BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

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REGIONAL RADIOELEMENT CHARACTERISTICS OF THE KOOLPIN FORMATION, PINE CREEK GEOSYNCLINE, NORTHERN TERRITORY

by

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CONTENTS

FIGURES

TABLES

SUMMARY

During November 1979, detailed surface gamma-ray spectrometer measurements were made at seven key sites in the Pine Creek Geosyncline, Northern Territory, to investigate the distribution of the radioelements potassium, uranium, and thorium in the Koolpin Formation.

The results indicate that thick units of massive ironstone and banded iron formation (containing ironstone, chert, and quartzite) within the Koolpin Formation are commonly enriched in uranium, and have uranium/thorium ratios of 0.4 or more. By comparison, neighbouring rocks have uranium/thorium ratios of less than 0.2. The iron-rich Koolpin Formation rocks are also characterised by a low potassium concentration.

The results suggest that high-sensitivity airborne gamma-ray spectrometry can be used to map Koolpin Formation rocks on a regional scale, and to assist in the delineation of areas which are prospective for buried uranium mineralisation.

1. INTRODUCTION

During November 1979, detailed gamma-ray spectrometer measurements were made over rocks of the Koolpin Formation and adjacent formations throughout the Pine Creek Geosyncline, Northern Territory. Measurements were made at seven widely distributed sites (Fig. 1) which provide exposures typical of the Koolpin Formation in each of the seven areas.

The work was undertaken to augment a regional geophysical study of the Pine Creek Geosyncline by Tucker & others (1980). The aim of the work was ito investigated the regional variation in the radioelements potassium, uranium, and thorium in a rock unit known to occur extensively within the Pine Creek Geosyncline, and known also to be associated with iron, uranium-gold, and other base metal mineralisation in at least some parts of the geosyncline.

The Koolpin Formation is the oldest unit of the Lower Proterozoic South Alligator Group and is made up in general of a distinctive suite of iron-rich chemical (carbonate, massive ironstone, and banded iron formation) and pelitic rocks. The stratigraphy, lithology, and distribution of these and surrounding rocks are summarised by Needham, Crick & Stuart-Smith (1980).

2. MEASUREMENT TECHNIQUE

Field radiometric assays were made with an Exploranium DISA-400A four-channel differential gamma-ray spectrometer. The energy windows used, and the stripping ratios, sensitivity, and background constants used in the processing of the raw 4-channel data are shown in Table 1. The stripping ratios and sensitivity constants are based on calibration tests and comparisons between geochemical analyses and spectrometer data from various parts of Australia. However, the determinations of zero or negative potassium radiometric assays at some sites where laboratory geochemical measurements indicate a very low potassium concentration, highlight errors in the stripping ratios used. Background counts used in the processing of the spectrometer data were those determined over deep water in Manton Dam (Fig. 1) 80 km south of Darwin.

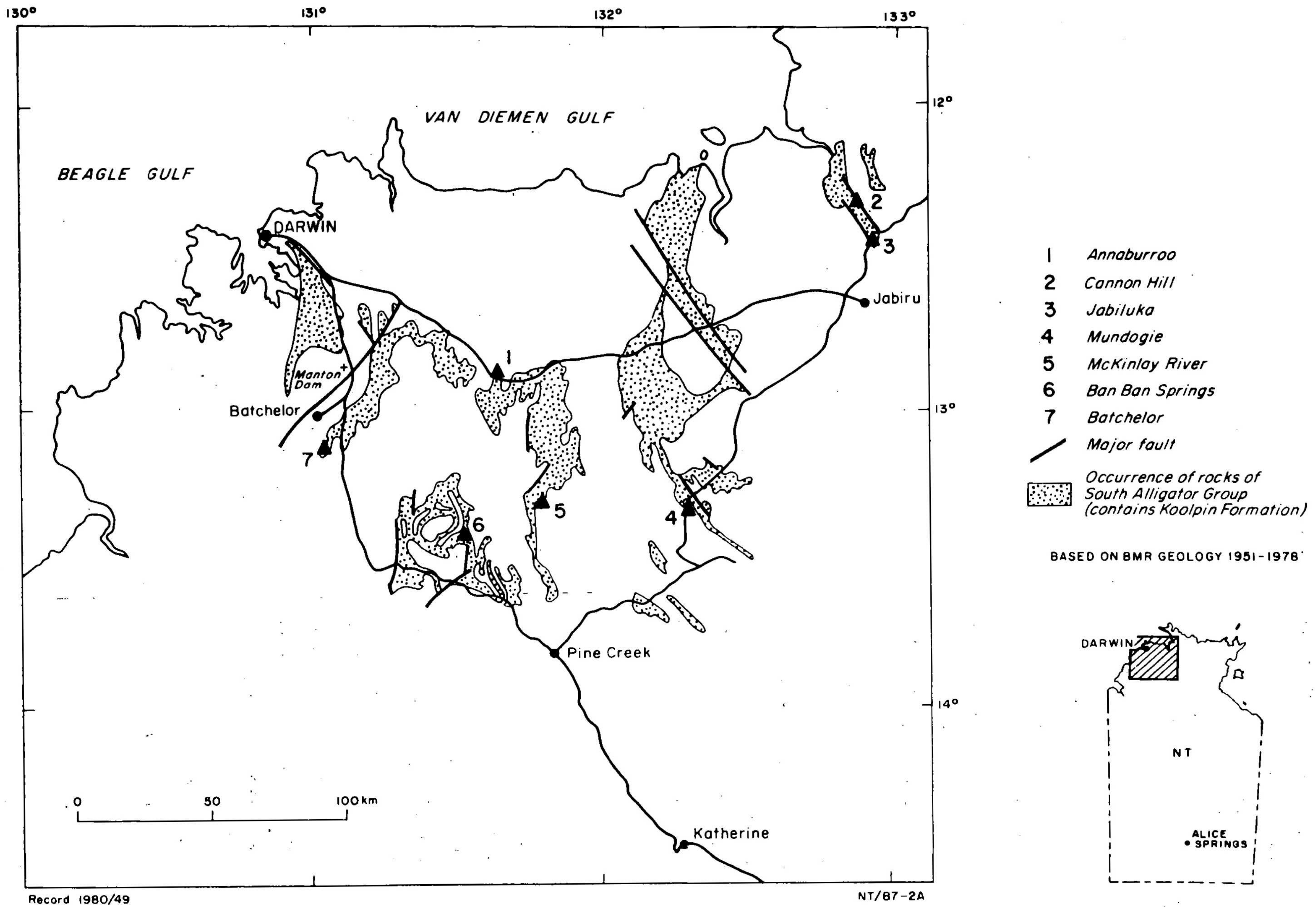


Fig I Locality map regional spectrometer study Pine Creek Geosyncline NT

TABLE 1 - DETAILS OF SPECTROMETER AND CONSTANTS USED FOR RADIOELEMENT DETERMINATIONS

Spectrometer: Exploranium DISA-400A portable 4-channel differential gamma-ray spectrometer (No. AE-071)

Detector: Exploranium NAL-21 7.6 cm diam. x 7.6 cm thick NaI(Tl) crystal (volume 21 cu. inches, or 350 cm^3) (No. Qe-080)

Stripping Ratios:	α (thorium x uranium)	β (thorium x potassium)	γ (uranium x potassium)	ε (uranium x thorium)
	0.65	0.80	1.10	0.06

Channels:	1	2	3	4
Name	Total Count	Potassium	Uranium	Thorium
Window setting (MeV)	0.4	1.36-1.56	1.66-1.86	2.42-2.82
Isotope sought (& energy)	-	K-40 (1.46)	Bi-214 (1.76)	Tl-208 (2.62)
Background (counts/min)	570	19	11	7.5
Sensitivity constant	660 cpm/µR/hr*	170 cmp/%K	21 cpm/ppm eU	8 cpm/ppm eTh

* Total count data are expressed in the results as exposure rate (µR/hr) which includes non-geological background.

