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GEOLOGY AND GEOPHYSICS.

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THE GEOLOGY OF THE EMBAYMENT AREA, RUM JUNGLE, N.T.

by

E.K. Carter.

DARWIN, N.T.

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C O N T E N T S.

SUMMARY.

This report deals with a triangular area of pre-cambrian meta-sediments, totalling about six square miles in which occur copper-uranium orebodies of the Rum Jungle area. The area is situated 55 miles south-south-east of Darwin, Northern Territory.

Plane table mapping of portion of the area was carried out by N.J. Mackay and D.J. Gates in 1950 and the area mapped was extended by E.K. Carter in 1951 to cover the whole of the embayment area.

The meta-sediments of the area form a large dragfold in the north side of the N 60°E striking Giant's Reef fault, along which there is a horizontal displacement of 3¼ miles. About 5,000 feet of varied meta-sediments are present. The carbonaceous slates are the host rocks for mineralization.

Granite and granitized sediments lie to the north, east and south of the area and they occupy the core of a domal structure in the meta-sediments.

Three periods or phases of faulting are recognised, the first is the post-granite Giant's Reef faulting, which produced the major dragfold, the copper-uranium mineralization may have been associated with this period of faulting. The second is an axial plane shearing of the dragfold, which is post-mineralization in age. The third system of faults consists of a large number of cross-faults which strike from N 60°W to N 30°E and which have displaced the granite margins, Giant's Reef fault and the axial plane shear.

The known copper-uranium mineralization is confined to the axial region of the dragfold and is found almost entirely in carbonaceous slates. The most favourable area for further prospecting appears to be under the deep soil along the axial plane zone, east-north-east of Dyson's Prospect.

INTRODUCTION.

The Rum Jungle uranium-copper field lies approximately 55 miles south-south-east of Darwin, Northern Territory, between the North Australia Railway in the West, and the Stuart Highway several miles to the East.

This report refers to a triangular area, totalling approximately six square miles, of pre-cambrian meta-sediments which are assigned to the Brock's Creek Group and enclosed to the north, east and south by granite. The western limit is marked by the North Australia Railway. The shape in outline of the region has led to its being named the "Embayment Area" (Plate 1). Within this area lie the Rum Jungle uranium orebodies.

The embayment area was mapped in 1950 and 1951 by means of a plane table survey, using a telescopic alidade and stadia rod. The purpose of the survey was to determine the structure of the region as an aid to the understanding of the controls of ore deposition, so that prospecting of the known orebodies and the search for new orebodies could be planned.

Prior to the commencement of the plane table survey in October 1950 geological mapping had been confined to small areas around the known centres of high radio-activity and to mine mapping. Development openings at this stage did not exceed 200 feet. In addition H.J. Ward had made some reconnaissance geological traverses and a number of radiometric traverses had been done. While the plane table survey was in progeess regional mapping, using airphotos, was undertaken, mine development was mapped and drill cores were logged by other geologists. The mine and regional mapping done to the end of 1952 is the subject of a separate reports (Matheson 1950 and 1953). References to other papers and unpublished records of the work by the Bureau of Mineral Resources in the Rum Jungle field appears in the bibliography. Matheson (1953) gives a comprehensive reference to all work done in the Rum Jungle area by intrim workers.

As Rum Jungle lies in the tropical monsoonal belt and experiences heavy rainfall from October or November to the end of March field mapping is only practicable in the dry months of the year, when the ground is not sodden and the profuse rank grass growth has died and has been burnt off. The area has a moderate tree cover; this, together with the profusion of smaller growth, particulary in the areas of rock outcrop, made the cutting of lines to take sights to the stadia rod a frequent necessity and materially retarded the rate of mapping.

Mapping of the Embayment Area was begun in October and November 1950 by N.J. Mackay, who mapped the north western portion, and D.J. Gates, who mapped the central portion. The remainder was done in April - June and August - October by E.K. Carter. Scale of mapping was 1 inch - 400 feet.

The topographic range in the area is to the order of 200 feet and as all beds, faults and contacts dip steeply topigraphic surveying and contourings was not considered necessary.

