.

5. MOUNT FITCH

The mineralisation at Mount Fitch includes uranium and copper minerals but the area is of interest now only as a copper prospect (Spratt, 1963).

A detailed study was made of the costeared area and adjacent outcrops and structural analysis attempted. The geometry of the structure was determined but difficulty was experienced in recognising lincations.

(a) Lithology

According to Mallor (1961) the succession at Mount Fitch is as follows :-

Top  -  Burrell Creek Formation
      -  Tan coloured slates.
      -  Golden Dyke Formation
      -  Chloritic and black slate and phyllite, silicified in places.
      -  Coomalie Dolomite
      -  Locally called "The Limestone".

Bottom  -  Crater Formation
      -  Grits and quartizes.

The area studied in detail includes the Coomalie Dolomite and the Golden Dyke and Burrell Creek Formations. The Coomalie Dolomite is coarsely crystalline and outcrops on the surfe.

The Golden Dyke and Burrell Creek Formations consist almost exclusively of slate, in the area of the Mount Fitch Prospect. In hand specimen the two differ only in colour, and in thin section (Appendix) both are mica-quartz slates. The Burrell Creek slates contain muscovite and abundant accessory tourmaline while the Golden Dyke slates contain green biotite and less abundant tourmaline. They are otherwise alike. In the opinion of the writer, any attempt, without further evidence, to put a formalional boundary between these two rocks in this locality is somewhat speculative. Such lithological variation could quite easily occur within the Golden Dyke.

A specimen of the silicified black slate (Mallor 1961) was examined in thin section. No evidence for silicification was observed and the writer is of the opinion that the rock is a wall foliated, primary grey quartzite.

A specimen of quartzite resembling the Acacia Gap Quartzite and occurring in the black slate of sub-area 8 (Fig. 22) was also examined in thin section. Approximately 25% of the rock is tourmaline. Presumably it has been subjected to tourmalinisation. Veins of quartz and tourmaline are common in the area.
(a) & (b) Examples of F₁ folds, Mt. Burton Open-cut.

(c) Boudin with area of recrystallised quartz.

FIG. 18

(a) Geometry of S & L₁, Mt. Burton Open-cut.  (b) Geometry of S₁, Mt. Burton Open-cut.

(c) Diagrammatic representation of the structure recorded in stereograms (a) and (b).

FIG. 19
(b) Structural Analysis

The slates have a prominent foliation, defined by preferred orientation of the constituent minerals (Appendix). No compositional boundaries were actually observed but the foliation is generally parallel to the inferred boundary between the slate and dolomite and between the two types of slate. It does not follow however, that the foliation is parallel to bedding. In fact, minor folds were recorded (Fig. 20) which indicate that the foliation is an axial plane foliation which has transposed on an earlier s-surface. The earlier s-surface may represent the original bedding. The axial plane foliation is referred to as $S_1$ and $S$ is the earlier relict surface which defines the transposed folds or fish (Fig. 20).

Measurements of the orientation of $S_1$ are represented in the stereograms on map Fig. 22. The stereograms indicate that $S_1$ is itself folded. There is therefore more than one generation of folds, $S_1$ being causally related to the folding of $S$ and itself folded by a later generation of folds.

Lineations, other than minor folds, are poorly developed in the area and no surfaces were discovered on which more than one lineation was visible. The lineations in sub area $S$ were the only ones which could be related to specific folds.

Minor folds were more useful and could be divided into two groups:

1. Those which rotate $S$ but not $S_1$.
2. Those which rotate $S$ and $S_1$.

The folds rotating $S$ are the transposed folds discussed above.

Fig. 21a is a synoptic diagram of:

1. All the $\beta$ axes about which $S_1$ is rotated.
2. The other lineations that are obviously related to folds that rotate $S_1$.

That is to say Fig. 21a is a synoptic of all the measured lineations that are thought to post-date the formation of $S_1$. Most of the points plot on a girdle. The girdle may represent the path of rotation of the lineations defining it or it may represent the movement plane of the deformation which produced the lineations, depending on whether the lineations were rotated into a girdle or developed that way.

The axes of two sub areas and one minor fold do not plot on the girdle but it is possible to draw another great circle though the three points. Unfortunately no more lineations are available to confirm this girdle. The folds plotted on it conform closely to the shape outlined by diamond drilling.

It appears therefore that $S_1$ is rotated by two generations of folds. Great circles can be drawn through the axes of both generations but in one case there is insufficient evidence to draw the great circle with certainty. If however, the great circles are both valid the situation is the same as in R.J.C.S. There are two generations of folds with axes plotting statistically on two great circles. One great circle represents the $H$ plane of one generation of folds and the other the plane in which the axes of the earlier generation are rotated.

As in R.J.C.S. the lineations defining the north-south striking plane are referred to as $l_3$ and the other $l_2$. 

Minor folds, Mt. Fitch Prospect.

(b) $\beta$ synoptic, Mt. Fitch Prospect.

(a) Diagrammatic representation of limestone/slate contact, Mt Fitch Prospect, sub areas 1—7.

$X = \beta$ axes from sub areas 1—8
$\ast$ = other lineations

trace of axial plane
It is again assumed that the final movement is according to the slip fold model. This means that \( a_2 \) is the movement direction for the final movement. The plane represented by the \( L_2 \) girdle does not appear to be a possible axial plane for the structure outlined by drilling (Fig 21). The plane defined by the \( L_3 \) girdle on the other hand is a possible axial plane for the \( F_3 \) folds. Therefore \( L_3 \) post dates \( L_2 \) and the intersection of the two great circles is \( a_3 \).

The axial plane and movement direction of the final deformation at Mount Pitch is therefore similarly oriented to \( aB_2 \) and \( a_3 \) of the final deformation at K.J.G.S.

(c) Discussion of Structure

The geometry of the structure as determined by structural analysis in this case agrees well, in a broad sense, with previous interpretation based on drill hole evidence. (Moller 1961) Moller recognized the main monocline though he apparently thought that it was due to faulting. He also recognized the presence of "offsets caused by monoclinal fold or flexures" which are now shown to be folds (Sub area 2, 3, 6 & 8 in Fig. 22).

There are however, three new facts arising from the structural analysis.

1. The prominent s-surface is not the original bedding.
2. The structure is a product of multiple deformation.
3. The Mount Pitch fault is not recognised since, the geometry of the limestone contact is adequately explained by folding, no evidence for a major fault was recognised and the writer is of the opinion that the stratigraphical evidence is insufficient reason to postulate a major fault, even if the dubious presence of Barrell Creek Formation is accepted.

(d) Mineralisation

The mineralisation occurs in the slates both above the limestone "shelf" and on the steeply dipping limb. (Sub areas 2 and 3). According to Moller (1961) torbernite and pitchblende are the principal uranium minerals and maldonite, asarite and chalcocyprite the principal copper minerals. He also points out that the copper and uranium mineralisation are closely associated. Both occur on \( S_2 \) and on joint planes. Maldonite also occurs in some of the glassy quartz which occurs in boudin-like masses parallel to \( S_2 \). There is patchy mineralisation in the limestone where phosphoranylite and autunite and copper minerals have been recognised.

6. AREA 55

(a) Lithology

In area 55 politic rocks with intercalated quartzites overlie "limestone". Several of the politic rocks, which are thought to belong to the Golden Dyke Formation were examined in thin section. Most of them have only a poorly defined foliation and some are actually hornfelses. Apatite and what is probably zircon and sphene are common accessories. The apatite occurs as euhedral crystals often in a fine ground mass and would appear to have been introduced.

Rounded boulders of a basic or ultrabasic looking rock were found near sub area 3 (Fig 26) (S. Yemen, personal communication). The rock has no foliation and looks like a recent intrusive. No thin section evidence is
available at present but if this rock is a post deformational intrusive it may explain the hornfelsic texture of some of the pelites in Area 55.

(b) Structural Analysis

Only a small part of Area 55 proved to be suitable for detailed structural work and even that was not ideally suited. There is a lack of outcrop and what rocks do outcrop are mainly quartzite. However, three small areas were examined in detail and the general structural picture is very similar to R.J.C.S. and Mount Pitch.

In sub area 1 (Fig 26c) the rock is siliceous but fairly well foliated. The foliation $S_1$ is a tectonic feature as is evidenced by fairly abundant tectonic fish. Examples of the fish which represent the earliest recognisable folds are illustrated in Fig. 23 a 2b and Fig. 24. In this sub area $S_1$ is folded about a number of gently plunging monoclinal folds ($F_2$). A minor example is illustrated in Fig. 24. In this diagram the effects of the monoclinal folding on the earlier tectonic fish is well illustrated. The area however, is not homogeneus in respect of $S_2$ or $F_2$ (i.e. axes of $F_2$ folds). This is due to the effects of a third deformation $F_3$. Fig. 26 is a sketch of an $F_3$ fold from sub area 1. The axial surface of the fold is rotated slightly about a steeply dipping cleavage. The cleavage is so oriented that it could not be related to the monoclinal folds and its relationship to the rest of the structure is very reminiscent of $S_3$ in R.J.C.S. As can be seen from the sketch the lineation ($L_3$) resulting from the intersection of $S_2$ with $S_1$ is very close in orientation to the lineation ($L_2$) resulting from the intersection of $S$ and $S_2$. For this reason no reliable record of the orientation of $L_3$ was obtained in sub area 1. The orientation of the minor $F_2$ folds is represented in Fig. 26d.

In sub areas 2 & 3 $S_1$ defines a good girdle, so the areas are presumably homogeneus in respect of $S_2$. $F_2$ fish were recognisable in sub area 2 but not in sub area 3. The geometry of $S_2$ for both the areas is represented in Figs. 26b and c. The lineations plotted in these diagrams were measured in quartzite layers and by comparison with such lineations elsewhere in the area are thought to be related to $F_2$. This is borne out by the fact that they plot axial to the folds defined by $S_1$.

In Fig. 26d the contoured area represents all the $L_2$ lineations measured. They define a partial girdle which is assumed to represent the movement plane (ab$_3$) which produced the folds. (The $S_2$ plane measured in Sub area 1 does not coincide with ab$_3$ exactly but the difference is no greater than the variation represented by the contours drawn round $L_2$). As described above for R.J.C.S. and Mount Pitch the orientation of the movement direction (a$_3$) during the $F_3$ deformation can be determined. It is represented by the intersection of the ab$_3$ plane with the plane containing the rotated $L_2$.

In summary, as at R.J.C.S. and Mount Pitch, three generations of folds are recognizable. The first is isoclinical and is accompanied by transposition of the earlier s-surface. The second movement is monoclinical and about gently plunging axes. The third plunges were steeply and has a gently plunging movement axis a$_3$, which coincides closely with the orientation of a$_3$ at R.J.C.S. and Mount Pitch.

(c) Mineralisation

Traces of copper lead and uranium minerals occur in the pelites adjacent to the limestone contact. Tourmaline is reported in the area.
Tectonic Fish, Area 55.

**FIG. 23**

Fi folds and S₁ rotated about β₂ in siliceous black slate, Area 55.

**FIG. 24**

Fi fold (defined by shaded area) and S₁ refolded about β₃ (F₃ fold axis) L₁ is parallel to β₁ and L₃ is parallel to β₃, Area 55.
(a) Area 55. Plan reduced and modified from T.E.P.

Plan No. RA 55/61.

Siliceous grey slate.  
Chloritic schists.  
Limestone.  
Sub Area boundaries.  
Interpreted fault.  
Costeans.

Scale of feet

(b) Sub Area 2, geometry of $\tilde{T}$ $S_1$ & $L_3$ Area 55.

(c) Sub Area 3, geometry of $\tilde{T}$ $S_1$ & $L_3$

Area 55.

(d) $L_2$ & $L_3$ synoptic, Area 55.  
$L_3$ is contoured.

FIG. 26
PART IV

Regional Geology
ABSTRACT

Evidence is presented indicating that the "Rum Jungle Granite" is an Archean landmass, predating the overlying sediments. A possible explanation of the outcrop shape is presented, suggesting that the granite is simply the core of a domal structure.

The hematite quartz breccia is interpreted as a primary quartzitic sediment.

Structures in the Gelia Dolomite previously identified as Colllonia are re-interpreted as tectonic structures.

Tourmaline rich quartz and certain basic rocks are recognised as late intrusives.

1. STRUCTURAL ANALYSIS

Introduction

A cursory examination was made of the regional structure. Slates and schists do not represent a very large proportion of the outcropping rock and this renders structural analysis more difficult. Further, the complexity of the area necessitates a detailed study in order to obtain a reliable picture of the structure. The work carried out by the writer is a compromise with time but it is believed that the main features of the tectonic history have been recognised and that the interpretation presented here will prove to be broadly correct. It differs from previous interpretations principally in that three generations of deformation are recognised, the Giant's Reef is regarded as a structure related by common cause to folding rather than the cause of folding, and the disposition of the granite is explained by folding instead of by intrusion.

Detailed work including statistical analysis was carried out in a number of widely separated, selected areas. The intervening ground was covered by landrover and on foot as extensively as possible.

Figure 27 is a plan of the area covered based on the Rum Jungle District Special Sheet prepared by the B.M.R. The area has been divided into a number of sub areas. These are not areas strictly homogeneous in terms of structure but are areas characterized by some broad structural feature. They are described in detail below.

(a) Regional sub area 1

Sub area 1 includes Mount Fitch and Mount Burton. Three generations of folds were recognized at Mount Fitch and three prominent s-surfaces. These features can be traced from Mount Fitch to Mount Burton. The surface labelled S2 at Mount Fitch can be traced all the way, as the most prominent foliation. It strikes generally north westly and dips at varying angles to the west. Tectonic fish representing the earlier transposed surface (G)occur throughout the area. A particularly large example occurs at Mount Fitch between the granite and the costeared area. In outcrop it is approximately semi-circular and measures 100 yards by 70 yards (Figure 28a). Compositional banding is well preserved and would appear to be relict bedding. This is evidenced by cross bedding and gravel and pebble beds. The cross bedding indicates a north younging, and therefore, also taking into account its outcrop pattern, suggests that the structure is a right way up north plunging syncline.
S1 is well developed throughout the outcrop. In the quartzite it is defined by bands of what appears to be recrystallised quartz. In the coarser grained material it is defined by the elongation of the pebbles. Figure 28b is a sketch of a typical piece of bedded rock from the outcrop.

Close to the contact, the granite is strongly sheared and reduced to a quartz sericite schist. The foliation is parallel to S1 in the sediments and the two are presumably of the same origin (Figure 29a). This statement holds good wherever S1 was recognised in both granite and sediments throughout the Hundred of Oynder. In sub area 1 S1 is also parallel to the granite contact.

At Mount Fitch and Mount Burton the effects of F3 were recognisable but S3 was not identified. However, elsewhere in the sub area S3 can be recognised. It is recognisable principally in the schist derived from the granite, this being the only good schist outcropping in the area.

The orientation of S3 in the granite (Figure 29a) is slightly different from its orientation in the sediments (Figure 29b). Generally throughout the area examined S3 has a strike closer to east-west in the granite than in the sediments and this fact is reflected in the Giant's Reef Fault which changes direction on entering the granite and again on leaving it (Figure 27).

For the most part F3 folds are very open in style in sub area 1, but at Jack White's Camp on the East Finnis, there is a minor F3 fold with much more appressed limbs. It resembles the Enbayment area on a small scale and the fold in the sediments gives way to a quartz-filled fault in the granite. The geometry of this fold is represented by the sketch map and stereogram in Figure 29c and Figure 29d. The movement direction a3 (Figure 29d) is determined from the intersection of the great circle representing the rotation of F1 lineations, and the great circle representing the orientation of S3, as determined from a synoptic diagram of L3 (Figure 29b). This movement direction corresponds closely to that determined for Mount Fitch.

Figure 29a is a plot of measurements made on Mount Fitch, that is to say, the hill named Mount Fitch. The readings were taken on the hill itself and close to the two caustics at the foot of the hill on the east side. The main points illustrated by this stereogram have already been referred to; they are parallelism of S1 in the granite and sediments and the slightly different orientation of S3 as measured in the granite (the TI S3 points). Also in this diagram there are partial L2 and L1 girdles. However neither girdle is well defined and the orientations of the two are very similar. Therefore any attempt to use them to determine the orientation of a3 would be open to error.

In summary sub area 1 can be divided into two areas along the granite contact, both of which are homogeneous in terms of S3 and the associated movement axes a3, b3 and c3. L3 is spread about a girdle and a3 may also have a girdle distribution but insufficient points were recorded to establish this.

(b) Regional sub area 2

Most of the observations made in sub area 2 were made in RJCS open-cut. Outcrops in the north, on the edge of the Enbayment Area, were examined in detail and the presence and orientation of S1 checked elsewhere.
RJCS has already been described. In the northern area the granite outcrops and as in sub area 1 the granite is strongly retrogressed and foliated ($S_1$) close to the contact. $S_2$ in the granite and $S_3$ in the sediments are parallel, and are parallel to the contact. They are rotated about a near vertical axis (Figure 30a) presumably by the $F_3$ movement. The contact in this area is tightly folded and $S_3$ is apparently parallel to the axial plane of the folds (Figure 30b and Figure 30c).

Sub area 2 is characterised by its well developed foliation, $S_1$, which dips steeply south westerly. $S$ is almost completely transposed and recognisable only as tectonic fish and $S_3$ is rotated by two later generations of folds. The picture is essentially the same as in sub area 1 and is summarised by the geometry and sequence of events recorded in RJCS open-cut.

(c) Regional sub area 3

Area 55 was the only locality in sub area 3 where the sequence of events was discovered. It proved to be the same as in regional sub areas 1 and 2. This sub area, which is essentially the Embayment Area plus Area 55, is characterised by its complexity, and the fact that many of the foliations and folds trend at right angles to the dominant structures recorded in regional sub areas 1 and 2. This is well illustrated in the Dyson's Open-cut Figure (Figure 17).

The granite contact in the Embayment area was examined and it was found that $S_1$ is not parallel to it (Figures 31a and 31b) and the angle between the two increases from west to east. In the sediments above the contact, another s-surface is recognisable and is parallel to the contact. This surface ($S$) and the contact are folded, apparently due to movement on $S_1$, into generally open folds. Where the folds are more apressed, as in Figure 31b, $S_1$ is parallel to the axial plane. Bands of pebbles parallel to $S$ and general appearance indicate that it is probably original bedding. The rotation of $S$ is illustrated by the stereogram Figure 31a. This is an $F_1$ fold since it is produced by movement on $S_1$ but it is very different in style to the $F_1$ folds in regional sub areas 1 and 2. The significance of this point will be discussed later. $S_3$ is also rotated a little but this is due to the effects of $F_3$ and is about a different axis. The axis lies on the $\beta_3$ girdle as determined in regional sub areas 1 and 2 and in Area 55.