Counting times of 4 to 8 minutes were used over Koolpin Formation rocks, and 2 to 4 minutes over adjacent rocks or cover. All measurements were made with the spectrometer detector supported on a tripod with the detector base 60 cm above ground level.

In most cases, a traverse was made perpendicular to the strike of the Koolpin Formation rocks, and was of sufficient length to intersect rocks of formations immediately above and below the Koolpin Formation. Spectrometer measurements were made at 50 m intervals adjacent to the Koolpin Formation outcrop and at 25 m intervals over the outcrop. Measurements were also made along strike over outcroppping Koolpin Formation rocks at 25 m spacings. The results of all readings over outcropping Koolpin Formation rocks were averaged to produce a radioelement assay of the Koolpin Formation at each location.

The determinations of radioelement concentrations were made with the assumption that the uranium and thorium decay series are each in secular equilibrium. Rock samples were collected at each site and subsequent laboratory fluorimetric analyses of the samples for uranium and thorium were compared with the field gamma-spectrometer assays to assist in establishing the radioequilibrium state at each site.

3. RESULTS

The processed results of ground spectrometer traverses from the seven sites (Fig. 1) are presented as profiles of exposure rate (total count), percent potassium, and equivalent concentrations of uranium and thorium in parts per million, in Figures 2 to 8.

Total-intensity ground magnetic measurements, made with a Geometrics G-816 proton-precession magnetometer, are also presented in the figures, along with a geological cross-section and an estimate of relief.

Details of traverse location, bearing, and length are described in Table 2.

TABLE 2 - DETAILS OF TRAVERSES

Site	1:100 000 Sheet Reference	AMG co-ords East (m)	(Stn.00) North (m)	End stations (m)	Traverse bearing (Grid degrees)
Annaburroo	Mary River	85900	71300	00-800E	074
Cannon Hill (a)	East Alligator	66400	36100	200W-200E	039
Cannon Hill (b)*	East Alligator	66700	32800	-	-
Jabiluka	East Alligator	69800	22300	100W-600E	064
Mundogie	Mundogie	07100	26700	00-1500E	058
McKinlay River	McKinlay River	00650	25100	00-1010E	060
Ban Ban Springs	McKinlay River	71500	18700	00-800W	300/270**
Batchelor	Batchelor	23500	50700	00-450E	090

* Traverse was not made at this site, but spectrometer measurements were made on 10 m grid over Koolpin Formation outcrop.

** Traverse direction changed at station 375W to allow for change in strike.

Comparison of field and laboratory assays

A comparison of field radiometric assays and laboratory measurements is shown in Table 3. Differences between the two sets of measurements for thorium are remarkably small. However, large but fairly consistent percentage differences are observed between the two sets of uranium and potassium assays.

As the differences between the two sets of uranium and potassium data do not appear to be be strongly influenced by change in the concentration of thorium, the differences in the results cannot be explained by calibration errors. It is probable that the differences are principally due to the substantially different sample volumes used by the field and laboratory techniques. However, the consistently high value of the uranium field assays compared with the laboratory assays might reflect the scavenging of uranium daughter products in the surface rocks.

Owing to the consistent relations between field and laboratory assays for all radioelements, the results indicate that field assays should provide at least a reasonable indication of the relative concentrations of radioelements in the rocks of the geosyncline.

Annaburroo traverse

The results of the magnetometer and radiometric surveys along the Annaburroo traverse are shown in Figure 2.

Interbedded ironstones and shales mapped as Koolpin Formation occur in a folded sequence between acid volcanic rocks of the Gerowie Tuff, a younger member of the South Alligator Group, and metasediments of the older Wildman Siltstone (Mount Part ridge Group), which are commonly magnetic.

Radiometric measurements over the outcropping Koolpin Formation rocks indicate a potassium concentration of less than 1%, a thorium concentration of approximately 20 ppm eTh (equivalent thorium) and a uranium concentration of greater than 5 ppm eU (equivalent uranium).

TABLE 3 - COMPARISON OF FIELD AND LABORATORY ASSAYS

Traverse	Station	Stratigraphy	Thorium(ppm)		Uranium(ppm)		Potassium (%)	
			field	lab.*	field	lab.**	field	lab.***
Annaburroo	350E	Koolpin Formation	16	18	7	3.4	0.5	0.17
Jabiluka	100E	Koolpin Formation	11	8	19	5.7	0.2	0.04
Ban Ban	700W	?Koolpin Formation	20	18	2.5	2.1	3.8	2.86
Ban Ban	200W	Koolpin Formation	16.5	20	8	3.2	2.8	4.26
McKinlay River	500E	Wildman Siltstone	19.0	26	3.0	0.7	3.0	2.58
Batchelor	175E	Koolpin Formation	9.0	4	11.0	12.0	1.2	0.50

Notes:

* Thorium assays by XRF, analysed by AMDEL
** Uranium assays by fluorimetry, analysed by AMDEL
*** Potassium assays by A.A, analysed by AMDEL

