BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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ANALYSES OF GEOLOGICAL, GEOPHYSICAL AND PHYSICAL PROPERTY DATA FROM THE SOUTHWEST ARUNTA BLOCK, NT

by

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SUMMARY

A regional aeromagnetic interpretation of the Mount Rennie and Mount Liebig 1:250 000 Sheet areas in the southwest Arunta Block is given based on ground geophysical and geological studies in seven sample areas. The aeromagnetic response is modelled along three north-south cross-sections and a solid geology map built up by interpolation between these section lines.

The work illustrates the importance of physical property measurements in aeromagnetic interpretation. Such physical property measurements should be made in the field where possible and should be supported by laboratory measurements aimed at instrument calibration and assessment of secondary effects such as surface alteration.

A large part of the report is devoted to detailed studies in the seven sample areas. These results will be a valuable data set for future detailed studies in the region. Geophysical methods used include ground magnetic and radiometric traverses, gamma-ray spectrometer measurements, in situ magnetic susceptibility measurements, and interpretation of Bouguer gravity anomalies and airborne radiometric anomalies.

A semi-quantitative interpretation of the geology is possible from the aeromagnetic data if there is sufficient control from physical property measurement or ground magnetic traverses over areas of exposure. Measurements of magnetic susceptibility were more valuable than the ground traverses; the latter were used to clarify the location of boundaries and add detail. For this reason, the results of ground traverses are illustrated from two areas only. The range of magnetic susceptibility values for each rock type is distinctive. Magnetic susceptibility shows an increasing range of values as the metamorphic grade increases. For this reason it is possible to interpret the distribution of metamorphic grade in a broad sense. Variations in specific gravity values suggest that detailed gravity could give additional control of the distribution of broad rock-compositional groups. The available airborne radiometric data in the area are of little value because of the small crystal used, and the

gamma-ray spectrometer measurements appear to require additional research and attention to instrument calibration before they can be used effectively.

The regional interpretation indicates the presence in the northern part of the area of a vast belt of strongly magnetic and dense rocks of very high metamorphic grade that may have been thrust up from the lower crust. Metamorphism and migmatisation of granites and sediments in the area may have been associated with the upthrusting. Deformed schists which occur near the southern margin of the southwest Arunta Block may be related to overthrusting along major east-trending faults.

1. INTRODUCTION

During April and May 1975 the Geological and Geophysical Branches of the Bureau of Mineral Resources (BMR) jointly carried out geological and ground geophysical (magnetic and radiometric) investigations within the northern parts of MOUNT RENNIE and MOUNT LIEBIG*, in the southwest Arunta Block approximately 200 to 500 kilometres west of Alice Springs, N.T. (Fig. 1).

The main objective of this work was to gain an understanding of relationships between the geology and magnetic and radiometric responses in a region where the main rock types of the southern Arunta Block are exposed. Such information would help to resolve discrepancies between existing 1:250 000 geological mapping (Wells & others, 1965; Ranford, 1968, 1969) as summarised in Figure 1, and results obtained from the 1965 BMR Amadeus Basin airborne magnetic and radiometric survey (Young & Shelley, 1977) included in Figure 2. For example, some areas mapped as granites correspond to areas of relatively high magnetic response, while several zones containing a high proportion of mafic granulite (probable metabasalt) correspond to strongly negative magnetic features.

Additional objectives were to investigate the importance of remanent magnetism, the use of a gamma-ray spectrometer to determine radioelement content *in situ*, and to check the adequacy of the survey design of the 1965 airborne work as related to the Arunta Block. The results of the present ground investigations should also assist the interpretation of an airborne survey carried out by BMR in areas north and east of MOUNT RENNIE and MOUNT LIEBIG during 1976 (BMR, 1976). An analysis of the techniques used and their application in the present survey would be of benefit to future ground survey work in this region. The areas covered by ground investigations are shown in Figure 4.

The nature, location and amount of work possible was restricted at times owing to problems of limited access and certain physiographic features (longitudinal sand dunes, mountain ranges and hills, difficult

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* Names in capital letters in text refer to 1:250 000 sheet areas.