The highest points lie along the line of the hematised breccia conglomerate which flanks the granite in the north and the south-west and along Giant's Reef. Both of these features form more or less continuous ridges with, in places, very steep slopes. Elsewhere, the highest country is to the west of Dyson's Prospect (Plate 1) where the breccia has proved resistant to erosion and to the east of Dyson's Prospect where there is a smaller outcrop of resistant quartzite. Quartzite near the North Australia Railway has also produced a high point.

Most of the area is drained by the East Branch of the Finniss River. Exceptions to this are the granite in the north-east, which drains to the north into the Darwin River, the granite to the south-west which is drained by Coomalie Creek to the south-east; and the area near and west of the railway which tends to drain west into Rum Jungle Creek and the South Branch of the Finniss River.

GEOLOGY.

GENERAL.

The density of rock outcrop is generally poor, but the presence of certain resistant beds, such as the hematized breccia conglomerate, has permitted a clear determination of the general structure and of the granite-sediment boundary.

Lack of outcrop in the less resistant beds and poor stratification of others has prevented the detailed resolution of structure and more particularly the tracing with any degree of certaintly of many of the lines of faulting through the sediments. Laterite formed in tertiary times has also served to mask bedding in many places. On the other hand the type of structure in the ferruginous laterite i.e. cellular or gritty, and inclusions in the laterite have aided interpretation of the underlying rock type. Prevalence of quartz fragments, if not transported, indicate the proximity of a fault.

Natural sections are non-esistent but valuable information has been obtained from railway cuttings, from old and present mine workings and from drill cores.

REGIONAL SETTING.

The Embayment Area is on the southern flank of a domal structure in meta-sediments the core of which is occupied by granite and granitised rocks. The granite complex is approximately 10 miles long in a north-south direction and 6 miles wide at the present land surface. The drag along the post-granite Giant's Reef fault, which strikes N60°E, produced the "embayment" of meta-sediments on the north side of the fault. The Giant's Reef fault is a major structural element which has been observed (or recognised on air photos) to the south-west as far as the Daly River 55 miles distant (Noakes 1949). It has also been traced on air photos many miles to the north-east. At Rum Jungle a horizontal displacement along the fault zone of 3¼ miles has taken place; the north block moving east with relation to the south block.

STRATIGRAPHY.

All the compacted sediments and meta-sediments with the exception of the laterites of tertiary age, are believed to belong to the Brocks Creek Group of lower proterozoic age (Noakes 1949).

Table I gives an approximate stratigraphic column for the sediments in the area. Certain beds show marked change in lithology and thickness along the strike so that the table is a generalisation only. Thicknesses shown are probable maximum thicknesses.

TABLE I.

	feet.
Post-tertiary soil and alluvium.	?
Tertiary laterite.	50?
Slate, with interbedded quartzite.	700
Chloritic and carbonaceous slate and Graphitic Schist	1,000 plus
Limestone	950
Quartzite Breccia.	800 plus.
Slate and quartzite	100 plus.
Limestone	100
Slate and quartzite ? - No outcrop; rubble and lateritized fragments only	600

Table I Cont.

	Feet.
Limestone, s ome well-bedded.	700
Quartzite, slate and grit.	350
Hematized breccia conglomerate	170
Quartzite, some interbedded slate	80 plus.
Possible maximum thickness	5,600 feet plus.

LITHOLOGY.

Soil and Alluvium. No attempt has been made to map soil type boundaries or to distinguish between soil and alluvium. Soils range from light grey fine sandy soil derived from the hematized breccia conglomerate and granite to red brown clayey to loamy soils formed from laterite, limestone and slate.

Laterite. This is all ferruginous but silicification of some of the limestone and quartzite may be related to lateritic processes. The laterite varies from a fairly compact gritty rock which is rather like a furruginous grit to a laterite with a coarse cell or pipe structure which may be connected in places to the type of rock from which it has been formed. Specifically, limy rocks apparently tend to give the cell-type laterite. The laterite has been formed both from fossil soils and from rocks in situ. Some indication of the rock type underlying the laterite may be obtained from the inclusions of rock fragments; these range in size from less than ¼" to greater than 3" across. The abundance of fragments of any particular rock type, the degree of rounding and the abundance relative to other rock types must all be considered in determining the validity of inclusions as an indication of the underlying rock type.