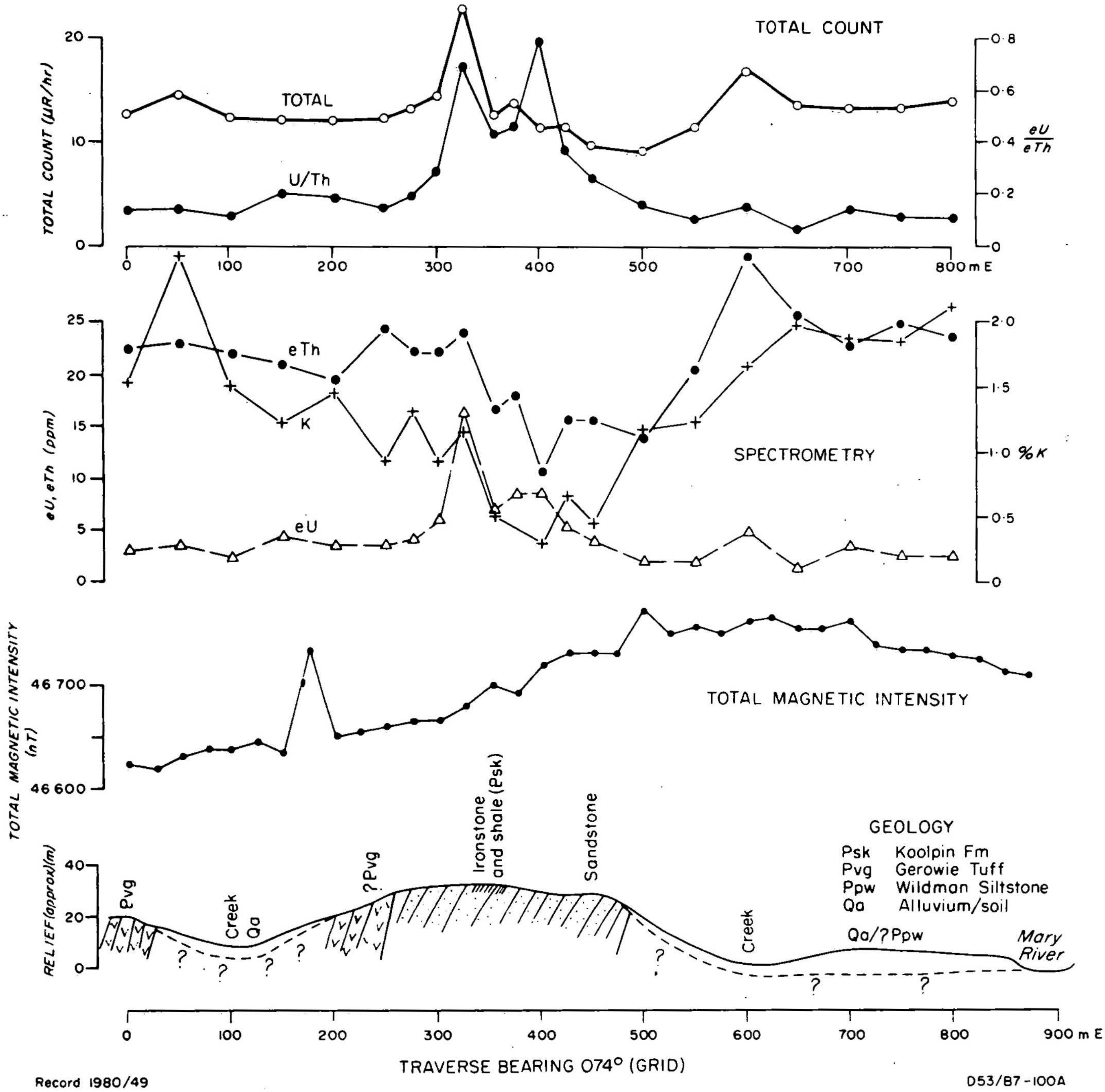


Fig 2 Annaburroo Traverse NT

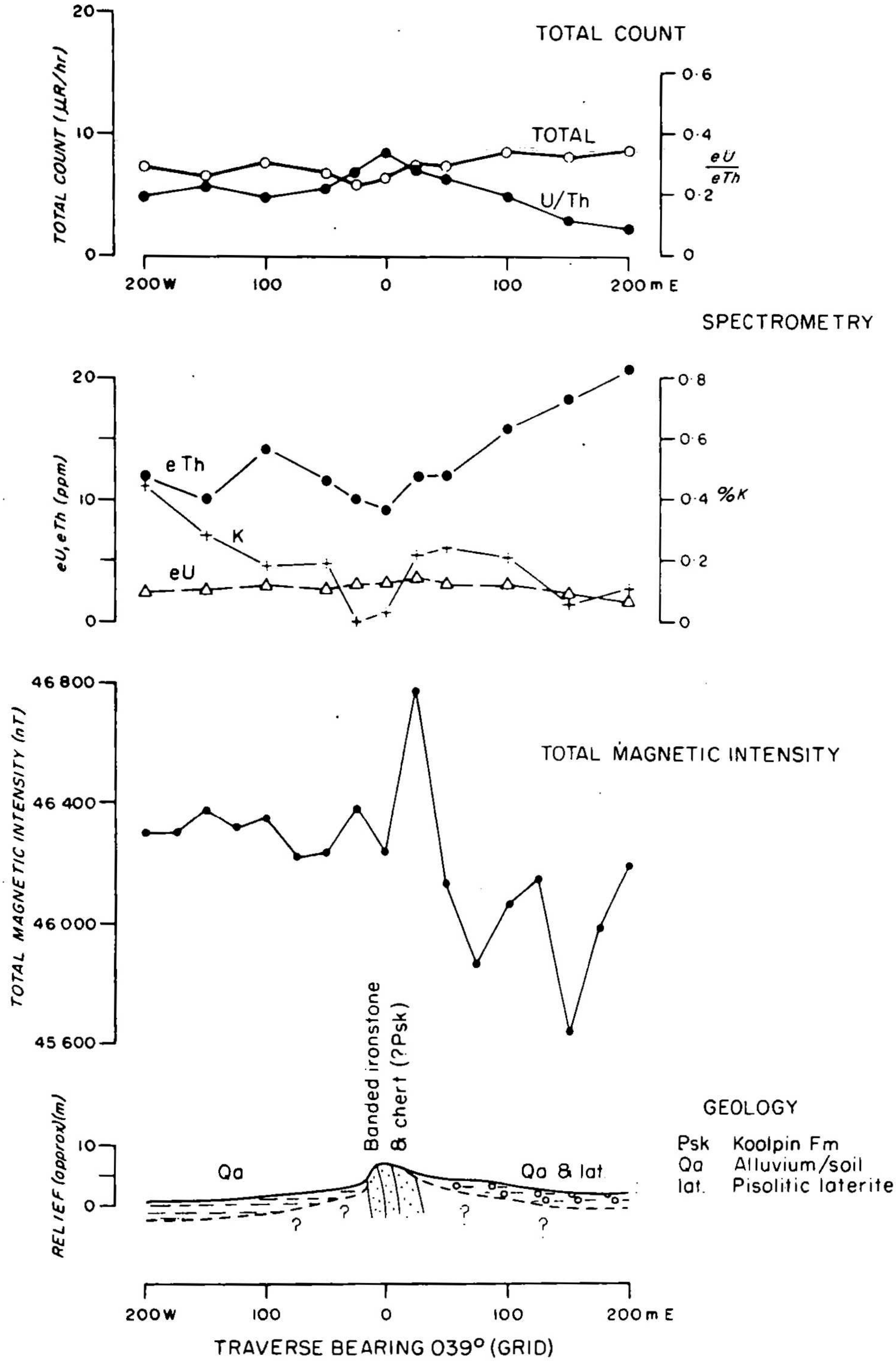
By comparison the Gerowie Tuff appears to have higher potassium and thorium concentrations than the Koolpin Formation rocks, but a lower uranium concentration. There is no outcrop of the Wildman Siltstone on the traverse but geological interpretation suggests that this unit underlies alluvium east of the Koolpin Formation outcrop. This proposition is supported by the magnetic data, which suggest the presence of magnetic rock to the east of the outcropping Koolpin Formation. The high thorium concentrations east of 500E occur over a thin layer of transported sandy soils and might reflect a characteristic of the underlying rock unit.

