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Crater Formation Investigation Rum Jungle District Northern Territory

1969

by

D. J. French

CRATER FORMATION INVESTIGATION

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NORTHERN TERRITORY

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SUMMARY

Mapping and surface and airborne radiometric investigations in the Rum Jungle area have continued since the early fifties. Most investigations to date have brought to light radiometric anomalies in the Crater Formation, but to date the source of the radioactivity has not been established. At least some of the anomalies are due to a thorium content in the sediments but it is possible that this source masks leached uranium mineralization in the weathered zone.

The present investigation was planned to consider all known anomalies, and to select those considered likely to reveal most information when tested by deep drilling.

A series of conglomerates and grits near the old Shirley Gold prospect were mapped and radiometrically surveyed in detail. A programme of rotary percussion drilling was used to obtain subsurface data.

An assessment was made of all available data, including palaeocurrent information, of the Crater Formation, and two sites chosen for diamond drill holes with vertical target depths of 1000 feet below the surface. The two deep drill holes are likely to provide accurate information about the radioactive mineral content of the unweathered, and consequently unleached parts of the sediments.

INTRODUCTION

Location:

The Crater Formation occupies a substantial part of the sedimentary succession around the Rum Jungle and Water House Granites, west of the Stuart Highway and from 40 to 60 miles south of Darwin.

The Shirley Area is about 57 miles from Darwin where it forms a prominent rocky rise immediately north of the Batchelor road. Other prominent outcrops of the Crater Formation are: in the vicinity of Manton Dam, Batchelor Township, and the Rum Jungle Mine road. The local relief is of the order of 150 feet.

The climate is tropical - monsoonal, with an abundance of thunder showers during a three to five month "wet" season. The rainfall averages about 40 inches per annum.

Weathering of the Crater Formation is not excessive, the heterogeneous succession tends to form variable topography; quartzite outcrops as rocky ridges, shaley horizons forming rounded soil covered profiles.

Geological Setting:

In the Rum Jungle District, Lower Proterozoic metasediments surround the Archaean Rum Jungle Complex and the Waterhouse Granite (Map 1) which form the cores of two structural domes.

As far as can be judged by the sparce outcrops in the area, the Archaean Basement appears to have a well defined east-west trend. The younger sediments were folded on north-south aligned axes. Tectonically the area is dominated by the north-east trending Giant's Reef fault which has a displacement of about three miles.

Purpose of the Investigation

While the Crater Formation has attracted attention in the past, the sediments have not been investigated below the zone of leaching. The present survey was planned to include deeper diamond drill holes which would allow such a study.

A resemblance between the Crater Formation and the basal formation in the Blind River Uranium Field in Canada has been considered from time to time. The similarities between the two areas are listed below:-

a) The Matinenda Formation of the Elliot Lake Group in Canada which is host to the Blind River Uranium mineralization has a similar lithology and was deposited under comparable shallow water conditions.

b) In both areas the mineralization is close to an unconformity.

c) Generally high radio-activity is contained in conglomerate beds over a considerable strike length.

d) The heavy mineral components of the conglomerates of both areas are similar.

e) Radio-activity is present in several conglomerate bands.

f) Variable amounts of pyrite are found in both formations.

A comparison between the Blind River Deposits and the Witwatersrand Deposits was made by Robertson (1969, p. 630) "It should be noted that the gold-uranium bankets of the Rand are in the Upper Witwatersrand Series, which was deposited in the central parts of a basin, to which material was contributed by reworking of the Lower Witwatersrand Series, exposed around the margin. Offlap dynamics therefore obtained at the time of ore-deposition at the Witwatersrand, whereas onlap dynamics were dominant at the Blind River". The Crater Formation sediments while showing certain similarities with the Witwatersrand bankets are more clearly relatable to the Blind River Deposits.

PREVIOUS GEOLOGICAL WORK

The Crater Formation has received sporadic attention since the discovery of White's Prospect. Wood and McCarthy (1952) prepared a preliminary report on airborne surveys over the Rum Jungle area, giving an account of the first airborne scintillometer survey in the Rum Jungle region.

In the same year Bureau of Mineral Resources (B.M.R.) put down two diamond drill holes ½ mile north of Batchelor (near the Crater Prospect). These were depressed at an angle of 45° and reached a maximum depth of 154 feet. Core recovery was only 10 - 20% and maximum *eU_3O_8 of sludge was 0.01%. Territory Enterprises Pty. Ltd. (T.E.P.) put down three diamond drill holes at two of the most radio-active spots located by detailed mapping and radiometric survey in the Batchelor area. Results of the drilling were as follows:-

1st Hole - About 1 mile west of Batchelor, about 100 feet deep. Intersected the pebble bed target but no increase in radioactivity was detected. Core was highly weathered.

2nd Hole - Same locality, 250 feet deep. Was drilled to obtain unweathered material but core again highly oxidised. Pebble bed was not intersected and was assumed to have lensed out.

3rd Hole - Near Batchelor to Rum Jungle power line. Was drilled to 213 feet but core recovery poor. Fragments of pebble bed recovered were only slightly radioactive.

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* eU_3O_8 is an abbreviation for "equivalent uranium oxide content" and is used to indicate that the sample in question has been assayed by a radiometric method which does not distinguish between thorium and uranium. The figure given thus represents the total thorium plus uranium content of the rock expressed as if all the radioactive material in it were uranium.

In 1955/56 Rio Tinto Ltd. put down three diamond drill holes north of Manton Dam and three holes south of the dam. Results of the drilling were as follows:-

1st Hole - 326 feet, depression 60°. Core recovery in the pebble bed interval 257 - 278 feet (21 feet), or 40% of section. Rock leached. Average eU_3O_8 0.07%.

2nd Hole - 400 feet, depression 75°. Core recovery 90% in pebble beds 339 - 355 feet (16 feet). Rock leached. Maximum eU_3O_8 0.06% (Average for the 341 - 347 feet section 0.02%).

3rd Hole - Deflected 2° from 228 feet in second hole, drilled 167 feet. Core recovery 85% in pebble beds 345 - 368 feet (23 feet). Rock leached. Radio-activity in 348 - 354 feet section 0.04% eU_3O_8.

4th Hole - 170 feet, depression 55°. Hole abandoned.

5th Hole - 575 feet, depression 55°. No pebble beds and no appreciable increase in radioactivity recorded.

6th Hole - 731 feet, depression 45°. Summary information only available. Pebble beds intersected in interval 487 - 655 feet (68 feet) but no pronounced radioactivity.

In 1956 T.E.P. drilled a line of waggon drill holes across the Crater Formation near the water reservoir, one mile east of Batchelor. The holes were drilled at 25 foot centres to 20 feet depth. Additional holes were put down where increased radioactivity was recorded.

The results indicated that radioactivity at depth was restricted to the pebble beds which exhibited anomalous radioactivity at the surface. In one hole probing gave 4 lb/ton eU_3O_8 while radiometric assay of the cuttings amounted to 1.3 lb/ton eU_3O_8. A chemical assay of the sample gave 0.17 lb eU_3O_8/ton indicating that the main source of radioactivity was probably thorium. These results were confirmed by a second hole drilled a few feet away.

In 1957 BMR carried out a low level airborne radiometric survey of the Rum Jungle region including the area occupied by the Crater Formation (Livingstone, 1959). The airborne radiometric anomalies were identified and investigated on the ground (Warin, 1959).

In 1959-60 BMR put down two diamond drill holes near the water reservoir, 1 mile east of Batchelor. Results of the drilling are as follows:-

1st Hole - Abandoned.

2nd Hole - 666 feet, depression 70°. Intersected three pebble beds in an interval of 34 feet (6'6", 5' and 4'4") from a vertical depth of 470 feet. Recovery in the pebble bed zone was 51%. Rock leached. Maximum eU_3O_8 was 0.02% but mineralization determined as mainly thorium.

Regional mapping on a scale of 1 inch = 1 mile was compiled and a Map Rum Jungle District - Special Sheet was published. (BMR 1960).

A ground radiometric survey of the Crater Formation in the vicinity of Batchelor Township was made in 1967-68; the investigation included 1" = 380' scale photomapping. (T.E.P. 1968 Annual Report).

During the mapping of the Crater Line area, a shallow arc of sediments along the southern edge of the Rum Jungle Complex, reference was made to a map by Marjoribanks (in Hughes and Emberton 1968).

Y. Miezitis (1968) made a compilation of available data in the Rum Jungle Area. The project included special surveys such as a ground investigation of the Beestons/Granite contact and a reassessment of the Beestons/Crater relationships and correlations. He concluded that the Rum Jungle Complex predated the Batchelor Group.

During the 1969 field season, alpha activity in auger drill holes was measured. Gas decay behaviour indicates thoron rather than radon as the source of radioactivity in the Crater Formation.

REGIONAL GEOLOGY

Mapping and ground radiometric survey of the Beestons and Crater Formations was undertaken to get a regional picture of the sedimentation and to outline areas of anomalous radioactivity. The wide coverage was to insure that no area of potential interest was overlooked. In the field, data were recorded on enlarged aerial photographs.

Semi-detailed mapping of the selected areas helped to locate further outcrops of Beestons Formation near the Waterhouse Granite. In addition it helped to clear certain anomalous features of the Mount Stratton area and brought to light previously unrecorded east-west folding near Mount Charles (Refer Map IV). In the Crater Line area east of Batchelor township, data were recorded on air photographs controlled by a grid located by a contract surveyor.

Part of the Crater Line area around the former Shirley gold mine was mapped on a scale of 1" = 400 feet (Map V).

Broadly speaking the sediments of Beestons and Crater Formations appear to have been derived from the Rum Jungle Complex and perhaps the Waterhouse Granite. The Rum Jungle Complex is anomalously high in uranium and thorium (Heier & Rhodes, 1966) containing an average of 10.3 ppm uranium and 45.7 ppm thorium, giving a Th:U ratio of 0.22. Whether the Crater Formation contains uranium and thorium in this ratio, or whether much of the uranium has been leached and, possibly precipitated in the Golden Dyke Formation, is not known.

The Batchelor Group consists of the following formations:-

Coomalie Dolomite
Crater Formation
Unconformity
Celia Dolomite
Beestons Formation
Unconformity

The successions in the Waterhouse and Rum Jungle areas are discussed separately as the differences are marked and the information on the Waterhouse area is largely new.

The Waterhouse Area

This includes the area to the west of the Giant's Reef Fault near the Waterhouse granite, (See 1 Mile Map I).

Beestons Formation

The succession is:

Grey Sandstone
Shale interbed - often sheared
White Quartz Sandstone
Basal Conglomerate

The Basal Conglomerate is well exposed on the Meneling Station north boundary fence, south-west from the Rum Jungle Creek South Open Cut mine. The conglomerate is at the most a foot thick, and overlies quartz-mica-feldspar schist with a vertical cleavage (see Plate 1). The schist is believed to be related to the Waterhouse Granite, but it may be remnant of an older formation. A basal pebble line is also exposed near the Finniss River, about two miles further south.

The basal conglomerate is overlain by a layer of white quartz sandstone which forms an arc around the northern half of the Waterhouse Granite. Outcrops of the sandstone tend to form prominent topographical features. The sandstone is well bedded, exhibiting cross-bedding and rare current ripple marks.

The thin shale interbed contact with the quartz sandstone is exposed at several localities. On the west side of the Waterhouse Granite in the vicinity of the Giant's Reef Fault the shale is sheared to a condition resembling mica schist.

The grey sandstone is present along the eastern side of the Waterhouse Granite as a fairly thin but persistent horizon overlying the white quartz sandstone and shale.

Celia Dolomite

Despite the sparsity of the outcrops between rocks of the Beestons and the Crater Formations, Celia Dolomite is believed to be present. Surface exposures consist mainly of grit, or near the top of the succession, quartz hematite breccia. This is a siliceous breccia with a red ferruginous matrix, best exposed just north of Eva Valley Homestead. No carbonate outcrops were found around the Waterhouse granite.