The laterite generally occurs as a level copping standing, by reason of its resistance to erosion, a few feet above the surrounding country; remnants which project through the soil as occasional small boulders are not uncommon. More than one level of leterite can be observed. For example, the flat hill of laterite in the extreme north is at least 50 feet higher than that in the centre of the area.

A number of the lateritic outcrops possess a higher than normal radio-activity, compared with the average background count for the area, as measured by Geiger-Muller Counter. These anomalies are apparently due to a concentration of uranium salts during weathering, but the degree of concentration has not been sufficient to produce economic deposits.

Slate. This generally does not outcrop well except in shears where it has been silicified. An indication of the distribution of the slate can often be obtained from the incidence of slaty fragments even over comparatively deep soil cover.

Carbonaceous, Chloritic and serecitic slates have been observed both underground and on the surface. The carbon of the former has been altered in the zones of greatest deformation e.g. near faults, to graphite giving graphitic schists, it is these carbonaceous slates and graphitic schists which provide the copper-uranium ore-bearing beds, though

though chalcopyrite and pyrite may extend into the more competent chloritic slates.

The slates occurring at other stratigraphic levels than the ore-bearing beds are commonly interbedded with quartzites. Some interbedded slates and grits have also been observed. This is an indication of the fluctuating shallow water conditions of sedimentation which are v believed to have prevailed.

Quartzite. Beds are generally thin, to the order of 1 - 2 feet, though some considerably thicker beds do occur. Cross bedding, while not common, has been observed. The lenticular nature of many of the quartzite beds is clearly demonstrated in the west of the area e.g. in the railway cutting west of Block 1097 and the outcrops to the east of the cutting. In the north-east of the area, north of the breccia conglomerate, the oldest meta-sediments in the area can be seen. They are quartzites with very subordinate thin interbedded slates. They have been permeated by epigenetic specular hematite.

Limestone. There are probably three formations of limestone. Between the two older successions there are no outcrops but rubble and soil type suggests an intervening sequence of slate and quartzite. A lens of limestone may possibly occur to the south-west of the Brown's line of mineralization. The only evidence for this is a terra rosa type of soil and two "floaters" of limestone.

East of the strong north-south fault which passes about 40 feet west of White's No. 4 shaft limestone outcrops have been observed only near Giant's Reef, north of West Track. A "floater" of limestone was found nearer the collar of the water bore in Block 1115; this may have come from the bore hole. There are also scattered inclusions of silicified limestone in portion of the laterite south of the bore hole.

Fragments of bedded limestone occur north of the datum line but otherwise the limestone is massive or coarsely bedded. It is also commonly altered so that dips and strikes are hard to obtain.

Some of the limestone beds vary considerably in calcareous content along the strike. In places they are, in fact, calcareous grits, or breccia with calcareous cement. Alteration of the limestone, particularly near faults and shears, is appreciable. Silicification is the chief process involved but radiating clusters of a fibrous asbestos-like mineral are common. The mineral has not yet been determined. The blue chert in the north-west of the area is probably a contact-altered limestone.

Quartzite Breccia. This occurs in the form of a large lens which in its maximum development between White's Extended and Dyson's Prospects. The thickening here may be due in part to flowage from the limbs to the nose of the dragfold. Although outcrops are extensive bedding information is extremely poor.

The breccia has a quartzitic matrix in which is enclosed angular translucent to milk-white quartz and quartzite fragments up to 6" in length. The matrix has been coloured cherry red by finely divided hematite. In some cases the breccia fragments can be seen to have been embayed. This suggests the action of introduced hydrothermol liquors which may have brought in the hematite.

At either end of the outcrop of breccia the rock assumes rather the character of a grit with the breccia fragments subordinate to absent. Lenses of quartzite occur within the breccia. The rock is essentially sedimentary in origin; the source of the quartz - quartzite fragments is unknown.