Differences between the radioelement characteristics of the Koolpin Formation and its surrounding rocks at this site are clearly indicated in the U/Th and U/K ratios. As shown in Figure 2, the average U/Th ratio for the Koolpin Formation is 0.6 compared with a value of about 0.15 for the Gerowie Tuff and the shallow transported soils overlying the Wildman Siltstone. The U/K ratio for the Koolpin Formation is approximately 10 times as great as that observed over the Gerowie Tuff.

Cannon Hill traverse

The Cannon Hill traverse is located in the northeast of the Pine Creek Geosyncline where metamorphic grade of the rocks is relatively high. The results of the magnetometer and radiometric, surveys are shown in Figure 3. A thin (20 m wide) outcrop of banded ironstone, chert, and quartz intersected on this traverse was mapped by Needham & Smart (1972) as a metamorphosed equivalent of the Koolpin Formation, and occurs as a low rise above the alluvial plain. No other outcrop occurs in the area. The results of recent geological mapping, auger drilling, and scintillometer and radon surveys carried out by the Australian Atomic Energy Commission (AAEC) in the area were described by Swingler (1977a).

The results of the gamma-spectrometer work indicate that the outcrop has a very low potassium concentration. However, thorium and uranium concentrations appear to be fairly typical of these rock types. The U/Th ratio appears to be significantly higher over the outcrop than over the alluvium-covered areas to the side. To the east of the outcrop the decrease in U/Th ratio and change in magnetic character may indicate a change in rock type. However, the soil in this area contains pisolites of



Record 1980/49

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Fig 3 Cannon Hill Traverse NT

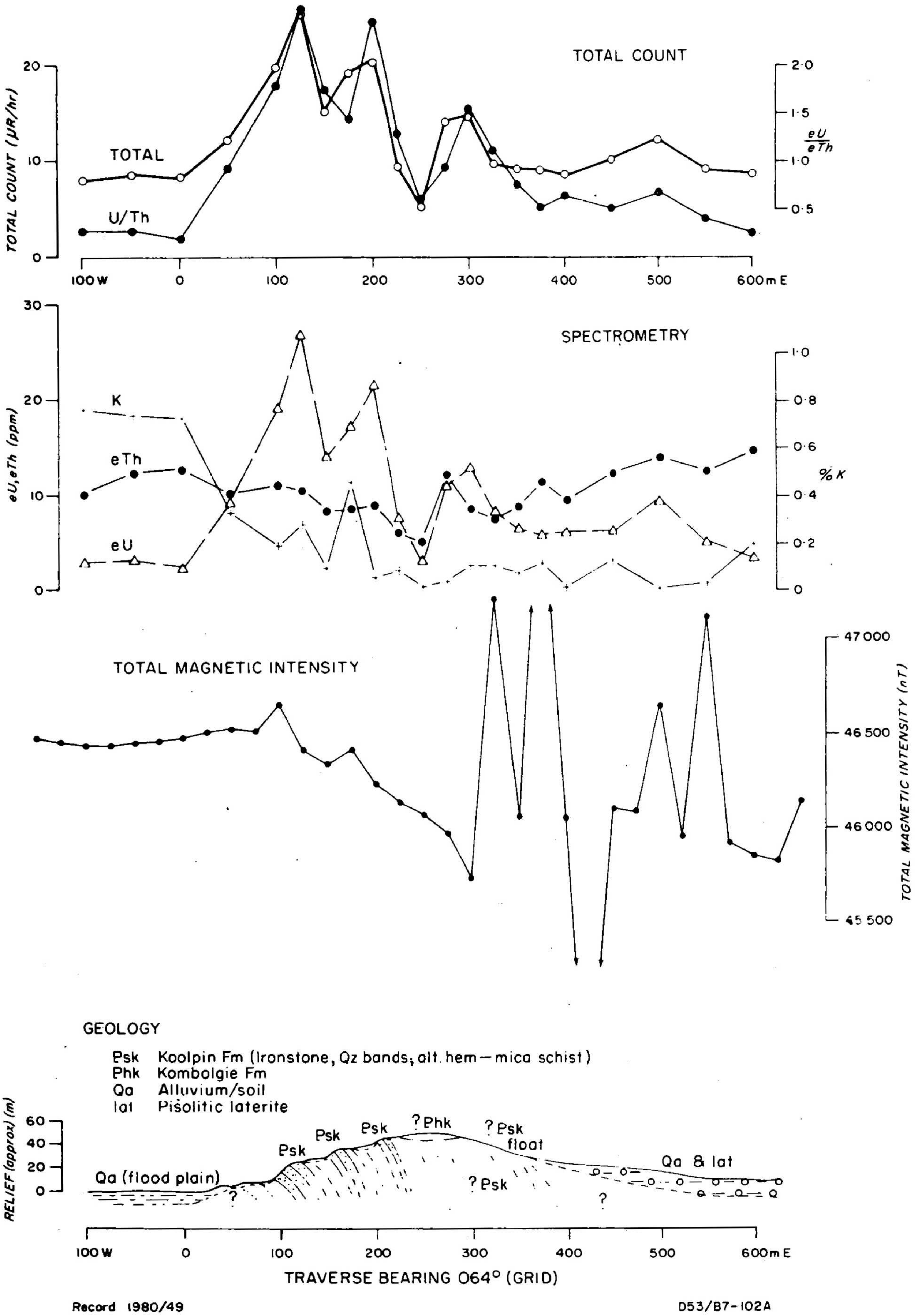

Fig 4 Jabiluka Traverse NT

laterite which could affect both magnetic and spectrometer responses. To the west of the outcrop, the continuation of relatively high U/Th ratios, coupled with generally higher and less irregular magnetic values, suggests that Koolpin Formation underlies the alluvium.

Jabiluka traverse

The Jabiluka traverse - which is about 10 km south of the Cannon Hill traverse - crosses the AAEC "Magela One" prospect (Swingler, 1977b). The results of the radiometric and magnetic measurements along the traverse are shown in Figure 4. The outcrop thickness in this case is much greater (about 250 m) than at Cannon Hill, but the geological setting is similar. A series of outcrops of quartz-hematite banded ironstones, which exhibit crenulation, cleavage, and schistosity, dips to the east beneath a large hill rising out of the Magela Plain. These rocks are believed to be metamorphic equivalents of the Koolpin Formation.

The results indicate that the potassium concentration of the ironstone outcrops is very low (less than 0.4%). However, the results indicate high uranium concentrations of up to 27 ppm eU. The U/Th ratio over most of the exposed Koolpin Formation rocks is quite high, reaching a maximum value of over 2.5. U/Th ratios over the soils to the east and west of the hill are all less than 0.5.

The low potassium and relatively high uranium values over soils east of the main outcrop suggest that Koolpin Formation rocks extend beneath this cover.

The relatively low radioelement concentrations and U/Th ratios measured at the crest of the hill (250E) coincide with a thin sandy outcrop which appears to be unconformable with the banded iron formations. This may be the eroded base of the younger Kombolgie Formation which, although not formally mapped at this locality, occurs extensively several kilometres to the east.

The magnetic data suggest a dipping contact with the Koolpin Formation near 100E. The erratic magnetic response east of 300E is indicative of the presence of pisolitic laterite.