The Beestons and Celia Formations are apparently conformable, but unconformable with the Crater Formation which transgresses the older formations near Eva Valley Homestead (Refer Map I).

Crater Formation

The Crater Formation is exposed as a prominent line of hills around the northern half of the Waterhouse Granite. In this area the formation is up to 150 feet thick. The Crater Formation consists of a number of bands of hematite boulder conglomerate ranging in thickness from a few feet to tens of feet and containing beautifully marked, sometimes distorted, banded iron formation pebbles and boulders. The iron content of this horizons is variable. White quartz sandstone pebbles or boulders, derived from the underlying Beestons Formation are contained in parts of the conglomerate.

Rodding and local refolding in the vicinity of the Giant's Reef Fault has rendered the hematite boulder conglomerate scarcely recognizable. Biotite and sericite form prominent constituents of the sandstones in this area.

The uppermost horizons of the Crater Formation show marked replacement by quartz and tourmaline, with or without some hematite, especially to the north of Eva Valley Homestead, where the original sedimentary banding is still discernible. (See Plate 2).

Rotary percussion drilling results proved that weathering of the Crater Formation sandstone and grit extends to about 20 feet below the surface, in shale to about 40 feet. The most obvious sign of weathering in shale is the growth of fine sericite and clay minerals from altered felspar.

Coomalie Dolomite

The Crater Formation around the Waterhouse Granite is particularly thin (less than 1000 feet thick) and is overlain by what superficially resembles laterite, similar in many respects to the lateritic rocks of the Castlemain Beds. This horizon is followed by normal facies of the Coomalie Dolomite, though no carbonate rocks outcrop around the Waterhouse Granite.

The Rum Jungle Area

Beestons Formation

The Beestons Formation extends from a little to the south-east of the Giant's Reef Fault on the Rum Jungle Mine road to Mt. Baxter (Map IV) and then northwards to where it disappears beneath the Crater Formation at Manton Dam.

The formation is cut at intervals by north-westerly trending quartz filled shear lines, causing the "stepped" appearance of the outcrop boundary. Mt. Stratton is believed to be at the north-west end of such a shear line. Surface evidence of the shear is a linear outcrop of sandstone on a regular east-west line, between the outcrops of arkose, sandstone, etc, on the Batchelor-Rum Jungle Powerline track, and Mt. Strattan.

The Beestons Formation Succession is as follows:-

Off-white sandstone
Arkose
Basal Fossil Soil horizon

Basal Fossil Soil Horizon. The unconformable contact of the Beestons with the Rum Jungle Complex is exposed at a number of places on either side of the Rum Jungle Road. The 10 - 20 feet or so of rock at the contact may be compared with a normal soil profile:-

Upper horizon - gritty bedded sandstone
Angular vein quartz boulder conglomerate
Weathered bedrock - reconstituted granite.

The basal sediment strongly resembles granite. On close inspection however, it is seen to contain pebbles, and is in fact an excellent example of an arkose, with abundant large feldspar crystals.

The off-white sandstone is best exposed along the eastern margin of the Rum Jungle Complex, particularly north from Mt. Baxter. In the vicinity of Mt. Baxter a folded, thin bedded sandstone is exposed. This is a rare exposure of strong folding in the Batchelor Group away from the Giant's Reef Fault.

The petrology of the arkosic sediments is discussed by Y. Miezitis (1969).

Study of cross-bed measurements was not very rewarding and no detailed assessment was made of the palaeocurrent directions or the provenance of conglomerate boulders, but the rock appears to be derived from the immediately underlying Rum Jungle Complex. Pebbles of schists, quartzite and quartz derived from sediments exposed within the Rum Jungle Complex just to the west are included in the conglomerates and "pebbly" arkoses on the Woodcutters South track.

A small exposure of possible Beestons sandstone occurs beneath the hematite boulder conglomerate just west of the Giant's Reef Fault, north east of Dysons; the exposure coincides with a perceptible rise of radioactivity.

Celia Dolomite

The Celia Dolomite consists of magnesite marble, silicified algal quartzite, shale and calcareous sandstone with local cappings of limonitic mudstone, and quartz hematite breccia. Exposures of the Celia Dolomite closely follows the Beestons Formation, south and east of the Rum Jungle Complex.

There was some sort of hiatus in the sequence at the close of the Celia Dolomite deposition.

The basal bed of the Crater Formation is extremely coarse locally derived hematite boulder conglomerate, in contrast with the chemical/detrital depositional sequence of the Celia. The Crater is also seen to transgress the older formations overlapping onto the granite near Rum Jungle and Manton Dam.

The boundary between the Celia and the Crater appears to be unconformable.

Crater Formation

In the Shirley Area the Crater Formation attains a maximum thickness of 1860 feet. The formation is divisible into the following units:-

Upper siltstone shale and sandstone
No. 2 conglomerate
Possible disconformity - Local unconformity
Sandstone
Shale band
No 1 conglomerate
Possible disconformity
Grit and pebble beds
Hematite boulder conglomerate
Grit and pink/brown crossbedded sandstone

Grit and pink/brown crossbedded sandstone. Dodd (1953) described a basal grit of 100' - 150', at the base of the formation. At the Shirley area however the basal sediment is a thin pink/brown beautifully Pi-cross-bedded sandstone. The Pi-cross-stratification, which Conybeare and Crook (1968) consider indicative of point bar deposits (see Plate 3), is 3 - 15' thick.

Hematite boulder conglomerate is exposed along the edges of the Rum Jungle Complex from south of Mount Fitch near the east Finniss River to the eastern side of the Shirley Area. The outcrops are discontinuous but differ little in appearance from one locality to another. The sediment is essentially a dense, poorly sorted coarse conglomerate with boulders up to two feet long, the average being 4 - 6 inches in diameter. The matrix is either hematite silt or, when in close proximity to the granite, ferruginous quartz grit. The individual boulders usually consist of banded ferruginous rock derived from the Rum Jungle Complex, or white quartz sandstone. The ferruginous material is often specular hematite. Pebbles of granite are extremely rare; milky vein quartz pebbles are occasionally present. Individual boulders are well rounded but the larger boulders are less rounded, and usually ellipsoidal.

The ratio-activity of the conglomerate itself is low although some silt bands overlying the conglomerate commonly have high values.

The hematite boulder conglomerate is invariably massive with rarely much more than a pseudolayering present. Two areas of marked thickening within the Shirley Area coincide with aero-magnetic anomalies. (J. Gardener, personal communication.).

Grit and pebble beds. Although the Crater pebble beds overlie the hematite boulder conglomerate the two units have different radiometric characteristics. Essentially a pebbly sandstone grading into conglomerate the unit contains few banded iron formation pebbles, the predominant composition being quartz and sandstone. The pebble beds also differ in that the pebbles are not "flattened" but are well rounded and more spherical.

The pebble beds are from 225' to 310' thick. They are coarse clastic rocks ranging from sandstone through grit to pebble conglomerate, and are characterised by high radio-activity. Exposures of the pebble beds extend from near Rum Jungle East to the boundary of the Hundred of Goyder and then north to near Manton Dam where the beds are transgressed by the uppermost horizon of the Crater Formation. Finer textured dark brown sandstone and crossbedded greywacke overlie the pebble beds or are interbedded with them.

No. 1 conglomerate. This is a fairly continuous conglomerate of variable thickness extending from the Rum Jungle road, around to Little Coomalie Creek. Correlation outside this area is doubtful. The conglomerate is usually steeply inclined, dips varying from 50^{o} to 75^{o}. All sub-surface drilling to date of both the No. 1 conglomerate and the pebble beds near Manton Dam show that they steepen to about 70 degrees at a depth of 500' below the surface. This suggests an angular disconformity between the No. 1 conglomerate zone and the underlying sediments.

The No. 1 conglomerate which includes an upper and lower Pi-crossbedded sandstone, and rare omikron crossbedded sandstone, is from 20 feet to 150 feet thick.

The radio-activity within this horizon is highly patchy and ranges from 5X to 30X background (0.01 mR/Hr = background) within a few feet. Lithologically the conglomerate is composed of small to medium well-rounded pebbles in a dark matrix. The individual conglomerate lenses pinch and swell, and grade into a gritty quartzite. (see Plate 4).

Shale band. A shale bed about 60 - 200 feet thick, occurs immediately above the No. 1 conglomerate in the Shirley Area. It is also present near the water tower. It has a relatively high base-metal content and constant low radioactivity. It is readily recognisable in percussion drill cuttings and is a good marker horizon in the Crater Bed succession.

Sandstone. Overlying the shale band is a series of siltstone and sandstone bands forming low featureless exposures. Of Radio-activity is higher than over the shale.

No. 2 conglomerate. This is a broad interval including up to 3 parallel sandstone bands which grade laterally into granule conglomerate. Locally the conglomerate becomes coarse textured. The conglomerate is composed mainly of small to medium sized pebbles in a matrix which is generally darker in areas of high radio-activity. At one locality, north-west of the Water-Tower, the heavy mineral banding is separate from the conglomerate, and when checked with a ratemeter gives a much higher reading than the conglomerate (See Plate 6). This supports the view that the radio-active minerals are heavy minerals concentrated under normal placer-type environmental conditions.

Upper siltstone, shale and sandstone. This is the most extensive lithologic unit of the Crater Formation and completely encircles the Rum Jungle Complex. In the Shirley area it is about 750 feet thick. It is highly arenaceous, but still exhibits Pi-cross-stratification (See Plate 7) and current ripple marks. Where the sandstone overlies the granite it is distinctly arkosic and looks very much like the sandstones of the Beestons Formation. Previous geological maps have shown such sandstone as Beestons Formation from Mr. Fitch north and east to Manton Dam. The contact between the upper siltstone, shale and sandstone with the granite in a small east-west trough near Celia Creek west of Manton Dam, is sheared and dips steeply south (Map I).

Palaeocurrent Mapping. During the reconnaissance mapping, palaeocurrent measurements of cross-bedding and ripple-marks, were made wherever suitable outcrops were located. The measurements of cross-bedding were corrected for the dip of the strata with the aid of a stereonet.

The measurements around the Rum Jungle Complex are in the Crater Formation, those around the Waterhouse Granite are in the Beestons Formation. The area to the south of the Rum Jungle Complex, on the basis of radiometric measurements, is considered the most likely host to radioactive mineralization. Palaeocurrent measurements tend to confirm this liklihood (assuming placer-type deposition), and within the "Crater Line" area they indicate a broad medial trough. The Shirley Area is believed to be the eastern half of this medial trough, the western half has still to be investigated. The basal portion of the Crater Formation (Refer Map III) in this area is only patchly exposed.

Folding. In an effort to get a more accurate picture of the fold trends in the Crater Line Area, three Pi-pole diagrams were drawn for the Shirley area and exposures of sediments to the east and west. The dips and strikes were plotted and contoured on an equal area Schmidt lower hemisphere stereographic net. (See Fig. 1)

West of the Shirley Area the Pi-pole plot shows that the bedding is deformed about a fold axis plunging 40° on a bearing of 195° Magnetic or 199° True. This is broadly in agreement with the visual interpretation - See Map IV. The rocks in the Shirley Area are weakly folded, the mean Pi-pole indicates a bedding strike of 66°, and dip to the south-east at approximately 46°.

East of Shirley Area quite strong deformation about a 77° fold axis plunging east at 46° is indicated. The Crater Line Area shows that this trend is in close agreement with the visible fold axial traces in the area.

Sedimentary Structures. Within the Shirley Area attention was paid to the conglomerate bands, with particular regard to the variation in thickness, pebble size, and continuity, in order to get some idea of the possible persistence of these horizons in depth.