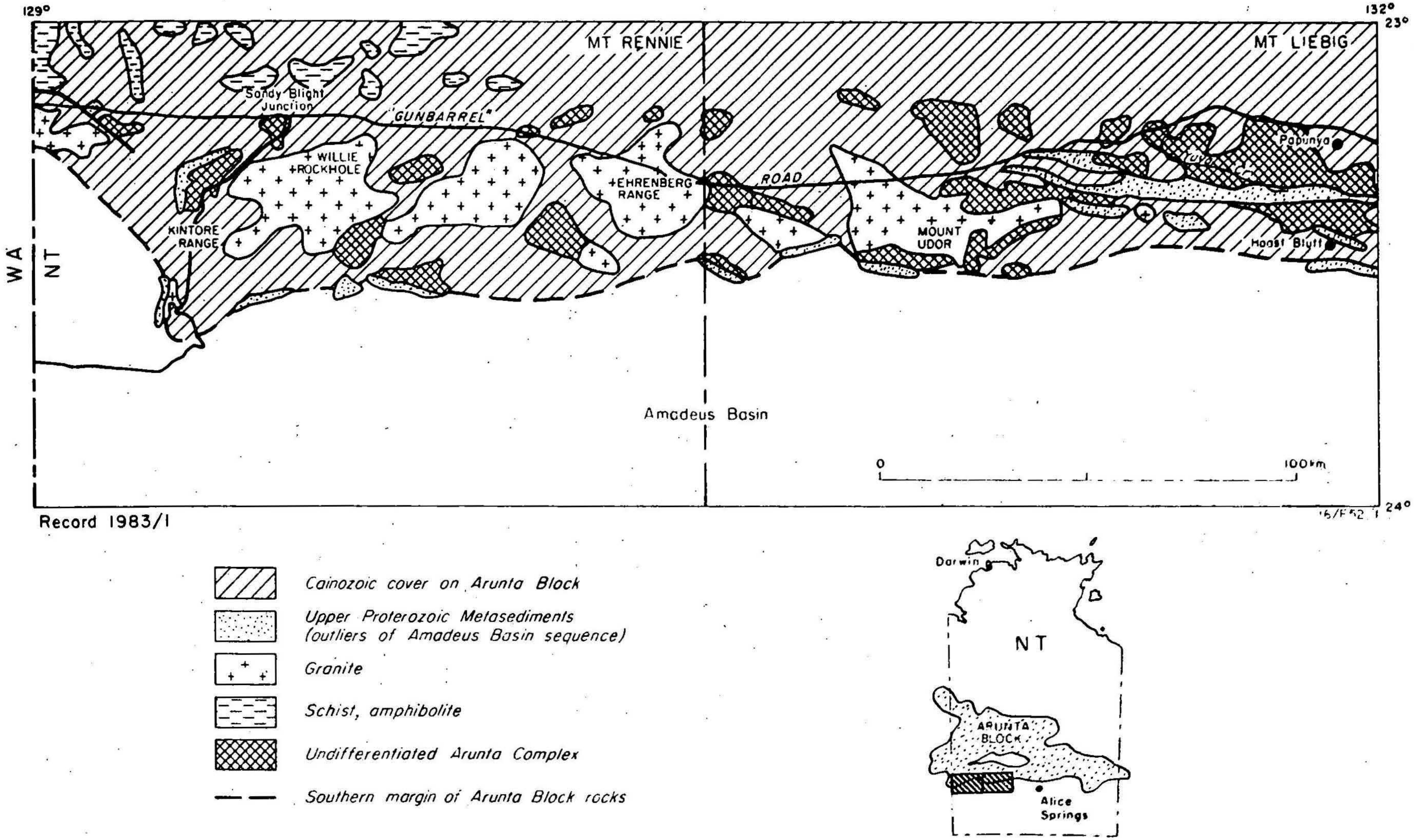


Fig. 1 SW Arunta Block, Northern Territory. Locality map and outcrop geology (based on BMR 1:250 000 geol. map)