<u>Hematized Breccia Conglomerate</u>. The hematized breccia CONGLomerate consists of a single bed which attains a maximum thickness of 170 feet, and which occurs only adjacent to the granite or granitized sediments. It is composed of numerous rounded to angular, rather illsorted fragments of quartz, quartzite and what was probably once a shale, set in a quartzitic matrix. In places the matrix is highly serecitic, apparently due to the alteration of shaly lenses. Boulders up to 18" long occur where the conglomerate is heaviest but the average size would be 2" - 4". Generally, rounded fragments predominate though locally the breccia character of the rock is more apparent, hence the name breccia conglomerate. In places the rock assumes the form of a grit or even quartzite but, considering the type of rock involved, the lithology is remarkably uniform.

Within the area mapped no outcrops of breccia conglomerate without hematite occur. The hematite is believed to be of secondary origin. In the first place the hematite may have been sedimentary but the presence of probably hydrothermol hematite in the quartz breccia suggests that this hematite may have been introduced originally by hydrothermol solutions into either the breccia conglomerate or other beds which have since been assimilated by granitic processes. The present specular form of the hematite is considered to be due to recrystallization during the incoming by the granite or the granitization process. The hematite is generally blue-black and specular. It has penetrated both the matrix and the more permeable portions of the boulders. The boulders of laminated material have taken up the hematite selectively giving a striking appearance to the rock (Plate 5, Matheson 1953).

Outcrops are practically continuous along the length of the bed. This continuity and the well defined though rough bedding make the formation a valuable one for the determination of structure.

<u>Granitized Sediments</u>. In so far as they are determinable, these appear to have been originally largely breccia conglomerate and quartzite. The criterean on which granitized sediments have been so classified is that of showing relict structure from which its sedimentary origin can be inferred. Some of the rock which occurs south of Giant's Reef, south of Dyson's and White's Extended Prospects, and which is described as granitized sediments with lineation, is strictly a banded granitic greiss. With the single important exception of the granitized sediments in the shear and cross fault in Block 1097, the granitized sediments are confined to the margins of the granite.

All stages of digestion of the hematized breccia conglomerate may be seen. The process appears to proceed as follows -

1. The hematite is desplaced, presumably "forwards" i.e. away from the granite.

2. The matrix loses its sedimentary character by corrosion or absorption of individual grains accompanied by the growth of new crystals of quartz, felspar and biotite. The quartz grains are the last to be assimilated.

3. Accompanying and succeeding stage 2 , the pebbles and boulders constituting the inclusions in the conglomerate are chemically attached, producing rounding and diminution in size, until as a final stage they are completey absorbed. It follows that lenses of heavy conglomerate will resist assimilation better than other parts of the rock. This can be seen in many places.

Granite. The granite is generally rather even grained. The grain size is medium, and orientation is lacking except near the margins of the granite, where a pronounced greissosity parallel to the margin of the granite or granitized sediments is common. Megascopically the granite appears to a biatite.granite. In places, notably adjacent to the river south of Dyson's Prospect, the granite is coarser in grain size and markedly porphyritic in texture. The felspar is pink. The granite in this area differs from the normal in other respects : Aplite dykes are more common than elsewhere. It is the only part of the Embayment Area where granite occurs immediately north of Giant's Reef.

Adjacent to this area, but south of Giant's Reef the banded granite or granite greiss is well developed.

A possible explanation is that the granite here is derived from the later granitization process and not from the magnetic granite (see later chapter) or alternatively that some reconstitution of the granite accompanied the Giant's Reef faulting.movements.

Hornsfels and high grade metamorphics are entirely absent adjacent to the Rum Jungle granite. The chief metamorphic effects seem to be the silicification of the sedments e.g. the alteration of limestone to blue chert in Block 1099. The development of the asbestiform mineral in some of the limestone may also be a contact effect, although some occurrences of this mineral are not near granite outcrops.

STRUCTURE.