Mundogie traverse

The results of the magnetometer and radiometric surveys along the Mundogie traverse are shown in Figure 5. Thin banded ironstone and chert mapped as Koolpin Formation occur in a folded sequence of acid volcanics and tuffs. Apart from the eastern and western ends of the traverse, outcrop is sparse. However, the thin banded iron formations (usually about 5 to 10 m wide) form distinct marker horizons which can be traced extensively.

Radiometric measurements on the ironstone outcrops indicate a low potassium concentration (less than 0.6%) and a relatively low thorium concentration (less than 12 ppm). However, the uranium concentration remains at between 2-3 ppm eU over all of the traverse. U/Th ratio measurements over outcropping Koolpin Formation rocks are also low (0.2), but are marginally higher than those recorded elsewhere on this traverse.

The Shovel Billabong Andesite (another unit in the South Alligator Group) surrounding the banded ironstone and chert, at the western end of the traverse exhibits a higher potassium concentration (1.2%) and a U/Th ratio of about 0.15. A weathered suboutcrop of very laminated rock (possibly shale or phyllite) mapped as Koolpin Formation at 900E has a relatively high apparent potassium concentration of 2.2%. Although this rock type can occur in the Koolpin Formation, its radioelement characteristics are distinctly different from other Koolpin Formation rocks found in this area, and it is possible that this particular outcrop could be an argillite of the Gerowie Tuff unit.

McKinlay River traverse

The results of the magnetometer and radiometric surveys along the McKinlay River traverse are shown in Figure 6. A folded sequence containing rocks of the Wildman Siltstone, Koolpin Formation, Gerowie Tuff, and Zamu Dolerite was reasonably well exposed on this traverse. A 200 nT magnetic anomaly coincides with the dolerite outcrop between 100E and 250E.