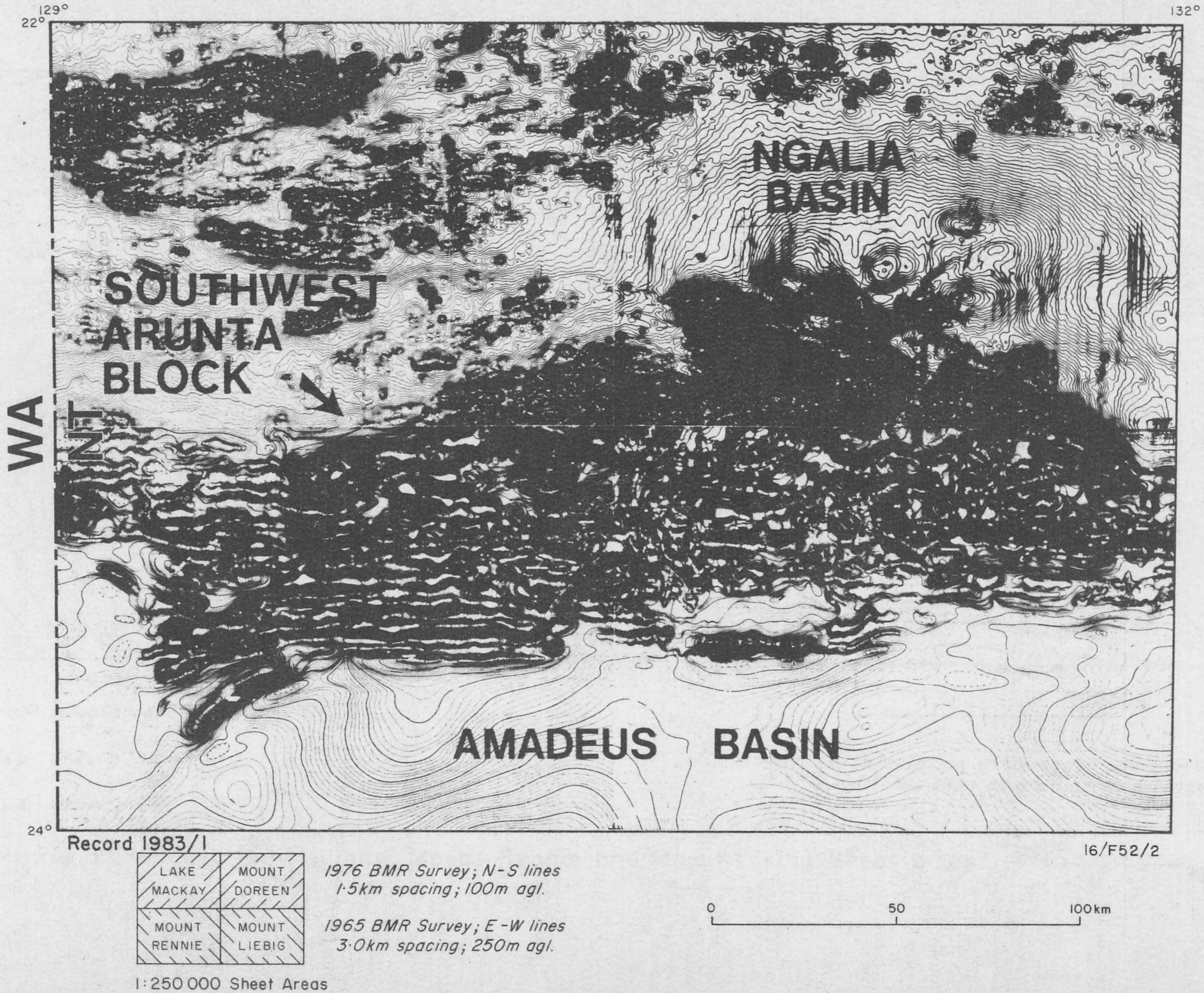
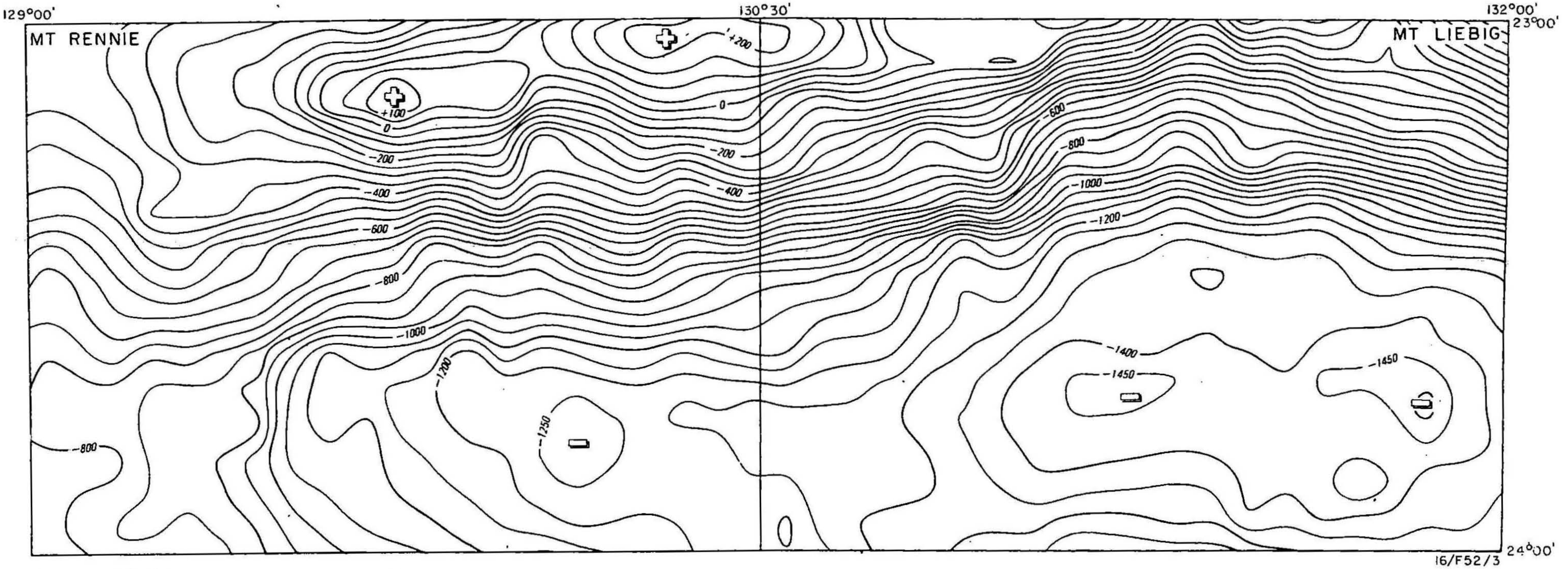


Fig. 2 Aeromagnetic contours showing extent of basement rocks of the SW Arunta Block



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—+20— *Bouguer anomaly (µm.s⁻²)*