Faulting. Three periods of faulting and shearing have occurred. The oldest and most impressive is the Giant's Reef faulting, of which Giant's Reef fault is probably the only representative in the Embayment Area. This is a N60°E - striking fault which dips 85°N to vertical. It is a complex fault which is marked by huge bodies of quartz and silicified sediments. Both fissure-filling and replacement by quartz has occurred in the fault zone. In places comb structure and intersecting veinlets are the main forms of the quartz; elsewhere replacement is predominant. Where replacement is not complete the fault zone has been shown on the map of the area by notching. The quartz in the Giant's Reef fault is completely barren.

Breccia fragments of quartz and intersecting quartz veins of different ages show that there was more than one period or phase of movement and quartz introduction along Giant's Reef fault zone.

The quartz and quartz tourmaline rock in Block 2827 mark the position of tension faults parallel to the bedding and not the course of Giant's Reef fault, which passes through the south-east of Block 1097. Its position is indicated by sporadic small outcrops of quartz.

Movement along the Giant's Reef fault has produced a huge dragfold in the meta-sediments.in the north block, giving rise to the Embayment area. The position of the hematized breccia conglomerate on either side of the fault shows that a horizontal movement of $3\frac{1}{4}$ miles along the fault took place; the north block has moved east.

Underground mapping at White's Deposit has revealed the existence of an axial plane shear in the dragfold produced by movement along the Giant's Reef fault. The shearing is parallel to Giant's Reef fault. The shear can be traced to the south-west through Brown's workings; the granitized sheared sediments in Block 1097 probably represent a further extension.

This zone of shearing and faulting is younger than the copper-uranium mineralization and since the location of the mineralization is considered to have been controlled by the dragfold the shearing must be younger than the Giant's Reef fault system.

Both the axial plane shear and the quartz-filled Giant's Reef fault have been displaced in places by faults which strike at from N 60° W to N 30°E. In the north of the area the granite margin has been similarly displaced. However, as quartz in-filling is extensive only near the granite margins the faults usually cannot be traced through the area. The longest of the cross-faults, which dips steeply east and has a horizontal displacement of about 2,000 feet in the north, passes approximately 40 feet west of White's No. 4 shaft and has caused a large displacement of the lode; this has given rise to White's South Prospect by faulting off portion of the main White's lode.

The order of faulting and age of the mineralization relative to the faulting is this clearly established -

1. Giant's Reef faulting, with which the Mineralization may have been associated.

2. Post-mineralization axial plane shear.

3. Cross-faulting.

<u>The Dragfold</u>. The dragfold is already exemplified by the outline of the hematized quartz breccia. The hematized breccia conglomerate in the north strikes east and dips 60° south and in the south-west strikes approximately north and dips 40° west. This indicates a west-pitching synclinal dragfold. However, in White's Workings, south of the axial plane, the bedding dips steeply south and folds pitch 20-30° east. At Dyson's Prospect beds dip up to 45° east. These conflict with the concept of a west-pitching syncline and are apparently not purely local phenomena. (Matheson, 1953) has postulated on overturning and rotation of the southern limit of the dragfold by movement along the axial plane shear. This would adequately account for the known structural facts, particularly having regard to the incompetence of many of the meta-sediments, and the extreme deformation which has taken place.

<u>RELATIONSHIP OF GRANITE AND GRANITIZED SEDIMENTS</u>.

It has been shown that the main body of Rum Jungle granite is older than the earliest of the faulting - the Giant's Reef fault, and also that granitization of sheared sediments in the two younger systems of faulting has taken place. Clearly the granite and the granitized sediments in the shears are of different ages. Whether all the granitized sediments are of a later age than the granite is not clear because some of the granitized sediments adjacent to Giant's Reef appear to the author to have been silicified after they were granitized.

The banded granite greiss south of Giant's Reef indicates that dynamic stresses were applied while the granite was still plastic; the presence of the porphyritic granite with aplite, north of Giant's Reef in the vicinity of Dyson's Prospect suggests that this granite is post-Giant's Reef faulting in age. These two facts lead to the conclusion that the Rum Jungle granite may have been still active at the time of the Giant's Reef faulting and that the faulting was accompanied by renewed granitic activity. The copper-uranium-pyrite mineralization can probably be related to this phase.