Note was also taken of the crossbedding and ripple-marking in the hope that channels could be outlined and consequently areas of maximum conglomerate persistence predicted. The crossbedding is of two types: Pi-cross bedding (a festoon variety) the dominant form and (Planar) omikron crossbedding. Both occur in "point bar" deposits. (Conybeare and Crook 1968). The cross-stratification is generally at an angle of about 30° with the horizontal. Ripple-marks are not normally well exposed and only occur in the uppermost part of the Crater Formation. They have straight to slightly arcuate ripple crests and are of the current variety. The ripples are believed to be of fluviatile origin. (See Map VII).

Data obtained from rotary percussion drilling indicates that the formation dip below No. 1 conglomerate ranges from 18° to 45°. The No. 1 conglomerate dips at from 55° to 75°, while the overlying sediments dip at between 45° and 55°. If the intraformational dip variation is an indication of an angular disconformity, the pebble beds may lens out down dip.

In the Shirley area the hematite boulder conglomerate appears to be a poorly sorted fanglomerate. The pebble beds occur in pebbly sandstone deposited in a beach environment.

The No. 1 and No. 2 conglomerates are generally rounded, well sorted and form a high angle or repose (30°) with the horizontal. The conglomerates exhibit festoon (Pi-cross-stratification) crossbedding and rarely, planar (omikron-cross-stratification). They are considered to be alluvial or point-bar deposits.

The sandstones vary from arkose and greywacke grit near the base to washed sandstone near the top of the formation.

All palaeocurrent measurements were plotted, (See Map VII) and the resultant pattern interpreted. The areas of current confluence are considered to be "lows", those of divergence are interpreted as "highs". Features considered indicative of specific palaeocurrent character are as follows:-

Troughs	Ridges
1. Both Crossbedding and Ripple-mark deduced currents are directed away from ridges and toward troughs.	
2. Grey quartz sandstone is essentially a trough facies.	Algal quartz sandstone is essentially a ridge facies.
3. Conglomerates tend to thicken towards the centre of a Trough.	Conglomerates tend to thin over ridges.
4. The minimum average pebble sizes are located at the base of a trough.	The maximum average pebble sizes are to be found on the flanks of ridges.
5.	In a single instance a conglomerate - filled channel is directed off a ridge.

Coomalie Dolomite A variable succession consisting of breccia, sandstone and grit overlies the Crater Formation in the Mt. Charles area and near Mantom Dam. The most characteristic rock type is a breccia consisting of angular fragments of white quartz and quartzite up to 3" in length embedded in a finer matrix of sandstone or reddish hematitic sandstone. The matrix also includes a few rounded pebbles. Specularite is common in some surface outcrops.

Carbonate rock with associated tremolite and intercalated shale of the Coomalie Dolomite is similar to the lithology of the Celia Formation.

Radioactivity of the Crater Formation

Mapping of the Crater Formation proved the presence of more radioactive conglomerates in the Crater Line Area than elsewhere in the Rum Jungle District. The following is a description of the salient features of radioactivity in the Crater Formation:-

Manton Dam Area: The values range from a general 0.05 - .07 mR/Hr to 0.2 mR/Hr. They have been tested by diamond drilling to 500 feet depth with inconclusive results. No deeper drill-holes have been put down.

Mt. Fitch South Area: A thin highly ferruginous grit band overlying hematite boulder conglomerate near the East Finniss River locally gives readings greater than 0.2 mR/Hr over a few feet.

Within the Crater Line Area radioactivity varies considerably, only those areas where intensity exceeded 0.2 mR/Hr are described:-

Flynn's Area. Situated at 31,000 E, 16,500 N (T.E.P. Mine Grid), is a small area of granule conglomerate, becoming coarser locally in a band of grit. Readings of 0.2 mR/Hr or over were recorded on a 300 foot strike length.

Power Line Area. Immediately east of the Rum Jungle - Batchelor power line, the No. 1 conglomerate is strongly faulted, one small fault block situated at 38,000 E, 12,500 N (T.E.P. Mine Grid) gives a radiometric reading of 0.2 mR/Hr.

The Base Line Origin. Station D on the Crater Line grid is at one end of an exposure of the No. 1 conglomerate giving readings in excess of 0.2 mR/Hr. The pebble beds are also radioactive. This area, known as the Crater Prospect, was investigated in the past.

Station E. A site near the water tower gives high readings in both the No. 1 and 2 conglomerate beds with local values over 0.2 mR/Hr. This area has been tested by T.E.P. and by B.M.R. (diamond drill hole 1A). Waggon drill holes in this area have yielded among the highest equivalent U_3O_8 values recorded by probes in the Crater Formation.

Local highs in the No. 1 and 2 conglomerate with readings generally over 0.1 mR/Hr are situated just to the east of Station E at 46,000 E, 10,000 N.

The Shirley Area. A string of small lenses of conglomerate with readings in excess of 0.2 mR/Hr, occur near an old gold prospect, the Shirley Gold Mine. The pebble beds and the No. 2 conglomerate are patchily radioactive.

The Mount Charles Area. Two parallel conglomerate bands, one giving readings of over 0.2 mR/Hr and the other, a thicker band giving 0.1 mR/Hr or over, are exposed over a strike length of 1000 feet. Some readings as high as 0.3 - 0.4 mR/Hr warrant further investigation.

The results of a detail radiometric survey of the Shirley Area indicate anomalous radioactivity in the lower part of the formation with generally low radioactivity in the upper part. In the eastern portion of the area No. 2 conglomerate of the upper part of the succession is slightly anomalous. (See Map VI).

The radiometric survey was made by surface measurement at 100 feet intervals, with additional readings at 50 feet intervals at strongly radioactive localities. Anomalous radioactivity was further tested by rotary percussion drilling to allow downhole radiometric probing and to obtain rock cuttings for detailed examination (see Map V).

Other areas of anomalous radioactivity include small patches of Crater Formation just west of the Giant's Reef Fault near the mine and a small area near Jeffrey's Homestead which yields 0.07 mR/Hr. Most other parts of the Crater Formation and the Beestons Formation are weakly radioactive. In the Waterhouse area, about three miles north of Eva Valley Homestead, readings of 0.05 mR/Hr were obtained over hematite free conglomerate.

Auger Drilling

Two lines of auger holes were drilled at right angles to the strike, from the base of the Crater Formation to a point stratigraphically above the No. 2 conglomerate. The traverses are located at the Crater Prospect and near the Shirley Gold Mine shown on Map IV. The geochemical results are tabulated in appendix 1.

The augering was planned to provide test holes in the Crater Formation for alpha counting (refer J.E. Gardener, in prep.) and to test the effectiveness of the Gemco drill in this lithology.

The drill provided adequate holes over most of the section tested but a thin band of compact quartzite immediately above the No. 1 conglomerate prevented penetration into the conglomerate itself.

The pebble beds and grit horizon was included in both traverses and was drilled satisfactorily. These beds often do not outcrop very well and even a few inches of cover greatly reduces radioactivity at the surface. Probing of the auger holes in the pebble beds showed they are a consistantly radioactive and warrant further investigation particularly where the No. 1 conglomerate gives a very high reading.

The geological usefullness of the auger drill is limited because of the difficulty of interpreting the cuttings in this arenaceous sequence, but shales are readily distinguished from the other rocks. Parts of the area of outcrop are too rugged for access by the Gemco drill.

Rotary Percussion drilling in the Shirley Area

The total footage drilled was 4,783 feet for 36 holes, an average of 132.8 feet per hole. Many holes were stopped because they had passed through the Crater Formation into the Celia Formation; the hematite boulder conglomerate was a particularly useful marker horizon. Many holes were terminated because the drill was incapable of drilling further. Casing off water allowed the 'down-the-hole' hammer to be used at greater depths. The hammer was found to be the most effective drilling tool in the Crater Formation and was used almost exclusively once the superficial weathered zone had been penetrated by rotary drilling.

On average one hole per day was drilled. The recognition of the cuttings is, however, extremely difficult when this hammer is used, and it was not possible to distinguish conglomerate from grit or quartz sandstone when cuttings consisted of completely pulverised quartz. Contamination of cuttings with material from higher in the hole was also a problem.

Radiometric Readings. All Rotary Percussion holes were probed with either a Widco Logger or a Widco Portalogger.

Radio-activity was lowest in the shale, overlying the No. 1 conglomerate, and slightly higher in the overlying sandstone. High values were obtained in the grit, pebble beds and the No. 1 conglomerate zone. The following is a summary of the logging results:-

The highest readings were obtained on the eastern edge of the Shirley Area, the individual highest reading was in hole R59 on section line G.H. 172.00 at depths of 85-100 feet, yielding values of nearly 1 lbeU_3O_8 in pebble beds. In the eastern area radioactivity increases with depth on section lines 172.00, and 168.00.

The maximum reading in the No. 1 conglomerate on both section A.B. and C.D. (line 164.00) is nearly 1lb/ton eU_3O_8. The best site for testing of the Crater Formation radioactivity by diamond drilling is on section line 172.00.

Geochemistry. Cuttings from selected intervals from the rotary-percussion holes were analysed for copper, cobalt, nickel, and manganese, and cuttings from the first ten holes were analysed for chromium. Results of the geochemical analyses were generally similar to those of the auger drilling survey, but gave a better overall idea of the geochemistry of individual lithological units.

The results of geochemical analysis are not sufficiently comprehensive to indicate the degree of leaching undergone by the Crater Formation.

GEOLOGICAL HISTORY

The Beestons Formation was deposited in very quiet conditions; a series of arkosic horizons with minor pebble conglomerate were deposited on a well preserved erosion surface.

The Celia Dolomite consisting of shallow water silts, clays and algal bioherms conformably overlies Beestons. A period of erosion, brecciation and rejuvination of ancient east-west and north-south welts appear to have preceded the deposition of the Crater Formation.

The Crater Formation unconformably overlies the Celia Formation. The existence of some relief on the pre-existing surface is indicated by the presence of fluvial fanglomerate, the hematite boulder conglomerate composed of sediments largely derived from rocks of the Rum Jungle Complex.

An apparent change in relief caused deposition of the No. 1 conglomerate next, as pebbles with finer sediments were carried over the lip of the Crater trough and deposited at a very high (30^{o}) angle of repose.

Shale was followed by sandstone as the basin shallowed and the overall relief became more subdued, the Crater Formation sediments finally transgressing the underlying formations. Current ripple-marks indicate the shallowness of the general level of deposition. The Crater Formation appears to consist of deposits marginal to an open marine basin.

Breccias and limonitic shales occur at the base of the overlying Coomalie Formation, indicating a possible hiatus between deposition of the Crater and the Coomalie Formations. The sediments near the base of the Crater Formation show limited transport and poor sorting. The upper horizons are of high rank but still of shallow water origin, and pyrite is abundant in the uppermost sandstones - possibly indicative of slightly stagnant conditions.

The Crater Formation could have been deposited under conditions broadly similar to those for a typical Molasse sequence (Potter and Pettijohn, 1963).

GENERAL CONCLUSIONS AND RECOMMENDATIONS

Sites recommended on present evidence for deep diamond drilling are E.G. 94.20/620S and G.H. 173.20/1430S (See Map VII). The sites are recommended on the grounds of thickness of conglomerate at the surface and maximum persistence down dip as deduced from palaeocurrent study: the dip at this site is in the order of 66° the drill site would have to be about 650 feet down dip from the outcrop to intersect the conglomerate at 1000 feet vertical dip. These figures are approximate only as terrain corrections have to be applied and they are subject to the drill holes being angled at 70° to the north and at 90° to strike. The dip of the conglomerate bed has been taken into account in addition to the orientation of the underlying sandstones, which are generally shallower dipping.

If further work on the Crater Formation is warranted, on the basis of the results of the diamond drilling, the regions from the Shirley Area west to the Water Tower and east to Mt. Charles area merit further investigation.

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APPENDICES

Auger Traverse Lines - Geochemical Results.

Rotary Percussion Holes - Geochemical Results.

APPENDIX I

Geochemical Data - Crater Line Area

Bottom hole samples from the two traverses auger drilled near Crater Prospect and near Shirley Goldmine are listed by sample number and co-ordinate position.

