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AIRBORNE GAMMA-RAY SPECTROMETER SURVEY, RUM JUNGLE, N.T., 1969

by

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SUMMARY

An airborne gamma-ray spectrometer survey of an area approximating the Hundred of Goyder, Northern Territory, was flown by the Bureau of Mineral Resources in 1969. The object of the survey was to evaluate the usefulness of the spectrometer method for uranium exploration and geological mapping. The Hundred of Goyder was selected as the test area, because it has been subjected to intensive ground and airborne radiometric investigation.

The interpretation is primarily qualitative, although the uranium channel anomalies were classified according to their amplitude in relation to the geological noise envelope and according to whether they were point or broad sources.

The thorium and potassium channels provide the most useful rock unit 'signatures' in the Rum Jungle area. The uranium-channel level appears to reflect the degree of leaching rather than the original composition. High amplitude thorium-channel anomalies were recorded over the Rum Jungle Complex, the Waterhouse Granite, and the basal conglomerates of the Crater Formation. The argillaceous Golden Dyke and Burrell Creek Formations in the southeast corner of the area are predominantly potassic. The remainder of the area is radiometrically flat except for uranium-channel anomalies over prospects and contaminated areas.

It has been possible with the gamma-spectrometer to eliminate areas of non-prospective thorium and potassium, and to locate anomalies which would have been masked by the high level of non-uranium anomalies. Otherwise agreement with previous airborne work is good. Few of the airborne anomalies warrant further study because many of them correspond to ground anomalies that have already been covered by detailed ground investigations.

A digitized spectrometer system would speed up data reduction and permit a more rigorous interpretation.

1. INTRODUCTION

In late 1968 the Bureau of Mineral Resources (BMR) purchased a 4-channel Hamner gamma-ray spectrometer, and in 1969 embarked on a series of test surveys to evaluate the usefulness of the spectrometer method compared with the earlier total-count scintillation methods. The first of these surveys was made over the phosphate-bearing formations in northwest Queensland. It has been described by Waller, Beattie & Downie (1971), who deal at some length with the theory and practical problems of airborne gamma-ray spectrometry. The second survey took place immediately afterwards, in the Rum Jungle area of the Northern Territory, and forms the subject of this present Record. Rum Jungle was chosen because the area had previously been investigated in detail using both airborne and ground total-count scintillometers.

The survey area is about 90 km from Darwin and approximates the land subdivision of the Hundred of Goyder. The survey extended over six weeks from late October to early December.

At the end of the 19th century, copper was discovered in the Rum Jungle area and some secondary ore was mined from trenches and shallow shafts. Uranium was discovered in 1949, and between 1953 and 1963 Territory Enterprises Pty Ltd (TEP) managed all the mining in the Hundred of Goyder on behalf of the Australian Atomic Energy Commission. Uranium was of major importance, but significant amounts of copper and lead were produced before mining ceased in 1963. Processing of stockpiled ore is continuing.

2. GEOLOGY

Much of the following is taken from the general description of the survey area geology by Spratt (1965). The area has been mapped at a scale of one mile to one inch by BMR and TEP geologists and this map has been used for Plates 2, 3, 4, and 6. More detailed geology of specific areas, such as mines and prospects, is available in BMR Records.

The Rum Jungle area consists essentially of lower Proterozoic granitic rocks forming the Rum Jungle Complex and low-grade metasediments. The Rum Jungle Complex occupies the core of the domed metasediments; brief descriptions of which are given in Table 1.

The older Batchelor Group, which consists of shelf deposits, is overlain conformably by the Goodparla Group, which was deposited in a trough environment. The Coomalie Dolomite, the 'quartz hematite breccia', and the Golden Dyke Formation are of particular interest, because of the close association of the mineralization with these beds. The 'quartz hematite breccia' consists of up to 150 m of angular fragments of quartz in a sandy matrix, and overlies the Coomalie Dolomite in the survey area. It has been recognized as a silicified limestone breccia from the work of Condon & Walpole (1955) 225 km south of Rum Jungle.

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The domed metasediments dip outwards from the Rum Jungle Complex at angles of 30 to 70 degrees, except where they are faulted against the granitic rocks or are locally contorted. Early workers (Sullivan & Matheson, 1952; Malone, 1962) considered that the metasediments were domed and intruded by the granite, however; recent work (Rhodes, 1965; Crohn et al., 1968) suggests that the sediments rest unconformably on the surface of the Complex and that the doming of the sediments around the granites appertains to a later period of folding and low-grade metamorphism.

Three periods of folding have been recognized in the Lower Palaeozoic metasediments (P. Williams, pers. comm. to Rhodes, 1965). The most prominent fold pattern is northwest, coinciding in direction with the main axis of folding in the Pine Creek Geosyncline. This was preceded by some early east-west folding, and was followed by a third period of folding sub-parallel to the Giants Reef Fault.

The only major fault in the area is the Giants Reef Fault, which has a dextral horizontal displacement of 5.5 km.

3. MINERALIZATION

Uranium and base metals

Copper was discovered in the Rum Jungle area at the end of the 19th century, and small quantities of secondary ore were mined. The first discovery of uranium mineralization was made in 1949, when torbernite and uranium ochres were found in association with copper minerals. In the survey area, White's and Dyson's orebodies together yielded 500,000 metric tons of ore averaging 3.28 Kg of U_3O_8 per metric ton, and the Rum Jungle Creek South mine produced 600,000 metric tons averaging 4.02 kg per metric ton (Corbett & McLeod, 1965).

Most of the deposits in the Rum Jungle area have certain important features in common:

(i) In general, ore occurrence is restricted to the fine-grained carbonaceous beds of the Golden Dyke Formation,

(ii) Most of the orebodies are localized against the contact with the underlying Coomalie Dolomite or the 'quartz hematite breccia',

(iii) The uranium mineralization appears to have preceded the deposition of the base metals,

(iv) Generally, uranium-phosphate minerals occur in the oxidized zone of the lodes, but pitchblende occurs in the primary zone.

Copper and lead are the main base metals, but small amounts of cobalt and nickel minerals occur in some lodes.

The evidence concerning the origin of the Rum Jungle deposits conflicts in some details, and the orebodies have been variously regarded as sedimentary by Condon & Walpole (1955) and Thomas & Whitcher (1965), replacement deposits by Fisher & Sullivan (1954), hydrothermal by Sullivan & Matheson (1952), and epigenetic by Roberts (1960). Those workers favouring an epigenetic origin have assumed that ore deposition was closely related to the intrusion of the granitic rocks into the Batchelor Group. Since Rhodes (1965) and Crohn, Prichard & Gardener (1968) have shown that the granites are older than the sediments, the origin of the Rum Jungle deposits is still far from clear.

Phosphate deposits

Phosphate was recognized in the Rum Jungle area in 1961 and Pritchard, Barrie, Jauncey & Fricker (1963) list sixteen occurrences: ten in the Castlemaine Hill area, four in the Embayment, and two in an area 10 km south of Batchelor. The deposits consist principally of fluorapatite considered by those authors to have been formed by supergene enrichment in an ancient regolith on the Coomalie Dolomite.

4. PREVIOUS EXPLORATION

Since the discovery of uranium in 1949, a large amount of geological, geochemical, and geophysical prospecting has been undertaken in the Rum Jungle area. These surveys have been reviewed by Langron (1969).

Most of the geophysical work has been of the nature of ground traverses, and electrical methods have proved the most useful. It has been shown that the sulphide orebodies produce strong electromagnetic anomalies. However, this is also the case for both the graphitic rocks of the area and the pyrrhotitic amphibolites of the Golden Dyke Formation.

Ground radiometric surveying and radiometric probing of drill holes has been carried out in many of the prospecting districts, generally with disappointing results.

Geochemical testing for copper, lead, zinc, cobalt, nickel, molybdenum, and bismuth has been done in the survey area, although most workers have concentrated their attention on the anomalous regions of copper and lead.

Earlier airborne magnetic and radiometric surveys have been described by Daly (1957), Wood & McCarthy (1952) and Livingstone (1959). The radiometric anomalies were classified into three groups, depending on the amplitude of the anomaly compared with the background noise amplitude. Almost seven hundred radiometric sources were located.