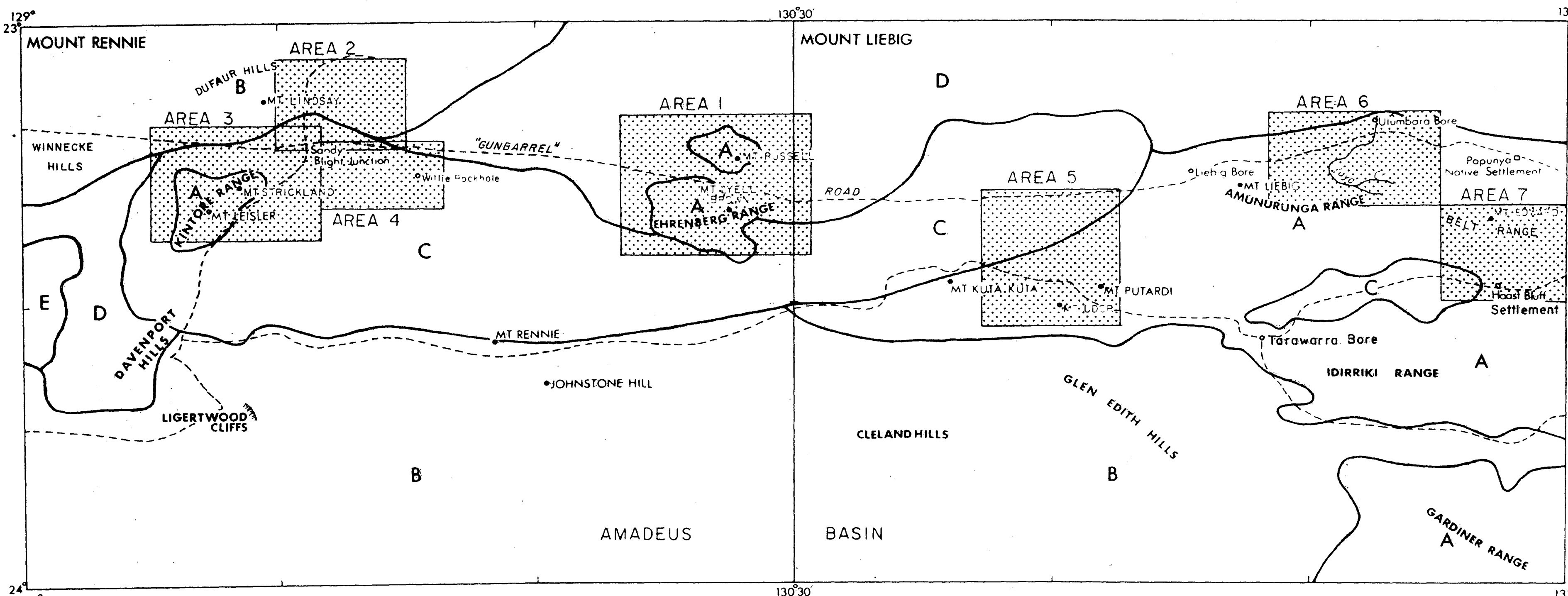
Gravity high

Gravity low

0 50km

For the calculation of Bouguer anomalies, 2·67 g.cm⁻³ has been adopted as an average rock density.

Fig. 3. Bouguer gravity map, Mount Rennie and Mount Liebig Sheet areas



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A *Mountain ranges and hills*
B *Low ranges and hills with intervening sand dunes and sand plain*
C *Sand plain with some dunes and low outcrops*
D *Sand plain with longitudinal dunes*
E *Salt lakes*

Selected survey areas 1975

Fig. 4 Physiographic divisions and individual study areas

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creek crossings). The physiographic divisions, as described by Wells & others, (1965) are shown in Figure 4, as are the relevant topographic features within the survey area. Access to the region has not improved since Wells' report was written. In fact it was found that the condition of many of the graded tracks had deteriorated badly mainly from flood damage in the intervening years.

2. PREVIOUS INVESTIGATIONS

Geology

Prior to the regional 1:250 000 mapping of both MOUNT RENNIE and MOUNT LIEBIG by BMR geologists in 1961 (Wells & others, 1965; Ranford, 1968, 1969), these areas had received only cursory geological examination, mainly by explorers such as Gosse, Chewings and Tindale between 1873 and 1935. Geological observations recorded during these expeditions and subsequent private company reconnaissance up to 1960 are outlined by Wells & others, (1965).

The regional mapping by BMR in 1961 concentrated on the stratigraphy of the sedimentary sequence of the Amadeus Basin, which occupies most of the southern halves of MOUNT RENNIE and MOUNT LIEBIG. Crystalline basement rocks were not mapped in detail, but broad lithological divisions were outlined. However, these were based largely on air-photo interpretation aided by identification of a minimum number of collected samples.

The first attempt to study the basement rocks further was by BMR between 1968 and 1972 (Forman & Shaw, 1973). Shaw visited MOUNT LIEBIG and the eastern margin of MOUNT RENNIE as part of a study of the distribution of metamorphic rocks in central Australia.

The groundwater potential of the alluvial fans north of the Ehrenberg Range (Fig. 4) was examined by Youles (1964). Up to 20 m of alluvium was intersected in each of six investigation bores.

Geophysics

During 1962, BMR conducted a reconnaissance helicopter gravity survey in the Amadeus and South Canning Basins (Lonsdale & Flavelle, 1963), which included both MOUNT RENNIE and MOUNT LIEBIG. Within these Sheet areas the gravity data (Fig. 3) define the northern extent of the 'Amadeus Gravity Depression' which represents the thick sediments of the Amadeus Basin. The denser crystalline rocks of the Arunta Block produce an east-west trending line of gravity 'highs', which extends from the centre of MOUNT RENNIE eastwards for approximately 500 km. Anfiloff & Shaw (1973), Mathur (1976) and Wellman (1978) used those data in their interpretations of the regional gravity patterns of central Australia.