Samples were analysed at A.M.D.E.L., by Atomic Absorption Spectroscopy (A.A.S.), or by Emission Spectroscopy (E.S.) as indicated. Results are expressed in parts per million.

Traverse A, near Crater Prospect

Part 1, A.A.S. Analyses

Sample No.	Co-ordinates	Cu	Pb	Zn	Remarks
69121199	50' S	5	15	80	Shale
200	25' S	5	20	10	sst
01	00 NS	10	30	15	) No 1 Cgl
02	30' W of 00N/S	5	30	10	
03	100' S	75	20	65	) Shale
04	150' S	60	15	70	
05	200' S	-5	15	5	
06	250' S	-5	15	5	
07	300' S	-5	12	5	
08	350' S	-5	15	5	
09	400' S	-5	8	5	
10	450' S	-5	10	5	Crater
11	500' S	-5	8	5	Sandstone
12	550' S	-5	5	5	
13	600' S	-5	8	5	
14	650' S	-5	8	5	
15	700' S	-5	8	5	
16	750' S	-5	5	10	
17	800' S	-5	10	10	
18	900' S	-5	8	5	
19	1000' S	-5	5	10	
20	1100' S	-5	20	5	
21	1200' S	5	15	5	
22	1300' S	20	20	10	
23	1400' S	15	15	10	
24	1500' S	35	15	65	
25	25' N	5	15	5	
26	30' N	-5	15	5	
27	100' N	-5	15	5	Crater
28	150' N	-5	15	5	Grit
29	200' N	5	15	5	
30	250' N	-5	10	5	
31	300' N	5	5	5	

../3

TRAVERSE B

Sample No.	Co-ordinates	Cu	Pb	Zn	Sn	Bi	Ag	Ga	Ge	Co	Ni	Cr	V	Mo	Mn	Be	Th
69121243	400' S	15	10	X	1	1	0.1	10	-	20	20	400	30	5	100	2	X
44	350' S	20	10	20	2	1	0.1	30	-	5	30	300	50	X	150	3	X
45	300' S	20	10	X	2	1	0.4	30	-	X	10	200	20	3	20	1	X
46	250' S	40	10	X	4	1	0.2	30	-	30	10	300	20	X	30	1	X
47	200' S	60	15	X	2	1	0.1	30	-	20	30	500	150	X	30	2	X
48	150' S	5	15	50	1	1	0.1	20	-	20	20	300	80	X	100	2	X
49	100' S	8	15	X	2	3	0.2	40	-	15	50	500	80	X	100	2	X
50	50' S	60	15	X	1	3	0.1	30	-	15	15	300	30	X	20	1	X
51	00' SN	40	15	X	6	1	0.1	30	-	60	30	300	800	X	20	1	X
52	50' N	50	20	30	2	1	0.2	30	-	300	80	400	200	X	150	5	X
53	100' N	50	1	30	X	1	0.1	10	-	250	200	800	300	X	1000	2	X
54	150' N	20	1	150	X	X	0.1	20	-	150	300	800	300	X	800	1	X
55	175' N	50	15	X	X	X	0.1	40	-	20	100	1200	150	X	200	3	X
56	200' N	40	30	20	2	1	0.1	20	-	10	30	400	150	X	20	X	400
57	250' N	40	5	X	3	1	0.4	20	-	5	20	400	300	X	30	X	100
58	300' N	40	15	X	1	1	0.4	30	-	5	20	300	100	X	30	X	X
59	350' N	40	15	X	1	1	1.5	30	-	5	5	400	100	3	20	X	100
60	400' N	40	15	20	2	3	0.1	20	-	5	5	300	250	X	50	X	100
61	450' N	40	40	20	2	1	0.4	40	-	5	5	300	250	X	10	X	100
62	500' N	60	20	20	1	1	0.2	30	-	5	30	200	250	X	150	X	100
63	550' N	60	30	X	6	2	0.4	40	-	5	20	400	150	X	10	X	100

cont'd

TRAVERSE B (continued)

Sample No.	Co-ordinates	Cu	Pb	Zn	Sn	Bi	Ag	Ga	Ge	Co	Ni	Cr	V	Mo	Mn	Be	Th
69121264	600' N	60	60	20	4	2	0.4	40	-	5	20	250	100	X	10	X	X
65	650' N	40	30	X	1	1	0.1	40	-	5	30	250	100	X	100	X	X
66	700' N	30	15	X	4	1	0.2	40	-	10	20	300	50	X	50	1	X
67	750' N	60	20	X	3	X	0.2	40	-	5	20	200	30	3	200	2	X
68	800' N	150	30	X	3	8	0.4	40	-	5	30	300	100	X	100	2	X
69	850' N	40	80	X	2	X9	0.4	40	-	5	15	300	80	3	10	3	X
70	900' N	20	60	X	2	X	0.2	40	-	5	15	300	80	X	10	2	X

Footnote : - X below the limit of detection E.S. Method

Elements below limit of detection E.S. method : - Cd, Au, As, Sb, W, Ta, Nb, Pt, Pd, Os, Ir, Rh, Ru, Ge.

Remarks : - No. 1 conglomerate at 175' N. Shales 100 and 150'N.

PART 2 E.S. ANALYSES

Sample No.	Co-ordinates	Cu	Pb	Zn	Sn	Bi	Ag	Ga	Ge	Co	Ni	Cr	V	Mo	Mn	Be	Th
69121232	350' N	40	15	X	3	2	0.2	30	X	5	15	100	200	X	30	1	X
33	400' N	10	15	X	3	2	0.4	40	X	10	15	300	100	X	60	1	100
34	450' N	8	10	20	3	2	0.1	30	X	10	20	300	200	X	80	2	X
35	500' N	15	15	20	3	2	0.1	20	X	5	30	500	150	3	150	1	100
36	550' N	15	5	20	4	4	0.8	40	X	10	20	300	100	3	30	1	X
37	600' N	8	5	X	1	1	0.1	10	X	10	20	300	150	3	60	2	X
38	650' N	5	5	X	3	1	0.1	40	X	15	20	300	100	X	300	3	X
39	700' N	60	30	20	4	2	0.1	40	2	15	20	300	150	3	100	2	X
40	750' N	15	15	20	2	1	0.1	30	1	20	20	300	150	X	150	1	X
41	850' N	30	30	20	3	2	0.4	40	X	20	100	300	200	X	200	3	X
42	800' N	40	30	X	3	2	0.1	40	1	10	100	300	200	X	250	3	X

Footnote:- X below limit of detection of E.S. method. Elements below limit of detection by E.S. method in all samples: Cd, Au, As, Sb, W, Ta, Nb, Pt, Pd, Os, Ir, Rh, Ru.

Remarks:- Celia Formation North of 6.5N, Crater Grit South

Range of trace element contents for Sandstones and shales for selected elements (After Hawkes and Webb 1962).

Rock	Be	Cr	Co	Cu	Pb	Mn	Mo	Ni	Ag	Sn	V	Zn	Bi
SST	less than 1	10-100	1-10	10-40	10-40	385	0.1-1	2-10	0.4	-	10-60	5-20	0.3
Shales	1-6	100-400	10-50	30-150	20	-	1	20-100	-	40 -	50-300	50-300	1

Discussion of Results:-

Part 1.

Copper is generally below normal except in the vicinity of the No. 1 conglomerate, the overlying shales and from 1300S - 1500S - close in to Batchelor township.

Lead is generally average to slightly below average but rising slightly in sympathy with copper.

Zinc is highly anomalous at 1500S (65 ppm = 3 X Normal).

Part 2.

Copper and lead average to slightly below average except for 700N (60 ppm) where copper has a peak.

HOLE 69-R35 Co-ordinates EG 8000 350N SHIRLEY AREA

Depth	Sample No.	Cu	Co	Ni	Cr	Mn
0 - 20'	69120505	15	5	30	70	25
20 - 70'	6	15	5	20	75	30
70 - 90'	7	10	5	20	60	30
90 - 110'	8	15	10	25	70	75
110 - 160'	69120509	25	20	35	50	140

Remarks:- 0 - 95' Crater grit and gritty clays. 95 - 110' HBC. Below 110' Celia weathered products. Below average manganese content.

HOLE 69-R36 Co-ordinates EG 8400 350N SHIRLEY AREA

Depth	Sample No.	Cu	Co	Ni	Cr	Mn
0 - 20'	69120510	15	5	25	35	30
20 - 40'	11	25	5	25	35	25
40 - 80'	12	20	5	20	35	10
80 - 100'	13	15	5	20	85	60
100 - 130'	69120514	15	5	25	25	50

Remarks:- 0 - 80' Crater grit and gritty shale. 80 - 100' HBC. Below 100' Celia weathering products. Below average manganese content.

HOLE 69-R37 Co-ordinates EG 8800 350N SHIRLEY AREA

Depth	Sample No.	Cu	Co	Ni	Cr	Mn
0 - 30'	69120515	15	5	20	55	30
30 - 90'	16	16	5	20	60	25
90 - 170'	17	35	10	25	50	100
170 - 190'	69120518	35	5	20	95	60

Remarks:- 0 - 170' Crater grit and pebbly grit. Below 170' HBC. Below average manganese content.

HOLE 69-R38 Co-ordinates EG 8800 565N SHIRLEY AREA

Depth	Sample No.	Cu	Co	Ni	Cr	Mn
0 - 30'	69120519	20	5	15	55	10
30 - 70'	20	20	5	5	65	10
70 - 130'	21	20	5	5	25	15
130 - 135'	69120522	30	5	20	70	20

Remarks:- 0 - 70' Crater grit and gritty shale. Below 70 ft Celia weathering products. Below average Manganese content.

HOLE 69-R39 Co-ordinates EG 8800 450N SHIRLEY AREA

Depth	Sample No.	Cu	Co	Ni	Cr	Mn
0- 30'	69120523	20	5	20	45	20
30 - 70'	24	25	5	5	60	10
70 - 110'	25	55	45	160	25	75
110 - 180'	69120526	20	40	130	25	55

Remarks:- 0 - 110 Crater grit and gritty shale. 110 - 115 Crater shales. Below 155 Celia weathering products. High nickel content below 70 feet but below average Mn content throughout.

HOLE 69-R40 Co-ordinates EG 9200 600N SHIRLEY AREA

Depth	Sample No.	Cu	Co	Ni	Cr	Mn
0 - 40'	69120527	30	5	10	40	25
40 - 80'	28	35	5	10	60	10
80 - 100'	29	25	5	10	55	10
100 - 150'	69120530	30	10	20	35	45

Remarks:- 0 - 100 Crater grit and gritty shale.
Below average Mn content.

HOLE 69-R41 Co-ordinates EG 9200 450N SHIRLEY AREA

Depth	Sample No.	Cu	Co	Ni	Cr	Mn
0 - 30'	69129531	20	5	5	60	30
30 - 50'	32	20	5	5	50	25
50 - 100	33	30	5	5	60	25
100 - 120'	69129534	25	75	10	110	30

Remarks:- 0 - 100 Crater grit and gritty shale. Below 100 HBC. Co and Cr content high in HBC. Mn below average for SSt and granite derived rocks.

HOLE 69-R42 Co-ordinates EG 8400 450N SHIRLEY AREA

Depth	Sample No.	Cu	Co	Ni	Cr	Mn
0 - 30'	69120535	30	5	25	75	30
30 - 60'	36	20	5	20	60	25
60 - 80'	37	20	10	50	70	30
80 - 100'	69120538	20	10	55	30	40

Remarks:- 0 - 60' Crater grit and gritty shale. 60 - 70' HBC. Below 70' Celia weathering products. Manganese below average.

HOLE 69-R43 Co-ordinates EG 8415 250N SHIRLEY AREA

Depth	Sample No.	Cu	Co	Ni	Cr	Mn
0 - 80'	69120539	25	5	20	45	30
80 - 130'	40	25	5	25	55	55
130 - 160'	41	30	20	20	60	400
160 - 175'	69120542	75	15	20	100	480

Remarks:- 0 - 160' Crater grit and gritty shale. Below 160' HBG. Mn below average only 0 - 130'.