TABLE 1

LOWER PROTEROZOIC METASEDIMENTS

Group	Formation	Description
FINNIS RIVER GROUP	Noltenius Formation	Quartz greywacke, greywacke, quartz pebble conglomerate and siltstone.
	Burrell Creek Formation	Siltstone, greywacke siltstone, greywacke and quartz greywacke.
GOODPARLA GROUP	Golden Dyke Formation	About 1800 m thick, and crops out mainly in the north and southeast of the area. A variable series of predominantly argillaceous sediments. Includes graphitic, sericitic and chloritic slates and siltstones, minor dolomite lenses, and amphibolite bodies.
	Masson Formation (Acacia Gap Tongue)	This consists of a wedge of arenaceous grey pyritic quartzite which interfingers with the Golden Dyke Formation. It crops out extensively in the north and east of the area.
BATCHELOR GROUP	Coomalie Dolomite	About 600 m thick, and outcrops are isolated but common throughout the area, and are usually silicified. The formation is composed of dolomite, dolomitic marl, and minor siltstone.
	Crater Formation	About 750 m thick, and crops out fairly continuously around the Rum Jungle Complex and the Waterhouse Granite. It is a clastic succession of greywacke, sandstone, quartzite, and conglomerate. Most beds are lenticular.
	Celia Creek Formation	About 300 m thick, and crops out in the south and north of the Rum Jungle Complex and to the east of Waterhouse Granite. It consists of silicified dolomite, dolomite, and dolomitic breccia.
	Beestons Formation	This is the oldest member of the Batchelor Group; about 300 m thick and has continuous outcrop along the south of the Rum Jungle Complex and on the north and east of the Waterhouse Granite. Consists of arkose with minor quartzite, slate, grit, and conglomerate.
	Rum Jungle Complex (Rum Jungle Granite) and Waterhouse Granite	The Waterhouse Granite may be younger than the Batchelor Group, and therefore intrusive into them, but recent work indicates that the Rum Jungle Complex is older than the metasediments and is overlain unconformably by them. The Complex consists of schists, gneisses, granite gneiss, metadiorite, coarse granite, large feldspar granite, and leucocratic granite (Rhodes, 1965). Less information is available for the Waterhouse Granite, but it is possibly similar in constitution.

(after Spratt, 1965)

The detailed airborne magnetic survey of Browne-Cooper & Gerdes (1970) covered the same area as the airborne spectrometer survey that forms the subject of this Record.

5. SURVEY TECHNIQUE

The survey was conducted at a nominal height of 85 m above ground level along E-W lines spaced 160 m apart.

Four channels of data were recorded. The total gamma-radiation count was recorded by channel 1, set to accept all pulses with energy between 1.0 and 3.0 MeV. Channels 2 to 4 were centred on the 1.46, 1.76, and 2.62 MeV gamma-ray peaks of K^{40}, Bi^{214}, and Tl^{208} respectively. The last two are the daughter elements of U^{238} and Th^{232}. Further instrumental and operational details are given in the Appendix.

Because of the interference between channels (referred to later in discussing the stripping process) and the possibility of disequilibrium in the decay series of uranium and thorium, the count rates in channels 2 to 4 are not directly related to the abundance of potassium, uranium, and thorium. For convenience, however, the terms potassium, uranium, and thorium are used in referring to the respective channels and to the count-rates recorded by the channels.

A time-constant of 2 seconds was used. A 1 second time-constant would have been more suitable for the survey, but was not available. The use of a 2 second time-constant produced a broadening of the anomalies by an unknown amount and also introduced a lag of 1.5 seconds, which was removed from the data prior to contouring.

The cosmic and atmospheric radiation contributions to channels 1 to 4 were assumed to be equal to the count-rates recorded at 750 m above ground level. These were 170-185 counts per second (c.p.s.), 14-18 c.p.s., 10-13 c.p.s., and 4 c.p.s. respectively, and were removed prior to hand smoothing and contouring. However, as they still contribute to the statistical noise level of the corrected data, it would be useful if this background level could be reduced by using anti-coincidence shielding (Heath, 1964) to eliminate gamma-rays entering through the sides and tops of the detectors.

Day to day variations in 'geological background' level, caused by rain and other climatic effects, were determined by flying a standard baseline at the survey height at the beginning and end of each flight. If the baseline values differed by more than 1-2 c.p.s. from the mean survey values, the zero level for contour cuttings was adjusted accordingly. Normally, with the onset of the wet season this method would not be allowable, because of the large variations in rainfall over short distances. However, only the first two (northernmost) flights were flown after heavy rain. These flights have a normal thorium-channel level, but many uranium-channel anomalies are higher than would have been expected in the light of subsequent flights over the more southern granites.

It was not possible to correct for altitude variations, and although the relief of most of the Batchelor area is small, there has been some degradation of the survey results. This is particularly evident for channels 3 and 4 in the southeast corner of the survey area, where anomalies commonly confined to one or two lines tend to be elongated in the direction of flight.

The lower-energy portions of the gamma-ray spectra of Bi^{214} and Tl^{208} contribute to the radiation recorded in channel 2 and channels 2 and 3 respectively, with the result that anomalies of interest due to uranium or potassium may be difficult to recognize in the presence of thorium (in the case of uranium) and of thorium and uranium (in the case of potassium). It is not practicable to overlay the contours of all three channels, but a stacked profile presentation would allow comparison of the channels and assist in assessing qualitatively the extent to which potassium and uranium-channel anomalies are contaminated. Ideally, the unwanted contributions should be stripped from the potassium and uranium-channel records after the manner of Doig (1968), but the amount of data collected during the survey is too great for this to be practicable.

The stripping ratio of uranium for channel 3: channel 2 is 10:11, determined using a radium source. (i.e., to remove uranium counts from the potassium channel, we would subtract uranium-channel counts multiplied by 11/10). Uranium also has a negligibly small (3 percent) contribution to channel 4. No suitable source was available for determining the stripping ratios for thorium. However, the Crater Formation has a high thorium and low uranium content according to French (1970), and if its associated radiometric anomaly is assumed to be entirely due to thorium, very approximate (maximum) stripping ratios of 10:9:15 were obtained for channels 4:3:2. The ratio 10:15 for channels 4:2 approximates the 10:17 ratio used by Doig (1968) for different window settings, and both give reasonable results when applied in the Rum Jungle area. Channel 3 (uranium) was stripped to remove the thorium contribution assuming a stripping ratio of 1:1 over a small test area centred on Mount Fitch. The results are presented in Plate 5.

The equipment has not been calibrated to give estimates of equivalent uranium and thorium concentrations. However, in view of the deep weathering and leaching, the variability of the soil cover, and the possibility that the uranium and thorium are not in equilibrium with their gamma-ray emitting daughter elements, such estimates would be meaningless in the Rum Jungle area.

6. INTERPRETATION METHODS

The interpretation has been divided into two parts; a discussion of the survey results on a regional basis, and a detailed semi-quantitative study of the anomalies of possible economic importance.

In the regional discussion, anomaly amplitudes are expressed in terms of multiples of the mean 'geological background', which is approximately 12, 9, and 7 c.p.s. for channels 2, 3, 4, respectively.

The discussion is based on the radiometric contours for channels 2 to 4 (as shown in Plates 2 to 4). Channel 1 was not contoured as, in general, it closely parallels channel 4.

In the detailed interpretation, which was carried out using the original chart records, the uranium-channel anomalies were divided into 'point' and 'broad' sources. These have half-widths of 3 to 5 sec and greater than 5 sec, respectively.

In radiometric surveying the normal practice has been to regard an anomaly as statistically significant if its amplitude is greater than 3 times the standard deviation (S.D.) of the gamma-ray background noise. Young & Tipper (1966) point out that two types of gamma-ray background noise can be recognized:

(a) 'Statistical noise' - i.e. statistical variation of the recorded gamma-ray intensity from a homogeneous source.

(b) 'Geological noise' - i.e. variation of intensity from a heterogeneous source, which may be produced by the nature of the geological environment.

For both types combined the envelope containing the background noise is taken to have a height of 4 S.D. of that noise.

Young & Tipper (1966) used a classification of the anomalies based on whether or not the anomaly was significant with respect to the 'statistical noise' envelope, the 'associated geological noise' envelope, or the 'neighbouring geological noise' envelope. This subdivision was not necessary in the Rum Jungle area, as 'geological noise' is almost always present, and most large 'neighbouring geological noise' anomalies are attributable to thorium.

The Rum Jungle anomalies have been classified as: first order (greater than 8 S.D.), second order (8 S.D. to 4.5 S.D.), and third order (less than 4.5 S.D.). These classes comprise 5, 35 and 60 percent, respectively, of the anomalies presented.