Further examination of the granite contact indicated that $S_1$ is strongly rotated and the evidence is presented in stereogram Figure 31d. The points represented were measured along the northern edge of the Embayment between the railway and the Giant's Reef Fault. The axis about which $S_1$ is rotated has a possible orientation for a $\beta_3$ axis and the general disposition of the Embayment is what would be expected of an $F_3$ fold. Considerable work would be required in the Embayment area to prove conclusively that it is an $F_3$ syncline. However, in the absence of further evidence and in view of the rotation of $S_3$ and the structure recorded in Area 55, this seems a reasonable assumption. This means that many of the folds trending parallel to the trend of the Embayment area are in all probability $F_3$ and $F_3$ folds rotated through almost 90°. It also means that the lenticular, lithological units recorded in Dyson's Open-cut may well be tectonic fish related to $F_1$. 
If this explanation of the embayment structure is correct then sub area 3 differs only from sub areas 1 and 2 in the intensity of the \( F_3 \) deformation, and is not the product of a unique movement. The Giant's Reef Fault may represent the climax of the \( F_3 \) deformation in the Embayment area, or it may represent a later movement along an existing plane of weakness. However, it cannot be the cause of the Embayment, as has been suggested (Allen 1960), since the main rotation is contrary to what it would then have to be. This point is demonstrated in Figure 32.

There is more than one crenulation cleavage in the Embayment area. They may all be related to the \( F_3 \) movement but insufficient is known about them to say more.

In regional sub areas 1 and 2 the structure is comparatively simple since although three generations of folds are recorded, the final deformation is not intense. However in regional sub area 3 the final deformation is intense and is again superimposed on two earlier fold systems; for this reason the resultant geometry is complex. This is particularly true since the \( F_3 \) movement has not completely transposed the earlier structures.

(d) Regional sub area 4

This area differs markedly from the previous three in that there is only one well-developed s-surface and it is the original bedding. The sedimentary origin of the surface is indicated most convincingly by ripple marks and current bedding. The current bedding is particularly common and both are well preserved. In all cases examined, where the "way up" could be determined, the result was the same and indicated that the sediments are right way up.

Minor folds are recognisable in the area. Those measured did not appear to be cylindrical, however this could be due to the effects of current bedding. Alternatively it may be due to the effects of later deformation or may be inherent in the folds. The folds trend approximately west-south-west, east-north-east and the largest example is quite obvious from the distribution of outcrop in Figure 27.

These folds do not appear to fit into the pattern observed in regional sub areas 1, 3 and 3. In style they do not resemble any of the previously recorded folds except that unusual \( F_1 \) folds recorded in the Embayment. In orientation they also differ greatly from the other generations of folds. It is thought that they probably represent gentle folding predating the \( F_1 \) folds recorded elsewhere in the area. They may be largely responsible for the rapid plunge reversals recorded in the \( F_1 \) tectonic fish and may have played an important part in the formation of the dome structure of the Rum Jungle Granite.

\( S_1 \) is recognisable locally in regional sub area 4. It is recognisable in the west on the edges of area 2 and is recognisable locally in the Beeston Formation and at the edge of the granite, where it folds the contact. Regional sub area 7 is a particularly large example and \( S_1 \) is sufficiently well developed to justify making it a separate area.

The effects of \( F_1 \) are not very obvious in the Crater Formation but it may have been "protected" by the considerable thickness of limestone on either side of it.
The limestone has been greatly deformed and bands of coarsely
developed carbonate and layers of quartz are contorted into
complex shapes. The so-called Collenia are probably an example of
such deformation.

(a) Regional sub area 5

The Golden Dyke Formation gives rise to high relief where it outcrops
in regional sub area 5. It consists largely of slates and therefore
records the structure quite well.

Two principal s-surfaces are recognizable. S is the earlier of the
two and is probably bedding. \( S_1 \) is a foliation generally striking
northwest and dipping steeply.

Area 65 and the ridges to the north east of it were examined in detail.
Since no obvious variation was recorded in the rest of the area this
would appear to be fairly representative. The geometry of \( SS_1 \) is
represented in the stereogram Figure 32a. It reflects the style of
folding which is apparent from the regional plan (Figure 27) and which
is illustrated by the diagrammatic representation of a minor fold in
Figure 33c. S is therefore folded into open folds which plunge steeply
to the south east.

Figure 33b represents the geometry of \( SS_1 \) measured in a larger area
than, and including, the area covered by Figure 33a. It indicates that
\( S_1 \) is not completely homogeneous but is itself rotated. The rotation
could well be due to the effects of the \( F_2 \) and \( F_3 \) deformations recorded
elsewhere.

(f) Regional sub area 6

Very little structural analysis was attempted in this area. Outcrop is
for the most part sparse and inaccessible. This is particularly true of
Area 44. However, a few general observations were made.

Where pelitic rocks outcrop they are well foliated and the foliation
tends to strike in a north south direction with near vertical dips.
In the other rocks, another s-surface is sometimes recognizable and
dips, like the granite contact, towards the east.

Locally, in the arkose, lying directly above the granite, there are
two s-surfaces recognizable. One is defined by compositional banding and
dips eastwards at about 60°. The other is a metamorphic foliation and
strikes approximately 350° and dips about 85° westerly.

In area 44 a number of minor folds were recognised resembling \( F_2 \) folds in
style. The orientation of the fold axes is such that they plot on the \( L_2 \)
girdles obtained in other sub areas. It is therefore quite probable that
they are \( F_3 \) folds.

(g) Regional sub area 7

Regional sub area 7 comprises Mount Stratton and the ridge to the south
of the hill. A prominent topographical feature, it consists of a well
foliated quartz-sericite rock. The foliation is labelled \( S_1 \) and is
thought to correlate with \( S_1 \) elsewhere in the area.
At the northern end of the ridge the orientation of $S_1$ changes considerably and the foliation is strongly crenulated. The crenulation cleavage strikes almost north south.

It is thought that this area represents a return to the conditions prevalent along the west side of the granite. $S_2$ is again the dominant foliation and is folded by a later crenulation cleavage. The orientation of the crenulation cleavage is a little unusual for $F_3$, in so far as it deviates from the statistical norm more than $S_2$ measured in any other area. However this does not preclude the possibility of it being $S_3$. Further, it seems likely that there is more than one crenulation cleavage related to $F_3$, but the work carried out has not been sufficiently detailed to clarify the situation. More work is required in the Embayment area in particular.

The geometry of regional sub area 7 is represented in stereogram Figure 34.

(h) Conclusions

A possible explanation of the observed facts recorded above is summarised in Figure 35. In Figure 35a the granite contact and overlying sediments are gently folded. The only evidence for this stage is in regional sub area 4 and there is no evidence of the folds rotating the granite contact. However, if folding was "plis de couverture" over the granite the significant effect of this stage, i.e. the up-folding of the granite, could have been achieved by the $F_3$ deformation in the final stage. That is to say, to produce a dome by interference of folds, there must be two upward movements and they may be in any order (O'Driscol, 1962).

If the first folds did not affect the granite, $F_2$ had a vertical component (i.e. $a_2$ is not horizontal) relative to the present surface and this alone would have been sufficient to produce a dome. The area of sediments, which from the map appear to be folded down into the granite at the northern end, could be related to such a deformation.

The second stage is intense folding according to the slip fold model. This is the $F_2$ folding. It is visualised uplifting the granite to form a series of domes, where $F_2$ anticlinal crests intersect the earlier fold crests and basins, corresponding to intersection of synclines. An axial plane foliation is associated with this movement. On the fold closures the foliation makes a large angle with the earlier a-surface and is not so well developed, except locally (e.g. sub area 7), since, though transport is great, deformation is slight. On the limbs, since the folds are isoclinal, deformation is great and the new foliation completely transposes the earlier a-surface. The granite contact is therefore parallel to the new foliation. Figure 36 shows this in section, in more detail.

The effects of $F_2$ are not represented in Figure 35 since they are thought to be only of minor importance with regard to the final shape, and would therefore complicate the diagram unnecessarily.

However the $F_2$ deformation may have been responsible for rotating $S_1$ away from a vertical position. It is usually assumed that the major strain axes are arranged, at the time of deformation, so that two are tangential and one perpendicular to the earth's surface.
Sketch map (based on the "Rum Jungle District Special Sheet" compiled by the B.M.R.) showing the positions of the regional sub areas.

Scale of miles
(a) Sketch map of outcrop of quartzite and grit, 100 yards east of old prospectors shaft at Mt. Fitch.

(b) Sketch of fragment of rock from outcrop represented in (a).

FIG. 28

(a) Geometry of s-surfaces and lineations on Mt. Fitch. \( \parallel \) Si as measured in sediments is contoured.

(b) Ls synoptic for regional sub area 1. (cf. FIG. )

FIG. 29

(c) Sketch map of minor fold near Jack White's camp.

(d) Geometry of minor fold shown in (c).
(a) Contours represent geometry of $\pi S$ as measured in the granite, regional sub area 2.

(b & c) F1 folds in granite contact, regional sub area 2.

FIG. 30

(a) Granite contact, Western end of Embayment.

(b) Granite contact, Eastern end of Embayment. Traced from photograph.

(c) Geometry of $\pi S$, $\pi S$ and Li for area part of which is illustrated in (a).

(d) Geometry of $\pi S$ as measured in the granite Embayment area.

FIG. 31
(a & b) Rotation theoretically resulting from a transcurrent movement in the same sense as the Giant's Reef fault. (c) Diagrammatic representation of Embayment area.

FIG. 32

(a) Geometry of $\Pi S \& L_1$, Area 65.
(b) Geometry of $\Pi S_1$, Area 65.

(c) Diagrammatic representation of minor Fl fold, Area 65.

FIG. 33

Geometry of $\Pi S_1$, $\Pi S_3$ & $L_3$, Mt. Stratton.

FIG. 34
Diagrammatic representation of the main structural stages in the sequence of events in the Hundred of Goyder. F₂ is not represented for the sake of clarity since no major F₂ folds were recognised. Note the similarity between the outline of the granite in the constructed diagram (c) and the actual outline FIG. 27.

(a) Gentle folding recognisable only in sub area 4, FIG. 27

(b) F₁ folding superposed on (a) to produce dome structure, granite contact shown intersecting present erosional surface.

(c) F₃ folding superposed on (b) modifying shape of granite outcrop.
Diagrammatic interpretative section through Rum Jungle Granite. Present erosional surface and the position of the regional sub areas, in relationship to the structure, is indicated.

FIG. 36

Synoptic diagram of F3 movement axes as determined west of the Rum Jungle Granite.

FIG. 37
The final drawing, Figure 35c, represents the $F_3$ movement. It refolds the granite and sediments and produces the final shape of the granite, including the Embayment area, and considerably complicates the structure. The movement direction $a_3$ is known fairly well for this deformation and is represented in Figure 37 which is a synoptic of $a_3$ points as determined in various areas. If the assumption that major deformational axes must be such that two are tangential and one perpendicular to the earth's surface, is valid, then considerable rotation of the rocks must have occurred since the $F_3$ folding.

From the above explanation it is apparent why the angle between the granite contact and $F_3$ becomes progressively greater in the embayment area. In travelling from west to east one goes from the limb of the $F_1$ fold towards the closure (cf. Figure 10).

A number of the above points are not proven and the explanation involves two possibilities. However, either explanation is consistent with the recorded facts.

2. STRATIGRAPHY

Spratt (1963) has already indicated that ideas have changed regarding the position of the Rum Jungle Granite in the sequence of events. Further evidence for considering the Rum Jungle Granite as pre-Beestons Formation land mass, has been discovered. This and other aspects of the regional geology are discussed below.

The stratigraphy, as it is now interpreted, in the area studied, is as follows:

Burrull Creek Formation
Golden Dyke Formation including Acacia Gap Quartzite
Hematite Quartz Breccia
Coomalie Dolomite
Grator Formation
Gellia Dolomite
Beestons Formation

"Rum Jungle Granite" basement rocks

(a) Rum Jungle Granite

Variation in the Rum Jungle Granite has been recognised for some time. Roberts (1960) quotes analyses carried out by the B.M.R. and refers to two periods of intrusion. However in 1962 B. Ruxton of the B.M.R. (personal communication) recognised pebbles of granite in the Beestons Formation north west of Batchelor, between the Batchelor-Rum Jungle road and the power line. He therefore postulated an Archaean, granite landmass and a more recent intrusive granite which he suggested may have been responsible for the apparent stock-like structure of the granite.

The writer examined the full length of the contact with the sediments, of the southern half of the granite between Mount Pitch and the intersection of the Giant's Reef Fault with the eastern edge of the granite. A number of different rock types were recognised and a partial sequence of events established.
On the western side of the Rum Jungle Granite three rock types were recognised. A quartz biotite hornfels, (Specimen R 75, Appendix) which is sometimes weakly foliated in hand specimen, is intruded by a coarse grained pink granite (eg. Specimen R 664, Appendix) which in turn is intruded by a fine grained pink granite (eg. Specimen R 668). The fine grained rock which is the most recent member of this series was the rock described by Ruxton as the "late granite".

The east side of the Rum Jungle Granite, south of the Giant's Reef Fault, is largely occupied by a coarse-grained, well foliated granite. This rock is again intruded by the fine grained, pink granite.

In the eastern half of the "Granite", close to the Giant's Reef Fault, there is an area of somewhat different rock types. A tightly folded quartz biotite gneiss (Specimen R 82, Appendix) is intruded by a rock which probably originally had the composition of a quartz diorite or granodiorite (Hatch, Wells and Wells, 1952) (Specimens R 80, 83 and 90, Appendix). Also in this area, and apparently within the bounds of the Rum Jungle Granite, there is a tightly folded banded ironstone (Specimen R 93, Appendix).

The time relationship between these three rocks and the granitic rocks is not known. However, both the gneiss and the banded ironstone are strongly folded and it seems probable that they pre-date the granite.

All of the rocks examined from the Rum Jungle Granite with the exception of the banded ironstone and tourmaline rich quartz and pegmatite (Specimen R 107, Appendix) were found to be foliated and retrogressed. In most cases the feldspars in the granite are heavily sericitised and locally, complete alteration to sericite has occurred. Feldspars in the granodiorite have been strongly muscovitised. The foliation varies in intensity and is particularly well developed along the western margin of the "Granite". It also varies in orientation but within the same limits as variation in the orientation of S1 in the sediments.

It appears therefore that all the rock types recognised in the "Granite" with the exception of the tourmaline rich veins and dykes, pre-date the deformation.

With the exception of the granodiorite, it is also apparent that the Rum Jungle Granite pre-dates the sediments, since pebbles of late granite are quite common in the overlying arkose, especially along the eastern margin of the granite. The identification of the pebbles in hand specimen has been confirmed by thin section examination (eg. Specimens R 1064, 1068 and 1030, Appendix). The granodiorite may also pre-date the sediments but at present there is neither evidence for nor against.

M. Rhodes of the B.N.R. (personal communication) was of the opinion that some of the rocks in the centre of the granite close to the Giant's Reef Fault may possibly post-date the deformation. Unfortunately his work was not complete at the time of communication and the writer is not aware of his final conclusions. However, his more detailed work on the granite should clarify a number of points.

Pyrite is a common accessory mineral in this series of rocks and appears to have been introduced at a late stage. Half inch, euhedral crystals occur in granite which has been reduced to quartz sericite schist.
This point is clearly demonstrated in the granite, close to the contact, near the two coast ends east of Mount Fitch.

Chalcopyrite has also been recorded near Kanyaka siding in calcite rich quartz veins (Rhodes, personal communication).

The absence of pegmatite intrusives in the overlying sediments is strongly in support of a pre Beestons age for the granite.

In summary, therefore, the evidence indicates that the southern half of the Rum Jungle Granite is mainly basement and existed before the deposition of the sediments from which it is separated by an unconformity.

(b) Beestons Formation

Being the basal rock of the sequence the Beestons Formation includes the arkose in which the granite pebbles are found. It is often difficult to distinguish from the granite and, as was pointed out by Ruxton, (personal communication) much of the rock mapped as granite around A in Figure 27 is actually arkose and presumably Beestons Formation. Beestons is also thought to outcrop at B in Figure 27.

The distribution of this Formation may reflect its original distribution. That is to say, the sediment may have existed in lenticular form and been absent from the succession in what is now regional sub areas 1, 2 and 3. However, its absence from these particular sub areas could equally well be a function of the intense deformation that they have undergone. It could have been completely attenuated in these areas.

(c) Celia Dolomite

The distribution of this rock type is similar to that of the Beestons Formation. It also may reflect the original sedimentary distribution or later tectonics effects.

Fossil localities are shown in the Celia Dolomite on the Rum Jungle District Special Sheet. The "fossils" have been tentatively identified as Colliuria. However, in the opinion of the writer, they are inorganic.

They are best developed where thin quartz lamellae are intercalated with the limestone. Figure 38a is a photograph of a typical example. Where the quartz is not present the structures are sometimes still recognisable but less obvious, and usually much larger. The largest recorded were of the order of ten feet along the long axis of the oval section. Where there is no quartz the banding in the limestone is defined by regular variation in crystal size. Layers of coarse crystals are intercalated with layers of very fine crystals. The shape and orientation of the non siliceous types is the same as that of the ones defined by quartz lamellae and any explanation of one must fit the other.

The specimen in Figure 38a has an obvious symmetry and this is even better developed in the structures lacking quartz lamellae. The geometry of these structures could easily be reproduced by the intersection of two fold systems, as has been demonstrated clearly by O'Driscoll (1962) with the use of models.
Figure 38b is a sketched section through a number of the structures. As can be seen the quartz lamellae are continuous and the amplitude of the structures decreases towards the top of the layer of rock in which the quartz lamellae occur. In Figure 38c the morphology is somewhat different. This variation could be explained structurally by variation in intensity of folding.

All of the above facts could possibly be explained while still considering the structures organic, however there are two further points which are more compatible with an inorganic origin. Firstly, isoclinal folding is common in the Celia limestone and the style of folding (Figure 38b) closely resembles the "Collenia" as seen in section. Apart from the coincidence of style it is difficult to imagine how an organic structure could have survived the deformation and suspected recrystallisation. Secondly, if the orientation of the two possible axial planes, shown in Figure 38a, is measured, they are found to coincide reasonably well with the predominant regional orientation of $S_1$ and $S_2$. The lineation defined by the "Collenia" is constant (Figure 38d) and coincides with the intersection of the two axial planes. The fact that the most obvious possible axial planes should show close coincidence with regional structure and the fact that the "Collenia" defines a lineation which does not vary in orientation, is consistent with a structural interpretation but seems rather coincidental if the "Collenia" are organic.

It is not suggested that all Collenia are inorganic. It is suggested that the structures in the Celia Dolomite, which have been described as Collenia, are in fact tectonic structures.