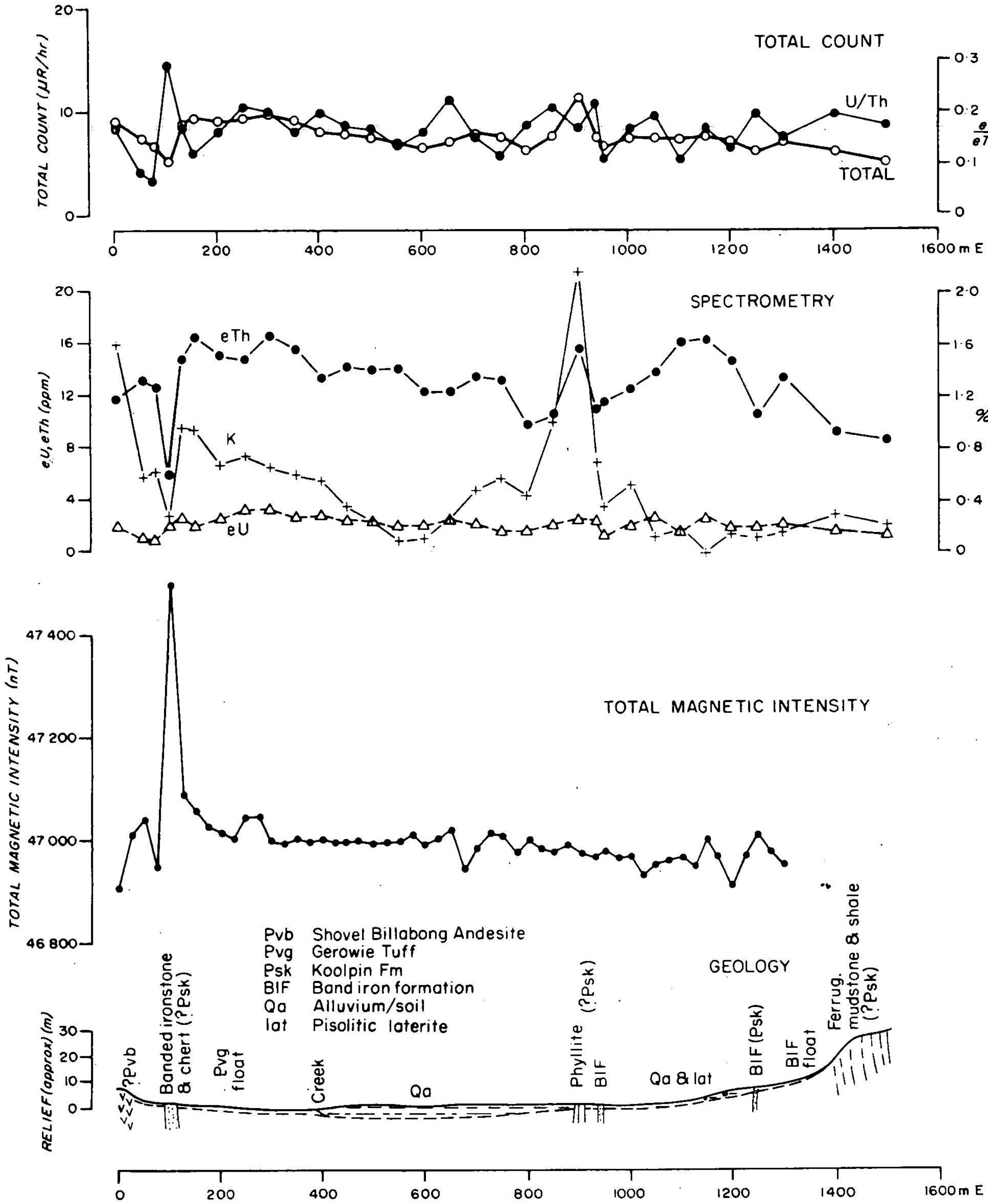

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Fig 5 Mundogie Traverse NT

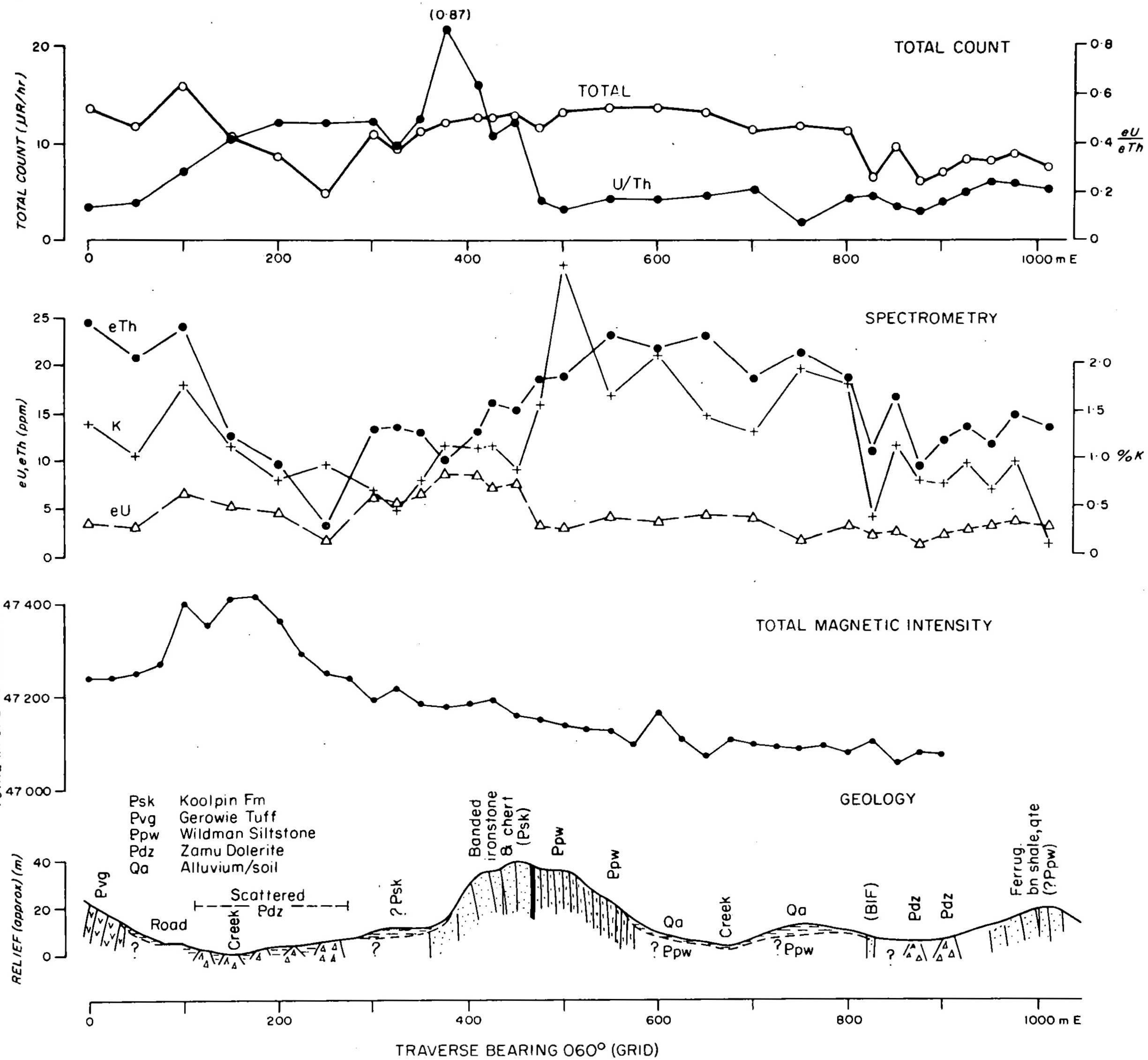

Fig 6 Mckinloy River Traverse NT

Rocks of the Koolpin Formation consist mainly of massive ironstone, banded ironstone, and chert with some siltstones and shales. The outcrop of Koolpin Formation rocks between 400E and 460E appears to have a relatively low potassium concentration (about 1%), an average thorium concentration (10-15 ppm eTh), and a higher than usual uranium concentration of approximately 8 ppm eU. In contrast, the acid volcanics and metasediments of the Gerowie Tuff and Wildman Siltstone have a relatively high thorium concentration (20-25 ppm eTh) and a low uranium concentration (3-5 ppm eU). The siltstone is also characterised by its high potassium concentration (about 2%), which highlights the contact at 460E with the Koolpin Formation.

Interbedded ferruginous brown shales and quartzite at the eastern end of the traverse are mapped as part of the folded Wildman Siltstone. Although the uranium concentration appears to be characteristically low, the potassium and thorium concentrations are also low, indicating perhaps a different lithology from that seen in other parts of the Wildman Siltstone.

The U/Th ratios clearly indicate the contact between the Koolpin Formation and Wildman Siltstone at 460E. This contact is not apparent in the total-count data, which demonstrates the value of spectrometry in this case. The scattered dolerite outcrop west of the main outcrop of Koolpin Formation also has high U/Th ratios (about 0.4) compared with the Gerowie Tuff and Wildman Siltstone.

Ban Ban Springs traverse

Figure 7 shows the results of magnetic and radiometric surveys along the Ban Ban Springs traverse. The traverse crosses a prominent outcrop of carbonaceous, phyllitic, and silty micaceous hornfels interbedded in places with quartzite and ironstone. The sequence has been mapped as Koolpin Formation, although it is possible that some of the rocks may be argillites of the Gerowie Tuff. The presence of hornfels indicates that these rocks occur in the contact aureole of the Burnside Granite, which crops out 2 kilometres to the west.

The apparent potassium concentrations of the Koolpin Formation rocks in this area are higher than those recorded at the other sites visited. However, the iron-rich units have distinctly lower apparent potassium concentrations than the hornfelsed units. Apparent thorium concentrations are fairly similar to the concentrations observed over Koolpin Formation rocks at other sites, and, like the potassium concentrations, are somewhat lower over the iron-rich units than over the hornfelsed units. Apparent uranium concentrations are also fairly similar to the results observed over Koolpin Formation rocks at other sites. The highest U/Th rations (about 0.4) occur over the eastern flank of the main outcrop and coincide broadly with iron-rich units. The broad increase in ratio to the east of 400W cannot be attributed to any specific rock type.

A 150 nT magnetic anomaly at 75W and an anomaly greater than 500 nT west of 800W are most likely due to Zamu Dolerite, bodies of which crop out elsewhere in the area.

Batchelor traverse

The results of magnetic and radiometric surveys along the Batchelor traverse are shown in Figure 8. A 100 m wide ridge of massive ironstones, quartzites, and chert breccia intersected on this traverse was originally mapped as part of the Golden Dyke Formation (Johnson, 1974) but has been reclassified as Koolpin Formation in the revised stratigraphy of Needham & others (1980). Acid volcanics of the Gerowie Tuff crop out in a parallel ridge to the east.

The apparent radioelement concentrations of the tuff sequence are characterised by high potassium (3-4%), high thorium (22 ppm eTh), and values of uranium (3-5 ppm eU) which are fairly typical of many rocks throughout the geosyncline. In contrast, the apparent radioelement concentrations recorded over the hematitic quartzite and chert sequence are highly variable, with potassium ranging from 0.5 to 2.5%, thorium from 3 to 15 ppm eTh, and uranium from 3-12 ppm eU. The U/Th ratios over the outcropping Koolpin Formation rocks are relatively high, ranging from 0.3 to 1.5, and the contact between the Koolpin Formation and Gerowie Tuff near 300E is clearly indicated by the U/Th ratio, but not by the total-count data. Between 75 and 150E, low potassium and relatively high uranium concentrations suggest that Koolpin Formation rocks may lie beneath the thin soil cover in this area.