As the analysis was carried out on the unstripped data, some uranium-channel anomalies may be significant (Fig. 1b), but because of interfering thorium anomalies have an amplitude less than 3 S.D. Although such an interpretation is subjective, these anomalies have been included where possible. However, in areas where the recorded profiles show broad parallel variations in the uranium and thorium channels (Fig. 1c), as over the Golden Dyke and Burrell Creek Formations east of Gould airfield, or where a uranium-channel anomaly coincides with a large-amplitude thorium-channel anomaly, it has not been possible to classify meaningfully the unstripped uranium-channel anomalies.

There is no criterion for accurately locating the boundary of an anomalous body. The boundaries of broad sources whose anomalies have steep flanks are assumed to be near the base of the steep slope. Those of poorly defined anomalies (Fig. 1b) are arbitrarily taken at the half-peak position, or more usually at about the upper boundary of the geological noise envelope. The sharpness or broadness of the anomaly peaks and boundaries is shown on the interpretation map (Plate 6).

A third order anomaly with poorly defined peaks and boundaries is of low significance, especially if it is present on only one survey line. Many broad low-amplitude anomalies can be used only as a rough guide for ground exploration, because the low signal/statistical noise ratio at low count rates prevents accurate location of the anomaly peaks. It is estimated that the anomaly peak positions shown in Plate 6 are correct to within ± 100 m.

7. RESULTS AND INTERPRETATION

The radiometric contours for channels 2, 3, and 4, which are the basis of the regional interpretation, are shown with the geology in Plates 2, 3, and 4. The results of the detailed interpretation are presented in Plate 6.

Contamination from uranium is readily apparent over the treatment plant, the downstream portions of the East Finniss and Finniss Rivers, and the several mined deposits, but is a poorly known factor elsewhere. Surface excavations have probably accentuated anomalies associated with the larger prospects. Uranium-channel anomalies, probably due to radioactive laterite fill, are present over some roads (e.g. 2 km east of Batchelor) and the Batchelor airstrip.

A spurious thorium-channel anomaly occurs over the treatment plant tailings pond. Hence, care is needed in evaluating survey data.

Regional interpretation

The survey area can be divided into a number of distinct radioactive zones, which agree well with the mapped geology. The most prominent feature is the broad high over the Rum Jungle Complex and fringing outcrops of Beestons Formation. The thorium-channel anomalies exceed 2 times the background over 70 to 80 percent of the Complex, with peaks of up to 9 times the background. In the test area (Plate 5), the contours of the uranium channel, after stripping the contribution from thorium, show similar count-rates over the Complex to those over the sediments and alluvium to the west. Except for the eastern portions of the northernmost flights (See Section 5), the same appears to be true for the remainder of the Complex, with only 10-25 percent of channel 3 count-rate being due to uranium. The low U/Th ratio may be a reflection of the composition of the Complex, but leaching of the uranium has certainly contributed to it. It is difficult to determine the potassium component in channel 2, but assuming that the ratio is 2:3 for stripping thorium radiation from the potassium channel, and that uranium radiation has a negligible effect on the potassium channel, values of roughly 10 to 35 c.p.s. are obtained.

Many of the thorium-channel highs, e.g. the broad high centred about 2.5 km east of Whites mine, the high of 60 c.p.s. on the northeast margin of the Complex near the Giants Reef Fault, the high of 45 c.p.s. 2 km southeast of Kanyaka Siding, and the high of 40 c.p.s. 3 km east-southeast of Mount Fitch, occur in the areas mapped as leucocratic granite by Rhodes (1965). This is in agreement with the analysis (of an inadequate number of samples) of Heier & Rhodes (1966). They obtained thorium values averaging 50 percent above the mean values for the Complex with a maximum value of 3 times the mean for a single sample from the area of the thorium-channel anomaly east of Whites mine. However, not all the leucocratic granites, e.g. the area 5 km southeast of Whites, are anomalously radioactive, and in some places other types of granite also have associated thorium-channel anomalies. For example, the broad anomaly of up to 50 c.p.s. in the Complex immediately north of the Embayment area occurs over large feldspar granite, and smaller anomalies are associated with granite gneisses. The anomalies are probably governed to a large extent by differential weathering of the granites and by the thickness of soil cover. This idea is supported by the decrease in radioactivity along the Giants Reef Fault and in the northern part of the survey area, where there are only sparsely scattered outcrops.

The anomalies associated with the Waterhouse Granite are of lower amplitude than those over the Rum Jungle Complex, but this is probably caused by soil cover. Small thorium-channel highs along the Finniss River north of the Waterhouse Granite may be caused by detrital material derived from the Granite.

As was expected, the thorium-rich basal conglomerates of the Crater Formation east of Batchelor gave rise to strong thorium-channel anomalies up to 7 times background. Smaller anomalies, which may also be associated with conglomerate beds, occur over the Crater Formation on the eastern margin of the Waterhouse Granite. The upper members of the Formation east of Batchelor and several other outcrops in the Rum Jungle appear to be non-radioactive.

The remaining anomalous areas are less well-defined. Potassium retained in the argillaceous material of the Golden Dyke and Burrell Creek Formations in the southeastern corner of the survey area has given rise to potassium-channel anomalies of up to an estimated 50 c.p.s. above background, thus outlining areas of outcrop. In contrast, the arenaceous sediments of the Acacia Gap Tongue have no potassium-channel anomalies. There are no potassium-channel anomalies associated with the soil-covered areas of the argillaceous sediments. Thorium-channel levels over the Golden Dyke and Burrell Creek Formations reach only about 2 times background, and the uranium-channel anomalies are of small amplitude. Hence it is inferred that most of the radiometric anomalies detected in the early DC-3 airborne surveys in the southeastern part of the present survey (Wood & McCarthy, 1952) are probably due to potassium.

Negligible thorium and potassium-channel activity was present in the remainder of the survey area, which comprises the Coomalie and Celia Dolomites and the adjacent alluvium covered areas of Golden Dyke Formation, the Acacia Gap Tongue, and portion of the Giants Reef Fault northeast of Dysons. This is probably a reflection of the low initial content of thorium and potassium, deep weathering, and soil cover. However, this remaining portion of the survey area contains most of the uranium anomalies, which will be discussed in the detailed interpretation. The Celia Dolomite and the Fault zone are relatively free of anomalies in all channels.

Detailed interpretation

Although the thorium-rich conglomerate beds of the Crater Formation are currently being investigated in the hope of finding uranium below the zone of leaching, thorium-channel anomalies will be ignored in the following discussion. This is probably justified as none of the mines and known prospects, with the exception of Rum Jungle Creek South, have associated thorium-channel anomalies.

The uranium-channel anomalies, presented in Plate 6, agree reasonably well with the total-count airborne anomalies located by Livingstone (1959), except that his anomalies over the Crater Formation (not presented) and the margins of the granites were attributed to thorium, and eliminated. A number of the weaker broad-source anomalies located by the present survey were not detected by Livingstone.

The airborne uranium-channel broad-source anomalies are usually more extensive than the corresponding ground anomalies. This probably occurs because the boundaries of the latter are taken at 1.5-2 times background. In view of the detailed investigations already made of the more obvious airborne anomalies, more attention should now be given to the less well defined low-amplitude uranium-channel anomalies. They should be used to define more accurately the areas of interest, but little importance should be attached to the peak positions, which are difficult to locate accurately because of the low signal-to-statistical noise ratios.

A ground radiometric survey by Duckworth (1966b) located a number of anomalies in the region west of the Stuart Highway from Coomalie Creek to north of Woodcutters L3 area. These anomalies are well delineated by the airborne uranium-channel peaks. The remainder of the airborne anomalies in this region are not well defined, and do not correspond clearly to the ground results. The region has been studied in detail (Douglas, 1963; Shatwell, 1966; Prichard & Ivanac, 1965). There is little contribution to the total-count anomalies from thorium. It is doubtful if the spectrometer survey has indicated any additional uranium anomalies that warrant further investigation except for the pair of third-order point sources on the contact of the Crater Formation with the Coomalie Dolomite 6 km west-northwest of Coomalie airfield and two others on the Crater Formation, 3 km northwest of Mount Deane.

The anomalous area over the Coomalie airfield and the anomalies farther to the south and southwest occur mainly over alluvium-covered Golden Dyke Formation. As these lie in an area that has not been studied in detail previously, ground investigation, particularly of the second-order peaks, is probably warranted, although the airfield anomaly may be caused by lateritic gravel.

Uranium-channel anomalies, probably also associated with the Golden Dyke Formation, were observed near the eastern ends of several lines to the north of Coomalie airfield. An extension of the airborne spectrometer survey would be required to locate these accurately.