HOLE 69-R44 Co-ordinates EG 8400 190N SHIRLEY AREA

Depth	Sample No.	Cu	Co	Ni	Mn
0 - 20'	69120543	25	5	15	5
20 - 100'	44	25	5	15	10
100 - 120'	45	25	5	5	20
120 - 130'	69120546	20	5	5	10

Remarks:- 0 - 130' Crater grit and gritty shale. Manganese extremely low.

HOLE 69-R45 Co-ordinates EG 8435 45N SHIRLEY AREA

Depth	Sample No.	Cu	Co	Ni	Mn
0 - 30'	69120547	90	25	65	180
30 - 90'	48	20	65	210	330
90 - 100'	49	50	50	40	620
100 - 130'	69120550	30	25	35	200
130 - 144'	51	25	25	25	70

Remarks:- 0 - 90' Crater shale. 90 - 100' Sandstone with No. 1 Conglomerate at 95 ft. 100 - 130' shale. Below 130' grit. Nickel average generally but high in 30 - 90' interval. Mn high 90 - 100 but average to low elsewhere.

HOLE 69-R46 Co-ordinates EG 8472 00N SHIRLEY AREA

Depth	Sample No.	Cu	Co	Ni	Mn
0 - 30'	69120552	30	5	20	10
30 - 100'	53	30	70	280	210
100 - 180'	54	30	55	200	350
180 - 187'	69120555	25	40	140	240

Remarks:- 0 - 180' Crater shale. Below 180' Sandstone and grit. Cobalt high in 30 - 180' interval, manganese about average to low, copper low for a shale.

HOLE 69-R47 Co-ordinates EG 8540 300S SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 30'	69120556	10	5	20	10
30 - 50'	57	10	5	20	5
50 -80'	58	20	5	20	10
80 - 90'	69120559	25	5	20	20

Remarks:- Entirely in sst with No. 2 Cgl approx 45'. Manganese extremely low.

HOLE 69-R48 Co-ordinates EG 8200 60S SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 20'	69120560	150	35	110	85
20 - 60'	61	40	65	240	190
60 - 140'	62	100	80	290	830
140 - 180'	69120563	100	65	220	580

Remarks:- Entirely in shale. Nickel high to very high, cobalt average to high, copper average. Manganese average.

HOLE 69-R49 Co-ordinates EG 8600 600S SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 40'	69120564	20	25	25	30
40 - 100'	65	25	20	20	25
100 - 130'	69120566	25	5	20	30

Remarks:- Entirely in off white quartz sandstone. Manganese extremely low.

HOLE 69-R50 Co-ordinates EG 8670 850S SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 10'	69120567	25	5	5	120
10 - 50'	68	40	5	5	40
50 - 100'	69120579	25	5	5	70

Remarks:- Entirely in off white quartz sandstone. Manganese low throughout.

HOLE 69-R51 Co-ordinates EG 9000 50N SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 40'	69120570	55	20	20	25
40 - 100'	71	40	10	25	50
100 - 200'	69120572	5	50	190	460

Remarks:- 0 - 100 off white Quartz Sandstone. Below 100 shale. Copper above average 0 - 40', Nickel above average in Shale, manganese low in sandstone.

HOLE 69-R52 Co-ordinates EG 9030 100N SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 70'	69120573	5	35	160	340
70 - 140'	74	30	60	200	1500
140 - 170'	75	5	40	170	400
170 - 179'	69120576	10	25	50	330

Remarks:- 0 - 170' Shale. 170 - 179' Pebbles and black Qz fragments - weathered. Copper below average, nickel above average throughout. Manganese average with a high peak at 70 - 140'.

HOLE 69-R53 Co-ordinates GH 164 60S SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 40'	69120577	10	5	8	5
40 - 80'	78	10	5	12	20
80 - 150'	69120579	5	5	18	45

Remarks:- 0 - 80' Grit and gritty shale. 80 - 120 Quartz and grit. below 120' Celia quartz sand. Cu is leached in the Celia, cobalt is low in the upper 40 feet and Manganese is very low throughout.

HOLE 69-R54 Co-ordinates GH 164 65N SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 20'	69120580	35	5	8	25
20 - 40'	81	10	5	10	25
40 - 70'	69120582	5	5	10	15

Remarks:- 0 - 30' Grit. 30 - 40 Hematite boulder conglomerate, below 40' Celia quartz sand.
Manganese is extremely low throughout.

HOLE 69-R55 Co-ordinates GH 164 100S SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 20'	69120583	10	5	10	15
20 - 80'	84	10	5	10	20
80 - 110'	69120585	5	12	10	55

Remarks:- 0 - 80 Grit and gritty shale. 80 - 110' Conglomerate and sandstone. Cu is below normal in the conglomerate, while Co is slightly above normal. Manganese is very low throughout.

HOLE 69-R56 Co-ordinates GH 168 55W SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 40'	69120586	20	5	20	30
40 - 70'	69120587	10	10	40	8

Remarks:- 0 - 35 Grit and gritty shale. 35 - 70' Celia Kaolinitic clay. Everything is low except Ni below 35 feet.

HOLE 69-R57 Co-ordinates GH 169 55S SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 20'	69120588	10	5	8	8
20 - 40'	89	5	5	8	8
40 - 60'	90	10	5	8	18
60 - 100'	69120591	5	5	8	8

Remarks:- 0 - 60' Grit and gritty shale. Below 60' Celia Kaolinitic clay. Everything is extremely low except nickel above 60'.

HOLE 69R-58 Co-ordinates GH 171.50 OONS SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 30'	69120592	5	5	10	8
30 - 70'	93	5	5	10	12
70 - 100'	69120594	4	4	10	20

Remarks: 0 - 70' Grit and gritty shale. Below 70' Weathered Celia shale. Copper is low in the shales, as is cobalt and Nickel. Manganese is exteemely low throughout.

HOLE 69R-59 Co-ordinates GH 172 45S SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 50'	69120595	5	5	8	15
50 - 90'	96	10	5	8	20
90 - 110'	97	10	5	18	120
110 - 130'	69120598	5	8	18	60

Remarks:- 0 - 110' Grit and gritty shale with cgl at 90 - 110'. Below 110' Celia silty clay. This hole had the highest radiometric values in the Crater, but copper is low, Nickel is high in the Conglomerate and Manganese though generally extremely low does rise somewhat in the conglomerate.

HOLE 69R-60 Co-ordinates GH 164 5275 SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 20'	69120599	25	50	190	330
20 - 70'	600	30	20	70	85
70 - 110'	01	5	15	15	30
110 - 150'	02	5	15	15	30
150 - 190'	69120603	10	12	15	30

Remarks:- 0 - 50' Shale. 50 - 70' Silt, shale with No. 1 Cgl at ± 55'. 70 - 120' Siltstone. 120 Approx Cgl lens. Below 120' Grit. Copper is low in the shale - No. 1 Conglomerate Zone; with Cobalt about average and Nickel high. Manganese is Normal in the shale below throughout in the underlying horizons. Except for all value below the No. 1 Cgl are slightly above average.

HOLE 69R-61 Co-ordinates GH 164 575S SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 60'	69120604	10	50	210	380
60 - 140'	05	5	60	220	360
140 - 165'	69120606	5	35	150	190

Remarks:- Shales down to 140' then grit and conglomerate at ± 165. Copper is generally low except in the conglomerate zone, cobalt is low average with nickel and manganese rather higher with Mn tailing off in the grits.

HOLE 69R-62 Co-ordinates GH 164 1127S SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 30'	69120607	5	15	15	10
30 - 80'	08	5	5	10	140
80 - 105'	69120609	5	12	18	230

Remarks:- Off-white sandstone with conglomerates possibly at 25' and 60'. Copper is low, with cobalt and nickel average to slightly above. Manganese increases with depth approaching average.

HOLE 69R-63 Co-ordinates GH 16410 1185S SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 10'	69120610	5	5	5	30
10 - 80'	11	10	5	8	45
80 - 100'	69120612	5	8	12	70

Remarks:- Off-white sandstone with conglomerates at approx. 60' and 85'. Copper and manganese low throughout others about average.

HOLE 69R-64 Co-ordinates GH 13995 50S SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 60'	69120613	30	15	100	250
60 - 70'	69120614	25	12	50	220

Remarks:- 0 - 60' Shale. 60 - 70' Silt and possible conglomerate (No. 1). Nickel a little above average throughout, Manganese approaching the average

HOLE 69R-65 Co-ordinates GH 139.95 50S SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 40'	69120615	10	5	15	30
40 - 90'	16	10	5	12	35
90 - 140'	69120617	10	5	20	45

Remarks:- Siltstone and grit with conglomerate at approx. 30' and 130'. Nickel slightly above average throughout - but Manganese extremely low.

HOLE 69R-66 Co-ordinates GH 150 345N SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 40'	69120618	10	8	15	260
40 - 90'	19	10	5	12	12
90 - 100'	69120620	10	5	15	30

Remarks:- Grit throughout with conglom. ± 15'. Manganese approaches normal in the first 40 feet otherwise it is extremely low. Nickel is generally above average and Co, Ni, average.

HOLE 69R-67 Co-ordinates EG 119.90 450N SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 40'	69120621	150	65	240	570
40 - 95'	69120622	50	50	200	1200

Remarks:- Shale throughout with correspondingly high geochemical values, Ni is 2 X normal and manganese 2 - 3 X normal.

HOLE 69R-68 Co-ordinates EG 119.0 575N SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 40'	69120623	45	5	20	30
40 - 60'	24	50	5	15	80
60 - 95'	69120625	10	5	15	25

Remarks:- Generally grits with a poor conglomerate lens at 20'. Copper above average down to 60', nickel throughout above manganese extremely low throughout.

HOLE 69R-69 Co-ordinates EG 119.90 725 N SHIRLEY AREA

Depth	Sample Number	Cu	Co	Ni	Mn
0 - 20'	69120626	10	5	15	60
20 - 50'	27	10	5	15	25
50 - 100'	69120628	20	5	8	25

Remarks:- 0 - 50' Silt. below 50' Sandstone. Copper rises above normal below 50 feet whereas nickel is above normal above 50 feet. Manganese low throughout.

REFERENCE

Hawkes, H.E. and, Webb, J.S. 1962 Geochemistry in Mineral Exploration. Harpers Geoscience Series New York p 359 - 377.

Reference

Hawkes, K.S. and, Webb, J.S. 1962 Geochemistry in Mineral exploration Harpers Geoscience Series. New York.

APPENDIX II

Geochemical Data - Shirley Area

Samples from rotary-percussion drill holes were collected at lithological intervals and analysed by A.M.D.E.L., using Atomic Absorption Spectroscopy. The number and co-ordinates of each hole is quoted, also by sample numbers, depth of samples and analyses in parts per million. The holes are within 5^{o} of vertical.

HOLE 69-R34 Co-ordinates EG 8000 435N SHIRLEY AREA

Depth	Sample No.	Cu	Co	Ni	Cr	Mn
0 - 10'	69120501	10	5	20	85	80
10 - 50'	2	15	5	20	75	50
50 - 80'	3	60	5	35	70	95
80 - 200'	69120504	35	10	55	30	80

Remarks:- 0 - 50' Crater gritty and gritty shales. Below 50' Celia Dolomite - weathered products. Below average in Manganese content (Hawkes & Webb 1962)

Traverse B near Shirley Gold Mine. E.S. Analyses

Discussion of results:

Copper is generally normal but has extreme lows at 150 and 100S with odd spots a little above normal and a peak at 800N (150 ppm). Lead is normal with an extreme low at 100N and 150N in the shales, and a peak at 850N of 80 ppm.
Zinc is normal in its distribution.
Tin has a peak of 6 ppm on the base line and at 550N.
Bismuth rises to 2 ppm locally otherwise it has a normal distribution, with a isolated peak at 800N (8 ppm).
Silver has normal distribution to a little below normal with a single peak at 350N (1.5 ppm).