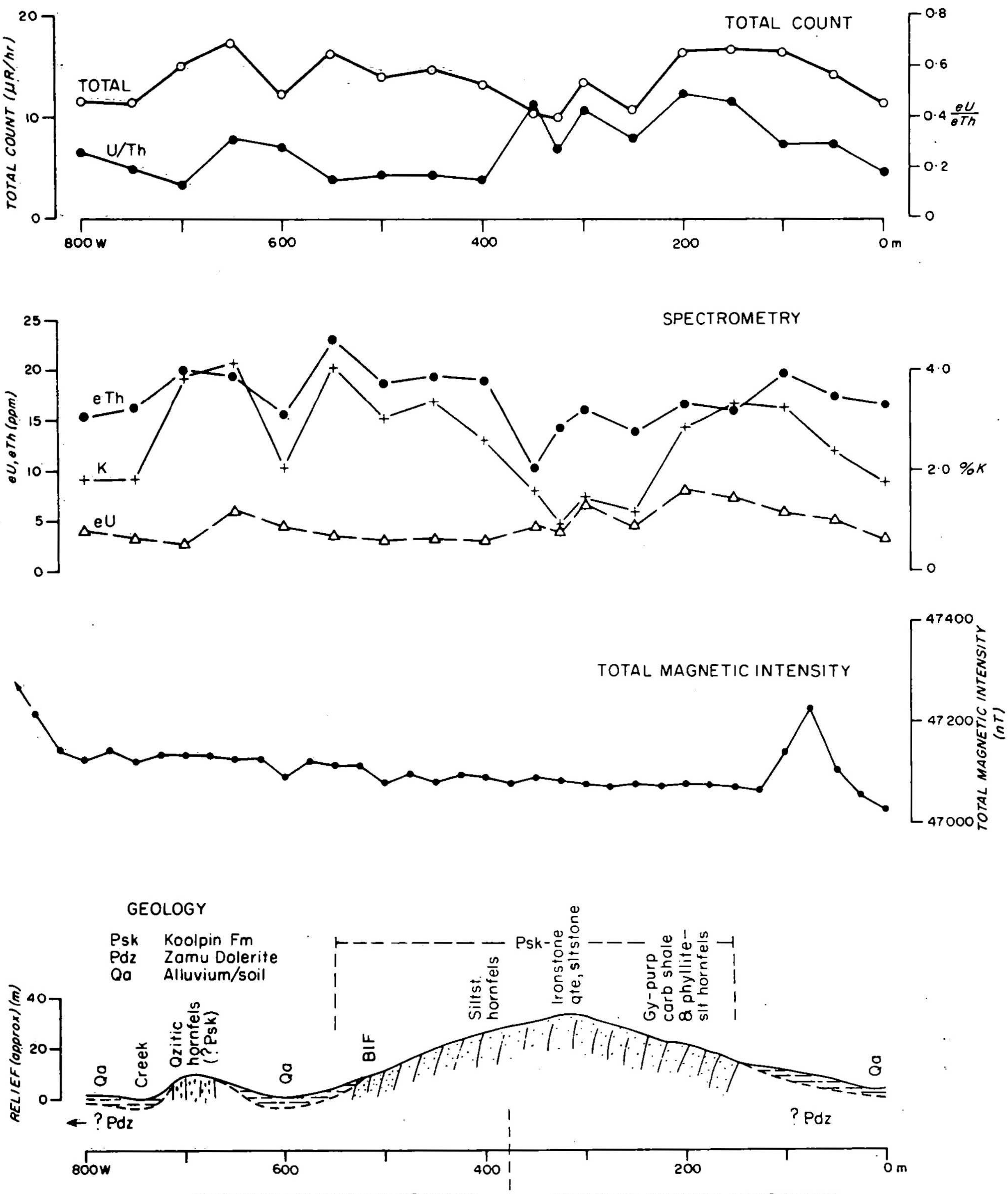

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Fig 7 Ban Ban Springs Traverse NT

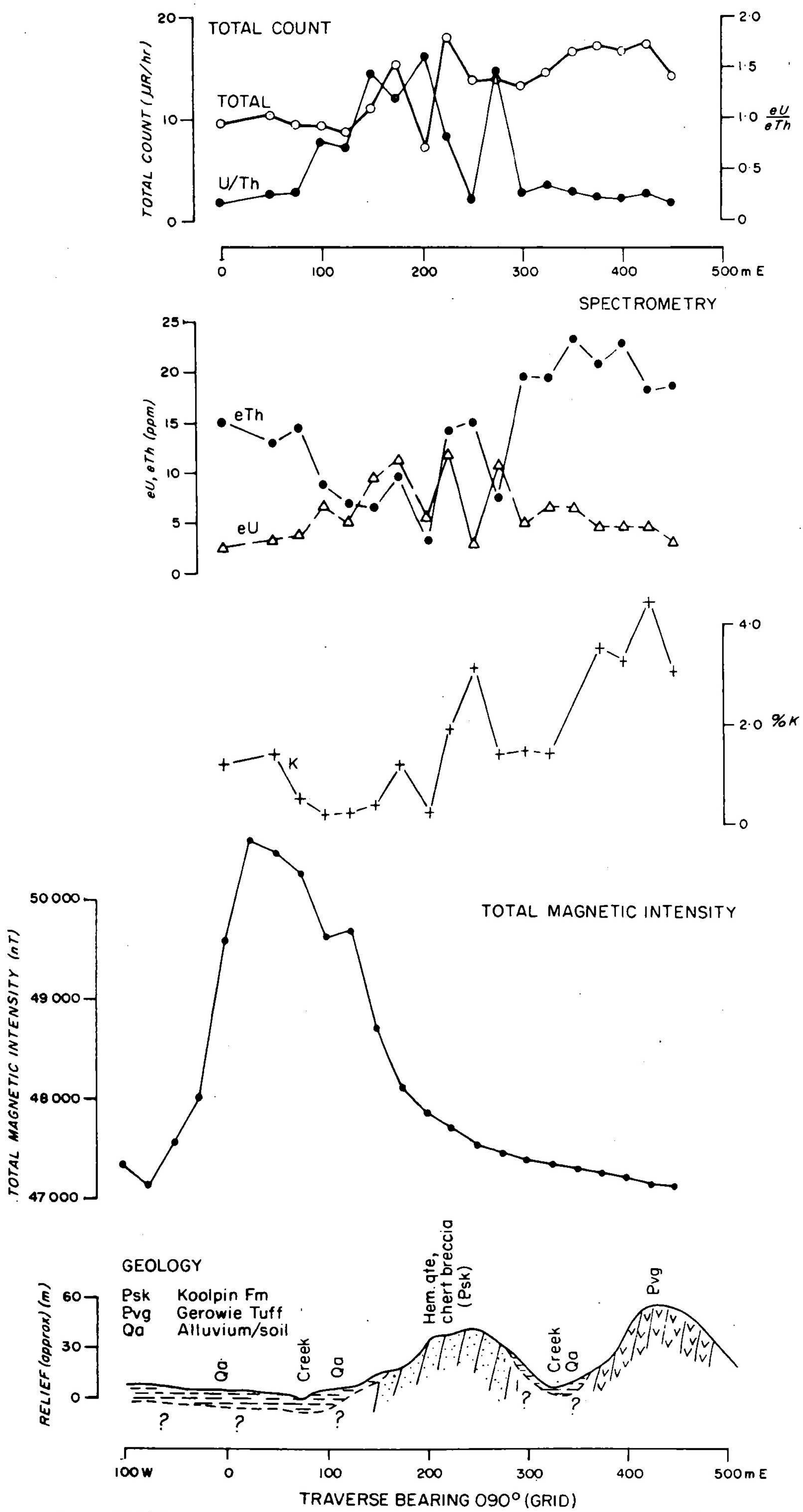

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Fig 8 Batchelor Traverse NT

The source of the 3500 nT magnetic anomaly centred on 25E is not certain. Modelling of the anomaly assuming a dyke-like source with induced magnetisation suggests the source could be an amphibolite body of width 150 m (centred on 25E), depth of 50 m to the top, and near-vertical dip. As the equivalent susceptibility of the body would need to be very high (about 0.5 SI units) a strong remanent magnetisation is suggested.