Few significant uranium-channel anomalies occur over the Golden Dyke and Burrell Creek Formations in the area between Coomalie Creek and the Stuart Highway. Most of Wood & McCarthy's (1952) airborne anomalies located on the ground by Duckworth (1966a) can probably be attributed to potassium. An exception is the anomaly 3 km north-northeast of area 65. The second-order point source 1 km northwest of the Stuart Highway/Glen Luckie Creek junction is outside Duckworth's area, and should be investigated. The third-order point sources near the Golden Dyke Formation/Coomalie Dolomite contact 6 km east of Batchelor should also be examined. No other work is recommended for this area.

The anomalies south of Gould airfield area were detected by Livingstone (1959). They occur in a ferruginized area and were not considered indicative of uranium mineralization by Prichard & Ivanac (1965).

The group of anomalies in the Rum Jungle Creek South/Batchelor Laterites area correspond closely to the ground anomalies over the known deposits and prospects. Flynns and the Geolsec prospect are of limited areal extent and do not give prominent airborne anomalies. The only anomalies which do not appear to have been adequately investigated are the two small anomalies 1 km due west of Batchelor; these were located by Douglas (1962a).

A large group of uranium-channel anomalies (1-18 in Plate 6) were located south of the Mount Burton open cut and west of the Giants Reef Fault. With the exception of Area 55, none of them are large, and a number are poorly defined. As this is an area with some interference from thorium, it is probably the best area for a test follow-up by ground spectrometer. Of the airborne anomalies delineated, Nos. 3, 5, 6, 7, 11, 14, 15, 17, and 18 coincide approximately with ground anomalies located by Ashley (1966) and also by Douglas (1962b, 1962c), and No. 8 with a number of localized anomalies of Langron (1969). However, in some cases they differ in detail from the ground anomalies. Nos. 6 and 17, for example, are much less extensive than the corresponding anomalies of Ashley (1966), presumably because of the elimination of neighbouring thorium-channel anomalies. Of Ashley's anomalies, only B and M have no airborne uranium-channel anomaly. Anomaly M is situated on an outcrop of the Crater Formation 2 km south of anomaly 15 and is probably represented by a thorium-channel peak. Anomaly B is located in an alluvium-covered area 0.5 km west of Dolerite Ridge. Anomalies 4, 9, 10, 12, 13, and 16, which occur on only one line, have not been recognized in previous ground work and would probably be difficult to locate.

The anomalies associated with the mine workings in the embayment area and along the Finniss River can be ignored, as they are clearly due to contamination. The anomalies north of Mount Fitch appear to coincide with low-amplitude ground anomalies. The anomalies northwest of Mount Fitch, in the northwest corner of the survey area, have not been investigated on the ground. Of these, the southernmost broad source is most worthy of further investigation.

Although the previous low-level total-count survey by Livingstone (1959) excluded most of the Rum Jungle Complex, it is of interest to compare his results on that part of the Complex which was covered with the results of the spectrometer survey. The anomaly 3 km north-northwest of Batchelor township has been confirmed as a uranium anomaly. Two anomalies about 2 km southeast of Dysons and the anomaly near the margin of the Complex west-northwest of Kanyaka siding are now shown to be caused primarily by thorium.

A few broad uranium sources were indicated over the Complex. The point source anomalies shown are mainly third-order ones. Many were detected on only one line and may be difficult to locate. The uranium anomalies in the Complex would require ground investigation to determine whether they are economically significant. Such investigation would derive a distinct advantage from the spectrometer survey, because attention could be confined to anomalies known to be caused mainly by uranium.

Several anomalies of up to second order have been located over the margin of the Waterhouse Granite, and the larger ones warrant further study.

8. CONCLUSIONS AND RECOMMENDATIONS

Good agreement was found to exist between the gamma spectrometer results and the mapped geology. The method could assist in mapping the granite bodies and differentiating between argillaceous (potassic) and more arenaceous sediments. With the present spectrometer system and using a contour presentation, the thorium-channel activity is the most useful geological indicator in the Rum Jungle area. However, digital acquisition would allow subsequent stripping of unwanted thorium and uranium contributions, and hence the potassium content and the K/Th ratio would become more useful. The uranium content and the U/Th ratio are probably less closely related to the geology. The uranium-channel count rate appears to be generally low outside the restricted anomalous areas, which probably reflects the degree of leaching rather than the original composition.

Through the use of the gamma-spectrometer, areas of granite and of thoric and potassic sediments can be rejected as potential uranium-bearing areas. Anomalies in these areas would have been included in the results of earlier total-count scintillation surveys. Most uranium-channel anomalies in the Rum Jungle area occur over the prospective

Coomalie Dolomite and its contact with the Golden Dyke Formation. The anomalies in the area west of the Stuart Highway up to 5 km north of Coomalie Creek and also in the area from Mount Burton south to the Giants Reef Fault were in general not detected by the previous low-level total-count airborne surveys. They are small, and were probably considered insignificant when compared with the much larger (thorium) anomalies in the survey area. Although a large number of uranium anomalies were located in the present survey, few recommendations for further work have been made as most of the prospective areas have already been subjected to intensive ground investigation.

In the present study, the airborne and ground anomalies were compared by inspection. It is suggested that all ground anomalies greater than 0.02 mr/h be plotted at the scale of the airborne results to permit a more definite comparison. The airborne thorium-channel anomalies for these areas should also be plotted.

The presentation of contour maps of each channel of unstripped data is unsatisfactory, as it is not easy to assess the relative contributions of the three radio-elements. Data reduction is also very laborious and time-consuming. Hence, for the subsequent surveys it is recommended that the data be displayed on extended sheets incorporating stacked profiles of all three channels. Stacked profiles permit the comparison of anomalies with those on adjacent lines and their grouping into zones of anomalies of similar character.

If maximum use is to be made of the survey data, it is essential that installation of a digital acquisition system be given high priority. Small-amplitude broad anomalies can be resolved with the present system, but the count rates and hence signal/statistical noise ratio are low. The count rates could be improved by using more detector crystals. However, if the number of crystals was doubled to four, it could become difficult to match and stabilize the detectors. Only a 40 percent increase in signal/statistical noise ratio would result.

As a check on the results of the survey, a number of airborne anomalies will be selected and investigated on the ground using a portable gamma-ray spectrometer.

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APPENDIX

OPERATIONAL DETAILS

Staff

Geophysicist (Party Leader)	: R.D. Beattie
Drafting Officer	: L. O'Toole
Technical Officer	: H. Alexander
Technical Assistant	: C. Carling
Pilot	: First Officer G. Brown (TAA)

Equipment

Aircraft	: Aero Commander VH-BMR
Gamma-ray spectrometer	: Hamner system with two 6" x 4" sodium iodide crystals, each with separate EHT supply and spectrum stabilization. The 4 channels were fed on to two 3-channel DeVar recorders
Radio-altimeter	: Bonzer, with record on both DeVar recorders.
Camera	: 35-mm Vinten with wide-angle lens
Timer	: BMR solid state

Survey Specifications

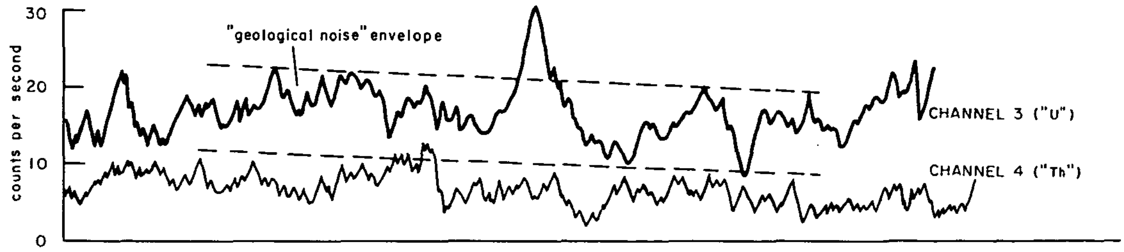
Altitude	: Nominally 85 m
Line spacing	: 160 m
Line orientation	: East-west
Navigation control	: Aerial photographs
Radio-altimeter	: 600 m fsd (logarithmic)

Spectrometer:

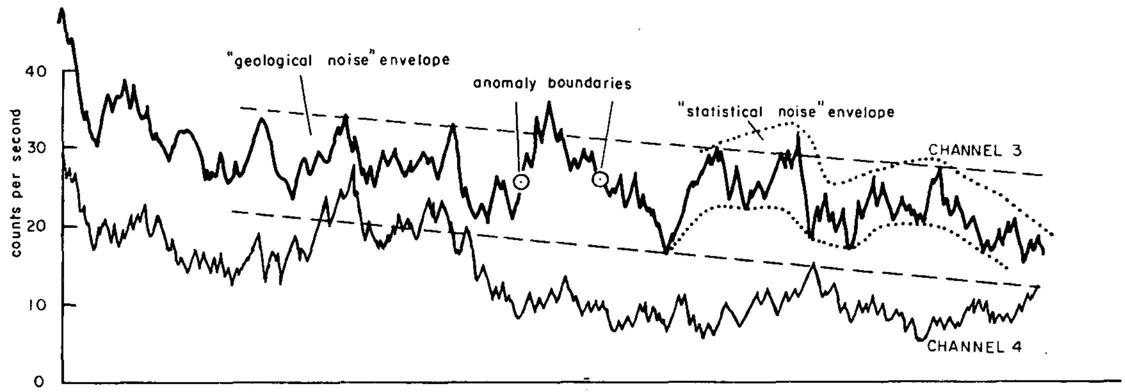
Channel	Energy Range	Recorder Sensitivities
1	1.0-3.0 MeV	1000 c.p.s. fsd.
2	1.3-1.6 MeV	200 c.p.s. fsd.
3	1.6-1.9 MeV	100 c.p.s. fsd. (200 c.p.s. fsd on lines 18-33)
4	2.4-2.8 MeV	100 c.p.s. fsd.

Time-constant : 2 seconds

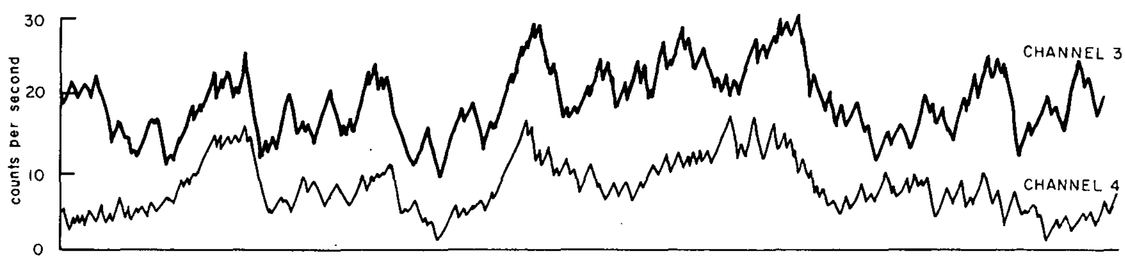
Zero suppression	: adjusted on each flight at 750 m a.g.l. to give an arbitrary predetermined background level in each channel.
Source Tests	: Carried out as an equipment check at beginning and end of each flight at 750 m a.g.l. using a Ra source and 10 sec time constant.
Base line	: Flown at beginning and end of each flight at 150 m a.g.l. and 10 sec time constant to eliminate climatically induced variations and as a further equipment check.



a. "U" anomaly significant with respect to geological and statistical noise.



b. "U" anomaly marginally significant with respect to the geological noise, but significant if the "Th" contribution is removed.

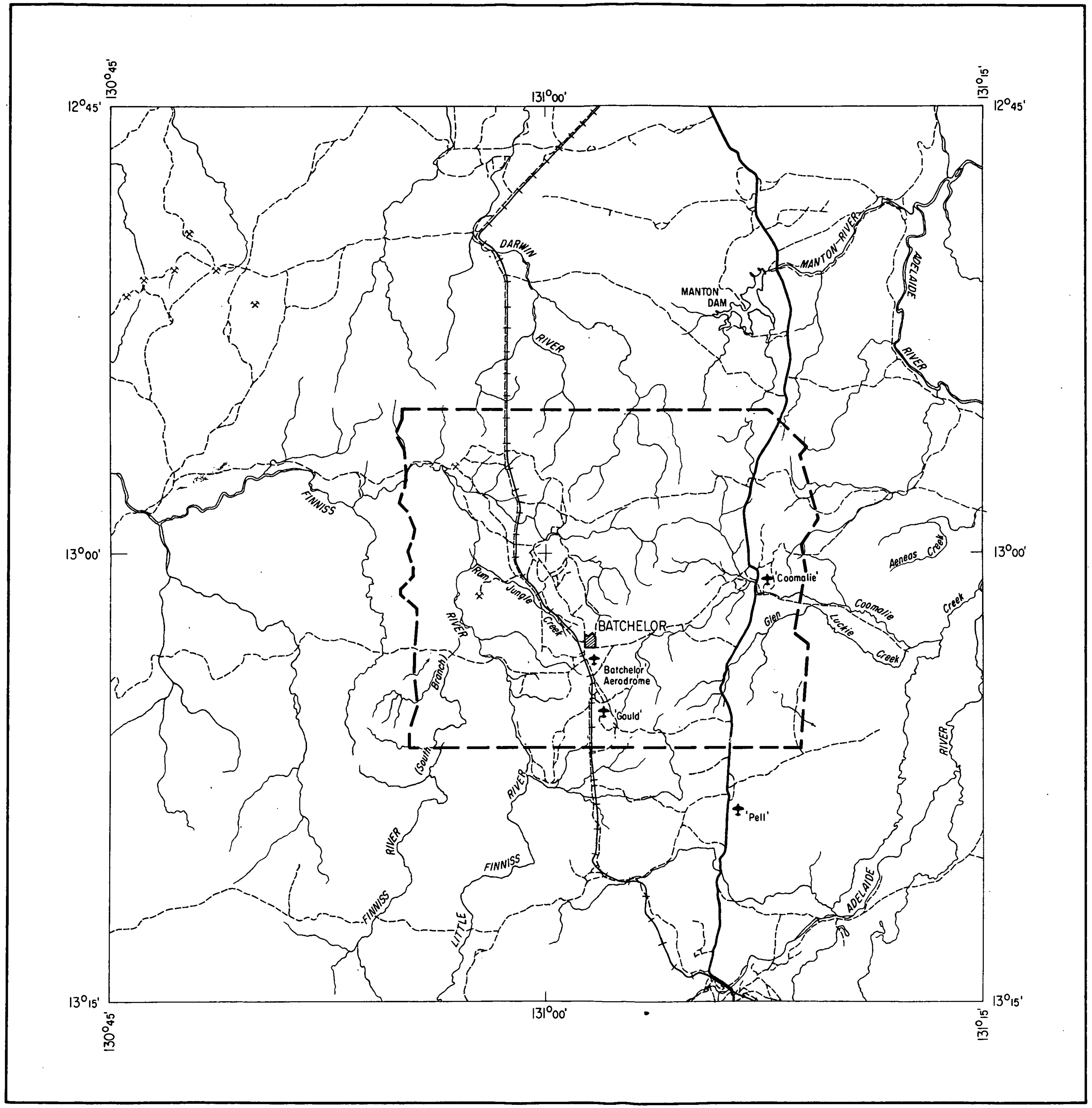


c. Similarly varying "U" and "Th". Significance of individual "U" anomalies difficult to assess without "stripping"

NOTE 7 COUNTS PER SECOND OF "COSMIC" AND "ATMOSPHERIC" BACKGROUND RADIATION HAS NOT BEEN REMOVED FROM CHANNEL 3. TIME CONSTANT IS 2 SECONDS.

Fig.1 TYPES OF GAMMA-RAY SPECTROMETER ANOMALIES

TO ACCOMPANY RECORD No 1971/85 D52/B1-80A



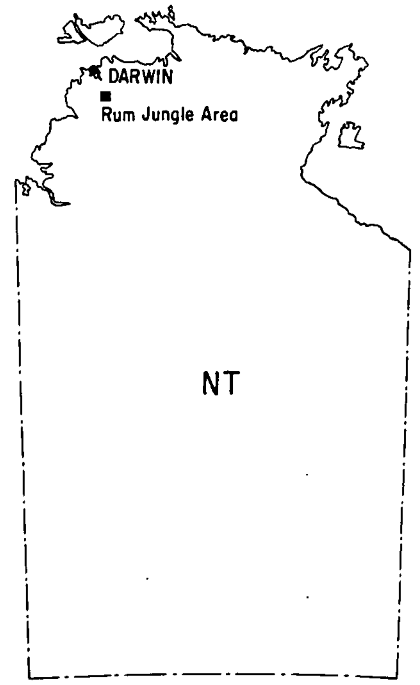
DETAILED AIRBORNE GAMMA-RAY SPECTROMETER SURVEY RUM JUNGLE NT 1969

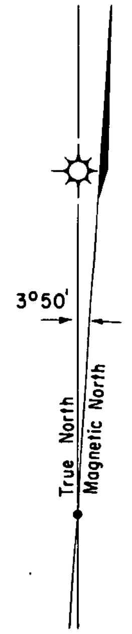
LOCALITY MAP

MILES 10 — 0 — 10 — 20 MILES

KILOMETRES 10 — 0 — 10 — 20 — 30 KILOMETRES

LOCATION DIAGRAM





TOPOGRAPHICAL LEGEND

River; river or creek

Dam

Highway

Road or track

Railway

Landing ground

Township

Mine

Boundary of survey area

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics. D52/B1-71

TO ACCOMPANY RECORD No. 1971/85

GEOLOGICAL LEGEND

QUATERNARY

Alluvium

UPPER PROTEROZOIC

TOLMER GROUP
BULDIVA SANDSTONE
DEPOT CREEK SANDSTONE MEMBER
Quartz sandstone, with lenses of haematite-rich breccia and lenses of quartz pebble conglomerate

LOWER PROTEROZOIC

RUM JUNGLE COMPLEX
Schist, gneiss, diorite granite, pegmatite etc.