A regional airborne magnetic and radiometric survey of the Amadeus Basin and adjacent basement areas was completed by BMR in 1965 (Young & Shelley, 1977). Results from the airborne magnetic survey in MOUNT RENNIE and MOUNT LIEBIG are presented in Figure 2. The survey was designed specifically to investigate basement features beneath the thick sediments of the Amadeus Basin, rather than structures in the outcropping basement complex, hence resulting in poor definition of anomaly trends over basement outcrop. In particular, the east-west flight line direction over predominantly east-west structures within the basement rocks resulted in inadequate definition of these features. The boundary between the Amadeus Basin sequence and the Arunta Block corresponds to a dramatic change in magnetic character (Fig. 2). The response over outcropping basement rocks is highly disturbed. Young & Shelley (1977) note a major difference in trend orientation within the basin as compared with surrounding basement outcrop. They suggest that northerly trends (in general) within the basin result from susceptibility contrasts between ancient crystalline rocks, whereas the common easterly trends over the Arunta Block reflect tectonic activity associated with basin development, probably during the Alice Springs Orogeny (at 400-300 m.y.).

BMR has conducted more-detailed airborne surveys to the north in MOUNT DOREEN and NAPPERBY (Carter, 1960) and to the east in ALICE SPRINGS (Tipper, 1969) and ALCOOTA (Wyatt, 1974). Ground geophysical follow-up of some of this work has also been carried out by BMR (Haigh, 1968, 1971).

The regional aeromagnetic and radiometric coverage of LAKE MACKAY, MOUNT DOREEN, NAPPERBY and MOUNT PEAKE was completed by BMR in 1976 using north-south flight-lines spaced 1.5 km apart at a height of 100 m a.g.l. (BMR, 1976). At the same time, the northern half of HERMANNSBURG was reflown using this same configuration, while a slightly more detailed survey was carried out over the Ehrenberg Range in northeast MOUNT RENNIE to aid the interpretation of the complex geology in that area.

There is no known record of detailed ground geophysical surveys carried out over basement rocks within MOUNT RENNIE and MOUNT LIEBIG apart from a small-scale ground magnetic and geochemical survey in 1973 by the Northern Territory Geological Survey (Barraclough, 1975) in the vicinity of some small copper prospects near Haast Bluff Settlement.

3. SURVEY METHODS

Pre-Survey Work

Qualitative re-interpretation of relevant parts of the 1965 airborne survey delineated several magnetic and radiometric zones, associated with Precambrian rocks of the Arunta Block, within MOUNT RENNIE, MOUNT LIEBIG and HERMANNSBURG. A comparison between these zones and the existing geological information gave rise to certain areas of interest suitable for ground follow-up work. Areas chosen generally exhibited a distinct magnetic character and were close to known outcrop so that maximum geological and geophysical control could be attained. The problem of access, as discussed above, was also an important factor in choosing areas for working.

The areas selected (Fig. 4) were:

(1) Ehrenberg Range and Mount Russell (eastern MOUNT RENNIE and northwest corner MOUNT LIEBIG).

(2) Sandy Blight North (central north MOUNT RENNIE)

(3) Kintore Range (central west MOUNT RENNIE)

(4) Willie Rockhole (central MOUNT RENNIE)

(5) Mount Putardi-Mount Udor (central MOUNT LIEBIG)

(6) Yaya Creek (central east MOUNT LIEBIG)

(7) Haast Bluff (eastern MOUNT LIEBIG)

Survey Techniques

Within each of the selected areas, the method of survey was first to determine suitable locations for traverses from air photos, taking into account locations of aeromagnetic and radiometric anomalies, proximity to outcrop, topography and access. Total magnetic intensity and total count radiometric data were collected along these traverses using a portable proton magnetometer (Geometrics G-816 with 2.4 m sensor height) and scintillometer (Austral SG-2B) respectively. Twenty-four traverses totalling approximately 66 line-kilometres of magnetic coverage were completed, with lesser radiometric coverage as this method was unsuitable in areas of thick alluvium. Examples of ground magnetic traverses are presented from two areas only (5 & 6), because in general the physical property measurements proved to be of more value in the regional interpretation than the ground magnetic traverses. Scintillometer readings are presented for these two areas only.

Rock samples were collected from outcrop along or close to the traverses where practicable. These samples were identified and described in the field and then retained for later laboratory testing (e.g. specific gravity and susceptibility measurements) as well as geochemical and geological analyses. In certain cases, oriented samples were collected for laboratory determination of remanent magnetisation, in an initial attempt to gauge the significance of remanence in the Arunta Block. Orientation of these samples (about 20 in all) was achieved using a sun-compass on _in situ_ surface samples. Although this is not the most suitable technique for palaeomagnetic sampling, it was considered some data on remanence should be obtained, since work done in basement areas in other countries (Hood, 1963; Kristoffersen, 1973; Aravamadhum, 1974; Lidiak, 1974; Coles & Currie, 1977) indicates that remanence is frequently a significant factor in the total magnetisation of rocks from basement regions.

Multi-channel gamma-ray spectrometer data were recorded using an Exploranium DISA-400A spectrometer (7.6 x 7.6 cm detector) at most specimen localities and occasionally along traverse to determine U, Th and K concentrations in the observed rocks. Ground spectrometer results are given in Appendix 1. In situ susceptibility measurements were recorded at some localities using a Bison 3101A susceptibility meter with external coil (flat-plate) attachment.