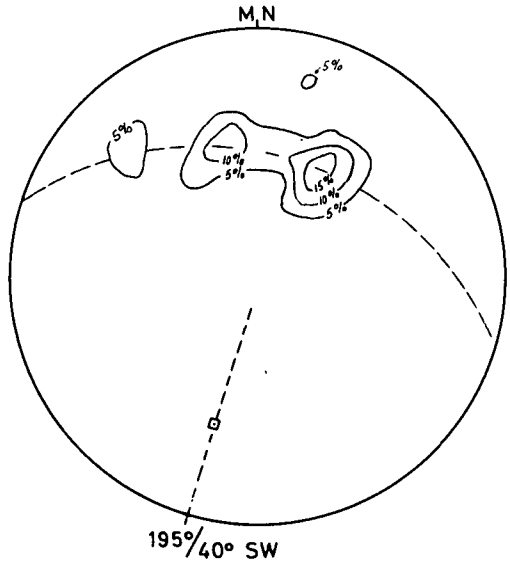
No reference values for gallium or Germanium are available but both deviate little from the mean; cobalt values rise to a peak over the shels. The peak of 300 ppm is 6 X Normal. The distribution of nickel and chromium are similar to the cobalt. The peaks here are 300 ppm (150N) and 1200 ppm (175N - over the No. 1 Conglomerate) respectively.

Vanadium has normal distribution in the shales but rises to 800 ppm (12 X Normal) in the sandstones (00NS).
Molybdenum and beryllium are generally normal, Mo having a peak of 5 ppm at 400S and Be a similar peak at 50N.
Manganese is generally low, being from 0.1 to 0.5 X Normal distribution except over the shales where a peak of 1000 ppm is reached.
Thorium reflects radiometric values rising to 400 ppm close to the No. 1 Conglomerate.

Silver has a high at 550N (0.8) whereas Bismuth is generally anomalous. Tin has no basis for comparison. Cobalt is 2 X normal at 750' N otherwise normal. Nickel is generally 2 X normal rising sharply in Celia. Chrome is generally 3 X normal and Vanadium 2 - 3 X normal throughout. Manganese is always below normal.

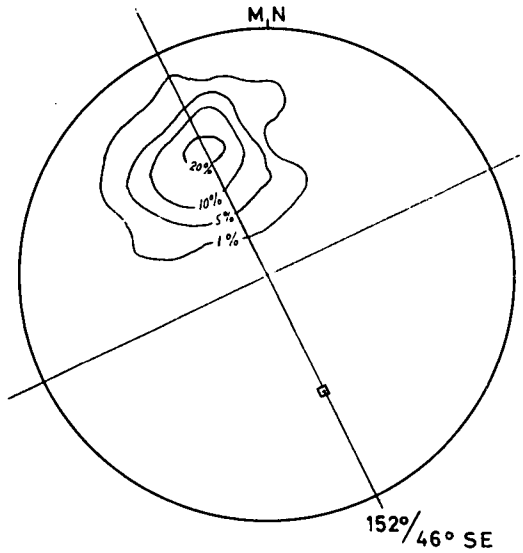
There is no direct correlation between radio-activity and trace element content except with No. 1 conglomerate and if leaching took place at any stage it must have been of copper, lead and manganese.

FIGURE 1



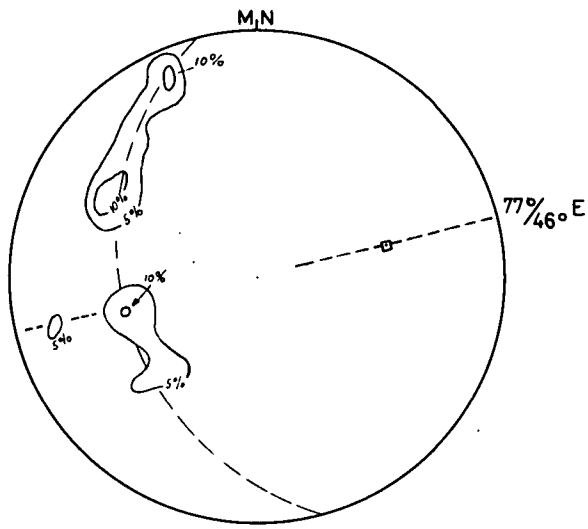
CRATER LINE WEST OF THE SHIRLEY AREA

π DIAGRAM USING
EQUAL AREA NET
35 POINTS
D.J.F. 30 - 10 - 69



SHIRLEY (GOLD MINE) AREA

π DIAGRAM USING
EQUAL AREA NET
172 POINTS
D.J.F. 30 - 10 - 69



THE CORNER AREA EAST OF SHIRLEY AREA

π DIAGRAM USING
EQUAL AREA NET
37 POINTS
D.J.F. 30 - 10 - 69

Pi-DIAGRAMS CRATER LINE

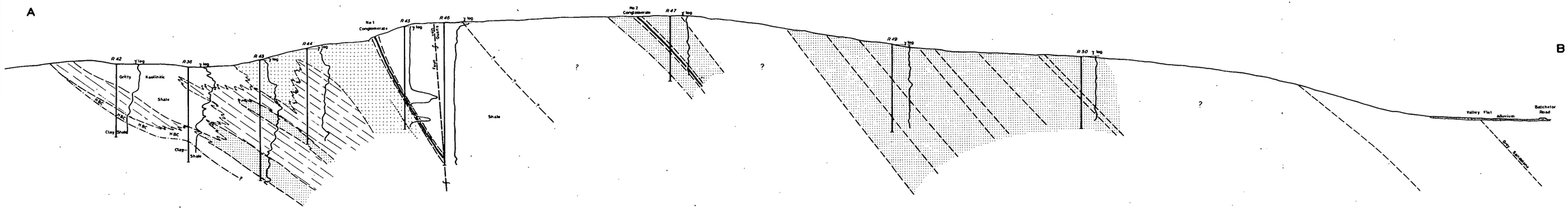
RUM JUNGLE DISTRICT N.T.

BY D.J. FRENCH

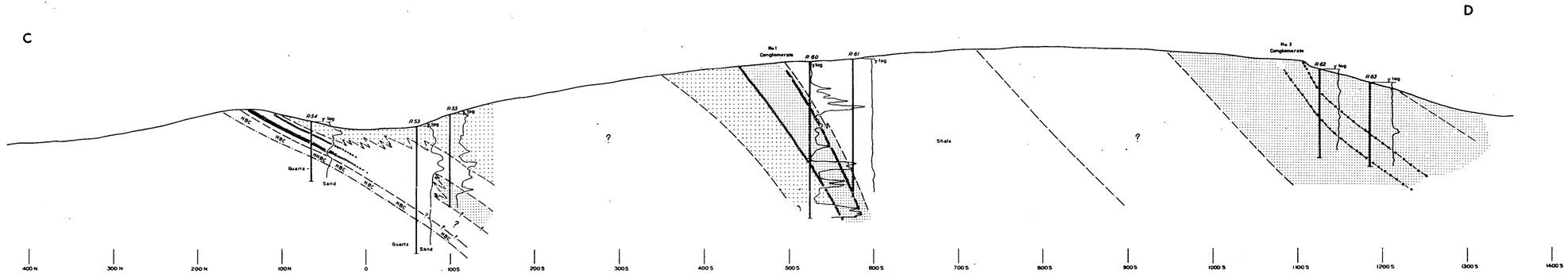
To accompany Record 1970/65

N.T./A327

FIGURE 2



SECTION A – B



SECTION C – D LINE 164·00 GH .

REFERENCE

- BASE OF CRATER FORMATION
- LITHOLOGICAL BOUNDARY
- FAULT
- CONGLOMERATE
- HBC HEMATITE BOULDER CONGLOMERATE BED
- γ log 0·4 mR/Hr / Inch
- SANDSTONE
- GREYWACKE GRIT
- MUSCOVITE SHALE

SECTIONS
SHIRLEY AREA
RUM JUNGLE DISTRICT N.T.