WATERHOUSE COMPLEX
Pgt — Porphyitic granite, and adamellite

Basic intrusives

FINNISS RIVER GROUP
BURRELL CREEK FORMATION
Siltstone, greywacke siltstone, greywacke, quartz greywacke

GOODPARLA GROUP
GOLDEN DYKE FORMATION
Quartz siltstone and carbonaceous siltstone, in places pyritic

MASSON FORMATION
ACACIA GAP TONGUE
Quartz greywacke, quartz sandstone, pyritic and silicified in places; pyritic, carbonaceous siltstone, siltstone

BATCHELOR GROUP
COOMALIE DOLOMITE
Silicified and metamorphosed dolomite

CRATER FORMATION
Quartz greywacke, greywacke, arkose, fine and pebble conglomerate, siltstone

CELIA DOLOMITE
Algal dolomite, in places silicified and metamorphosed, silicified dolomitic breccia, tremolite schist

BEESTONS FORMATION
Arkose, greywacke, siltstone, conglomerate, arkosic conglomerate, white friable quartz sandstone

- Geological boundary
- Dip and strike of strata
- Trend lines
- Established synclinal trough - position accurate
- Established synclinal trough - concealed; position approximate
- Plunge of syncline
- Plunge of anticline
- Established fault - position accurate
- Established fault - position approximate
- Established fault - concealed
- Probable fault
- Quartz vein
- Quartz-tourmaline vein
- Fossil locality

GEOLOGY AFTER RUM JUNGLE DISTRICT
SPECIAL SHEET, 1:63,360, 1960 EDITION

TOPOGRAPHICAL LEGEND

- Highway
- Road or track
- River or creek
- Railway with station and siding
- Mine or prospect
- Open cut
- Dump
- Transmission line
- Dam

GEOPHYSICAL LEGEND

- 50 — Radiometric contours

DETAILED AIRBORNE GAMMA-RAY SPECTROMETER SURVEY, RUM JUNGLE, NT 1969

RADIOMETRIC CONTOURS

CHANNEL 2 - "POTASSIUM"

AND

GEOLOGY

1 0 1 2 3 MILES
1 0 1 2 3 4 KILOMETRES

CONTOUR INTERVAL 10 c.p.s.
CHANNEL WIDTH 1.3 - 1.6 MeV

GEOLOGICAL LEGEND

QUATERNARY

Alluvium

UPPER PROTEROZOIC

TOLMER GROUP
BULDIVA SANDSTONE
DEPOT CREEK SANDSTONE MEMBER

Quartz sandstone, with lenses of haematite-rich breccia and lenses of quartz pebble conglomerate

LOWER PROTEROZOIC

RUM JUNGLE COMPLEX

Schist, gneiss, diorite granite, pegmatite etc.

WATERHOUSE COMPLEX

Pgt — Porphyitic granite, and adamellite

Basic intrusives

FINNISS RIVER GROUP
BURRELL CREEK FORMATION

Siltstone, greywacke siltstone, greywacke, quartz greywacke

GOODPARLA GROUP
GOLDEN DYKE FORMATION

Quartz siltstone and carbonaceous siltstone, in places pyritic

MASSON FORMATION
ACACIA GAP TONGUE

Quartz greywacke, quartz sandstone, pyritic and silicified in places; pyritic, carbonaceous siltstone, siltstone

BATCHELOR GROUP
COOMALIE DOLOMITE

Silicified and metamorphosed dolomite

CRATER FORMATION

Quartz greywacke, greywacke, arkose, fine and pebble conglomerate, siltstone

CELIA DOLOMITE

Algal dolomite, in places silicified and metamorphosed, silicified dolomitic breccia, tremolite schist

BEESTONS FORMATION

Arkose, greywacke, siltstone, conglomerate, arkosic conglomerate, white friable quartz sandstone

Geological boundary
Dip and strike of strata
Trend lines
Established synclinal trough - position accurate
Established synclinal trough - concealed; position approximate
Plunge of syncline
Plunge of anticline
Established fault - position accurate
Established fault - position approximate
Established fault - concealed
Probable fault
Quartz vein
Quartz - tourmaline vein
Fossil locality

GEOLOGY AFTER RUM JUNGLE DISTRICT
SPECIAL SHEET, 1:63,360, 1960 EDITION

TOPOGRAPHICAL LEGEND

Highway
Road or track
River or creek
Railway with station and siding
Mine or prospect
Open cut
Dump
Transmission line
Dam

GEOPHYSICAL LEGEND

Radiometric contours

NOTE

The 5c.p.s contour level has been omitted to improve the clarity of presentation.

DETAILED AIRBORNE GAMMA-RAY SPECTROMETER SURVEY, RUM JUNGLE, NT 1969

RADIOMETRIC CONTOURS
CHANNEL 3 - "URANIUM"

AND

GEOLOGY

1 0 1 2 3 MILES
1 0 1 2 3 4 KILOMETRES

CONTOUR INTERVAL 5 c.p.s.
CHANNEL WIDTH 1.6 - 1.9 MeV

TO ACCOMPANY RECORD No. 1971/85 D52/B1-77

GEOLOGICAL LEGEND

QUATERNARY

Alluvium

UPPER PROTEROZOIC

TOLMER GROUP
BULDIVA SANDSTONE
DEPOT CREEK SANDSTONE MEMBER

Quartz sandstone, with lenses of haematite-rich breccia and lenses of quartz pebble conglomerate

LOWER PROTEROZOIC

RUM JUNGLE COMPLEX

Schist, gneiss, diorite granite, pegmatite etc.

WATERHOUSE COMPLEX

Pgt — Porphyitic granite, and adamellite

Basic intrusives

FINNISS RIVER GROUP
BURRELL CREEK FORMATION

Siltstone, greywacke siltstone, greywacke, quartz greywacke

GOODPARLA GROUP
GOLDEN DYKE FORMATION

Quartz siltstone and carbonaceous siltstone, in places pyritic

MASSON FORMATION
ACACIA GAP TONGUE

Quartz greywacke, quartz sandstone, pyritic and silicified in places; pyritic, carbonaceous siltstone, siltstone

BATCHELOR GROUP
COOMALIE DOLOMITE

Silicified and metamorphosed dolomite

CRATER FORMATION

Quartz greywacke, greywacke, arkose, fine and pebble conglomerate, siltstone

CELIA DOLOMITE

Algal dolomite, in places silicified and metamorphosed, silicified dolomitic breccia, tremolite schist

BEESTONS FORMATION

Arkose, greywacke, siltstone, conglomerate, arkosic conglomerate, white friable quartz sandstone

Geological boundary
Dip and strike of strata
Trend lines
Established synclinal trough - position accurate
Established synclinal trough - concealed; position approximate
Plunge of syncline
Plunge of anticline
Established fault - position accurate
Established fault - position approximate
Established fault - concealed
Probable fault
Quartz vein
Quartz-tourmaline vein
Fossil locality

GEOLOGY AFTER RUM JUNGLE DISTRICT
SPECIAL SHEET, 1:63,360, 1960 EDITION

TOPOGRAPHICAL LEGEND

Highway
Road or track
River or creek
Railway with station and siding
Mine or prospect
Open cut
Dump
Transmission line
Dam

GEOPHYSICAL LEGEND

25 — Radiometric contours

NOTE

The 5c.p.s contour level has been omitted to improve the clarity of presentation.