(d) Crater Formation

Radioactivity in the Crater Formation is abnormally high. A 4X background anomaly is the rule rather than the exception in the areas where this formation outcrops. Work carried out by W.M.B. Roberts of the B.M.A. indicated that the radioactivity was due to Thorium occurring as thorite. This mineral is associated with other heavy minerals including rutile, tourmaline and zircon. Roberts points out that the association strongly suggests a syngenetic origin, as a placer deposit.

The hematite boulder conglomerate (H.B.C.) is a prominent member of the Crater Formation. It is a very distinctive rock consisting of cobbles of tightly folded, banded ironstone. Two outcrops of banded ironstone were recorded amongst the "Rum Jungle Granite" basement rocks. One has been mentioned already in the discussion of the "Rum Jungle Granite". The other occurs at the south east corner of the "Granite" at the point marked C in Figure 27. It outcrops between the Boonston formation and the granite and its contact with the granite could be intrusive. Specimens from both of these outcrops closely resemble the boulders and cobbles of banded ironstone which constitute the bulk of the H.B.C. It seems probable that they are the same rock which has been eroded and redeposited in the Crater Formation.

(e) Coomalie Dolomite

Collenia-like structures are recorded in the Coomalie Dolomite but were not examined by the writer.

A number of specimens of Coomalie Dolomite were examined in thin section (eg. R 3B, Appendix). In some cases the rock is strongly foliated, elsewhere recrystallisation can be seen to obscure the foliation. The Hematite Quartz Breccia occurs closely associated with this rock.
(ii) Hematite Quartz Breccia

(1) Introduction The origin of the Hematite Quartz Breccia (H.Q.B.) is a controversial topic and may be of no special significance in a study of ore genesis. However, two of the theories of its origin require complete silicification of considerable volumes of limestone. If such silicification has occurred then in view of the proximity of the H.Q.B. to the larger ore bodies it must become an important consideration in a study of ore genesis.

(2) Current Theories Allen (1960) quotes Condon and Walpole on the origin of the H.Q.B. He goes on to agree, with them, that the H.Q.B. is an Upper Proterozoic, silicified dolomite, slump breccia.

A more popular theory amongst T.S.F. and S.M.R. geologists in the Rum Jungle area at present, is that the H.Q.B. is a silicified, collapse breccia resulting from the collapse of caves in the dolomite.

The writer does not feel that either of these explanations satisfactorily explain the facts.

(iii) Age of the H.Q.B. In considering the age of the rock, if it is a slump breccia, there does not appear to be any evidence in the Rum Jungle area for considering it of a different age to the rocks with which it is intercalated.

It has been suggested that the H.Q.B. is Upper Proterozoic while the rocks with which it is intercalated are ascribed to the Lower Proterozoic. If this is correct the Upper Proterozoic in the Embayment and Castlemaine Hill areas is down folded into the Lower Proterozoic so as to underlie the Golden Dyke Formation. While this is possible it is an unnecessary complication, within the area examined, especially in view of the fact that throughout the Territory the Upper Proterozoic is usually considered to be only slightly affected by folding.

(iv) Evidence for Silicification Both of the theories mentioned above require replacement of carbonate by quartz. There is no doubt that quartz can replace other minerals. However, in dealing with the volumes of rock involved in this problem, it would appear surprising that there is no evidence of carbonate in the H.Q.B. When specimens of "brecciated" silicified limestone are examined, they are found to contain quartz but there is no reason to believe that the quartz has been introduced; it could equally well be of sedimentary origin (cf. Appendix). It has been suggested that the rhombic sections of quartz fragments, often resembling calcite crystals, (Allen 1960) are evidence of a limestone origin. There are a number of points against this argument. Firstly, in a rock where quartz fragments are occurring in angular form in all shapes and sizes, it is not valid to attach any importance to a particular shape, unless it occurs more frequently than would be expected of a randomly chosen shape. In the opinion of the writer there is no reason to claim that rhombic prisms of quartz are significantly common. Secondly, a rhombic prism is a shape easily produced by intersecting joints. Such shaped blocks are not uncommon locally in the black slate. Finally, if the replacement has reproduced the texture of the limestone, as is implied by this statement, the original rock must have had an unusual texture with large euhedral rhombic crystals in a fine grained matrix.
The H.Q.B. is known to persist on Castlemaine Hill to a depth of 600 ft and may persist much deeper locally. Adjacent to Castlemaine Hill and elsewhere in the Hundred of Goyder the limestone, which is thought to have undergone silicification to produce the H.Q.B., outcrops as dolomite with no signs of silicification. This fact does not seem consistent with recent silicification.

The fact that the H.Q.B. is always found "capping" limestone is also put forward as evidence of its being a product of silicification. However, in the area studied this would not seem to be a valid argument. There are two masses of H.Q.B. One is Castlemaine Hill and as mentioned above it goes at least as deep as 600 feet in places. The other is in the Ebeyment area and Thomas (1956) describes its occurrence there as lenticular masses in the Mudstone Sequence.

In the above examples it can equally well be interpreted as lenses of siliceous material. In both cases the siliceous material occurs between the Coomalie Dolomite and the Golden Dyke Formation.

(v) Cave Breccia Adherents of the cave breccia theory are apparently of the opinion that brecciation and silicification occurred in comparatively recent times. Ruxton (personal communication) for instance, was of the opinion that it may have occurred during the Cretaceous. There is however, good evidence to suggest that brecciation predated at least part of the deformation. Figure 39 shows a number of H.Q.B. outcrops in Dyson's Open-cut. As can be seen the H.Q.B. is occurring in pelitic schists of the "Mudstone Sequence". The brecciation cannot have post-dated the foliation of the schists, since the foliation is unaffected by any movement intense enough to produce the breccia. On the other hand at Mount Pfitz a small pocket of breccia closely resembling the H.Q.B. was found to be a post P1 feature and of undoubted tectonic origin (Figure 40). No absolute age can be ascribed to the deformation, but in view of the horizontal disposition of the Upper Proterozoic and more recent sediments, it seems improbable that the deformation was post Proterozoic.

Thomas (1956) recorded cross bedding in the H.Q.B. Such a structure would be unusual in a slump breccia or a cave breccia but not impossible.

(vi) Thin Section Evidence In thin section many of the quartz and quartzeous grains are definitely rounded and are apparently of clastic origin. Some of the quartzes from Castlemaine Hill could be described as millet seed sandstones and contain occasional rounded pebbles. If silicification has occurred the rock has subsequently been stressed since many of the crystals are cracked or polygonal.

(vii) Summary The brecciation predates at least part of the deformation which is thought to have occurred during the Proterozoic. It therefore seems improbable that it is a cave breccia unless the cave was pre-deformational. Silicification cannot be disproved but there does not appear to be any evidence for it. All of the available evidence is compatible with the H.Q.B. being an original sediment. It appears to have been a somewhat unusual sediment in that quartz represents of the order of 95% of the component minerals. In spite of this it is a poorly sorted rock with a disrupted framework. However, how much of the texture is due to later tectonic effects is not known. There are undoubtedly pebbles which have been broken up, presumably, during the deformation but what proportion of the matrix has originated in this way cannot be determined. It is possible that the rock was originally an orthoquartzitic conglomerate intercalated with orthoquartzites and owes its present texture to tectonic brecciation.
The association of aeolian sandstone and orthoquartzitic conglomerate is quite feasible in a coastal environment. At Mount Pitch, brecciation of quartzite has produced a similar rock, except that it lacks any degree of rounding of the large clasts.

There is also the possibility that the sediment represents the redispersion of the erosional products of an orthoquartzite. In this case the disrupted framework and angularity of clasts could be an original sedimentary feature.

(g) Golden Dyke Formation

This formation west of the granite consists largely of black slates and chloritic slates and schists, with numerous lenses of quartzite. It is in this formation that all the known uranium mineralisation is thought to occur. It was not examined in any detail outside the intensely deformed area west of the "Granite", except in Area 65. In both of these areas the outcropping rocks are mainly quartzitic, but this is no doubt a function of weathering.

One interesting fact that arises from the examination of thin sections is the abundance of heavy minerals such as rutile, zircon and sphene. These heavy minerals are also common in the rocks of the "Rum Jungle Granite" and may have been derived from there.

(h) Burrell Creek Formation

It is not certain that Burrell Creek Formation outcrops in the area examined. It possibly occurs at Mount Pitch where it closely resembles the slates of the Golden Dyke Formation.

3. MINOR INTRUSIVES

(a) Tourmaline Rich Dykes

Quartz-tourmaline dykes are common in the area and intrude both granite and sediments. They are thought to have been intruded in post deformational times. One outcrop at the southern end of the granite is a tourmaline pegmatite (R 107, Appendix) containing abundant feldspar but no other outcrop of this rock type is known. Gold was mined from a quartz tourmaline vein south of the "Rum Jungle Granite".

(b) Quartz Veins and Dykes

Vein quartz is very common. In many cases it is intrusive. Elsewhere what appears to be vein quartz is quartzite recrystallised under stress (eg. Figure 13). There are undoubtedly a number of periods of quartz intrusion. The most prominent quartz dykes are associated with the Giant's Reef fault and other F3 structures.

(c) Basic Intrusives

A number of basic igneous rocks have been recorded. None of them show signs of having been metamorphosed and they are therefore thought to be post deformational. A number of the specimens are rich in iron sulphides.
(a) Photograph of dome and basin structure or Collenia in Celia Dolomite, Coomalie Creek. Trace of possible axial planes for fold systems indicated.

(b) Sectional view of top of "Collenia bed". Amplitude of folds decreases rapidly.

(c) Rod-like structures occurring locally in the "Collenia bed.

(d) Style of folding observed at several localities in the Celia Dolomite.

(e) Geometry of "Collenia" measured as a lineation and orientation of two axial planes indicated in (a).

- Structures defined by quartz.
- Structures defined by regular variations in crystal size.
- Possible axial planes for two fold systems.
Outcrops showing relationship between H.Q.B. and "Mudstone sequence" in Dyson's Open-cut.

**FIG. 39**

Brecciation of folded quartzite, Mt. Fitch. Folds belong to F1 generation.

**FIG. 40**
ACKNOWLEDGEMENTS

The writer gratefully acknowledges R.N. Spratt, D. Berkman and members of the B.N.R. 1962 and 1963 field parties, especially B. Ruxton and M. Rhodes, for their assistance during his stay in Rau Jungle and for valuable discussion.

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Microfolds in St, TS 12179 Quartz sericite slate from White's Open-cut.

**FIG. A 1**

Small folds in dolomitic marble TS 12182 White's Open-cut.

**FIG. A 2**

Quartz clasts from H.Q.B. Specimen R 46 A.

**FIG. A 3**

Voids in quartzite after pyrites. Specimen R 68.

**FIG. A 4**
APPENDIX

Description of Thin Sections
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Fig. A1 Microfolds in quartz sericite schist
Fig. A2 Microfolds in dolomitic marble
Fig. A3 Quartz clasts from H.Q.B.
Fig. A4 Voids after pyrite in quartzite
INTRODUCTION

Some of the thin sections were described at A.M.D.L. and the descriptions are quoted here with comments added by the writer. Where there is any difference in opinion, there is a statement to that effect and both sides are presented.

Terminology, as defined by Pettijohn (1956) has been used to describe relict sedimentary features.
B.J.C.S.

A2 - East Wall

Hand specimen: Black slate with hematitic stains. Two s-surfaces - one defined by pyrite, the other defined by a cleavage.

Thin Section: TS 11572

"Graphitic slate analogous to other slates described above. Bedding (S1) is shown by bands of sutured quartz grains and opaques. Micro-shearing has distorted the bedding to some extent and developed another s - surface (S2) at an apparent angle of approximately 35° with S1. Again the opaques show the "streaming" effect. Chlorite (? developed from the argillaceous component of the rock) is reasonably abundant and is aligned parallel to S2."

Quartz is sutured in part but much of it is polygonal.

Small crystals resembling zircon and having pleochroic haloes are present in accessory amounts.

Coarse grained opaques, which are largely pyrite, are associated with coarse grained quartz.

There is no definite evidence to suggest that the surface S1 is bedding - this is purely supposition. It is not even compositional banding but banding defined by regular variation in crystal size.

A2 - Front Ore Body

Hand specimen: Dark green phyllonite with scotty patches parallel to schistosity. There are white stains and also iron oxide stains. Traces of pyrite are visible and there are druse elongate parallel to the foliation with buff encrustations.

Thin Section: TS 11573

"This rock is a quartz-biotite schist and is therefore of a slightly higher metamorphic grade than the chlorite schists. The biotite is green in colour and the flakes show a well developed parallelism. Some bands are rich in dust like opaques which may represent heavy mineral bands in the original sediment. The bands have been diluted in part by the secondary introduction or metamorphic segregation of quartz into them.

Quartz bands themselves are not abundant. As well as the dust like opaques, coarser grains occur but are not particularly abundant. Sphene is present as aggregates of rather rounded grains and also as a replacement mineral of the opaques; the latter occurrence shows a skeletal habit. Zircon is accessory. Crypto or micro-crystalline material, which is thought to be silica, occurs interstitially in the chlorite bands. Voids in the rock have been filled with secondary cryptocrystalline quartz, sometimes showing concretionary banding."
Some have been filled with chlorite, the origin of which is doubtful. The rim consists of flakes aligned perpendicular to the walls while the core is of needles lying parallel to $S_2$. This seems to suggest that they were filled before the development of $S_2$.

The mineral referred to as sphene has low birefringence and occurs as nodular crystals within the aggregates. In some examples there is alteration to leucoxene but the mineral in some properties is more like zircon and in others more like rutile. Where it is altered to leucoxene the writer prefers to call it rutile. Some of the unaltered may be zircon. The way the foliation swells around some of the aggregates suggest that structurally they have behaved as a single unit which in turn suggests that they have developed into an aggregate from a single crystal.

Quartz aggregates consist of polygonal crystals and have associated opaque minerals, thought to be pyrite.

Radiometric analysis of the thin section with cover slip in place revealed counts 1½ times background.

A10 - From Ore Body

Hand specimen: Dark green schist or phyllonite with black smears on the foliation. Crenulation cleavage well developed.

Thin Section: TS 11574

"This is a quartz-biotite-chlorite schist similar in most respects to the foregoing schistose rocks. It is banded as before, this being $S_2$, and the alignment of the micaceous elements $S_3$. Fibrous chlorite bands show crenulations with some flakes aligned with the axial plane ($S_2$). In some cases there has been slippage along the axial plane. The green-brown biotite occurs as truncated flakes within the fibrous chlorite bands in varying amounts. Sometimes chlorite is dominant and sometimes biotite. Apparently biotite is forming from chlorite indicating an increase in metamorphic grade. Six sided sections are seen which suggest the former presence of an amphibole. They are aligned with their long axis parallel to $S_2$ and have now been replaced by chlorite. If they were in fact amphiboles then this indicates an even higher grade of metamorphism. It may be that there were local increases in these areas and migration of material to zones of weakness along the axial plane cleavage. Opaxites and sphene occur as before."

Mineral referred to as sphene has habit and birefringence of zircon. Many of the opaque and semi-opaque minerals are elongate and rectangular in shape – almost needle-like and are altering to leucoxene – they are probably rutile.

There is no reason to suggest that the foliation has developed parallel to the compositional banding. It can only be stated from thin section evidence that lenticular areas defined by variation in composition together with preferred orientation of minerals define an $s$-surface which can be designated $S_1$ rather than $S_1$ and $S_2$. 
Radiometric analysis of the thin section with the cover slip in position revealed a 3x background count.

A11 - From Ore Body

Hand specimen: Chloritic schist.

Thin Section: TS 11575

"This is a quartz-biotite-chlorite schist analogous to the above. The (?) amphibole sections are not as abundant."

Crenulation cleavage is well developed.

Radiometric analysis of thin section with cover slip in position revealed a 1½ x background count.

A15 - West Wall of Open-cut

Hand specimen: Chloritic schist.

Thin section: TS 11576

"This rock is a quartz-biotite-chlorite schist similar in most respects to A10 and A11."

Leucoxene is common on opaque mineral presumably ilmenite. Not very radioactive, counts only slightly above background.

A17 - West Wall of Open-cut

Hand specimen: Chloritic schist.

Thin Section: TS 11577

"This rock has been classified as a biotite-chlorite schist. It shows rather poor foliation but the micaceous minerals show good parallelism. Quartz is a minor constituent, the grains not occurring in bands but scattered through the rock. Opaques are quite abundant as dust-like and sometimes coarser grains in discontinuous bands (possibly indicating sedimentary bedding). The bands may be discontinuous through shearing, thus causing the bands to break up. Very finely divided iron oxide occurs in patches, giving these areas an orange colour. Cryptocrystalline material (? silica) again occurs interstitially with the mica. Rutile is a reasonably abundant accessory mineral; it is present as rods and rounded grains and occurs with zircon and sphene with the opaques but also scattered through the rest of the rock."

A18 - West Wall of Open-cut

Hand Specimen: Chloritic schist.
Thin Section : TS 11578

"This rock is a quartz-sericite-chlorite schist which appears to have undergone several successive phases of dynamic metamorphism. There is a moderately developed S₁ - surface with the constituent minerals reasonably well aligned. Lateral compression in a minor degree then caused the development of crenulations in some of the sericite bands and the alignment of some flakes parallel to the axial plane. Following this, the rock was subjected to tensional forces as the bands have been drawn out and broken up into lenticular, boudin-like bodies. This may have also destroyed some of the crenulations. The sericite is extremely fine grained and it is difficult to make out discrete flakes. The chlorite is somewhat coarser and occurs as masses of flakes within the sericite; sometimes the flakes are decussate and sometimes aligned. The reason for the chlorite occurring in such masses is obscure but it may be due to the greater mobility of the chlorite and its movement to areas of lower stress. Quartz is of silt-grade and it occurs, with opaques, more or less interstitially with the micaceous minerals. The opaques are dust-like and again occur in "streams".

There is only evidence of two phases of deformation. The boudin-like structures are parallel to S₁. Both are indicative of the same strain axes and there is no necessity to invoke two movements to explain them. There is no evidence for lateral compression. There are micro folds or crenulations post dating S₁ but it is not possible to say what forces produced them.

A22 - East Wall of Open-cut

Hand Specimen: Chloritic schist

Thin Section : TS 11579

"This is a quartz-biotite schist with biotite as the dominant mineral. It is green-brown in colour and the flakes vary considerably in length and are rather ragged in shape. They show good parallelism with a few showing varying degrees of divergence. Quartz is of silt grade and shows marked strain extinction. The grains are not elongated parallel to the foliation of the biotite. Cryptocrystalline material occurs in patches as do dust-like opaques. Zircon and sphene are common accessories with sphene replacing some of the coarser opaques. (?) Rutile occurs as inclusions in biotite."

Variation in orientation of micas seems to suggest two foliations with almost the same orientation, i.e. diverging by an angle of the order of 20°.

A28 - West Wall of Open-cut

Hand Specimen: Light grey limonite stained slate.