BY D.J. FRENCH

50 0 50 100 FEET

To accompany Record 1970/65

NT/A328

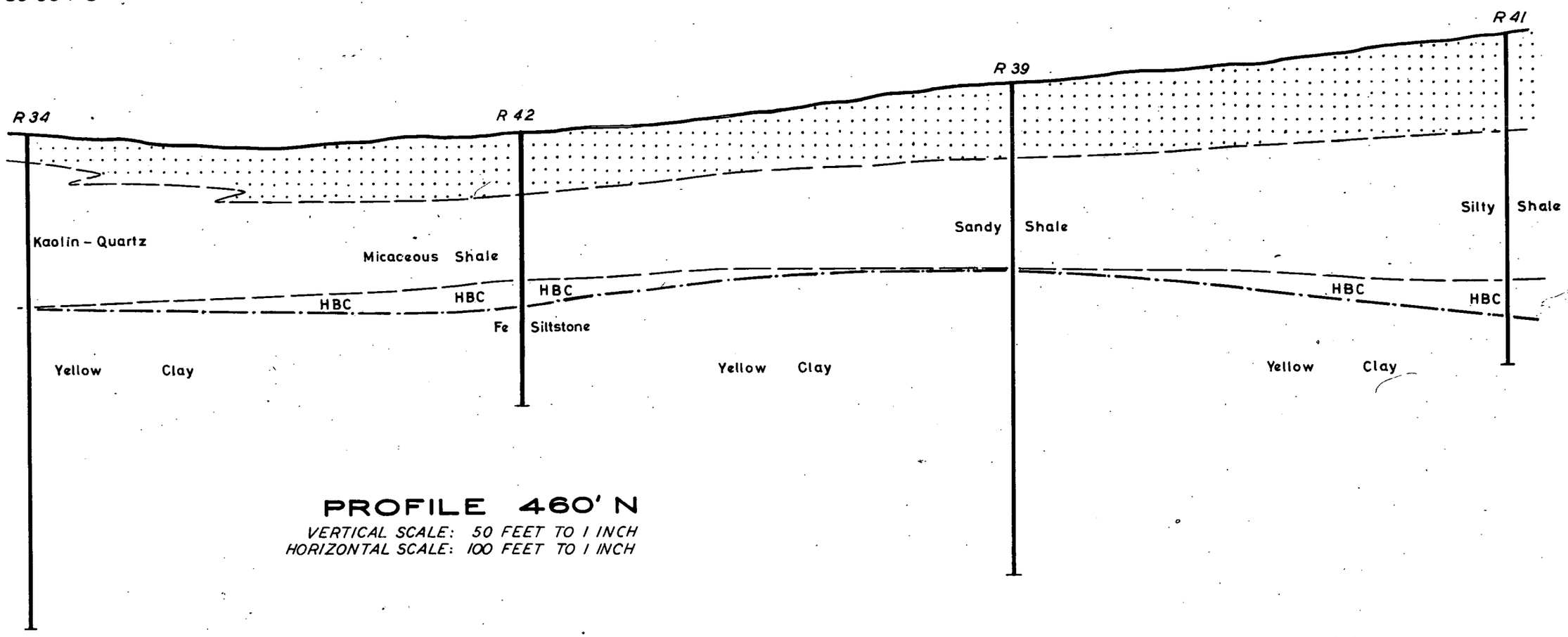
FIGURE 3

80·00 F G

84·00 F G

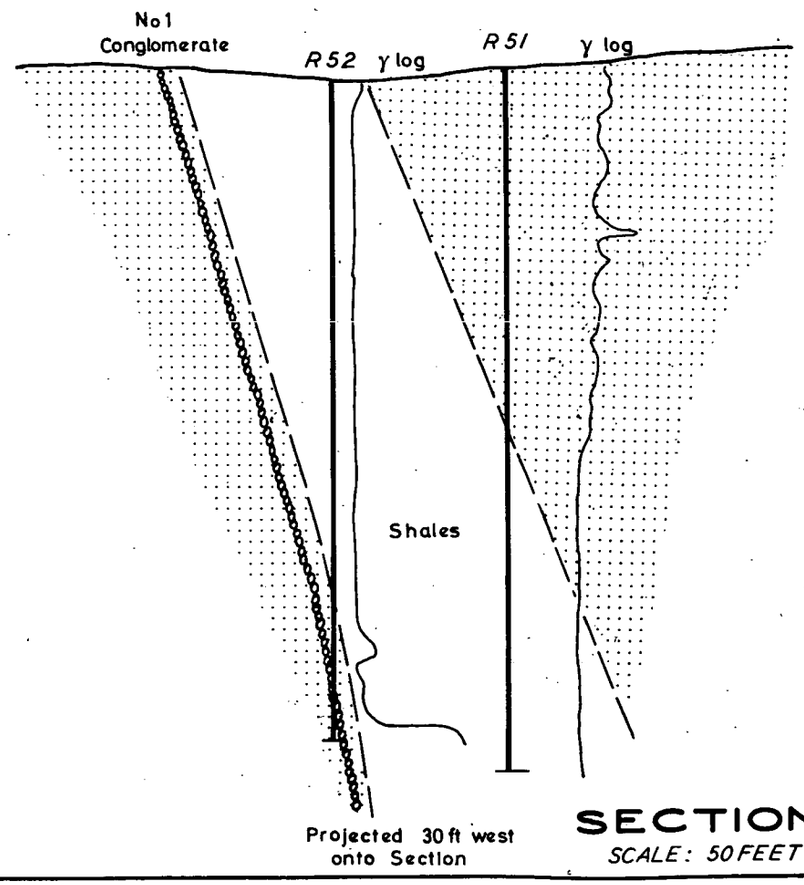
88·00 F G

92·00 F G



PROFILE 460' N

VERTICAL SCALE: 50 FEET TO 1 INCH
HORIZONTAL SCALE: 100 FEET TO 1 INCH



SECTION 90 F–G

SCALE: 50 FEET TO 1 INCH

REFERENCE

- BASE OF CRATER FORMATION
- LITHOLOGICAL BOUNDARY
- CONGLOMERATE
- HBC — HEMATITE BOULDER CONGLOMERATE BED
- γ log — 0·4 mR/Hr / Inch
- SANDSTONE
- GRIT

SECTION AND PROFILE
SHIRLEY AREA
RUM JUNGLE DISTRICT N.T.

To accompany Record 1970/65

N.T./A329

PLATE 1

GEOLOGY

RUM JUNGLE DISTRICT N.T.

CRATER INVESTIGATION 1969

SCALE: 1 MILE TO 1 INCH

1 0.5 0 1 2 MILES

BY D.J. FRENCH

REFERENCE

LOWER PROTEROZOIC

- Plr — CRATER FORMATION
- Hematite Boulder Conglomerate
- Conglomerate
- Pll — CELIA DOLOMITE
- Ple — BEESTONS FORMATION

ARCHAEAN

- RUM JUNGLE COMPLEX
- Felspar Mica Schist
- Banded Iron Formation
- WATERHOUSE GRANITE

- Quartz Vein
- Hematite Quartz Breccia
- Granite Boundary
- Geological Boundary
- Outcrop Boundary
- Fault
- T_{50} Dip and Strike of Bedding
- Anticline
- Syncline
- Mine or Prospect
- Road
- Track

DARWIN

RUM JUNGLE COMPLEX

WATERHOUSE GRANITE

NORTH AUSTRALIAN RAILWAY

ADELAIDE RIVER

HIGHWAY

STUART

REEF

FAULT

BATCHELOR

MANTON DAM

Overturned Beds

Granite

Sheared Contact

Granite/met Sedimentary Contact

Unconformity

Basal Conglomerate

Basal Cgl

Unconformity Basal Cgl

Rum Jungle Creek

Rum Jungle Creek South

Meneling H.S.

Esa Valley H.S.

Mt Fitch North

Mt Fitch

Whites

Tourmaline Quartz Replacement

Plr

Ple

Pll

GIANT'S

FANNISS RIVER

Creek

Coomalie

PLATE 2

RUM JUNGLE COMPLEX

WATERHOUSE GRANITE

DARWIN

MANTON DAM

Overturned Beds

Granite

Sheared Contact

Overturned Beds

Overturned Beds

NORTH

Mt Fitch North

Mt Fitch

FINNISS RIVER

Granite / met Sedimentary Contact

AUSTRALIAN

REEF

Basal Cgl.

HIGHWAY

White's

Unconformity

GIANT'S

Basal Conglomerate

Basal Cgl.

V.Q

Rum Jungle Creek

Rum Jungle Creek South

BATCHELOR

Creek

STUART

Unconformity Basal Cgl.

Meneling H.S.

Granite

Replacement

Tourmaline Quartz

Eva Valley H.S.

RAILWAY

FAULT

ADELAIDE RIVER

RADIOACTIVITY

> 0·2	mR/Hr
0·05 – 0·2	mR/Hr
0·01 – 0·05	mR/Hr

REFERENCE

- QUARTZ VEIN
- OUTCROPS
- FAULTS
- GRANITE BOUNDARY
- HEMATITE BOULDER CONGLOMERATE
- CONGLOMERATE
- HEMATITE QUARTZ BRECCIA
- FELSPAR MICA SCHIST
- BANDED IRON FORMATION
- MINE OR PROSPECT
- ROADS
- TRACKS
- SYNCLINE
- ANTICLINE
- DIP AND STRIKE T_{50}

130°55' 131°00' 131°05' 131°10'

12°55' 13°00' 13°05' 13°10'

RADIOMETRIC SURVEY
RUM JUNGLE DISTRICT N.T.
CRATER INVESTIGATION

SCALE: 1 MILE TO 1 INCH

1 0.5 0 1 2 MILES

BY D.J. FRENCH

To accompany Record 1970/65

N.T./A 331

PLATE 3

RECONNAISSANCE PALAEOCURRENT MAP

RUM JUNGLE DISTRICT N.T.

SCALE: 1 MILE TO 1 INCH

1 0.5 0 1 2 MILES

BY D. J. FRENCH

RUM JUNGLE COMPLEX

WATERHOUSE GRANITE

DARWIN

ADELAIDE RIVER

130°55′ 131°00′ 131°05′ 131°10′

12°55′ 13°00′ 13°05′ 13°10′

NORTH AUSTRALIAN RAILWAY

FINNISS RIVER

REEF FAULT

GIANT'S REEF

HIGHWAY

STUART

MANTON DAM

Mt. Fitch North

Mt. Fitch Mg

White's

Mt. Stratton

Mt. Baxter

Rum Jungle Creek

Rum Jungle Creek South

BATCHELOR

Meneling H.S.

Eva Valley H.S.

Cosmatic Creek

Mg

REFERENCE

- GRANITE BOUNDARY
- TROUGH
- RIDGE
- PALAEOCURRENT DIRECTION
- CONGLOMERATE WITH GREATER THAN 0·2 mR/Hr READING ON HARWELL RATEMETER 1386 A
- Mg MAGNESITE

To accompany Record 1970/65

NT/A332

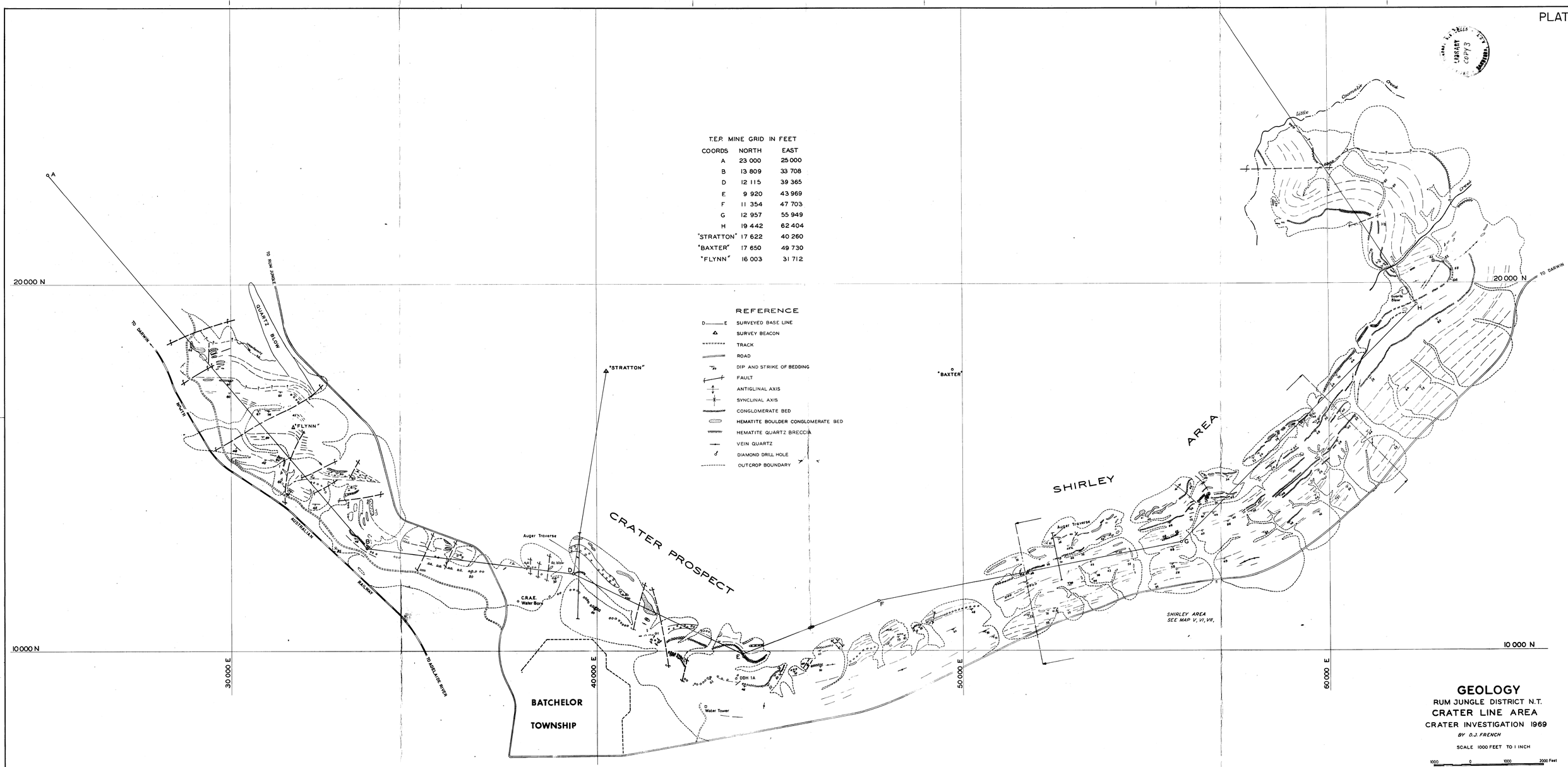
PLATE 4

T.E.P. MINE GRID IN FEET

COORDS	NORTH	EAST
A	23 000	25 000
B	13 809	33 708
D	12 115	39 365
E	9 920	43 969
F	11 354	47 703
G	12 957	55 949
H	19 442	62 404
"STRATTON"	17 622	40 260
"BAXTER"	17 650	49 730
"FLYNN"	16 003	31 712

REFERENCE

- D——E SURVEYED BASE LINE
- SURVEY BEACON
- TRACK
- ROAD
- DIP AND STRIKE OF BEDDING
- FAULT
- ANTIGLINAL AXIS
- SYNCLINAL AXIS
- CONGLOMERATE BED
- HEMATITE BOULDER CONGLOMERATE BED
- HEMATITE QUARTZ BRECCIA
- VEIN QUARTZ
- DIAMOND DRILL HOLE
- OUTCROP BOUNDARY



GEOLOGY

RUM JUNGLE DISTRICT N.T.