DETAILED AIRBORNE GAMMA-RAY SPECTROMETER SURVEY, RUM JUNGLE, NT 1969

RADIOMETRIC CONTOURS

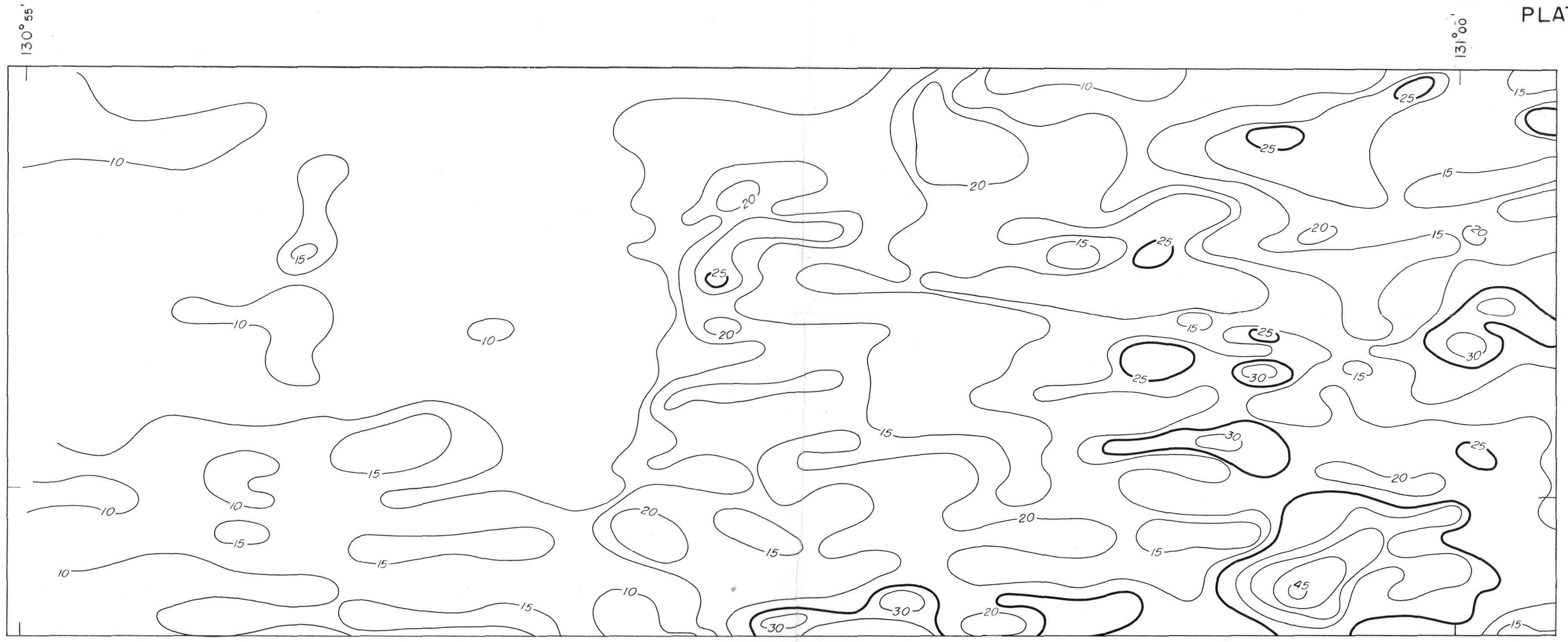
CHANNEL 4 - "THORIUM"

AND

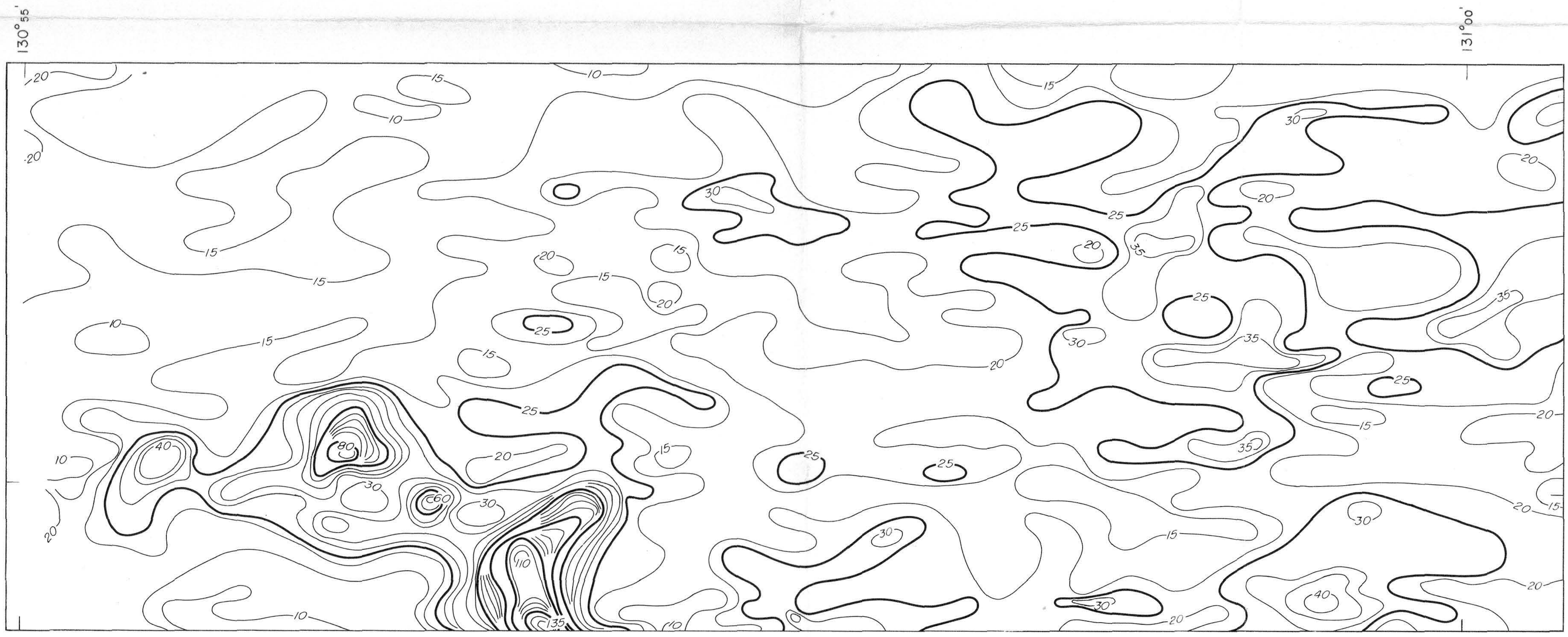
GEOLOGY

1 0 1 2 3 MILES
1 0 1 2 3 4 KILOMETRES

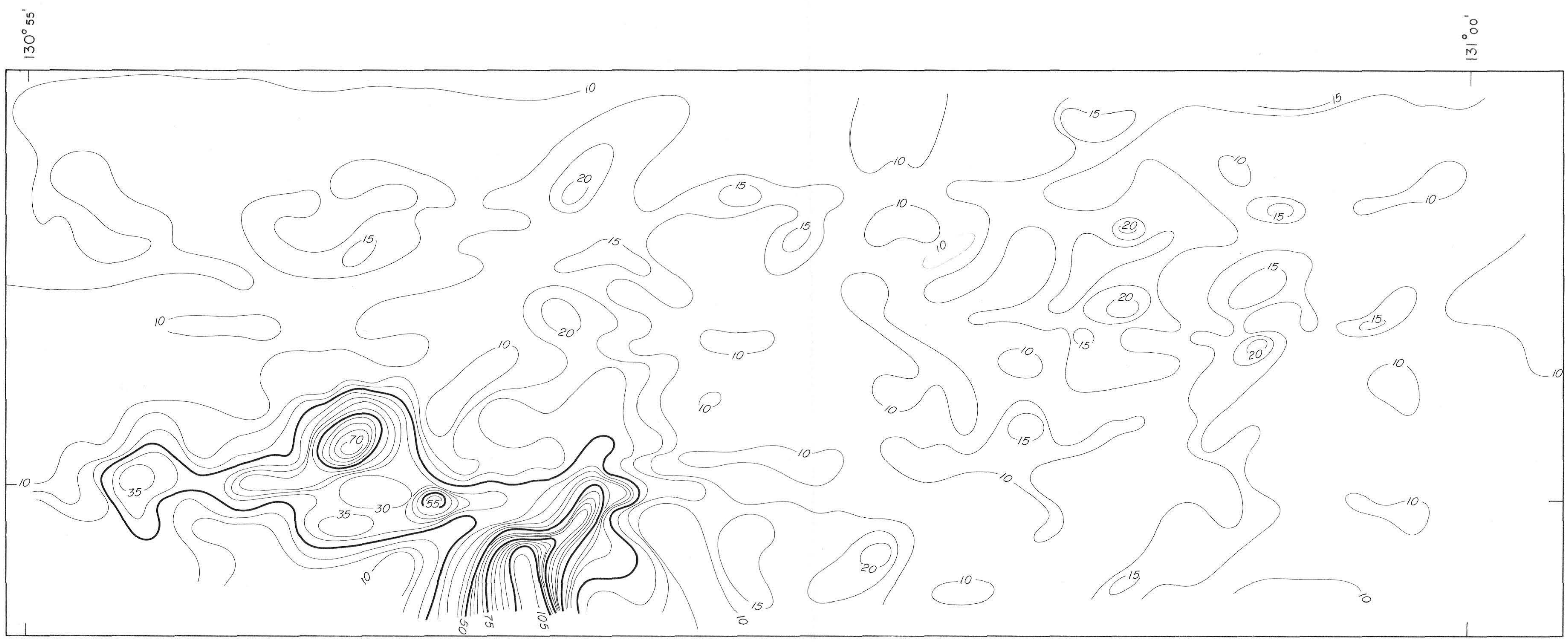
CONTOUR INTERVAL 5 c.p.s.
CHANNEL WIDTH 2.4 - 2.8 MeV