Thin Section : TS 11530

"This rock is again a quartz-biotite schist. Bedding is obscure but it appears that the biotite is aligned
parallel to the bedding. Originally the rock was an argillaceous sediment as there is still an appreciable amount of argillaceous material still present. The quartz grains have been drawn out parallel to $S_1$ and $S_2$ and are sometimes four or five times longer than they are broad. Opaque are a minor constituent; they are very fine grained and occur scattered throughout the rock. Other heavy minerals present in accessory amounts are zircon, (7) rutile and tourmaline. The tourmaline varies markedly in size from fine prismatic crystals to some which are much coarser than the quartz or biotite. They are aligned with the biotite and are possibly authigenic."

**B4 - East Wall of Open-cut**

**Hand Specimen:** Haematite stained, pyritic, black slate. Very porous.

**Thin Section:** TS 11555

"This rock has been classified as a slate. It is composed of quartz and very fine, often dust-like opaques with minor graphite and argillaceous material. Two s-surfaces are evident in the rock. $S_1$ is the bedding; this is shown by bands of quartz and opaques of a coarser grain than that in the rest of the rock. Recrystallisation under stress has resulted in the banded quartz grains submerging together to form mosaics which have been drawn out into lenticular bodies almost perpendicular to the bedding, thus giving rise to $S_2$. Some of the bands are warped after the form of a monoclinal fold; this is possibly due to shearing. Biotite shows incipient development, probably as a result of recrystallisation of the argillaceous material. It occurs as truncated flakes generally parallel to $S_2$ but sometimes diverging widely."

**B5 - West Wall of open-cut**

**Hand Specimen:** Buff coloured, limonite stained, weathered green schist.

**Thin Section:** TS 11556

"This rock is a slate showing good bedding characteristics ($S_1$) and another s-surface parallel to this. Originally the rock was a siltstone composed of silt-grade quartz and opaque material varying in size from silt to clay-grade. The original grain shape of the quartz has been destroyed by recrystallisation and they are now elongate with the long axis parallel to the bedding; this elongation has formed the $S_2$-surface. The opaque material occurs in bands some of which are not continuous but lens out. Others show dilation features or split apart to leave an "isogen" of clean quartz. Biotite shows incipient synkinematic development with the flakes lying approximately parallel to the bedding, thus making $S_2$ more pronounced. Shearing has caused the development of numerous minute cleavages at an angle of approximately 60° with $S_1$ and $S_2$. The cleavages often occur in "swarms" and have another s-surface ($S_3$) incipiently developed with them shown by the parallelism of some mica flakes in this direction."
S\textsubscript{1} and S\textsubscript{2} are one s-surface. It is defined by compositional banding and by preferred orientation of micas. There is no evidence to suggest that S\textsubscript{1} is bedding. It may be transposed bedding, since field evidence it is known to be a tectonic foliation.

B6 - West Wall of Open-cut

Hand Specimen: Buff coloured, limonite stained, weathered chloritic schist. Strongly crenulated.

Thin Section: TS 11557

"Originally this rock appears to have been a quartz-biotite schist but has subsequently been cataclastically deformed. Quartz and biotite were apparently mainly restricted to discrete bands (with occasional grains of quartz within the biotite bands) and probably showed a well marked foliation. The quartz is mainly of silt grade with some grains reaching fine-sand size. The grains have been recrystallised and now form an interlocking mosaic with rare minute flakes of biotite. Parallelism of flakes of biotite is retained in some areas but the bulk of the mineral has apparently been recrystallised and now forms clots and discontinuous bands of ducussate flakes. Along shears, the biotite and quartz have been crushed to a "flour". Zircon is a fairly common accessory and iron oxides have caused considerable staining."

Crenulation cleavage is not recognisable in the thin section although it is prominent in the hand specimen. It may however explain the lack of orientation in the biotite.

B7 - Same as B6

Hand Specimen: Like B6

Thin Section: TS 11558

"This rock is problematical in origin and classification. Lenticular quartzitic bodies are set in a fine-grained "ground mass". The bodies consist of a mosaic of fine grains of quartz and vary somewhat in size, the largest measured being 3 mm across (grit-grade). They are drawn out parallel to a rather poorly developed s-surface which, in turn, appears to be parallel to bedding. Some are tear-shaped and some contain fine flakes of chlorite which show a reasonably good parallelism with S\textsubscript{1} and S\textsubscript{2}. These factors suggest that, if the granules are discrete rock fragments, they were crystallised and drawn out after incorporation in the rock. However, the granules may be remnants of what were once quartz bands which were broken up during a phase of cataclastic metamorphism.

The bulk of the rock consists of angular and subangular, silt-sized grains of quartz, argillaceous material, biotite, and opaques (? goethite). The biotite is of metamorphic origin and shows a rough parallelism (S\textsubscript{2}). Like the biotite in the above rocks it is a pale yellow-brown in colour and the flakes small and truncated. Muscovite shows minor development. Opaques are quite abundant as dust-like and silty grains; they have produced some staining.\"
There is no evidence to say that \( S_3 \) and \( S_2 \) are parallel and the disposition of fish suggests an earlier foliation \( (S_1) \) inclined to the main foliation \( S_2 \) \( (S_1 \) and \( S_2 \) according to A.M.I.B.I. by about 30°).

The fine grained ground mass is not very well foliated.

Fish are mainly quartz and are "tear drop" shaped. The blunt end is more coarsely crystalline than the tapered end.

**BS - West Wall of Open-cut**

**Hand Specimen:** Light grey slate with white stains and iron oxide stains.

**Thin Section:** TS 11559

“This is a quartz-biotite-opaque schist derived from a banded argillaceous siltstone. The bands of opaques probably represent heavy mineral bands in the original sediment and show that \( S_2 \) (foliation of micaceous minerals) has developed parallel to \( S_1 \) (bedding). The quartz is of silt grade except for a few grains of fine-sand size. The majority of the grains are drawn out in the direction of \( S_2 \) but show no preferred optical orientation. Argillaceous material occurs interstitially. Biotite occurs as fine needles and shows a form of "flow" structure around the quartz grains. Opaques are scattered throughout the rock as irregularly shaped grains and are also concentrated in bands; presumably the bands consisted of discrete grains but they have now recrystallised together. Shearing has caused the development of tension cracks in which quartz and some muscovite have crystallised together. Tourmaline and zircon are rare accessories.”

Areas of coarse grained polygonal quartz are mostly associated with opaques, which are apparently iron minerals. Quartz aggregates may be fish. The opaque minerals form continuous parallel aggregates along which the knotty aggregates of quartz occur.

The quartz and fine grained biotite ground mass seem to define two foliations, one parallel to the chains of opaques and the other at 20° to it.

The writer cannot identify the tension cracks.

**B9 - West Wall of Open-cut**

**Hand Specimen:** Dark green, chloritic schist with pyrite and crenulations.

**Thin Section:** TS 11560

“This rock is a quartz-biotite-chlorite schist. Schistosity is not well shown in the oriented section but the similarity between this sample and B10 from which a section was cut in a different orientation suggests that they are the same.”
The oriented section shows the quartz to occur in discontinuous bands. The grains are all of approximately the same size and fall into the silt-grade. Minute needles of chlorite occur in these lenses and show a good foliation. Biotite and chlorite occur in bands and show reasonable foliation. The biotite is probably forming from the chlorite. The fact that the quartz and micaceous minerals are confined to separate bands probably indicates banding in the original sediment. The biotite could also have been brought about by migration during metamorphism but the former is more likely. The hand specimen shows crumpled surfaces. In section large, almost porphyroblastic, flakes of biotite can be seen cutting $S_2$ at an angle of approximately $60^\circ$. These flakes, formed during a second period of crystallisation, are probably parallel to the axial plane of the crumulations, and forming the $S_3$ surface. Argillaceous material has recrystallised to sericite in patches throughout the rock. Oreoxes (sulphides) occur principally in irregular, elongated aggregates and also as discrete grains. The aggregates are often intergrown with sericite. There is some replacement of the opaques by sphene and/or anatase. Tourmaline is a rare accessory and secondary quartz occurs in fractures."

The compositional variation probably owes its origin to sedimentary factors rather than metamorphic differentiation. Its present disposition however is almost certainly due to transposition.

There appears to be an association between opaque minerals and quartz. The mineral is pyrite where coarse enough to identify.

The porphyroblastic biotite mentioned as making an angle of $60^\circ$ with $S_2$ varies a little and has two principal directions not one. They are $60^\circ$ and $300^\circ$.

B10

Hand Specimen: Like B9

Thin Section: TS 11561

"This is a banded quartz-chlorite schist, the banding probably representing sedimentary bedding ($S_1$). The bands show a different mineralogical composition; some are composed solely of chlorite, some of quartz and chlorite and others of quartz with a few minute flakes of chlorite. The quartz is very fine grained and shows a granoblastic texture with many of the grains drawn out into lenticular shapes. Chlorite occurs as fine needles and flakes, pale green in colour, pleochroic and showing anomalous violet, blue and brown birefringence colours. The sections show a sub-parallel arrangement ($S_2$). The chlorite bands are often crumpled with some flakes aligned parallel to the axis of the micro-folds and forming the $S_3$ surface. There has been some development of boudins as lenticular bodies composed of the same minerals but showing no structure occur in the rock. Oreoxes occur throughout the rock and are often concentrated in the chlorite bands. There has been some
replacement of opaques by sphene. Fractures are reasonably common and have been principally developed parallel to \( S_1 \). They have been filled with quartz, both fine-grained and cryptocrystalline, to form a lining and sulphides in the core. The fractures show dilation. Whether the opaques are secondary is open to doubt. They may be original and have migrated to the fractured areas."

Again there is no evidence that \( S_1 \) is bedding and field evidence is to contrary. Some opaque minerals occur as rings around quartz crystals.

Quartz veins in some cases post date \( S_1 \) but elsewhere are apparently sheared and in one case chlorite crystals appear to pass through quartz vein.

**B11**

**Hand Specimen**: Foliated black slate with little pyrite.

**Thin Section**: TS 11562

"This rock is a very fine-grained, silty, carbonaceous, shaley dolomite. The rock has been recrystallised under stress resulting in the suturing of quartz grains in juxtaposition and the development of a cleavage parallel to the bedding plane. Graphite and goethite occur as dust like particles with goethite sometimes in aggregates randomly dispersed through the rock to give a spotted appearance. The aggregates tend to be slightly elongated parallel to the bedding. Chlorite occurs in minor amount as small, truncated flakes showing no marked orientation. There has been incipient replacement of some quartz grains by carbonate."

Quartz occurs scattered through the rock and also as lenticular aggregates of polygonal grains with a few dolomite crystals.

Quartz aggregates, aggregates of opaque minerals, elongation of minerals and streams of fine grained opaque minerals all combine to define a foliation \( S_1 \). There is no evidence to suggest that it is bedding and field evidence is to the contrary. There is a weak foliation perpendicular to \( S_1 \) defined by common extinction.

**B12**

**Hand Specimen**: Pale green chloritic schist. Crenulated and has pyrite in joints.

**Thin Section**: TS 11563

"This rock is similar to others described above. It is rather well foliated quartz-chlorite schist, the foliation apparently representing the original bedding planes (\( S_1 \)). The quartz, which shows marked undulatory extinction, is slightly coarser than that in the foregoing rocks. This could be due to either the sediment being coarser or to coarsening during recrystallisation. The quartz bands are not entirely free from chlorite, some containing approximately equal amounts of the two
minerals and others just a few scattered needles. The bands are not of uniform thickness and some lens out. Chlorite occurs in two different forms. Some bands are composed of fine needles while others consist of flakes. The needles show marked parallelism (S), while the flakes are aligned in a sub-parallel manner; some flakes show a marked deviation from the overall orientation. Some flakes contain needle-like and hexagonal inclusions of an unidentified mineral; the needles are not aligned in any particular orientation. Many flakes contain minute opaques along cleavage traces; these were possibly formed by exsolution. The bands of chlorite needles are pucker with an S4 - surface developing parallel to the axial plane as shown by the rotation of some sections. Plication is not always shown by the bands of flakes. Opaques are dust-like and minor in amount. Sulphides of a coarser grain occur in the chlorite bands. As before, these may be secondary. Zircon is a very fine grained accessory mineral; they sometimes occur in clusters which are drawn out parallel to S1 and S2.''

Two s-surfaces inclined to S1 by 60° to the east and west.

S3 is not very well developed.

B12

Hand Specimen: Hematite stained, pyritic black slate. Strongly foliated.

Thin Section: TS 1156

"This rock is a carbonaceous slate. It is composed of recrystallised silt grade quartz, very fine grained graphite and minor amounts of chlorite and sericite. The micaceous minerals show moderate parallelism with the bedding. The quartz shows marked strain extinction and is generally free from inclusions. Iron opaques are present in minor amount and other sulphides and quartz are possibly of secondary origin. Minute zircons are accessory."

Compositional banding (S1) is noticeably absent in this specimen.

B14

Hand Specimen: Dark green schist with streaks of pyrite parallel to a well developed plane of schistosity. Good crenulation cleavage.

Thin Section: TS 1156

"This rock is again a quartz-chlorite schist and is analogous to the schists described above. The chlorite appears to be approaching biotite as it is taking on a brown colour and the extinction is almost straight. Fractures cut the rock and are generally parallel to the banding (i.e. bedding). The chlorite along the fractures has recrystallised and the needles are aligned perpendicular to the walls. The fractures are filled with
quartz with inclusions of (?) carbonate and sometimes opaques. Opaques in the body of the rock are occasionally concentrated into rectangular or lath-like aggregates; this is possibly due to metamorphic segregation."

There is no evidence to suggest that banding is bedding and field evidence is to contrary.

Micas seem to define two foliations which are close enough to suggest one. The principal orientations are 350° and 310° (oriented specimen).

A mineral thought to be rutile, but very fine grained, is abundant.

\[\text{D1}\]

\textbf{Hand Specimen:} Black slate.

\textbf{Thin Section:} TS 11566

"This is a slate composed of quartz, garnet, and iron opaques. The quartz varies in grain size from silt to fine sand; the original grain size was possibly finer, with coarsening occurring during recrystallisation. Bedding (S₁) is shown by variations in grain size of the quartz. Micro-shearing has led to the development of an S₂ - surface at an apparent angle of approximately 35° with S₁. S₂ is shown by the quartz which is drawn into lenticular grains aligned in this direction and by the opaques which are concentrated into 'streams' (movement of the opaques may have been necessary for this). Chlorite and sericite as very small flakes occur aligned parallel to S₂ and were probably derived from argillaceous material. Recrystallisation of the rock was probably contemporaneous with the development of S₂. Zircons of varying size are accessory."

Once again there is no reason to believe that S₁ is bedding.

Opaque minerals are aggregated in streams parallel to S₂ and into bigger but less frequent streams parallel to S₁.

\[\text{D2}\]

\textbf{Hand Specimen:} Black slate.

\textbf{Thin Section:} TS 11567

"Like the above, this rock is a slate which shows two s-surfaces. It consists of silt grade quartz, iron opaques and garnet and has been recrystallised so that juxtaposed quartz grains have sutured together. Strain extinction on quartz is marked. The opaque minerals are extremely fine grained. Bedding (S₁) is shown by bands of quartz and opaques of fine sand grade. The bands are rather discontinuous, that is, the quartz occurs in aggregates, possibly as a result of metamorphic segregation but more likely an effect
of shearing. The $S_3$ - surface, developed as before by micro - or incipient shearing, is almost perpendicular to $S_1$. It is shown in the same way as in the above, that is, by "streams" of opaques which can sometimes be traced around the aggregates of quartz. These aggregates have a tendency to be drawn into lenticular bodies. Minor chlorite and sericite, which occur as minute needles and small flakes, show a sub-parallel arrangement. Zircon is accessory and sometimes occurs as inclusions in quartz. Fractures have been healed by (?) secondary opaques."

D3
Hand Specimen: Black slate.
Thin Section: TS 11568

"This is again a slate, essentially analogous to D1 and D2. The component minerals are the same and bedding of $S_3$ is shown by bands of quartz. $S_3$ is developed almost parallel to $S_1$. Green-brown chlorite shows a greater development in this sample than in either of the above two. It occurs as small flakes and shows a well developed parallelism with $S_1$ and $S_2$; it was probably derived from argillaceous material. Part of the rock shows marked shearing where there has been concentration of sulphides and quartz."

$S_1$ and $S_2$ above are one foliation which should be labeled $S_3$. There is an earlier set surface $S_1$ which is inclined to $S_2$ by approximately 30°. $S_1$ is more readily seen with the naked eye than with the microscope.

Radiometric analysis of the thin section with the cover slip in place revealed a 2X background count.

D7 - West Wall
Hand Specimen: Black slate with leisegang rings.
Thin Section: TS 11569

"This rock is a shale consisting of clay and silt grade quartz. Synkinematically with incipient shearing the rock has recrystallised resulting in the saturaing of some quartz grains, the lengthening of the same into lenticular bodies and the incipient development of $S_2$ parallel to $S_1$. $S_3$ is shown by micaceous material formed from the argillaceous component of the rock during recrystallisation. Opaque material is not particularly abundant but, where present, shows the same streaming effect as seen in the slates described above.

Surface weathering has given the rock a banded appearance. In thin section this is seen as bands of iron material deposited from percolating ground waters or by the oxidation or hydration of the material already present."

No evidence for $S_2$ having developed parallel to $S_1$. 
There appears to be zircon present.

**DK - West wall of open-cut**

**Hand Specimen:** Chloritic schist.

**Thin Section:** TS 11570

"This is a quartz-chlorite schist similar to others described above. Puckering of chlorite bands is incipient and there is poor development of laths. The chlorite is approaching biotite."

There is a good deal of variation in the orientation of the chlorite crystals and there are radiating clusters.

Rectangular prisms of pyrite have a preferred orientation.

**FG**

**Hand Specimen:** Chloritic schist.

**Thin Section:** TS 11571

"This rock is again a quartz-chlorite schist of the same type as the others. Chlorite is the more abundant mineral in this specimen. Banding is irregular in that they thicken and thin and sometimes lens out; this could be a feature imposed during compaction of the original sediment. Again, some bands of chlorite are composed of needles and others of flakes; puckering is best shown in the needle bands."

Crenulations are well developed, but related cleavage is only incipient.

Randomly oriented micas are common and quite large. There are also radiating clusters.

**HIGA.1**

**Hand Specimen:** Very porous black slate. Two well defined foliations, S and S', are clearly visible and intersect in an angle of approximately 60°. S' appears to be defined by compositional variation marked by druse and iron stains. S_2 is a cleavage plane. The rock tends to fracture parallel to S_1 and perpendicular to it. (i.e. parallel to the ac joint)

**Thin Section:** Quartz-mica slate, S and S_1 clearly defined. S is defined by bands of coarse grained quartz and pyrite. Individual grains within the bands are aligned parallel to S; S_1 is defined by elongation of often lenticular quartz grains and by "streams" of opaque minerals.