Overall, rock samples were collected from about 200 localities for subsequent laboratory work, while another 50 localities were described without samples being taken. The method of describing rocks in the field was in accordance with the requirements of BMR Geological Branch computer programs (Mayo & Long, 1976), in particular those related to storage, retrieval and sorting of geological data (programs DBLSRT, SERLFL and SFEDIT (SURFAUST SYSTEM) as devised by W. Anfiloff). As a consequence of the present survey, slight modifications were made to the data format of these programs so as to incorporate all relevant geophysical and geochemical data into the system. This data file and the remaining ground magnetic traverses are housed in the BMR Geological Branch Technical File under the classification - MOUNT RENNIE Sheet area. A copy of the data file is also available at the Alice Springs Branch of the Northern Territory Geological Survey.

4. AREA 1: EHRENBERG RANGE AND MOUNT RUSSELL

The existing MOUNT RENNIE 1:250 000 geological map (Ranford, 1968) shows this area (located in Fig. 4) to consist almost entirely of Precambrian gneissic granite (p€g) with some dolerite dykes and minor metamorphic and igneous rocks (undifferentiated). The 1965 BMR airborne survey (Figs 2 and 5) delineated a large variation of about 1000 nT in magnetic response, from north to south over these rocks. A broad positive anomaly was recorded immediately north of an area of low hills and ridges which include Mount Russell (200 m above the surrounding plains and sand ridges), whereas by comparison the rocks of the more prominent east-west trending Ehrenberg Range some 10 km to the south appear to be less magnetic or even reversely magnetised. On the basis of the magnetic response, it was decided to investigate rocks in the east and west of the

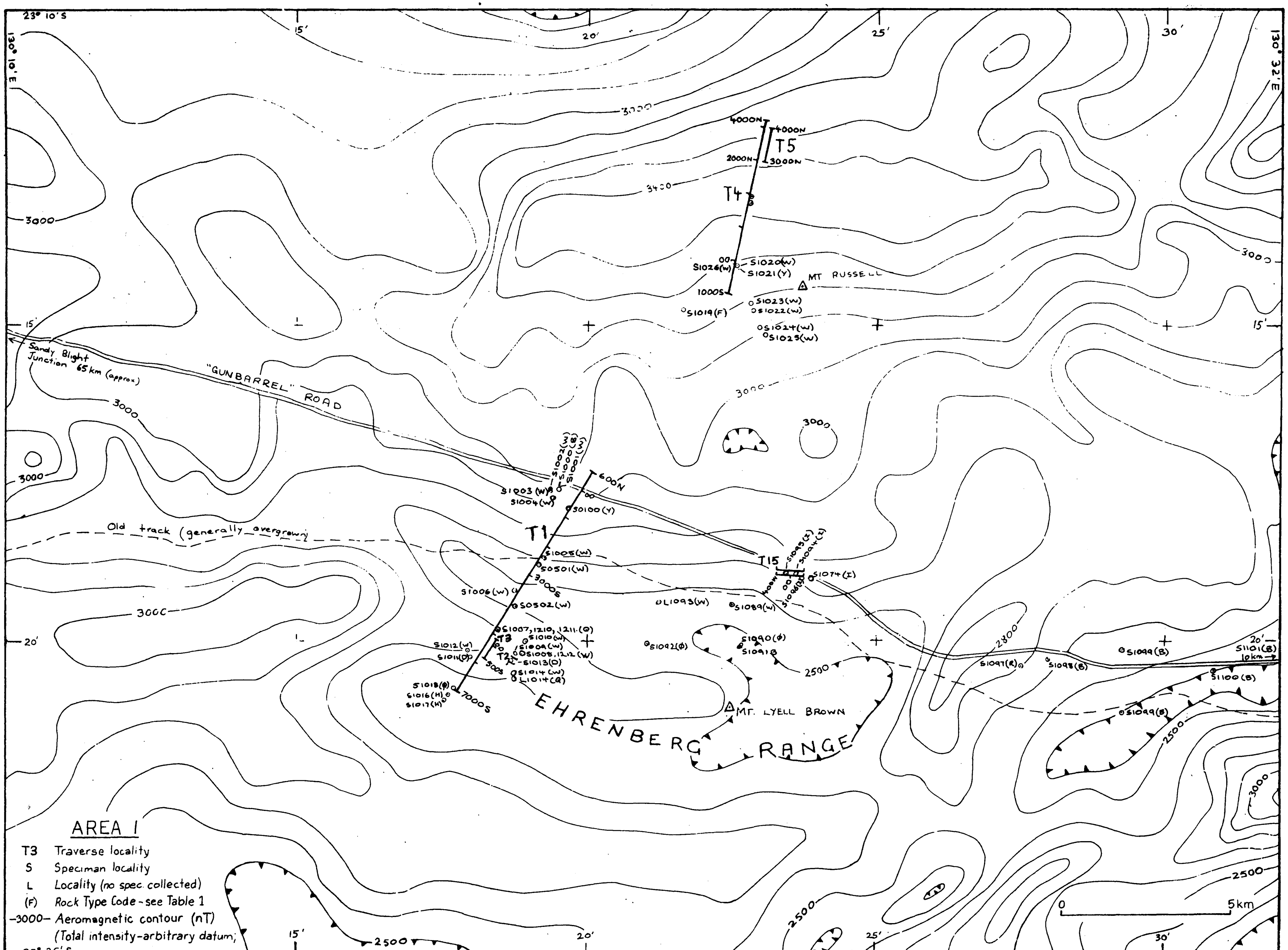

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Fig. 5 Area I - Ehrenberg Range and Mount Russell, showing aeromagnetic contours and sample and traverse locations (refer to Fig. 4 for locality map)

Ehrenberg Range and in the Mount Russell area, anticipating that rock types of more variable magnetic response than granite should be encountered.