4. CONCLUSIONS

A summary of the results for each area is presented in Table 4. The radioelement concentrations shown in this table are based on analyses of all spectrometer data over outcropping rocks on each traverse.

The results of the work at the seven sites throughout the Pine Creek Geosyncline indicate that ironstone units of the Koolpin Formation which are interbedded with cherts, quartzites, and other sediments are relatively enriched in uranium and have relatively high uranium-to-thorium ratios which are frequently greater than 0.4. An exception to this are the thin beds of ironstone in the Mundogie area, but the result at this site may be due to inadequate sampling of the formation owing to sparsity of outcrop. A very low potassium concentration (less than 1.5%) is a common characteristic of the ironstone units.

Other rock types within the Koolpin Formation, such as shale, siltstone and quartzite, have relatively low uranium concentrations unless they are interbedded with the ironstones. Adjacent metasedimentary and metavolcanic rocks of the Wildman Siltstone and Gerowie Tuff units have in general relatively low uranium concentrations (less than 4 ppm eU) but higher potassium concentrations than the Koolpin Formation rocks, and uranium/thorium ratios commonly less than 0.2.

The high uranium/thorium ratios observed over outcropping Koolpin Formation rocks are also observed in adjacent areas where it is clear that similar rocks of the Koolpin Formation are buried by a thin soil cover. Although the absolute concentrations of the radioelements are naturally depleted in these cases, the retention of the significant U/Th ratio enhances the use of high-sensitivity gamma-ray spectrometry (either ground or airborne) for mapping rocks buried by a thin veneer of eluvial cover derived from the underlying rock. The thickness of this cover could be several metres.

Possible mechanisms for the apparent uranium enrichment of the massive and banded ironstone sequence of the Koolpin Formation may be: (i) primary concentration of the uranium during formation; or (ii) scavenging and retention by the iron-rich rocks of uranium ions which have been weathered out of the surrounding rocks. The latter proposal is supported by observations that laterites in parts of the Pine Creek Geosyncline are commonly enriched in uranium. I.H. Crick (pers. comm.) believes that the basal massive ironstones of the Koolpin Formation in the Batchelor area are in fact fossil laterites/regoliths, suggesting a mechanism for uranium enrichment of the ironstones which is similar to that observed in the present-day laterites.

It may be significant that the highest average uranium/thorium ratios for Koolpin Formation rocks were observed on the Jabiluka and Batchelor traverses, which are close to granitic basement complexes and known uranium occurrences. In both these areas the major uranium deposits do not occur in the Koolpin Formation, but in older formations. It might be speculated that the transport mechanisms which produced the uranium deposits have also enriched the uranium concentration of the iron-rich units in the Koolpin Formation; this hypothesis suggests that high U/Th ratios observed in the Koolpin Formation may indicate the presence of uranium deposits in older, possibly buried formations.

The comments above indicate that high sensitivity regional airborne gamma-ray spectrometry can be used to map the occurrences of Koolpin Formation rocks under thin soil cover. Furthermore, careful data analysis may also be useful in indicating target areas for possible uranium mineralisation beneath the Koolpin Formation.

TABLE 4 - SUMMARY OF RADIOELEMENT CONCENTRATIONS DERIVED FROM GAMMA SPECTROMETRY

Locality	Lithology	Potassium (%)+ Range	Mean	SD	Uranium (ppm)* Range	Mean	SD	Thorium (ppm)* Range	Mean	SD	U/Th	U/K
(a) Koolpin Formation Rocks												
Annaburroo	Ironst & lam. silty shale	0.00-1.52+	0.64	0.54	5.4-16.3	9.7	3.5	10.5-24.0	17.8	4.0	0.54	15.2
Cannon Hill	Banded ironstone & chert	0.00-0.22	0.06	0.08	2.7-3.6	3.2	0.4	5.1-11.8	8.2	2.3	0.39	53.3
Jabiluka	Banded qz-hematite mica schist	0.00-0.27	0.18	0.15	14.1-26.7	19.3	4.0	8.2-11.9	9.8	1.4	1.99	107.2
Mundogie	Banded hematite & chert	0.13-0.69	0.30	0.20	1.5-2.4	1.8	0.3	5.2-11.1	8.5	2.4	0.21	6.0
McKinlay R.	Banded hematite & chert	0.71-1.15	1.00	0.19	4.9-8.6	7.2	1.5	8.2-16.0	12.4	3.4	0.58	7.2
Ban Ban	Banded iron, qte, siltstone, hornfels	0.95-1.61	1.32	0.34	3.9-6.9	5.1	1.6	10.2-16.1	13.5	3.0	0.38	3.9
Ban Ban	Carbonaceous phyllitic hornfels (poss. argillite of Gerowie Tuff)	2.61-4.02	3.20	0.49	2.9-8.0	4.7	2.3	16.1-23.0	18.8	2.5	0.25	1.5
Batchelor	Hematitic qte, chert breccia	0.28-3.13	1.56	0.94	2.9-11.7	7.7	3.8	3.3-19.4	11.5	5.9	0.67	4.9
(b) Other rock types												
Annaburroo	Gerowie Tuff	1.44-2.50	1.85	0.57	2.7-3.3	3.0	0.3	20.7-23.0	21.9	1.2	0.14	1.6
Mundogie	Shovel Billabong Andesite	0.58-1.61	1.23	0.57	1.0-2.3	1.7	0.7	11.8-13.3	12.6	0.8	0.13	1.4
McKinlay R.	Gerowie Tuff	1.05-1.46	1.26	0.21	3.0-3.6	3.3	0.3	20.7-27.2	24.2	3.3	0.14	2.6
McKinlay R.	Wildman Siltstone	1.58-3.08	2.29	0.71	2.4-4.0	3.2	0.6	18.4-23.1	20.1	2.1	0.16	1.4
McKinlay R.	?Wildman Siltstone (qte, ferrug. bn shale)	0.11-0.97	0.68	0.40	2.6-3.3	2.9	0.3	11.5-14.5	13.2	1.2	0.22	4.3
McKinlay R.	Zamu Dolerite	0.76-1.14	0.91	0.17	1.1-5.2	2.4	1.9	3.2-12.5	9.2	4.2	0.26	2.6
Batchelor	Gerowie Tuff	3.07-4.45	3.51	0.55	2.9-4.8	4.3	0.8	18.1-22.7	20.4	2.1	0.21	1.2

* Values represent "equivalent" uranium and thorium concentrations assuming secular equilibrium between U-238 and Bi-214, and Th-232 and Tl-208.

+ Potassium values of 0% indicate errors in stripping ratios. Potassium concentrations for these cases could be regarded as extremely low.

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