Mica is apparently, mostly sericite but some chlorite is present.
The coarse grained opaque mineral occurring with the quartz is pyrite.

Fine grained opaque minerals are too fine to identify.

There is a fine grained accessory which may be zircon. It occurs as rounded grains with high relief and is a murky yellow or red under crossed nicols. It is too fine to identify with certainty.

In the areas of coarse grained quartz, grains tend to be polygonal. Mica is also coarser in these areas and overlies the quartz and pyrite. This banding could be metamorphic.

RGS 24

Hand Specimen: Dark green schist or phylonite. Very lenticular fabric. Individual lenses are parallel to the schistosity. There is a well developed crenulation cleavage and a second very weak set.

Thin Section: Quartz-mica schist or slate.

Quartz is polygonal and micro-crystalline and some elongate grains help to define S.

Chlorite occurs as coarse, fibrous crystals with anomalous interference colours - green and 'Berlin blue'. Therefore it is probably pennite and is preferentially oriented parallel to S. There are also smaller less well oriented crystals of biotite.

A semi opaque mineral altering to leucoxene occurs as an accessory mineral. It is thought to be sphene.

Iron oxides are common and occur as vein-like deposits as well as defining fish.

Foliation is well defined but strongly crenulated.

RGS 233 - DDH 439, 169 ft.

Hand Specimen: Pale greenish grey schist with visible muscovite and a weak crenulation cleavage.

Thin Section: Quartz-mica schist. Quartz is widespread in micro-crystalline form and also occurs as small aggregates. Chlorite is abundant and defines a weak foliation.

Opaque minerals are common and include pyrite, a black (in reflected light) mineral and ilmenite which is altering to leucoxene.

A very fine grained mineral with high relief is almost an essential mineral. It occurs in aggregates which have outlines often suggestive of crystal boundaries. The mineral is too fine grained to identify.
with certainty but is possibly zircon.

RIGS 34R - DDH 377, 154 ft.

Hand Specimen: Dark green chloritic schist or phyllosite very much like RIGS 24.

Thin Section: Chloritic schist. Lenticular aggregates of quartz with a little zircon and very fine grained opaque minerals occur in a chlorite rich matrix. Zircons are occurring in characteristic habit in this section.

Chlorite is giving anomalous, 'Berlin blue' interference colours.

RIGS 35A - DDH 411, 222 ft.

Hand Specimen: Grey, green slate. Well foliated compact rock with carbonate veins. There is a pyrite rich area showing parallelism, along most of its length, with the carbonate veins.

Thin Section: Chloritic slate.

Polygonal quartz, interlocking carbonate crystals, chlorite and zircon all tend to occur as monomineralic, lenticular aggregates. The aggregates and preferred orientation of the mica define the foliation.

Pyrite is a fairly common accessory and is fairly abundant in some areas of this section.

Carbonate veins are fairly common.

RIGS 35B - DDH 411, 209 ft.

Hand Specimen: Grey slate. Fine grained compact rock rich in carbonate. Carbonate veins are vuggy and have two orientations differing by about 30°.

Thin Section: Marble.

Very much like RIGS 59 but foliation is less well defined and opaque minerals are not so abundant. Some veins appear to pre-date deformation, others post date it. Fractures occur at an angle to S.

RIGS 36 - DDH 413, 205 ft.

Hand Specimen: Pale grey marble with sutured vein of pyrite. No obvious foliation.

Thin Section: Marble.

Almost pure marble with a weak foliation defined by preferred
There are carbonate and quartz veins. One vein, approximately $\frac{1}{2}$" broad, is rich in pyrite and consists of carbonate with a little quartz. Elsewhere there are veins consisting predominantly of quartz with pyrite and a little calcite. There are also scattered quartz and muscovite crystals associated with opaque minerals with a vein-like distribution but not actually in veins.

RJCS 37 - DDH 372

Hand Specimen: Grey slate. Very much like RJCS 358.

Thin Section: Marble.

Fine grained carbonate crystals are elongate and therefore define a weak foliation. Very fine grained opaques are common but too fine to identify.

A number of veins intersect the rock. They consist essentially of coarse grained carbonate crystals with euhedral or embayed boundaries. One vein includes lenticular areas of sutured and polygonal quartz with a few carbonate crystals. One vein is $\frac{1}{2}$" broad and is rich in iron oxides. It contains a lenticular mass of banded quartzite. Banding in the quartzite is defined by variation in grain size and the association of sericite with the coarse grained quartz.

A "fringe" of very fine grained opaque minerals occurs parallel to the broad vein. It occurs in the "wall-rock", very close to the contact. The contact is defined only by the coarseness of the crystals and recrystallisation of the wall-rock makes it difficult to recognise locally.

RJCS 46

Hand Specimen: Green phyllite. Porous rock rich in pyrite and with a fabric resembles that of RJCS 2A. Slightly stained by iron oxides and weakly crenulated. Lenses of black material, probably black slate.

Thin Section: Quartz-mica slate.

Quartz is polygonal and embayed. It occurs as scattered crystals and in aggregates. There are also aggregates of micro-crystalline quartz.

Mica is very fine grained. It has normal interference colours and is probably chlorite or sericite. It is too fine grained to be sure. It is preferentially oriented and defines $S_1$.

Pyrite is common as euhedral crystals, irregular masses and elongate masses aligned parallel to $S_1$.

There are also opaque minerals which are black in reflected light.

A semi-opaque mineral is common as very fine grained crystals and is probably sferien.
The foliation 3, is well defined and irregularly crenulated. Lenticular fabric is markedly defined by quartz rich and mica rich lenses.

RIJS 47
Closely resembles RIJS 46 in all respects.

RIJS 48
Closely resembles RIJS 47 but is less porous and more crenulated.

There is some tarnished sulphide resembling chalcopyrite but chemical tests indicated that it is pyrite.

Thin Section: Very much like RIJS 46. Rutile occurs as a needle like accessory mineral and is altering to leucoxene. Much of the quartz is micro-crystalline.

RIJS 50 - South end of open-cut

Hand Specimen: Contact between black slate and green schist.

Thin Section: Black slate is a quartz-opaque mineral-mica slate. Quartz and very fine grained opaque minerals are main constituents of this part of the section.

Quartz is very fine grained except in occasional fish.

The opaque minerals include very fine grained pyrite.

Mica is very fine grained and could be sericite or chlorite.

The green schist is a quartz-mica slate. Lenses of material identical to the black slate are intercalated with chloritic rich rock.

Quartz is polygonal and micro-crystalline.

Mica is green, strongly pleochroic and has second order interference colours. It is probably chlorite.

There is a semi-opaque mineral which could not be identified with certainty but could be fahloen.

Needles of ? ilmenite are present and altered to leucoxene.

Other very fine grained opaques occur in streams.

The rock is well foliated.
RJCS 51 - South end of open-cut

Hand Specimen: Green schist.

Thin Section: Quartz mica schist.

Quartz is polygonal and elongated so as to define $S_1$.

Mica is green and gives very low, first order interference colours and 'Berlin blue'. It is chlorite and probably pennine. Coarse crystals are crenulated and there are also fine grained crystals. Both are preferentially oriented parallel to $S_1$.

Needle-like opaque and semi-opaque crystals are common. They are probably rutile since they are altering to leucoxene. Degree of opacity is presumably due to degree of alteration. Most of the needles are parallel to $S_1$ but some are parallel to $S_2$.

Semi-opaque mineral - possibly siron is also present.

Rock is well foliated.

RJCS 52 - South end of open-cut

Hand Specimen: Green schist.

Thin Section: Quartz mica schist.

Quartz is polygonal and where elongate, has a preferred orientation.

Mica is pleochroic in green. Some is coarse grained and gives anomalous, 'Berlin blue' interference colours; it is presumably pennine and is strongly crenulated. There are fine grained crystals, equally pleochroic but with normal first order interference colours. They are also chlorite but possibly a different variety. They are not so preferentially oriented as the first type. Finally there are patches of micro-crystalline mica, pleochroic in green and with interference colours up to second order blue.

There are needle-like opaque crystals altering to leucoxene and probably, originally rutile. There are also streams of very fine grained opaque minerals.

A semi-opaque mineral is probably sphene and less altered rutile.

$S_1$ and the lenticular fabric are well developed.

RJCS 55D - DDH 596

Hand Specimen: Coarse grained dolomitic marble.

Thin Section: Dolomitic marble.

Coarse grained crystals of carbonate are markedly embayed. They are elongate but not preferentially oriented.
There are small inclusions of quartz. They are lenticular and cross crystal boundaries.

Pyrite crystals surrounded by iron oxide stains occur along crystal boundaries.

RJGS 59 - DDH 364, 495 ft.
Hand Specimen: Grey slate.
Thin Section: Very well foliated marble. The foliation is defined by preferred dimensional orientation of carbonate crystals and by streams of opaque minerals. The rock is rich in fine-grained, unidentified opaque minerals.

There are scattered grains of quartz and ? zircon.

There is a small quadrangular area of coarse grained calcite bounded on two sides by opaque minerals.

There are veins of opaque minerals parallel to S₁ and quartz veins perpendicular to it.

RJGS 60A - DDH 516, 249 ft.
Hand Specimen: Same as RJGS 59
Thin Section: Same as RJGS 59 with large euhedral crystals of pyrite. ? Zircon crystals associated with scattered quartz.

RJGS 60B - DDH 516, 249 ft.
Hand Specimen: Black slate.
Thin Section: Quartz-mica slate.

S₁ is well defined. S is not very well defined but appears to be perpendicular to S₁. The minerals present are the same as in the other black slates with sphene or zircon present as an accessory mineral.

RJGS 61 - South end of open-cut R.L. 800 ft.
Hand Specimen: Weathered green schist.
Thin Section: Quartz-mica schist.

Quartz is elongate parallel to S₁ and locally polygonal. It also occurs in micro-crystalline aggregates associated with chlorite.

There are a number of types of mica; there are large strongly crenulated crystals of pennine, small less well preferentially oriented chlorite crystals associated with the micro-crystalline quartz. Finally there
are radiating crystals and irregular patches of micro-crystalline chlorite.

Semi-opaque minerals are abundant and represent about 5% of the rock. They include needle-like rutile, altering to leucoxene and rounded aggregates of ? zircon.

Opaque minerals are skeletal and are red in transmitted light. There are also "streams" of very fine grained opaque minerals. Some of the rutile is opaque due to advance stage of alteration to leucoxene.

RJCS 70 - From ore body.

Hand Specimen: Crenulated green schist.

Thin Section: Very much like RJCS 61. Pennine not so abundant and less radiating chlorite. Opaque minerals include pyrite and zircon is less abundant.

RJCS 71 - From ore body.

Hand Specimen: Crenulated green schist.

Thin Section: Very much like RJCS 70 with slightly more rutile and zircon.

RJCS 72 - From ore body.

Hand Specimen: Crenulated green schist.

Thin Section: Very much like RJCS 61 but zircon is rare, rutile common and pyrite present. Fine-grained chlorite seems to result from alteration of pennine.

RJCS 73 - From ore body

Hand Specimen: Crenulated green schist.

Thin Section: Very much like RJCS 61. "Streams" of opaques are common. Ilmenite is present but there is no zircon. Microfolds are particularly well developed.

RJCS 75

Again both of these specimens are from the ore body, are crenulated green schists and in thin section resemble RJCS 61. The pennine is not so abundant and there are regular four sided areas altering to fine grained chlorite.

RJCS 72, 73, 74 and 75

Radiometric analysis of the thin sections with the cover slips in place yielded a greater than 2X background count.
RJGS 81 - DDH 375

Hand Specimen: Green slate.

Thin Section: Calcareous-quartz mica slate or schist.

Quartz is polygonal, elongate parallel to S, and locally micro-
crystalline.

Mica is biotite in part and probably also sericite. It is mostly
parallel to S but locally suggests another foliation.

Carbonate is an essential mineral as scattered crystals, aggregates
and veins.

There are opaque minerals altering to iron oxides and semi-opaque
minerals, presumably sphene altering to leucoxene.

? Apatite occurs in accessory amounts.

RJGS 82 - DDH 370

Hand Specimen: Green slate.

Thin Section: Calcareous quartz-mica hornfels.

Quartz is polygonal and micro-crystalline.

Carbonate occurs as fine grained irregular patches.

Mica is sericite and shows no preferred orientation on scale of whole
thin section.

Opaque minerals include skeletal ilmenite, locally altering to
leucoxene, skeletal hematite possibly after pyrite and skeletal
pyrite (different habit to the hematite though still skeletal).

The hematite occurs with the sericite. Within small areas (i.e.
small areas of the thin section) the sericite has a well developed
preferred orientation and the skeletal hematite has the same
preferred orientation. It is possible that these associations
represent the alteration of chlorite and relict chlorite is present
in some cases.

RJGS 83 - DDH 375

Hand Specimen: Grey Slate.

Thin Section: Very much like RJGS 59. Some of the calcite veins
appear to pre-date deformation. There are skeletal pyrite crystals.
MOUNT BURTON

Mt. B. 34 - Mount Burton open-cut

Hand Specimen: Grey Acacia Gap type, pyritic quartzite.

Thin Section: TS 11582

"This is a fine to medium-grained ortho-quartzite cemented by suturing of the grains. The quartz shows marked undulatory extinction. There has been some shearing resulting in the granulation of grains and, apparently accompanying this, the introduction of marmides. Small flakes of muscovite occur scattered through the rock. Fractures are lined with iron opaques."

Quartz is fairly polygonal.

There is no reason to believe that sulphide was introduced during shearing or to believe that quartz has been granulated.

Mt. B. 35 - Mount Burton open-cut

Hand Specimen: Glassy quartz from region of necking in quartzite boudin (cf. Fig. 18c).

Thin Section: TS 11583

"This is a sample of coarse-grained vein quartz with a minor amount of a sulphide mineral, probably pyrite. Micrographic examination was thought not to be warranted but if required will be carried out at a later date."

Course grains are sutured and fractured.

Extinction is undulose.

Despite appearance it is the product of metamorphic recrystallisation.

Mt. B. 36

From same locality as 38 which it resembles closely being just a little more fractured.

WHITES OPEN-CUT

R. 213 - DDH 79, 555 ft.

Hand Specimen: Green poorly foliated rock, resembling green slate, with hematite stains.
Thin Section: TS 12170

"Quartz-chlorite breccia. Angular, medium to coarse-grained fragments of micro-crystalline to fine-grained quartz are contained in a matrix of micro-crystalline to fine-grained chlorite. Portions of the silica are stained by iron hydroxide (goethite?). Cryptocrystalline silica (quartz?) is present within the chlorite matrix. Micro-crystalline to fine-grained, subhedral or granular grains of opaques are scattered through the rock. A number of fractures cut the specimen and commonly aggregates of carbonate (calcite) are associated with them."

Many of the mineral aggregates occur as rounded masses.

The carbonate mineral has been identified by optical means only, it may well be dolomite.

R 27E - DDH 221, 130 ft.

Hand Specimen: Black slate with very well developed foliation. Almost a schist.

Thin Section: TS 12174

"Quartz-sericite slate. Sericite is dominant and quartz is present in only a few laminae-like concentrations within a matrix of sericite. Opaques are present but not very abundant and occur as fine to medium-sized linear bodies which are parallel to the foliation. Foliation (S1) is displaced by the development of microifications."

"In places chlorite aggregates are present and several 'pool-like' occurrences of quartz were observed."

There is an incipient cleavage, parallel to the axial plane trace of the microfication which intersects S1 in an angle of approximately 70°.

S1 is defined by preferred orientation of minerals and mineral aggregates including quartz and there is a suggestion of an earlier foliation, S2, defined by aggregates of quartz which appear to line up across the trend of S1. There are also quartz veins sub-parallel to S2.

R 26A - DDH 152, 4 ft.

Hand Specimen: Green slate with irregular areas of sericite which does not appear to have a preferred orientation.

Thin Section: TS 12175

"Chlorite-muscovite slate or schist. Foliated muscovite, fine to medium-grained, is the major constituent of the rock. Opaques are scattered through the rock to a degree but tend to be concentrated in thin aggregates paralleling
the mica foliation. Several more deformed and fractured areas, in which concentrations of opaques occur, are present as randomly located circular shaped aggregates, however, the greatest development of the mineral occurs in association with the opaques. A few concentrations of apatite, as fine-grained granular crystals in aggregates and scattered grains, were observed in association with the chlorite and opaques.

No other "primary" minerals other than muscovite were observed in the three sections examined, therefore, it is rather unlikely that "sericite" formed as a hydrothermal, etc. alteration product of earlier minerals. The rock seems likely to have originated by regional low grade metamorphism of argillaceous sediments (shales, etc.). The concentration of opaques, (either from primary constituents of the rock or hydrothermal deposition), the selective crystallisation of chlorite, and the concentrations of apatite suggest that the rock may have undergone a period of hydrothermal or pneumatolytic alteration post metamorphism. Some deformation (brecciation) of the rock has also occurred. Colour differences observed in the hand specimen result from contrasting colours of muscovite and chlorite, and oxidation of iron of the opaques."

There is a mineral with high relief in accessory quantities. It may be sphene but if so it is showing anomalous interference colours.

The foliation is not very well defined and is folded with local rupture.

R 280 - DDH 152, 54 ft.

Hand Specimen: Grey slates with a weak foliation and veins of carbonate.

Thin Section: TS 12176

"Meta siltstone. The specimen has been metamorphosed under low grade regional conditions. The siltstone was comprised dominantly of clastic quartz and argillaceous minerals before metamorphism. It has an excellent crystallisation foliation, shown by very lenticular crystals of quartz, which have formed by recrystallisation of clastic quartz under conditions of stress. Fine, disseminated grains of opaques are an important minor constituent of the rock. Numerous fine, flakes of sericite are scattered through the rock. Occasional aggregates of sericite, and coarser areas of recrystallised quartz with some associated opaques, were observed.

The rock has been partially brecciated, post development of its metamorphic structure, and these brecciated portions reconstituted with micro or cryptocrystalline silica (referred to as carbonate in the rock descriptions accompanying the specimens). Sphene was observed as fine crystals present in minor accessory amounts."
Brecciation has accompanied folding. Opaques (appear to be chalcopyrite) are abundant and coarse grained in the quartz-sericite gangue filling the spaces between the brecciated fragments.

R 285 - DDH 152, 174 ft.

Hand Specimen: Pale green, well foliated, sericitic schist.
Thin Section: TS 12177

"This rock compares in original sedimentary type to R 28C and also appears to have a similar metamorphic history. However the rock has a matrix of fibrous chaledonic silica. Opaques are present as finely disseminated grains but most abundant as elongate grains and granular aggregates which parallel the crystallisation foliation of the rock. Semi-opaques grains, thought to be sphene, are also present in accessory amounts. Anatite occurs in accessory amounts as granular aggregates. There are fractured areas within the rock and here chaledony is the dominant silica. Numerous, very fine, flakes of sericite are scattered through the specimen.