a. Channel 4 "Thorium" contours



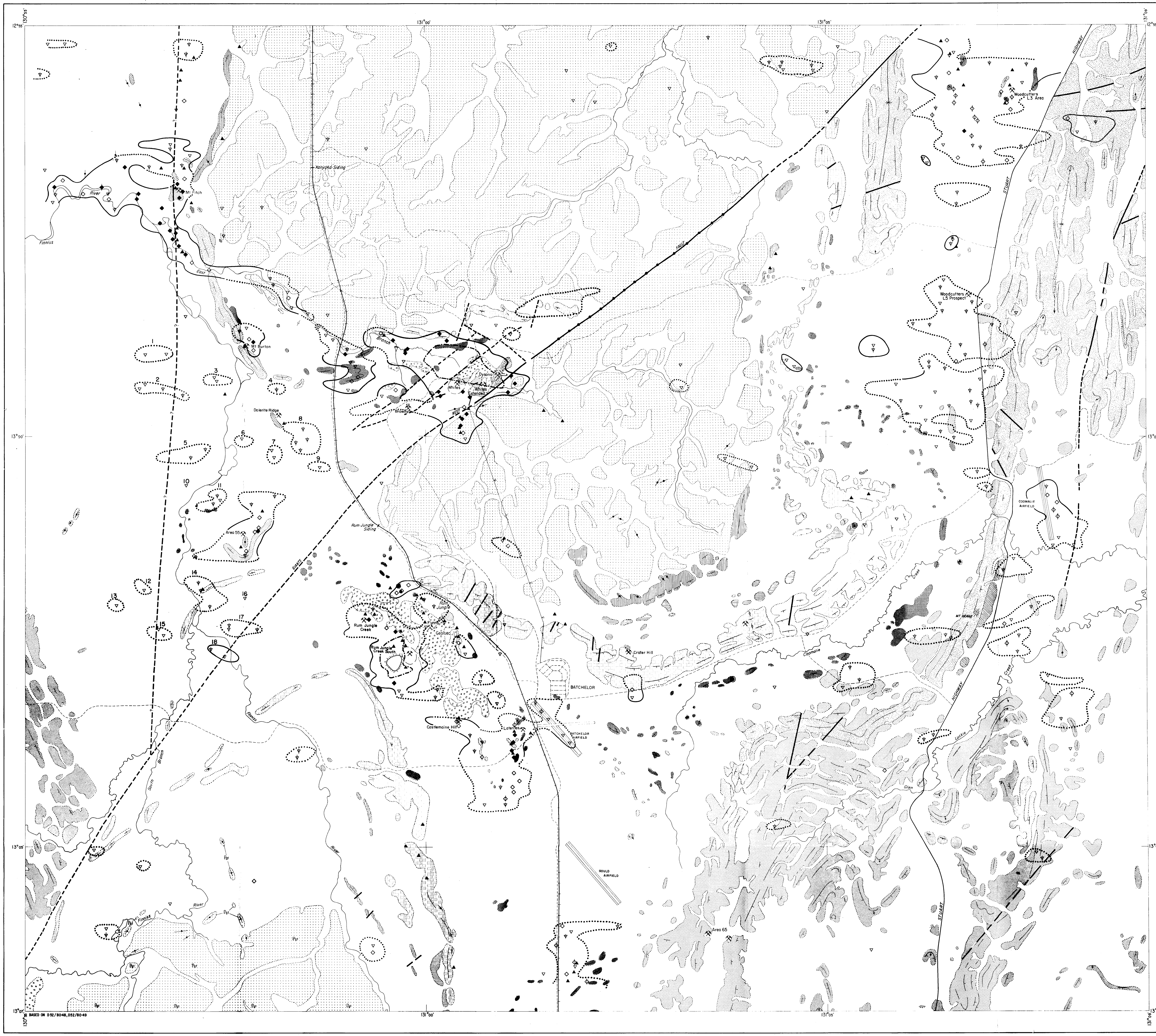
b. Channel 3 "Uranium" contours



c. Channel 3 contours after stripping of Thorium contribution

EXAMPLE OF THORIUM STRIPPED DATA

TO ACCOMPANY RECORD 1971/85 D52/B1-81



GEOLOGICAL LEGEND

QUATERNARY

Alluvium

UPPER PROTEROZOIC

TOLMER GROUP
BULDIVA SANDSTONE
DEPOT CREEK SANDSTONE MEMBER

Quartz sandstone, with lenses of haematite-rich breccia and lenses of quartz pebble conglomerate

LOWER PROTEROZOIC

RUM JUNGLE COMPLEX

Schist, gneiss, diorite, granite, pegmatite etc.

WATERHOUSE COMPLEX

Pgt — Porphyitic granite, and adamellite

Basic intrusives

FINNISS RIVER GROUP
BURRELL CREEK FORMATION

Siltstone, greywacke siltstone, greywacke, quartz greywacke

GOODPARLA GROUP
GOLDEN DYKE FORMATION

Quartz siltstone and carbonaceous siltstone, in places pyritic

MASSON FORMATION
ACACIA GAP TONGUE

Quartz greywacke, quartz sandstone, pyritic and silicified in places; pyritic, carbonaceous siltstone, siltstone

BATCHELOR GROUP
COOMALIE DOLOMITE

Silicified and metamorphosed dolomite

CRATER FORMATION

Quartz greywácke, greywacke, arkose, fine and pebble conglomerate, siltstone

CELIA DOLOMITE

Algal dolomite, in places silicified and metamorphosed, silicified dolomitic breccia, tremolite schist

BEESTONS FORMATION

Arkose, greywacke, siltstone, conglomerate, arkosic conglomerate, white friable quartz sandstone

Geological boundary
Dip and strike of strata
Trend lines
Established synclinal trough - position accurate
Established synclinal trough - concealed; position approximate
Plunge of syncline
Plunge of anticline
Established fault - position accurate
Established fault - position approximate
Established fault - concealed
Probable fault
Quartz vein
Quartz-tourmaline vein
Fossil locality

GEOLOGY AFTER RUM JUNGLE DISTRICT
SPECIAL SHEET, 1:63,360, 1960 EDITION

TOPOGRAPHICAL LEGEND

Highway
Road or track
River or creek
Railway with station and siding
Mine or prospect
Open cut
Dump
Transmission line
Dam

GEOPHYSICAL LEGEND

POINT SOURCE "URANIUM" ANOMALIES
- 1st Order (> 8 s.d. above mean geological background noise)
- 2nd Order (4·5 – 8 s.d. " " " " ")
- 3rd Order (< 4·5 s.d. " " " " ")
- Anomaly peak not well defined

BROAD SOURCE "URANIUM" ANOMALIES
- Anomaly boundary well defined
- Anomaly boundary not well defined

Channel 3 trace offscale (> 100 counts/second)

Radiometric anomalies after Livingstone 1959

DETAILED AIRBORNE GAMMA-RAY SPECTROMETER SURVEY, RUM JUNGLE NT 1969

GEOPHYSICAL INTERPRETATION

CHANNEL 3 - "URANIUM"

AND

GEOLOGY

1 0 1 2 3 MILES

1 0 1 2 3 4 KILOMETRES

TO ACCOMPANY RECORD No 1971/85 D52/B1-82