Later the forces which caused the cross-faulting were associated with or followed by further granitic activity which caused the granitization of the sheared sediments in Block 1097 and possibly also of the margin of the granite.

REGIONAL CONTROL OF MINERALIZATION.

All the known localities of copper and uranium mineralization within the Embayment Area lie along or near the dragfold axis and all but that at Dyson's Prospect appear to lie in the carbonaceous slate formation which overlies the youngest limestone formation. Dyson's Prospect also occurs in slates, graphitic and carbonaceous in part, with which are interbedded quartzites.

The regional controls therefore appear to be threefold :-

1. The axial region of the dragfold, due to the extreme deformation.

2. The slate formations, which are so commonly are favourable rocks due to their extreme incompetence.

3. The presence of carbon in the slates. The relationship between uranium and carbon is widely recognised. Apparently the carbon acts as a precipitant for uranium oxide.

The most favourable area for further prospecting would appear to be that zone along the dragfold axial region, east-north-east of Dyson's Prospect. There are no outcrops through this region but the underlying rock type is probably slate and limestone. The depth of soil is deep enough to mask radio-activity in the rocks below and drilling would be necessary to test the area.

SUMMARIZED HISTORY OF THE AREA.

1. A rather varied assortment of sediments were laid down in Lower Proterozoic time under shallow water and fluctuating shore line conditions.

2. Continuance of the geosynclinal cycle produced strong meridianl folding of the region and low grade dynamic metamorphism. The area under consideration occurs on the southern flank of the domal structure.

3. A concordant granite was quietly emplaced at low temperature, producing only slight contact effects.

4. A regional shearing couple produced Giant's Reef fault. The north block moved east relative to the south a distance of approximately 4 miles. Dragging on the Giant's Reef fault produced a strong west-pitching fold in the north block. The copper-uranium-pyrite mineralization may have occurred at this stage; also the introduction by hydrothermol solutions of hematite into the quartz breccia.

5. An axial plane shear in the dragfold developed, resulting in overturning and rotation of the south limb of the dragfold and the probable displacement of portions of the copper-uranium lodes.

6. North-south tensional faulting developed, possibly due to a relaxation of the shearing forces. One of these faults further displaced portion of White's copper-uranium lode. A number of the faults appear to die out in the granite to the north.

7. Renewed granitic activity produced at least some of the granitized sediments.

8. No evidence for the deposition of later sediments or of major tectonic movements is forthcoming. Apparently stable conditions have prevailed, except for possible warping or faulting which affected the erosional base level from time to time. Laterite was formed in tertiary times, in a period of still stand and there has been a slight uplift since which caused the stripping off of much of the laterite.