Chaledony appears to have formed by recrystallisation of original quartz. Similar replacement of quartz by chaledony has been observed by the writer in specimens of "duricrust"."

Aggregates of sphene are elongated parallel to the foliation. There are also bands of comparatively, coarse grained, polygonal quartz parallel to the main foliation.

R 285 - DDH 152, 252 ft.

Hand Specimen: Green slate with irregular patches of sericite which does not appear to have a preferred orientation.
Thin Section: TS 12178

"The rock is comprised of muscovite, chlorite, carbonate and fine-grained quartz with associated opaques. The rock has been intensely deformed and fractures are common. Carbonate is a very common fracture filling mineral and opaques also occur within them. Chlorite appears to have formed, during the brecciation and fracture filling, by alteration of muscovite. The original rock is not determinable because of the altered nature of the sample. However part of it resembles the mica slates, and another portion is comparable to the metasiltstones of this group of rocks. Contacts between these two rocks (i.e. of tectonic or sedimentary origin) were not determinable from examination of the rock-slides."

Carbonate is one of the main constituents of the rock. It occurs as veins and also as irregular masses which are not bounded by regular lines as are the veins. In these masses the growth does not appear to have been restricted as in the veins and they appear to be an integral part of the rock rather than introduced material.
Muscovite is coarse grained and frequently folded. Much of it is fresh but where it is altering to chlorite there are alternating bands (parallel to the cleavage) of muscovite and chlorite.

A high relief mineral, again possibly sphene, with anomalous interference colours occurs in accessory amounts.

In this section it is impossible in the opinion of the writer to recognise the original rock type. From the hand specimen it would appear to be related to the mica slates.

**R.31A - DDH 212, 31 ft.**

**Hand Specimen:** Black slate.

**Thin Section:** TS 12179

*Quartz-sericite slate*. The mica of the rock shows a foliation and has also been "folded" into micro-plications. In the axial areas of the plications an incipient $S_2$ is developed parallel to the axial planes. Micro-shearing along these planes and in some places along $S_1$ (foliation) has disturbed the structures of the mica.

The mica of the rock is sericite or fine-grained muscovite and dominates the mineral assemblage. *Quartz* is fine-grained or microcrystalline in size and some grains show a crystallisation foliation. *Opnques* occur in fine to medium-grained, linear aggregates or as finely disseminated grains amongst the sericite laths. They are a minor constituent and give the rock its dark colour. Several grains of accessory *tourmaline* were observed.

Secondary quartz has crystallised along several of the larger micro-shears."

There are two sets of folds rotating the $S_1$ foliation of this rock. They are shown in Fig. A1. (a) is the earlier of the two and is largely transposed.

**R.32A - DDH 200, 13 ft.**

**Hand Specimen:** Green slate with hematite stains.

**Thin Section:** TS 12180

*Sericite slate*. The rock is composed entirely of sericite (some is altered) with a few iron containing accessory minerals. The sericite is well foliated and some micro-plications are present. Scattered fine-grained semi-opaque and opaque minerals are present in accessory amounts; sometimes they are concentrated in linear aggregates. Lens-like aggregates and patch-like bodies of a micro-crystalline mineral, with similar structure to sericite, occur and are thought to altered sericite (chlorite or one of the kaolin group of minerals).

The red bands seen in the hand specimen probably result from oxidation of a portion of the iron in the opaques of the linear aggregates."
The semi-opaque mineral is the sphene or zircon.

**Hand Specimen:** Brecciated black slate with quartz fragments and pyrite and chalcopyrite in the matrix. Fragments are angular except for a few of the slate fragments which are slightly rounded.

**Thin Section:** TS 12181

"**Breccia.** Angular fragments of quartz-sericite slate are cemented by a matrix of quartz. The quartz is fine-grained and appears to be sedimentary, it has a matrix of fine-grained mica (sericite) or is cemented by secondary growth of silica. In places the matrix quartz appears to have recrystallized into a coarser grained aggregate. The foliation of the slate was formed before its brecciation and metamorphic recrystallisation of the matrix quartz is not evident. Opaque occur as fine, disseminated grains in association with the mica of the slate and as medium to coarse-grained fragments and crystals in slate fragments and the cementing quartz matrix.

Some fine-grained or cryptocrystalline aggregates of a mineral with low birefringence were observed. It is suggested that the mineral is apatite, although, this suggestion is tentative because positive identification by this technique is not possible as the grain size of the mineral is too small."

The matrix of the slate is much coarser than that of the slate. There are individual grains of quartz and fragments consisting purely of quartz crystals. The individual grains are usually angular but rounded fragments do occur. There are fine grains of sericite intermingled with these quartz grains. There are one or two quartz crystals that are much larger than the rest and which are cracked. Some of the smaller grains also show signs of cracking.

The fragments of quartzitic material appear fairly rounded to the naked eye; under the microscope the boundary and rounded appearance are less obvious. The interface between crystals with the fragments varies between interlocking and polygonal.

**Hand Specimen:** Grey dolomitic marble with a suture-like line which may be due to folding of a narrow band of fine-grained opaque minerals.

**Thin Section:** TS 12182

"This is a fine to medium-grained dolomite. The carbonate grains show a crystallisation foliation which is interpreted as resulting from recrystallisation of the carbonate under stressed conditions. The carbonate was found to be entirely dolomite by X-ray diffraction methods; no quartz was observed in
the thin section and no quartz lines were recorded on the X-ray diffractograph of the sample."

There are small folds (described as "sutures" in hand specimen) defined by lines of opaque minerals which are symmetrical about the foliation. Within the closures of the folds Fig. A2 there are patches of a green mineral which looks as though it may be very fine-grained chlorite.

**RUN JUNGLE COPPER PROSPECT**

**R 23A - DDH 63, R.J.Cu. 3, 191 ft.**

**Hand Specimen:** Pale green, well foliated, chloritic, sericitic schist.

**Thin Section:** TS 12172

"This is a sericite-quartz schist and assigned to the green schist facies of regional metamorphism (op.cit., Turner and Verhoogen). The minerals of the specimen are fine-grained or micro-crystalline. Sericite shows an excellent foliation and some of the quartz is lenticular or elongated in the direction of foliation (i.e. quartz shows a moderate crystallisation foliation).

The mica of the rock appeared to be muscovite (sericite) by optical examination, rather than talc, but because of its fine-grained nature definitive optical properties were not applicable. X-ray data was not sufficiently definitive for the identification of the phyllosilicate. Quartz appears slightly more abundant than muscovite. A number of fine-grained transparent and opaque minerals occur in accessory amounts. Opaques and semi-opaques (sphene ?) are the most abundant. Transparent minerals are apatite (?) (common) and zircon (?). Because of their fine-grained and micro-crystalline nature absolute determination of the accessories by the petrographic microscope is not possible."

Crystals referred to as sphene represent approximately 25% of the section. They include cubic crystals with a cubic or tetragonal habit which is almost certainly zircon.

**R 23B - DDH 63, R.J.Cu. 3, 204 ft.**

**Hand Specimen:** Black slate with chalcopyrite.

**Thin Section:** TS 12173

"This is a sericite-quartz slate. Quartz and sericite are the dominant constituents of the rock and opaques are present as minor constituents. Sericite has an excellent foliation and quartz grains sometimes show a crystallisation foliation. Mineral constituents are dominantly fine-grained. Opaques are scattered through the matrix as dust-like grains and occur as angular and linear shaped, fine to coarse-grained bodies also. The
coarser opaque bodies occur in localities paralleling the foliation and in cross cutting micro-fractures."

Sulphides including chalcopyrite represent of the order of 25% of the constituent minerals.

**DISCOT'S OPEN-CUT**

R 44 - DDH 181, 595 ft.

Hand Specimen: Black slate.

Thin Section: TS 12185

"Chlorite muscovite slate. This rock is fairly coarse grained for a slate and in fact bordering on schist. Areas, generally laminar in form, of chlorite and coarser muscovite are present. More opaques are much less abundant than in other portions of the rock. Also a few grains of sphene are present in these areas. The exact process or genesis of the formation of them is not certain. However the chlorite of the rock is suggestive of a secondary period of crystallisation and the linear bodies may have formed during that recrystallisation (i.e. post-metamorphism). Several irregularly shaped quartz aggregates were observed."

There are four lineations recognizable on this thin section. The main lineation is the trace of the main foliation S, and is defined by preferred dimensional orientation of quartz and mineral aggregates and preferred orientation of micas. There are two other lineations L1 and L2, oblique to S and symmetrical about it. They are defined by lines of common extinction, elongation of occasional crystals and the axial planes trace of minor foliations in S. Individual micas in the coarse-grained aggregates appear to be oriented preferentially parallel to L1 and L2, and are themselves folded. The fourth lineation is perpendicular to S and is defined by lines of common extinction.

**MOUNT FITCH**

R 20 - Sub area 2

Hand Specimen: Buff coloured slate.

Thin Section: TS 12189

"Mica-quartz slate and has formed by low grade meta- morphism of a sediment. The rock has a strong structure formed by foliated micas, micro-shearing which parallels the foliation, and similarly oriented crystallisation foliation shown by some of the quartz. Quartz and muscovite (or sericite) are present in about equal quantities and both constituents are in general fine-grained. There are a number of semi-opaque and opaque aggregates and scattered dust-like grains of the same material within the rock. The muscovite of the rock appears to be stained - some is
yellow coloured in plane polarised light. It is suggested that the opaque of the rock have been oxidised and are now goethite or hematite and the staining of the muscovite occurred during this process. Very, fine-grained, green coloured Tours-
line is an abundant accessory mineral."

R.51 - Contam 57, Sub area 3

Hand Specimen: Furblish black slate.

Thin Section: TJ 12190

"Mica-quartz slate. It is similar in structure, nature and alteration of neo and opaque grains, and general mineralogy to sample R50. Both rocks have formed by low grade, most likely regional meta-
morphism of argillaceous siltstones. Some of the fine-grained mica of this rock has a green pleochroism; this pleochroism was not observed in mica of R50. It is suggested that this mica is a green coloured biotite. If these two units are lithologically correlative, original composition differences or pressure/temperature conditions (resulting from depth of burial, tectonism, etc.) could account for the mineralogical differences observed. Toursmaline, while present, is not as abundant accessory as in R50."

R.56 - Sub area 4

Hand Specimen: Silicicous black slate. Well foliated with quartz veins parallel to the foliation and also cross-cutting.

Thin Section:

Quartzite. Thin section consists almost exclusively of quartz. Locally the quartz grains suggest a weak foliation sub-parallel to the banding which is obvious to the naked eye but far from obvious under the microscope. Boundaries between quartz grains are polygonal. Banding appears to be due to varying concentrations of yellowish translucent material which is probably the product of the weathering of an iron mineral.

Scattered very small crystals of sericite define a weak foliation inclined to the observed banding.

Quartz veins are both parallel to banding and at right angles to it. In the veins quartz crystals have interlocking boundaries and there are occasional crystals of muscovite.

Both the vein quartz crystals and the quartz crystals comprising the bulk of the rock have undulose extinction and are cracked.

This is an example of a rock type that is generally thought to be silicified. However there is no evidence of silicification in this thin section and all the quartz including the vein quartz is stressed.
Is this compatible with silicification due to tropical weathering?

R 57 - Sub area 3

Hand Specimen: Foliated grey quartzite.

Thin Section:

Tourmalinised quartzite. Quartz is main constituent. It is polygonal and has wavy extinction. Tourmaline represents approximately 25% of the rock. It is buff coloured and not very pleochroic. Crystals are subhedral to euhedral and locally embayed giving a somewhat ruggy appearance. They also have a strong basal fracture in prismatic sections. Inclusions of quartz are fairly common in the tourmaline.

There are aggregates of semi-opaque minerals possibly sphene or zircon but too fine-grained to identify with certainty.

Area 55

R 110A - DDH 679, 71-96 ft.

Hand Specimen: Dark green clayey rock with contorted compositional banding. Suggestion of crenulation cleavage.

Thin Section:

Subhedral to euhedral crystals of apatite, pyrite and sphene or zircon occur in a very fine-grained ground mass. The ground mass is too fine to identify with certainty but is thought to be quartz with a little mica.

Subhedral to euhedral crystals of apatite are common and fairly dense aggregates occur locally.

Pyrite is a common accessory and occurs as skeletal and subhedral crystals. A vein of pyrite with coarse crystals of quartz traverses the slide. There may also be apatite associated with the vein but it could not be identified with certainty. A semi-opaque mineral thought to be sphene or zircon is present in quite large quantities.

The opaque and semi-opaque minerals define the banding in the rock which is not foliated.

R 110B - DDH 679, 71-96 ft.

Hand Specimen: Same as 110A.

Thin Section:

Very similar to 110A. The ground mass is again thought to be mainly quartz but there are also areas in this slide which appear to be essentially very fine-grained chlorite.
Apatite is even more abundant than in the previous slide and occurs as euhedral crystals.

The semi-opaque mineral is again present. Associated with it are minute, fresh-looking crystals of what appears to be the same mineral and which are almost certainly zircon. There are occasional knee-shaped twins.

Pyrite occurs mainly as euhedral grains and very fine grains.

There are a few large, scattered crystals of mica. They show only grey and white interference colours.

The rock is not really foliated and banding is defined by opaque and semi-opaque minerals.

R 111A - DDH 63, 240-250 ft.

Hand Specimen: Polished grey sericitic talcose schist. Slightly vaggy and has traces of iron oxides.

Thin Section:
Quartz, mica, schist. Quartz occurs as aggregates of polygonal crystals. Most aggregates are elongate and help to define the foliation.

Mica is very fine-grained and gives the impression of being relift after coarser crystals. There is a suggestion of pleochroism but it is very weak. May be sericite or chlorite.

What is thought to be sphene or zircon is present and is a fairly abundant accessory as very fine grains.

Very fine grains of what is thought to be tourmaline are also present.

Foliation is fairly well defined by mica and quartz and is plicated.

R 111A - DDH 63, 240-250 ft.


Thin Section:
Quartz, mica, opaque minerals, slate. Quartz occurs as scattered grains and aggregates of polygonal crystals.

Mica is very fine-grained and appears to be sericite.

Opaque minerals are very common and are in fact an essential mineral or minerals. They occur as falted masses and consist in part of fine-grained pyrite.
Semi-opaque mineral possibly zircon or ilmenite is present and abundant in areas where opaque minerals are not plentiful. In the areas where the opaque minerals are abundant zircon is probably present but obscured.

Two foliations are developed in this rock. The earliest, S₁, is defined by preferred orientation of mica and by the compositional banding defined by the opaque minerals and to a lesser extent quartz. The second S₂ is defined by the elongation of aggregates of polygonal quartz. S₁ is folded and S₂ is parallel to the axial trace of the folds. The style of the folds varies from chevron to isoclinal to transposed. There is a secondary generation of folds which, being later, rotate both S₁ where it is favourably oriented and S₂ into minor plications the axial traces of which intersect the axial trace of the earlier generation of folds in an angle of approximately 60°.

R 112A - DDH 679, ca 246 ft.

Hand Specimen: Weakly foliated pyrite - rich green schist.

Thin Section:

Chloritic schist or hornfels. There are two forms of chlorite. One is coarse grained and weakly pleochroic. In polarised light it gives an anomalous apple green interference colour and has straight extinction. For the most part it appears to be randomly oriented but locally defines a weak foliation. The second form of chlorite occurs as scattered irregular masses amongst the other crystals of chlorite. It is very fine-grained and consists of many feather aggregates. It is very pale green and weakly pleochroic in ordinary light and gives the anomalous 'Verlin blue' interference colour typical of pennine in polarised light.

Quartz occurs as an accessory mineral and apatite is fairly common. Pyrite and a semi-opaque mineral thought to be zircon, complete the list of accessory minerals. Both occur as skeletal crystals. The zircon skeletal crystals having a rectangular outline.

R 112B - DDH 679, ca 246 ft.

Hand Specimen: Same as R 112A.

Thin Section: Chlorite Hornfels.

As in R 112A, which this rock resembles, there are two types of chlorite. They are the same as the two types described in R 112A but the pennine is now as coarse grained as the other form. Both forms also occur in composite crystals. In some such crystals the boundary between the two types is parallel to the 001 cleavage in others it is irregular and distribution is patchy.

The suspect zircon and pyrite are again abundant accessories. The zircon occurs largely as skeletal crystals. The pyrite varies from euhedral to anhedral and also occurs as a crack filling.

Quartz is again a minor accessory and occurs as embayed grains.
The texture is markedly deccorate.

ARKOSE AND CONGLOMERATES

B91

Close to granite contact, east side of granite on Woodcutter's road.

**Hand Specimen:** Compact pink feldspar - quartz rock. In outcrop it is banded and contains what appear to be pebbles. It is therefore presumably arkose, but in hand specimen looks more like an igneous rock. It is rich in iron oxide and contains pyrite. Iron oxides occur in rounded masses and as very flat lenses.

**Thin Section:** Arkose

Angular to well rounded fragments of quartz, feldspar and granite occur in a quartz sericite groundmass.

Feldspar includes *microcline* and an albite plagioclase. It is fresher than the feldspar in most of the granite specimens there being very little sericitisation.

The quartz in the groundmass is very fine-grained and could be secondary in part.

Zircon, sphene and apatite occur as accessories.

Opaque minerals occur as accessories and include pyrite ?, hematite and ilmenite altering to leucocoxene.

B 101A

Close of granite contact near intersection of Rijcs ore haulage road and railway.

**Hand Specimen:** Fine-grained, grey, quartz-feldspar-biotite rock with pebble-like pink areas of quartz and feldspar. There are occasional rounded fragments of blue quartz. There are coarse grained feldspar crystals in the matrix some of which appear detrital.

**Thin Section:**

This rock is problematical. Some crystals are rounded but others are polygonal, none are sutured. Large crystals tend to be "outlined" by very fine-grained minerals - principally micas. If this rock is sedimentary it has presumably been subjected to considerable low grade metamorphism. This is possibly supported by the condition of the feldspar.
Quartz is mostly polygonal and is strained.

Feldspar is mainly microcline and is perthitic in part. What microcline occurs is albite. Locally the feldspar is unusually fresh but many crystals are heavily altered to sericite and there are large patches of sericite where no feldspar is recognisable but which may still be after feldspar.

Greenish brown biotite is a fairly common constituent and there is a little limonite altering to leucoxene.

Very fine-grained euhedral zircon and ? apatite are present as rare accessories.

R 101F - Same locality as R 101A

Hand Specimen: of R 101A.

Thin Section:

This rock is much the same as R 101A but is traversed by a shear. The movement has produced a narrow zone of fine-grained polygonal quartz accompanied by sericite and lesser amounts of biotite.