Geology

The present work indicates that a complex situation (both geologically and geophysically) exists in this area, and that the relationship between rock type and magnetic response is not simple. The following observations are based on an analysis of some 50 samples collected from outcrop in this area. The locations of these samples are shown in Figure 5, with an indication of the rock type. The key to the rock type code is presented in Table 1.

It was found that most of the outcrops in the western Ehrenberg Range and Mount Russell areas consist of granodioritic and tonalitic granitoids containing ortho and clinopyroxenes which appear to belong to the charnockite-enderbite suite. Many have compositions close to the tonalite-granodiorite transition and could be termed charno-enderbites. In other granitic rocks potassium feldspar content exceeds 25 percent of the total feldspar and pyroxenes are lacking. Both types of granitic rock are interlayered with rare biotite gneiss and small amounts of felsic gneiss which in places intrude the charno-enderbites where the gneisses have been mobilised by migmatisation. Several factors suggest an igneous origin for the main rock type (granitoid) of the western Ehrenberg Range and Mount Russell:

(i) The consistent inclusion of both angular and rounded rock fragments which are generally biotite-rich, but include quartz-rich types containing plagioclase feldspar megacrysts and rare basic xenoliths containing labradorite, spinel and talc (S1206).

(ii) Some varieties have a well-developed compositional layering, but this may be of metamorphic origin.

(iii) Subhedral plagioclase feldspar megacrysts set in a fine-grained matrix of anhedral grains occur in many varieties. The megacrysts are commonly rounded and surrounded by exceptionally quartz-rich matrix.

(iv) Many of the rocks include rare patches of white aplite(?) up to 2 mm across.

TABLE 1. ROCK TYPE CODE USED IN TABLES AND FIGURES

A. Amphibolite, actinolite schist

B. Biotite gneiss (metasediments and gneiss of tonalite and granodiorite composition)

C. Conglomerate

D. Dolerite

E. Epidosite, calc-silicate, limestone, marble

F. Felsic gneiss (largely granitic gneisses of aplitic, calc-alkaline composition)

G. Granite, granodiorite

H. Hornblende gneiss

I. Migmatite

J. Quartz-rich metasediments (incl. Heavitree Quartzite)

K. Laterite, kunkar

L. Leucocratic (biotite) gneiss; ci 10-25; mainly of adamellite and granodiorite composition

M. Mafic granulite

N. Norite, gabbro

Ø. Orthogneiss, granitic gneiss

P. Porphyroblastic gneiss

Q. Quartzite, (quartz-schist)

R. Retrograde schist, mylonite

S. Schist, schistose, muscovite, biotite gneiss

T. Siltstone

U. Ultramafic rock

V. Garnet staurolite and cordierite-bearing gneiss

W. Granitoid, Opx-bearing Granodiorite-Tonalite (charnockite, charno-enderbite, enderbite)

X. Porphyritic hypersthene norite

Y. Sand, alluvium

Z. Sillimanite, kyanite-bearing rocks

1. Acid)
2. Intermediate) volcanic
3. Basic)
4. Acid)
5. Intermediate) metavolcanic
6. Basic)
7. Cordierite-hypersthene granofels
8. Pegmatite, aplite

TABLE 2. METAMORPHIC GRADE CODE USED IN TABLES AND FIGURES

METAMORPHIC GRADE	CODE	MINERAL ASSEMBLAGE
	10	unmetamorphosed
Greenschist	20	muscovite sericite
	30	biotite ± muscovite
	40	staurolite garnet
Amphibolite	50	muscovite + sillimanite
	60	sillimanite (no muscovite)
	70	orthopyroxene - hornblende abundant
Granulite	80	orthopyroxene - mafic
	90	orthopyroxene - felsic

In thin section the megacrysts of plagioclase can be seen to have reacted with the matrix to produce irregular plagioclase grain boundaries and an unusual zoning which parallels these boundaries. A foliation, where present (e.g. S1002), also disrupts the plagioclase megacrysts. Hypersthene and clinopyroxene relics (some of which have exsolution lamellae) are generally present and show breaking-down to hornblende and biotite. This reaction, together with the coarse-grained, polygonised nature of the matrix and the presence of poikiloblastic aggregates of biotite, suggest the rocks have been metamorphosed under amphibolite facies conditions. As the rocks are in contact with migmatised gneiss, metamorphism may have reached the upper amphibolite facies. The pyroxene-bearing granodioritic and tonalitic granitoids contain both ilmenite (up to one percent) and magnetite (up to one percent). The opaque may be rimmed by hornblende, biotite or, less commonly, sphene, which is a typical accessory. Apatite is a less common accessory (S1020, 1010, 1018). Almandine is rarely present, in small quantities (S1012).