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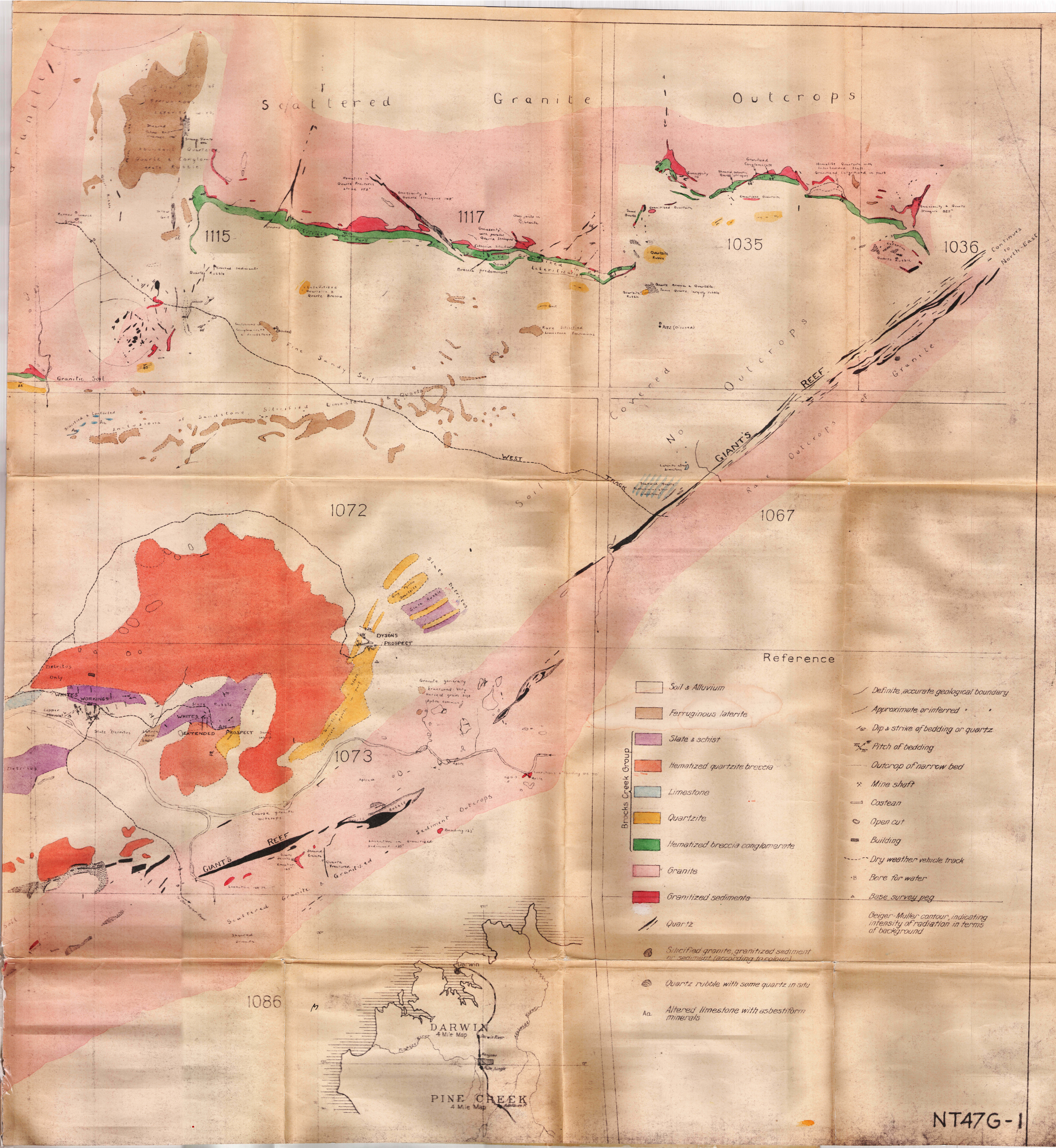
Geology in the Vicinity of the Rum Jungle Uranium Deposits - Sheet 2 - Scale 1" = 400'. Geology by E. K. Carter October 1951

NT47G-2



Scattered Granite Outcrops
1115
1117
1035
1036
Continues to North-East
Hematized breccia predominant
Lateritic
Granitic Soil
Fine Sandy Soil
Inclusions of Sandstone, Silicified Limestone, Quartz
WEST TRACK
No Covered Outcrops
GIANT'S REEF
Rare Outcrops of Granite
Soil
1072
1067
DYSONS PROSPECT
WHITES WORKINGS
WHITES EXTENDED PROSPECT
Detritus only
Slate Detritus
Slate Rubble
1073
Sediment Outcrops
GIANT'S REEF
Scattered Granite & Granitized
Soil
1086
Reference
Soil & Alluvium
Ferruginous laterite
Slate & schist
Hematized quartzite breccia
Limestone
Quartzite
Hematized breccia conglomerate
Granite
Granitized sediments
Quartz
Brocks Creek Group
Silicified granite, granitized sediment or sediment (according to colour)
Quartz rubble with some quartz in situ
Aa Altered limestone with asbestiform minerals
Definite, accurate geological boundary
Approximate or inferred
Dip & strike of bedding or quartz
Pitch of bedding
Outcrop of narrow bed
Mine shaft
Costean
Open cut
Building
Dry weather vehicle track
Bore for water
Base survey peg
Geiger-Muller contour, indicating intensity of radiation in terms of background
Darwin
DARWIN 4 Mile Map
PINE CREEK 4 Mile Map
NT47G-1