CRATER LINE AREA

CRATER INVESTIGATION 1969

BY D.J. FRENCH

SCALE 1000 FEET TO 1 INCH

1000 0 1000 2000 Feet

T.E.P. MINE GRID
CRATER SURVEY 1969
TIMBS & BRITTEN

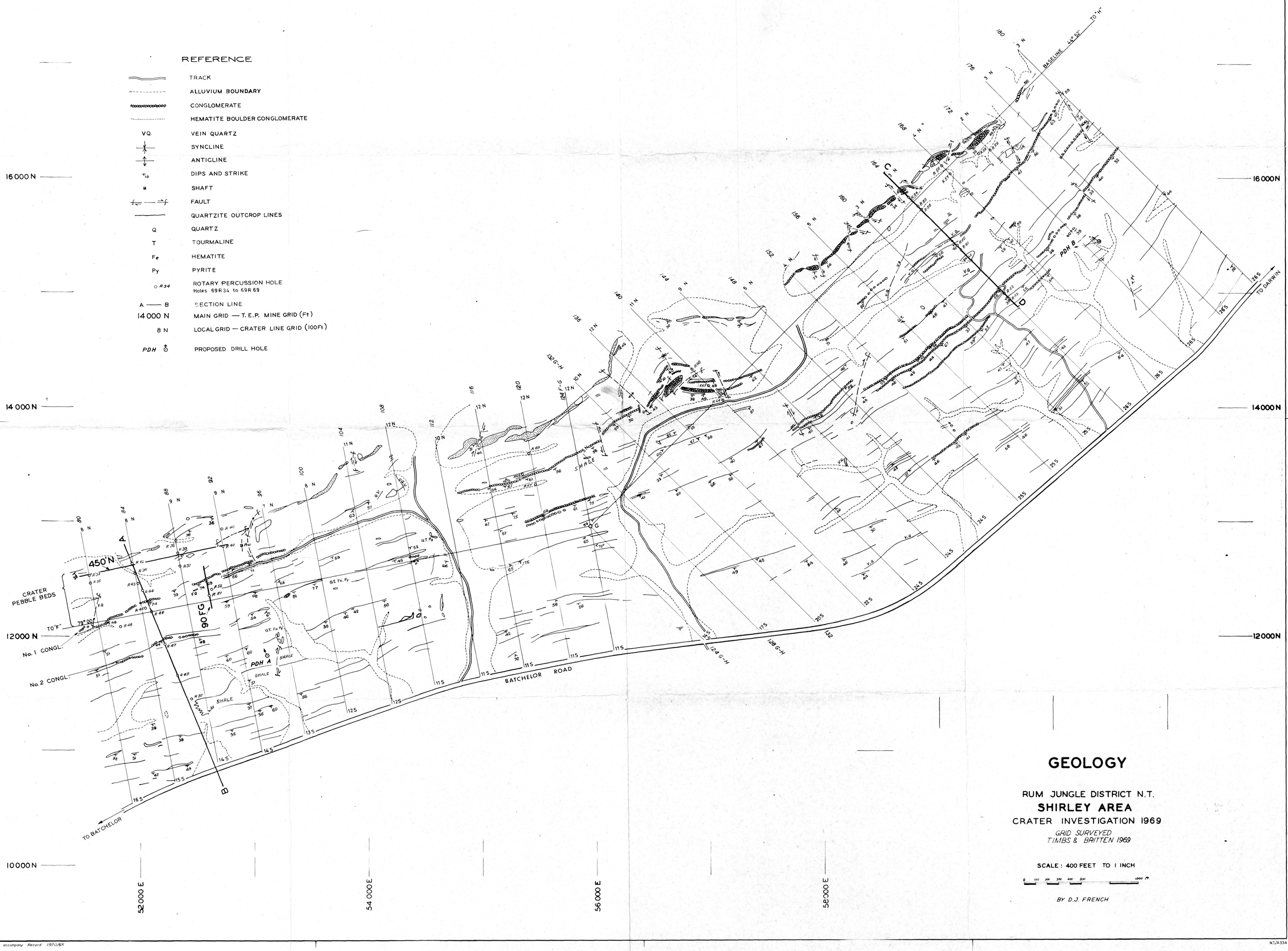
To accompany Record 1970/65

N7/4333

PLATE 5

REFERENCE

- TRACK
- ALLUVIUM BOUNDARY
- CONGLOMERATE
- HEMATITE BOULDER CONGLOMERATE
- VQ — VEIN QUARTZ
- SYNCLINE
- ANTICLINE
- T_{10} — DIPS AND STRIKE
- SHAFT
- FAULT
- QUARTZITE OUTCROP LINES
- Q — QUARTZ
- T — TOURMALINE
- Fe — HEMATITE
- Py — PYRITE
- ○ R34 — ROTARY PERCUSSION HOLE Holes 69R34 to 69R69
- A — B — SECTION LINE
- 14 000 N — MAIN GRID — T. E. P. MINE GRID (Ft)
- 8 N — LOCAL GRID — CRATER LINE GRID (100Ft)
- PDH ⊙ — PROPOSED DRILL HOLE



GEOLOGY

RUM JUNGLE DISTRICT N.T.

SHIRLEY AREA

CRATER INVESTIGATION 1969

GRID SURVEYED TIMBS & BRITTEN 1969

SCALE : 400 FEET TO 1 INCH

0 100 200 300 400 500 1000 Ft

BY D.J. FRENCH

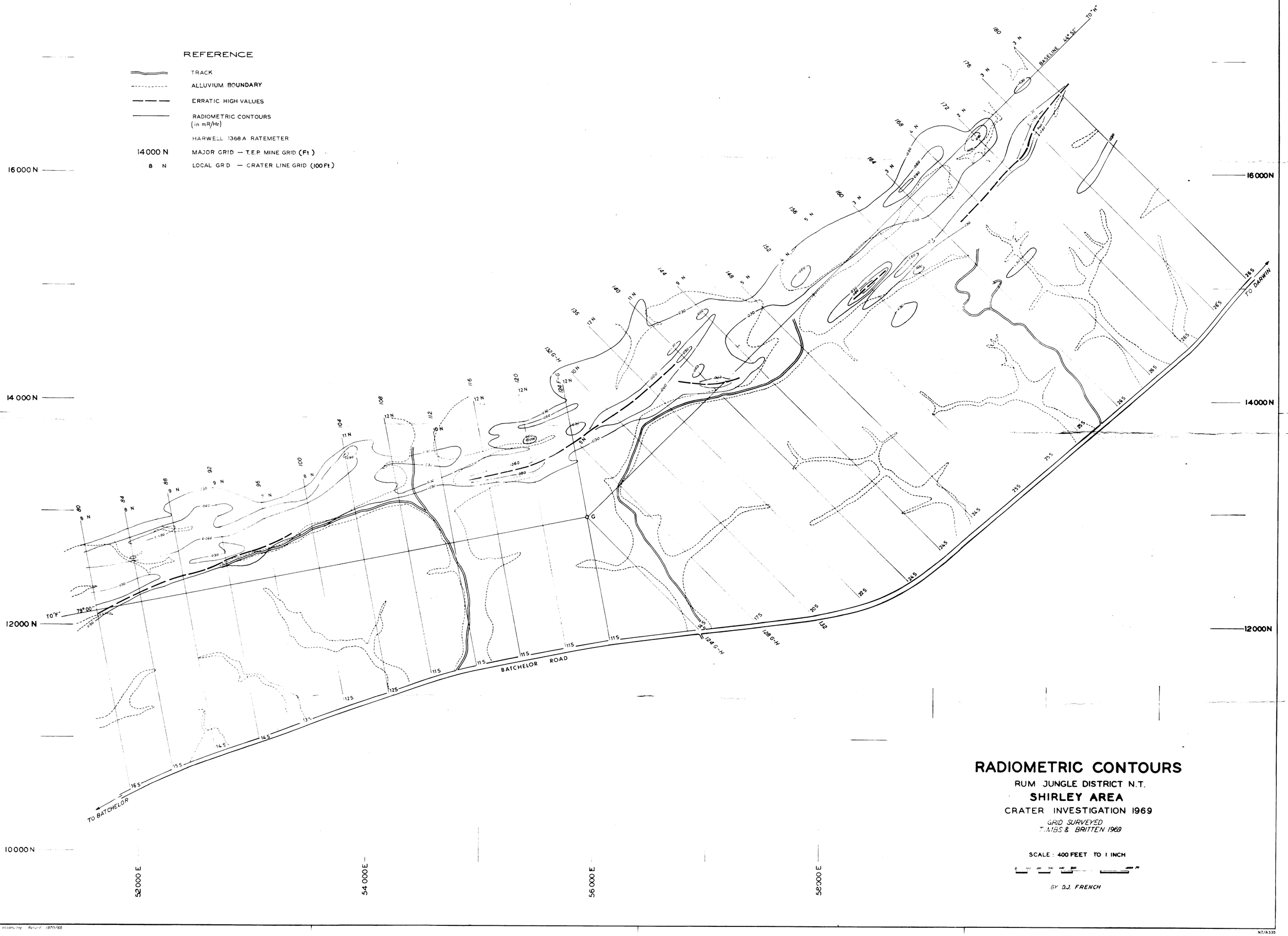
To accompany Record 1970/65

N.T./A334

PLATE 6

REFERENCE

- TRACK
- ALLUVIUM BOUNDARY
- ERRATIC HIGH VALUES
- RADIOMETRIC CONTOURS (in mR/Hr)
- HARWELL 1368A RATEMETER
- 14000 N — MAJOR GRID — T.E.P. MINE GRID (Ft)
- 8 N — LOCAL GRID — CRATER LINE GRID (100 Ft)



RADIOMETRIC CONTOURS

RUM JUNGLE DISTRICT N.T.

SHIRLEY AREA

CRATER INVESTIGATION 1969

GRID SURVEYED T.NIBS & BRITTEN 1969

SCALE : 400 FEET TO 1 INCH

0 100 200 300 400 800 1000 Ft

BY D.J. FRENCH

PLATE 7

REFERENCE

TRACK

ALLUVIUM BOUNDARY

GQ — GRAY QUARTZ SANDSTONE

AQ — ALGAL QUARTZ SANDSTONE

BASE OF CRATER FORMATION

BASIN TOPOGRAPHY:

RIDGE AND/OR ANTICLINE

TROUGH AND/OR SYNCLINE

CONGLOMERATE THICKNESS:

6"

18"

PEBBLE SIZES (AVERAGE)

A — GRANULE < 1/4"

B — 1/2" – 3/4"

C — 3/4" – 1"

D — 1" – 2"

E — > 2"

CURRENT DIRECTIONS

7 — MEAN CURRENT RIPPLE AND RIPPLE INDEX

25° 3" — CORRECTED CROSSBEDS WITH THE ANGLE OF THE FORESET TO THE HORIZONTAL AND THICKNESS

STRUCTURE

FAULT

PDH A — PROPOSED DRILLHOLE

MAJOR GRID — T.E.P. MINE GRID (Ft.) 14000 N

LOCAL GRID — GRATER LINE GRID (100Ft) 8 N

BASELINE 44° 52' TO 74°

TWO BANDS

PDH B

BATCHELOR ROAD

18000 N

16000 N

14000 N

12000 N

10000 N

52000 E

54000 E

56000 E

58000 E

60000 E

PALAEOCURRENTS AND BASIN ANALYSIS (IDEALIZED)

GEOLOGY : D.J. FRENCH

RUM JUNGLE DISTRICT N.T.

SHIRLEY AREA

CRATER INVESTIGATION 1969

GRID SURVEYED TIMBS & BRITTEN 1969

SCALE : 400 FEET TO 1 INCH

0 100 200 300 400 500 1000 Ft

To accompany Record 1970/65

N.T./A336