R 106A

Close to granite contact on east side of Rum Jungle Granite about 1 mile south of Woodcutter's road.

Hand Specimen: Pebble from arkose. Fine-grained pink quartz and feldspar rock with small patches of biotite.

Thin Section:

This rock does not differ greatly from R 101A in texture and yet is apparently a granite pebble. The difficulty experienced in separating arkose and granite is some measure of the metamorphism the rocks have undergone since intrusion and deposition.

Quartz and feldspar are fairly equal in quantity. The feldspar is microcline and an albite plagioclase. It is not very strongly sericitised.

Large crystals are outlined by fine-grained minerals but no rounded crystals were observed.

Rutile, ? apatite and very fine-grained zircon are present as accessories.

Opaque minerals are altering to iron oxides which stain boundaries of crystals.
R 106f - Same Locality as 106a.

Hand Specimen: Arkose very compact with rounded fragments of feldspar and quartz including blue quartz. Many of the fragments are angular and there are pebbles of the fine-grained, pink, late granite.

Thin Section: Arkose.

Most of large clasts are sub-rounded to well-rounded. They consist of albite plagioclase, microcline, quartz, vein quartz (i.e. aggregates of sutured quartz) and quartz and feldspar.

Matrix is mostly muscovite plus fine-grained quartz and feldspar with a little biotite. Mica has preferred orientation.

Zircon (uniaxial positive) and zircon occur as accessories.

Opaque minerals are subhedral to euhedral, steely grey spinel, locally altering to hematite. Presumably magnetite.

R106 E - Same locality as 106a.

Hand Specimen: Same as 106a.

Thin Section: Arkose.

Quartz, feldspar and quartzite clastics occur in a sericite rich matrix. Matrix is more abundant than usual and represents about 15% of the rock.

Feldspar is mostly microcline but there is a little albite plagioclase. Sericitisation is widespread but not very advanced. Some of the feldspars have retained rectangular shape with only slight rounding.

Clastics vary in degree of rounding some being well rounded others angular.

Biotite occurs in small aggregates and there are a few grains of hematite.

Opaque minerals are common. They are subhedral to euhedral, steely grey and cubic. Presumably magnetite.

R 106f - Same locality as R 106a.

Hand Specimen: Same as R 106a but with a pebble of black quartzite.

Thin Section:

Little different to R 106g except for a large pebble (\(\frac{1}{4}\)) of quartzite. Quartzite is rich in very fine-grained oxides which appear to be steely grey and are thought to be magnetite.
R 106C

Granite contact south - south east of Mount Stratton.

**Hand Specimen:** Rounded masses of medium-grained, grey, quartz-feldspar rock with traces of Ferromagnesian minerals in a fine-grained, grey matrix. Matrix contains quartz and sericite - nothing else is identifiable.

**Thin Section:** Arkose.

Two granite pebbles in a matrix like R 106E except that it contains more biotite and calcite.

One pebble consists of quartz and microcline with a little albite plagioclase and very fine crystals of alunite as accessory mineral.

The other pebble consists of quartz, microcline and albite plagioclase (more abundant than in the first section). Biotite occurs as an accessory mineral and large euhedral zoned alunite are fairly common. Calcite is also a common accessory and sericite, due to the sericitization of feldspar is present.

**HEMATITE QUARTZ BRECCIA**

R 10 - Rum Jungle Creek, DDH 509

**Hand Specimen:** Quartzite with bands defined by hematite staining.

**Thin Section:** Quartzite.

Quartz is mostly polygonal occasionally sutured. Preferred orientation of slightly elongated crystals defines a weak foliation. Bands of coarse-grained, polygonal quartz crystals parallel to banding.

Banding seen in hand specimen is defined by fine-grained hematite which is a common accessory. Sericite is also common as an accessory mineral.

R 11 - Rum Jungle Creek, DDH 509

**Hand Specimen:** Quartzite boudins in hematite-rich matrix.

**Thin Section:** Boudinaged quartzite.

Boudins of pure quartzite occur in a quartz-sericite-hematite rich matrix.

In boudins, quartz is polygonal; in matrix its boundaries are obscured by hematite. Sericite shows slight preference of orientation and the foliation, thus defined, is parallel to the length of the boudins.
R.12 - Run Jungle Creek, DDH 509

Hand Specimen: Breccia. Fragments of very finely banded hematite-rich quartzite (like R 10 but more finely banded) in a hematite-rich matrix.

Thin Section: Consolomorata. 
Angular to well rounded grains of quartz and quartzite in a quartz-hematite-sericite matrix.

Quartzite clastics consist of sutured to polygonal crystals suggesting an igneous origin.

Quartz in matrix is angular or interlocking.

Nica is mainly sericite and shows no preferred orientation. Chlorite, probably penning since it gives 'Berlin blue' interference colours, and biotite occur as accessory minerals.

Hematite is a common accessory.

R.17 - DDH 555, 750 ft.

Hand Specimen: Fine-grained H.Q.B. with fragments mostly less than 1/2" but locally as large as 1/2". Fragments angular to rounded.

Thin Section: 
This rock is very similar to R 46 which is described by A.W.B.V. as a quartz arenite. It is an unusual rock in that the clasts are poorly sorted in size and vary greatly in degree of rounding but the clasts consist almost exclusively of quartz.

The coarse-grained clasts are angular to rounded but mostly sub-rounded.

The fine-grained clasts are angular to well rounded but mostly sub-rounded or rounded. Hematite occurs as cement and chlorite is a fairly common accessory.

R 22A - White's Open-cut, DDH 76

Hand Specimen: Brecciated ? silicified limestone. Rounded areas of grey quartzitic material surrounded by quartz veins and veins with a zoned appearance.

Thin Section: TS 12171

"This is a recrystallised and partially brecciated dolomite. The rock is primarily composed of carbonate. Where recrystallisation is not evident, the dolomite is fine, and less often, medium-grained. Fine-grained,
apparently clastic quartz is present in laminar bodies. These were probably liminae of clastic quartz grains. Quartz is also present as scattered grains within the carbonate. There are finely disseminated opaque grains and mica flakes in the clastic laminae. Areas of coarse to medium-grained carbonate and quartz are present with a few scattered opaques. They are presumed to be recrystallised portions of the original rock. No calcite was recorded on the X-ray diffractograph of the specimen."

There is no decisive evidence for the quartz having a clastic origin.

Both quartz and carbonate, where coarse grained, are polygonal. Polygonal grains of carbonate occur in the quartz laminae. Fine-grained carbonate occurs as rounded and angular aggregates.

R 36A - Dyson's Open-cut, DDH 120 ft.

Hand Specimen: Brecciated limestone, angular fragments in a pink matrix.

Thin Section: TS 12183

Marble - presumably magnesium marble like R 36B which it closely resembles. In thin section there is no evidence of brecciation. The rock appears to be brecciated in hand specimen due to the patchy distribution of iron oxide. Carbonate varies in grain size but is typically polygonal in part. It is coarser grained than 36B and where coarsest it is sutured. This suggests recrystallisation.

Cordierite occurs as an accessory mineral. It occurs as pseudohexagonal twins and is biaxial negative with a very high 2V.

No quartz was observed and chlorite occurs as an accessory mineral.

R 36B - Same locality as R 36A but 122 ft.

Hand Specimen: cf. R 36A

Thin Section: TS 12184

"This is a fine to coarse-grained, magnesium marble or dolomite. The carbonate of the rock was found to be entirely dolomite by X-ray diffraction methods. No quartz was observed by petrographic methods or on the X-ray diffractograph of the sample. A few opaques were observed in association with chlorite in the red coloured portion of the sample. Other dusty or non-transparent grains of uncertain nature (e.g. opaques or organic material) were observed in this portion of the sample. Most of the specimen is comprised of coarse or medium-grained dolomite."

For the most part carbonate is polygonal.
Hand Specimen: Typical M.Q.B. with angular to well rounded quartz clasts in hematite rich quartz matrix.

Thin Sections: TS 12191-12193, 12194 & 12195

"The rock sections (10) compare very well in general aspects to R 46C and no differences except in number and size of the fragments were observed.

(a) There is no fabric, in general, present within the matrix. The grains themselves do not appear to have recrystallised post-diagenesis. The iron oxide (hematite(?)) appears to have been a primary constituent of the sediment. Where hematite is most abundant secondary overgrowths on quartz grains are very restricted and original clastic surfaces are preserved.

(b) Individual quartz clasts, in which quartz shows a dimensional orientation, are in general not oriented. Several features indicate that the lineation observed within quartz of the clasts is pre-sedimentation:-

1. Matrix grains have not been recrystallised.
2. Some clasts contain relatively few or no oriented grains. This may be a feature only of the direction of sectioning.
3. The clasts do not show mutual orientation of quartz lineations.
4. Clastic borders of the fragments are still well preserved. They indicate to the writer that the fragment quartz has not recrystallised post-diagenesis.

(c) Regarding the postulated silicified limestones - there is no indication what-so-ever of carbonate ever being present in any of the sections. The matrix of all of these samples is composed of angular to sub-rounded grains of quartz. These are most certainly of a sedimentary origin."

R 41

Clasts vary from 0.02 mm. to 75 mm. Coarse-grained clasts are angular to well rounded but mostly sub-angular.

Fine-grained clasts are also angular to well rounded but mostly sub-angular to sub-rounded.

R 42

Coarse clasts angular to rounded. Fine-grained clasts, angular to well rounded. Rounded and well rounded are very common and locally grains are "millet seed".
R 43
Grains polygonal to sutured and fine to coarse. Extinction is undulose and cracks are fairly common.

Apatite is a common accessory and there are needle-like crystals of hematite.

The coarse clasts are missing from this rock.

R 54 - cf. R 41
Iron minerals look as though they could be clastic.

R 55
Coarse grained clasts are angular to rounded and mostly sub-rounded. Fine-grained clasts are angular to well rounded but mostly sub-rounded and rounded.

R 65 - Dyson's Open-cut, DDH 174, 100 ft.

Hand Specimen: Quartzite from H.Q.B. with hematitic matrix. Quartz fragments appear rounded and are up to 3/32" but mostly less than 1/16".

Thin Section: TS 12186

"This is a poorly sorted, medium to coarse-grained quartz arenite. Medium to coarse-grained, sub-angular to rounded grains of quartz are enclosed by a finer matrix of quartz grains. There appears to have been only a small fraction of argillaceous material in the sediment. The arenite is cemented by secondary silica, chlorite, and in a few areas semi-opaque material (hematite?). Some of the interstitials are stained by iron hydroxide? (goethite). Most of the coarser quartz grains are sutured in outline. A few granular aggregates of apatite (?) are present. A single grain of zircon was observed."

There are opaque minerals which are thought to be ilmenite.

For drawings of clasts see Fig. A3.

R 65 - Dyson's Open-cut, DDH 174, 185 ft.

Hand Specimen: Quartzite from H.Q.B. with hematitic matrix and chlorite smear on one surface.
Thin Section: TC 12187

"This is a fine to medium-grained, lithic quartz arenite. Quartz as angular to sub-rounded grains, which show medium sorting, is the major constituent of the rock. There are also some grains which appear to be rock fragments, of siltstone and quartzite, but they are not an important constituent. Some grains, of microcrystalline silica and sericite, may be altered feldspar. Cement is primarily iron hydroxide or oxide (goethite, hematite). A very fine-grained clay mineral, probably kaolinite, is also an important cementing mineral. Secondary quartz and cryptocrystalline silica also cement grains."

Clasts are less well rounded than in 46A.

R 46C - Dyson's 174, 188 ft.

Hand Specimen: H.Q.B. fairly fine-grained with rounded to angular quartz fragments.

Thin Section: TC 12188

"The rock is a quartz breccia. The breccia fragments, medium-grained and coarser, are composed of a mosaic of quartz grains. They are clear in plain light and cemented by the interlocking nature of the quartz crystals (cremulated in outline). There is a variation of grain size of the quartz forming them, grains have an average diameter of 0.29 mm, and a slight crystallisation. Foliation is shown in some fragments. The fragments appear to have been of quartzite (i.e., a quartz arenite, which was possibly metamorphosed). The matrix of the breccia is composed of angular to sub-rounded grains of quartz cemented by iron hydroxide or oxide (goethite or hematite). The grains are fine sand sized with an average diameter of 0.083 mm. Accessory amounts of chlorite, as a matrix cement, and analcite(?) as intergranular "patches", was observed.

There is no indication what-so-ever that this is a silicified limestone breccia."

Some of the larger clasts have rounded surfaces and look very much like the angular fragments resulting from the breaking up of a rounded pebble.

SPECIMENS FROM THE RUM JUNGLE GRANITE

R 20A

Granite contact east of Rum Jungle Batchelor road. 13° 01' 30" 131° 01'. 2 or 3 ft. from contact.

Hand Specimen: Arkose, compact and siliceous with abundant fragments of blue quartz.
Thin Section: TS 12165

"In its present metamorphosed state the rock is not an arkose. It is termed a mica-feldspar-quartz hornfels. The rock has a poikiloblastic texture with varying shaped, medium to coarse-grained, porphyroblasts of feldspar and quartz enclosed by a medium to fine-grained matrix of quartz and mica. The writer assumes, from the description of the sample as an arkose, that the specimen comes from a body of rock which is an unmetamorphosed arkose. If this premise is correct, then the rock has been thermally metamorphosed by the nearby intrusion of an igneous body and the rock has been metamorphosed under albite-epidote hornfels conditions as defined by Turner and Verhoogen (Igneous and Metamorphic Petrology, 1960).

The rock would then be a metaarkose and the present mineral assemblage is consistent with such an origin.

Quartz appears to be the most abundant constituent. Feldspar is primarily microcline with some plagioclase which is within the albite-sodic oligoclase range of composition. Mica is green biotite and muscovite. Several porphyroblastic appearing aggregates of calcite occur and biotite crystals commonly mantle these aggregates. Zircon is present in accessory amounts."

Pebbles of sutured quartz are still recognisable though sheared. Many of the clasts are fractured and some have a rounded surface on one side and angular surfaces on the other sides.

This rock is definitely an arkose but is more positively identified in outcrop than in thin section. It has not been metamorphosed by an intrusive but has been subjected to regional metamorphism of the green schist facies.

Calcite and biotite occur in veins cutting larger clasts and in the matrix. Quartz in matrix is angular to sub-rounded and polygonal locally.

Microcline is perthitic and feldspar in general is heavily sericitised.

R 208

Same locality as R 204 but actually on the contact.

Hand Specimen: Arkose/granite contact. Contact is well defined and is parallel to s-surface in arkose.

Thin Sections:

Three thin sections were cut to determine the nature of the contact. The contact is not obvious despite the fact that it is readily seen in hand specimen. However in the opinion of the writer apart from the colour difference mentioned below there is a difference in texture. All three rocks are sheared but (i) looks more like a sheared igneous rock, while (ii) looks like a sheared conglomerate. That is to say
there are structures in (ii) that look like the remains of rounded pebbles. These also look like a sheared conglomerate, except for one corner which looks more like specimen (i).

From field observation there is little doubt that the contact is the contact between an arkose and its parent granite. Boulders and pebbles of the granite occur in the arkose. The thin sections indicate the degree of metamorphism that must have followed deposition.

Thin Section (i) : TS 12166

"This is a medium to coarse-grained, quartz-feldspar rock. Feldspar is generally microcline but plagioclase in the albite-sodic oligoclase range of composition is also present. Feldspar occurs as medium to coarse-grained crystals which are often broken or deformed appearing. Microcline is characteristically twinned according to the Carlsbad law and the plagioclase is unzoned (from petrographic study it is more likely to be albite). There are areas of fine-grained quartz within the section but medium and coarse-grained quartz is equally as common. The rock does not show a typical hornfelsic texture and the feldspar is in general coarser-grained than feldspar of specimen R 204.

While the petrogenesis of the rock is not clearly delimited from thin section examination alone a similar origin to sample R 204 does not conflict with the mineralogy or textures observed in the specimen.

Many of the microcline grains are sericitised. The process appears selective (i.e. some grains are completely sericitised while others are entirely, or nearly, unaltered). This process may then have occurred with a post metamorphic fracturing and selective replacement of feldspar along fractures.

Zircon and apatite occur in accessory amounts."

Sphene also occurs as an accessory.

Thin Section (ii) : TS 12167

"No major difference in rock type is discernible between the rock on either side of the marked contact. The mineralogy and relative proportions of major constituents in type (ii) compare to type (i). A colour difference is the most apparent contrasting feature of either rock. This is ascribed to the difference in amount of sericite of type (i) and (iii). There is also green chlorite within type (i) with contributes to this contrasting colour."

Thin Section (iii) : TS 12168

"The rock section cut in the directed locality again compares very nearly to type (i)."
R 30C

Same locality as R 20A but from granite side of contact.

**Hand Specimen:** Granite, medium-grained pink granite with blue quartz, pink feldspar and patches of a green mineral. Twinning visible in feldspar. Very weak foliation defined by quartz elongation.

**Thin Section:** TS 12169

"This is a feldspar-quartz rock. *Microcline* is the dominant feldspar and plagioclase and orthoclase are present as subordinate constituents. *Quartz* appears to be the most abundant constituent of the specimen. This rock, like others of the group, shows a selective sericitisation. *Plagioclase*, in the An20-40 range of composition, has been more altered than potash feldspar by the process. The rock-section shows no igneous textures. It differs from other specimens of the group, only in that it is coarser grained."

The texture of this rock resembles that of R 20B (i).

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R 60

Close to two costeans east of Mount Fitch.

**Hand Specimen:** Sheared granite. Well developed foliation - crenulated locally.

**Thin Section:** Quartz-sericite schist.

Aggregates of polygonal and occasionally sutured quartz occur in a mica matrix. Quartz aggregates tend to be elongate and "streamlined" parallel to the foliation defined by the mica.

Mica is pale buff *muscovite* and defines $S_1$, c.f. streams around the quartz fish and is crenulated, thereby defining $S_2$.

Accessory minerals include *ilmenite* and *hematite* or *magnetite*. There are also aggregates of a mineral with general properties of *zircon* including a uniaxial positive figure. It is almost certainly zircon although it is associated with ilmenite and looks more like sphene in ordinary light. There appear to be two varieties of the same mineral a transparent one and a semi-opaque.

R 66A, B, C & D.

Series of specimens collected across granite contact close to two costeans east of Mount Fitch.
R 66A - Collected from granite.

Hand Specimen: Weakly foliated igneous rock, for the most part fine-grained but with some coarse grained (up to 1") pink feldspar crystals. There is abundant white quartz and biotite occurs as an accessory mineral. There are patches of pale green which may be epidote or chlorite and certainly includes mica. Chlorite or sericite is abundant particularly in the green areas.

Thin Section: Retrograded granite.
Quartz is most abundant mineral and occurs mainly in polygonal form but is sometimes sutured.
Feldspar is mostly microcline in various stages of alteration to sercite. It is often perthitic. Plagioclase is not uncommon and is albite.
Biotite is a common accessory mineral.
Opaque minerals are present, and appear to have a spinel habit. Probably magnetite.
The rock is strongly sheared. It does not have the same texture however as the sheared arkose.

R 66B
Some locality as above but much closer to granite contact.

Hand Specimen: Quartz sercite schist. The rock is strongly foliated and from its field relationships is almost certainly sheared granite. Quartz is saccharidal and there may be some residual feldspar. There appear to be two foliations and a crenulation cleavage. One of the foliations is not too well defined and may not be penetrative.

Thin Section: Quartz sercite schist.
Quartz occurs as "streamlined" aggregates in a quartz and sercite matrix. It is mainly polygonal but also sutured. It is greatly strained and cracked.
Mica is sercite. Its orientation varies greatly but the bulk of it is preferentially oriented and defines S1. It is crenulated by crenulation cleavage S2.
There may be a little feldspar in the sercite areas but if so, it is too fine-grained to identify with certainty.
Small zircons and also hematite or magnetite are common accessory minerals.

R 66C

Same locality as above but appears to be from sediment side of the granite contact.

**Hand Specimen:** Quartz, sericite, hematite tourmaline schist. Well foliated. There is a colour banding parallel to the foliation. It is defined by iron oxides.

**Thin Section:** Quartz muscovite schist. There is no means of telling whether the schist has resulted from shearing of granite or shearing of arkose.

Quartz is more abundant than in R 66A. It is polygonal and sutured.

Muscovite. Muscovite has preferred orientation locally but it varies considerably on scale of thin section.

Magnetite or hematite is a common accessory mineral.

Tourmaline is green and strongly pleochroic. Crystals are nearly all six sided and zoned and tend to be euhedral.

R 66D

Same locality as R 66A but from base of H.B.C.

**Hand Specimen:** Very much like R 66C but richer in hematite and poorer in tourmaline. Also this specimen contains pebbles of hematitic quartzite.

**Thin Section:** Rounded and sub-rounded clasts of quartz occur in a mica rich matrix.

Quartz is polygonal sutured and invariably strained and cracked. One of the quartz clasts contains an area of sericite which looks as though it could have resulted from the alteration of feldspar.

The mica is exclusively muscovite and occurs as felted masses.

An opaque mineral probably hematite or magnetite is very common—almost an essential mineral and iron oxide stains are common.

? Zircon and ? apatite occur as accessory minerals.
Green tourmaline is a common accessory and is most common on one end of the slide where the opaque minerals are noticeably less abundant.

R 67A

Granite contact east of East Finnis opposite Jack White's Camp.

**Hand Specimen:** Coarse grained pink granite. Feldspars are altered and sheared but still recognisable and up to 3/8" across. Blue quartz and sercite are recognisable and there are patches of a green mineral. Small black iron minerals are visible and the rock is strongly foliated with apparently two foliations.

**Thin Section:** Retrograded granite.

Quartz occurs in aggregates as both polygonal and sutured grains.

Feldspar is microcline and is heavily altered to muscovite.

Zircon and sphene (altering to leucoxene) occur as accessories along with hematite or Magnetite and ? Ilmenite (tends to be skeletal and cubic).

There is a definite foliation developing.

R 67B - Same locality as R 67A.

**Hand Specimen:** Very similar to R 67B but much finer-grained and occurring as veins in the latter.

**Thin Section:**

Similar to R 67A only more fine-grained and not so sheared. Microcline is not so altered and an albitic plagioclase is recognisable. Opaque minerals are again present and tend to be skeletal and cubic.

Foliation is less well developed than in R 67A but is defined by muscovite.

R 73

West of East Finnis just south of Jack White's Camp.

**Hand Specimen:** Sheared granite or arkose with abundant accessory iron minerals.

**Thin Section:** Quartz mica schist.

Quartz occurs in irregular-shaped aggregates some of which define fold hooks. Individual crystals are sutured. Matrix consists of polygonal quartz and muscovite and the foliation is well defined.
Cubic opaques, possibly magnetite, are common. ? Zircon also occurs in accessory amounts.

R 74

About 100 yards from railway bridge over East Finnis.

Hand Specimen: Sheared granite. Quartz sericite and feldspar recognisable and patches of a green mineral. Iron stains are quite common. Shearing is not so prominent as in some of the above specimens.

Thin Section: Retrograded granite.
Irregular, sometimes rounded masses of quartz and feldspar in a sericite matrix.

Quartz is polygonal where fine-grained. Where it is coarse-grained it is mostly sutured and much cracked.

Feldspar is mostly perthitic microcline in various stages of alteration to sericite. Plagioclase is rare and is albite.

Muscovite is abundant and varies from very fine-grained (sericite) to quite coarse-grained. It defines a reasonable foliation.

Hematite stained opaques and ? zircon are common accessories.

The rock in general is heavily fractured.

R 79A

Woodcutter's road. 12° 58' 30"  131° 02' 30" B.M.R. locality 21.

Hand Specimen: Coarse-grained biotite-rich granite. Slightly foliated in outcrop but not apparent on scale of hand specimen. Contains traces of pyrite. Feldspars generally grey - some pink - up to 1 inch long.

Thin Section: Granite.
Quartz 35%, Feldspar 55%, Biotite 5% and sphene, zircon etc. 5%.

Quartz is sutured but locally fine-grained and polygonal.

Feldspar is mostly perthitic microcline. Plagioclase is rare and albite. Both are sericitised.

Biotite is daccussate.
Sphene is euhedral and up to 2-3 mm. It gives 2nd and 3rd order interference colours (an anomalous property). It is biaxial positive with a small 2V, and locally intergrown with ilmenite. It is pale brown in colour.

Zircon is euhedral and tetragonal. It is uniaxial positive and occurs as large zoned crystals.

Both the sphene and zircon occur with the biotite.

Apatite is also common and occurs largely in the biotite as euhedral crystals.

Calcite is not uncommon as an accessory mineral.

The muscovite resulting from the alteration of feldspar is coarse-grained locally but decussate.

R 79B - Same locality as R 79A.

Hand Specimen: Very much like R 79A but lacks pyrite and is better foliated. It occurs as veins in R 79A.

Thin Section: Granite.

Feldspar 80%, quartz 10%, biotite 5%, high relief minerals <5%.

Quartz for the most part is sutured, locally it is cracked and polygonal. In a shear that traverses the section it is micro-crystalline.

Feldspar is porphyritic microcline and albitic plagioclase and both are heavily sericitised.

Biotite is randomly oriented and quite coarse-grained.

Muscovite is fairly coarse-grained in the shear.

A mineral with a high relief is common and associated with the biotite. It is probably zircon having the zircon habit and birefringence. It does not give pleochroic haloes.

Apatite is a rare accessory occurring in the biotite crystals.

Calcite is a rare accessory.

The rock has an igneous texture and except for the shear is generally less retrograde than R 79A. It is however generally stressed and cracked.
R 81

East of White's Open-cut. 12° 59' 30" 131° 02' 00".

Hand Specimen: Medium grained pink-grey feldspar (more pink where weathered). Visible biotite and sericite. Good foliation defined by quartz elongation. Close jointing perpendicular to the foliation. Feldspars are up to ¼".

Thin Section:

Much the same as R 79B but zircon and biotite are less common. Texture is igneous but quartz is strained and cracked. The plagioclase seems to be altering to sericite more readily than the microcline.

R 92

East side of granite, south of Woodcutter's road.

Hand Specimen: Coarse-grained grainitic gneiss with coarse (1") cylindrical shaped, brownish feldspars in a biotite matrix. Well foliated. Pyrite is a fairly common accessory.

Thin Section:

Like R 79B but coarser grained. Zircon is well zoned. Calcite is fairly common as an accessory mineral. There are a number of minor shears filled with sericite.

R 107 - South edge of Rum Jungle granite.

Hand Specimen: Tourmalinised granite. Tourmaline is black and radiating. Rock is crumby and medium-grained with cream and pink feldspars.

Thin Section: Tourmaline granite.

Feldspar 55%, quartz 20%, tourmaline 25%. Feldspar is mainly perthic microcline. It is greatly cracked but only slightly altered.

Quartz is sutured but strained.

Tourmaline is coarse, euhedral and green. Some crystals are zoned with a brown centre.

It is a very fresh igneous looking rock compared to the other granite specimens.

R 121 - Southern edge of Rum Jungle granite.

Hand Specimen: Fine-grained pink granite. Referred to as late granite by Ruxton & Rhodes (personal communication).
Thin Section:
Feldspar 45%, quartz 45%, sericite 5%, biotite 5%.

Quartz is sutured but strained.
Feldspar is albite plagioclase and perthitic microcline.
Opaque minerals are probably magnetite. There are parallel shear zones consisting of fine-grained polygonal quartz with sericite and a little biotite.

R 122 - From creek west of Mount Stratton.

Hand Specimen: Fine-grained pink granite with blue quartz and rectilinear pattern defined by fine-grained greenish grey material. Accessory pyrite.

Thin Section:
Quartz 35%, feldspar 60%, mica 5%.

Quartz is sutured, strained and locally cracked.
Feldspar microcline and albite plagioclase. Differentially sericitised. There appears to be a tendency for plagioclase to sericitise more readily. Microcline is not very perthitic.

Biotite is fairly fine-grained and decussate.
Semi-opaque mineral occurs in rare aggregates. It is very fine-grained and apparently altering to leucoxene. Therefore presumably sphene.

Euhedral and subhedral zircon occur and are zoned. They do not have pleochroic haloes but are definitely uniaxial positive.

Carbonate occurs as an accessory mineral with lamellar twinning.
Ilmenite is present and altering to leucoxene.

There are a number of narrow shears occupied by muscovite and there is also a broad shear zone occupied by fine-grained polygonal quartz, biotite and muscovite.
Texture is fine-grained and igneous.

GRANODIORITE

R 40 - Woodcutter's road west of B.M.R. locality 21. 12° 58' 30"
131° 03' 30".
Hand Specimen: Dark greeny grey, feldspar-biotite rock. Foliation defined by feldspar elongation.

Thin Section: Retrogressed Granodiorite (or possibly diorite)
Feldspar 50%, biotite 20%, quartz 15%, epidote 15%.

Quartz is sutured and polygonal.

Feldspar, mostly plagioclase of oligoclase composition. There is some microcline twinning but it could still be plagioclase. The feldspar is associated with epidote and calcite.

Biotite is green and decussate and contains zircons with pleochroic haloes.

Calcite occurs as an accessory mineral with the epidote.

Epidote, high relief, needle-like crystals with hexagonal shaped cross section and basal cleavage. Extinction is usually straight but many crystals are strained, have undulose extinction. Interference colours are 2nd and 3rd order and an anomalous blue. Interference figure is biaxial positive with a large 2V.

Zircon occurs as an accessory and also magnetite.

R 82 - Same locality as R 80.

Hand Specimen: Like R 80 but with accessory pyrite.

Thin Section:
Like R 80 but quartz tends to be more polygonal and locally microcrystalline.

R 90 - 200-300 yards north west of R 80.

Hand Specimen: Contact between granodiorite and biotite gneiss. The contact is sharp and distinct in the field but a common foliation occurs in both rocks. Both are pyritic. There does not appear to be a chilled margin.

Thin Section:
The granodiorite is much the same as R 80 but twinning is uncommon in plagioclase. However it is albite and probably still oligoclase.

In thin section the contact is far from obvious. The composition is much the same on both sides. There is a little sphene in the gneiss which was not seen in the granodiorite and calcite is much more abundant in the gneiss.
The gneiss is banded due to variation in the concentration of biotite and quartz but this is more readily seen with the naked eye.

**Banded Ironstone**

**R 76**

Crater formation on north side of embayment area.

**Hand Specimen:** Pebble of banded ironstone from the H.B.C. Magnetite bands intercalated with quartz.

**Thin Section:** Banded ironstone.

Quartz is mostly polygonal and greatly strained and cracked. In the bands rich in opaque minerals the quartz is finer-grained than in the opaque mineral free bands. There are small veins of quartz cut across the banding. The iron mineral is magnetite and is largely responsible for defining the banding. It also cuts across the banding locally, where the magnetite grains are arranged in herring-bone like structures. Magnetite is altered to hematite locally. There are occasional grains of muscovite.

**R 93** - South of Woodcutter's road. 12° 59' 00" 131° 03' 30".

**Hand Specimen:** Banded ironstone closely resembles R 76 but is more altered to hematite.

**Thin Section:**

Very similar to R 76 but quartz is sutured and though strained, is far less cracked than R 76. The banding is less well defined and the variation in the quartz grain size is less regular. The magnetite is greatly altered to hematite. There is no muscovite.

**R 100**

Close to granite contact at the south east corner of the Rum Jungle granite.

**Hand Specimen:** cf. R 76.

**Thin Section:**

Very much like R 76. Quartz is mainly polygonal but sometimes sutured and is less cracked than R 76. Variation in grain size, though regular, is not as regular as in R 76. There is no muscovite and the magnetite is altering to hematite.

**Quartz Vein**

**R 68** - On east bank of East Finnis opposite Jack White's camp.
Hand Specimen: Red, hematite-rich, slightly porous, quartzitic rock from centre of quartz blow.

Thin Section: Quartzite.
Polyhedral and micro-crystalline quartz with voids after cubic minerals (Fig. A). Material remaining in voids where they have not been refilled by quartz is iron oxide. Voids are presumably after pyrite.

R 69 - Same locality as R 68.
Hand Specimen: Sheared quartz from same quartz blow as R 68.

Thin Section: Foliated, sericitic quartzite.
Quartz is mostly polyhedral and frequently cracked. Sericite is about as abundant as quartz and occurs scattered through the rock.

Some of the quartz is micro-crystalline.

Hematite and euhedral zircons occur as accessories, the latter being fairly rare and possibly fragmented. (where faces are developed they are very regular but half a crystal may be missing.)

R 70 - Same locality as R 68.
Hand Specimen: Colourform quartz from quartz blow. Banding is defined by degree of iron staining of quartz. Heavily stained areas are more porous, suggesting that colourform banding represents compositional variation.

Thin Section: Sericitic quartzite.
Quartz and sericite occur in fairly equal proportions.

Quartz is sutured and polygonal and stained and cracked.

Sericite occurs in regular shaped areas and could possibly be after feldspar.

There are a few voids after ?pyrite as in R 68.

Sphene is occurring as an accessory and there is ? magnetite present. This suggests that the voids are after magnetite rather than pyrite, and since only the two dimensional shape of the voids is known they are both possible.

This rock could be intensely sheared granite.

Banding due to distribution of hematite and magnetite.
REGIONAL SEDIMENTS

R 58 - 200 yards east of coasted area at Mount Pritch.

Hand Specimen: Quartzite with a weak bedding parallel to the axial plans of minor folds.

Thin Section: Feldspathic quartzite. Quartz is strongly sutured. Plagioclase and microcline occur as accessory minerals and are fairly fresh. They tend to be rounded.

Sphene and zircon also occur as rounded accessory minerals and there are traces of sericite.

Quartz is apparently recrystallised.

R 77A - ¼ mile north east of Flynn's Cottage

Hand Specimen: Arkose. Glassy and milky quartz clasts. There are quartz veins, and iron oxides are abundant in veins as well as being disseminated through the rock. There is a well defined s-surfaces due to preferred orientation of elongated quartz clasts.

Thin Section: Sericitic quartzite. Angular to rounded clasts of quartz occur in a matrix of quartz and sericite. The matrix quartz occurs as elongate polygonal grains.

Sericite occurs in micro-crystalline aggregates and could have resulted from alteration of feldspar.

There are occasional grains of muscovite.

Hematite is a common accessory.

Elongation of the matrix grains and larger clasts defines a weak foliation.

R 125 - Area 44

Hand Specimen: Compact grey cherty looking rock with much iron staining.
Thin Section:
Very fine-grained quartzite consisting of micro-crystalline quartz and sericite. High relief accessory minerals are also present but are too fine-grained to identify.

R.126 - Area 44
Hand Specimen: Fine-grained, compact, dark gray rock with a dark brown to black weathered surface.

Thin Section: Fine-grained iron rich quartzite.
There is abundant magnetite altering to oxides. Iron oxides obscure the texture of the quartz. There are a few coarse-grained, altered magnetite crystals.

Lissengang's rings are common.

GNEISS FROM KIN JUNGLE GRANITE

R.75
North of Embayment, east of railway. 12° 58' 30" 130° 59' 30".

Hand Specimen: Quartz biotite rock. Intruded by pink granite.

Thin Section: Quartz biotite hornfels.
Quartz is polygonal and strained.

Biotite is green, to brown and decussate.

Apatite is a very common accessory.

It is euhedral and represents up to 10% of the rock.

Opaque mineral is common and is either magnetite or ilmenite.

R.82
Woodcutter's road close to B.M.A. locality 2.

Hand Specimen: Tightly folded quartz biotite gneiss.

Thin Section: Quartz-feldspar-biotite sericite-gneiss.
Feldspar is mostly albite. There is a little microcline. Greatly altered to sericite and in some cases very fine-grained epidote.

Biotite is greenish brown and locally shows a weak preferred orientation axial to a minor fold.
Sericite shows much better preferred orientation.

Apatite and zircon are present as accessories and the zircon is causing pleochroic haloes in the biotite, where not included in biotite it looks detrital.

Carbonate is a common accessory and occurs as polygonal grains.

There is a little ?sphene.

R 62 - Same locality as R 62.

Hand Specimen: Sheared quartz rich vein in the quartz biotite gneiss (R 62). There is visible sericite.

Thin Section:
Very similar to R 62 except that biotite is only a minor accessory and quartz and calcite are sutured. There is no foliation but quartz is strained and alteration is just as great.

R 89 - Same locality as R 82.

Hand Specimen: Biotite gneiss with grey feldspar augen and patches of pink feldspar.

Thin Section: Quartz feldspar biotite rock.
Quartz is sutured but strained.

Feldspar. Mostly microcline and highly sericitised feldspar. What plagioclase there is is albite. Feldspar is slightly in excess of quartz.

Biotite and sericite are common accessories and both are decussate.

Apatite occurs quite commonly as euhedral crystals and zircons and rounded sphene are also present.

Much of the material between the large quartz and feldspar crystals is micro-crystalline quartz.

R 94

Close to eastern contact of Rum Jungle Granite about 100 yards south of Woodcutter's road.

Hand Specimen: Pale green schist with yellowish iron stains. Strongly lineated in two directions but poorly foliated.
Thin Section: Chloritic schist.
Section consists of chlorite plus 2 or 3% accessory minerals.

Chlorite is colourless with grey interference colours and lamellar twinning.

Large zirconia which give good interference figures and fine-grained crystals which may also be zircon were recorded. Very fine-grained, randomly oriented, needle-like crystals, possibly rutile are associated with zaphire.

Magnetite or ilmenite is also present.