Other varieties, lacking hypersthene or clinopyroxene, are more even grained and, in general, are coarser grained. These types are typically granodiorite and, less commonly, granite in composition and are much more like intrusive rocks in appearance. The granodiorites contain both hornblende and biotite and closely resemble the charno-enderbitic granitoids in thin section. They differ in containing a reduced proportion of magnetite (01. to 0.6 percent), negligible ilmenite and, in some cases, in containing hematite.

Hornblende and biotite gneisses (S1016, 1017) crop out in the low hills south of the Ehrenberg Range. These consist of schistose hornblende gneiss which generally contains biotite and rarely contains garnet. A ridge formed of granitic gneiss of granodioritic composition (S1018) occupies a transitional position between the charno-enderbitic granitoids and hornblende gneisses. The granitic gneiss is considered to be related to the hornblende gneiss as it is garnet-bearing.

Small lenses of quartzite (S1007, L1015) are localised in several places along faults in the Ehrenberg Range. Most varieties are feldspathic and many of these are epidote-rich. The quartzites rarely contain biotite. Numerous north-trending dykes of unmetamorphosed fine-grained dolerite

(S1013) intrude the charno-enderbitic granitoids in the south of the Ehrenberg Range, near the contact between these rocks and gneissic granite which is the most abundant rock type further to the east.

In the Mount Russell area, rock types are granodiorite in composition, and are very similar to, but consistently more basic than the rocks in the Ehrenberg Range; plagioclase commonly accounts for more than 85 percent of the total feldspar. The rocks in both areas have generally been metamorphosed to the amphibolite facies, but in the vicinity of Mount Russell, the presence of hypersthene-bearing granodioritic rocks indicates the granulite facies may have been reached. These hypersthene-bearing rocks are possibly related to highly magnetic norites which were found further to the west in Area 2 (see below).

Gneissic granite (S1090, 1092) and migmatite (S1094-1096) crop out extensively in the eastern Ehrenberg Range and in the low-lying hills to the north and south where migmatite appears to be more common. The main body of gneissic granite at Mount Lyell Brown (Fig. 5) is extensively intruded by dolerite dykes which have been previously described (Wells & others, 1965). The migmatitic gneisses are commonly of adamellite and granodiorite composition. North-trending dykes have a sinuous outcrop pattern, and are typically medium-grained, jointed and blocky. They are much more abundant than the more-sheared and finer-grained west-trending dykes which they appear to cut. Some dolerites (e.g. S1011) contain ilmenite only, others contain magnetite (e.g. S1013). Both sets of dykes are intruded by rare white, fine and medium-grained hornblende and biotite granite aplite dykes which also trend westerly.

Physical Property Measurements

Forty-one samples from this area were collected and measured for susceptibility and density. The remanent magnetism of 6 of these samples was also determined. These results are presented in Table 3. Susceptibility values were on the average higher than for the whole of MOUNT RENNIE and MOUNT LIEBIG (Precambrian rocks only). In particular, the rocks at Mount Russell had significantly higher susceptibilities than those in both the eastern and western Ehrenberg Range. This implies that the surface rocks have similar magnetic properties to those at greater

TABLE 3. PHYSICAL PROPERTIES OF ROCKS - AREA 1, EHRENBERG RANGE AND MOUNT RUSSELL

Sample No.	Lat. (S)	Long. (E)	Rock Type	Rock Unit	Code (*)	Met. Grade Code (**)	Susceptibility (SI units X 10^6)	REMANENT MAGNETISM Intensity (mA/m)	Decln. (Deg)	Incln. (Deg)	Q Ratio	Specific Gravity	Comments
(a) WEST EHRENBERG RANGE (T1, T2, T3)													
0100	23°17.90'	130°19.65'	Sand	-	Y	-	8 800	-	-	-	-	-	
0501	23°18.80'	130°19.15'	Opx-granitoid	Ehrenberg Metm.	W	65	23 700	-	-	-	-	2.73	
0502	23°19.45'	130°18.75'	Granitoid	"	W	50	15 400	-	-	-	-	2.74	Deformed
1000	23°17.60'	130°19.50'	Granitoid	"	3	80	31 400	-	-	-	-	2.72	
1001	23°17.60'	130°19.50'	Opx-granitoid	"	W	80	22 000	26 000	92.7	49.2	27.6	2.75	
1002	23°17.58'	130°19.35'	Opx-granitoid	"	W	80	30 000	5 300	309.4	-67.1	4.1	2.74	
1003	23°17.60'	130°19.35'	Opx-granitoid	"	W	80	36 000	-	-	-	-	2.74	
1004	23°17.72'	130°19.40'	Opx-granitoid	"	W	80	30 100	-	-	-	-	2.75	
1005	23°18.70'	130°19.25'	Opx-granitoid	"	W	70	20 300	-	-	-	-	2.71	
1006	23°19.20'	130°18.75'	Opx-granitoid	"	W	80	21 200	-	-	-	-	2.75	
1007	23°19.80'	130°18.45'	Sandstone	Mt Lyell Quartzite	Q	20	190	-	-	-	-	2.85	Deformed
1008	23°20.20'	130°18.85'	Granitoid	Ehrenberg Metm.	W	20	8 800	-	-	-	-	2.75	
1009	23°20.20'	130°18.80'	Opx-granitoid	"	W	20	21 000	-	-	-	-	2.74	
1011	23°20.25'	130°18.00'	Dolerite	Ehrenberg Dolerite	D	0	19 000	16 000	297.6	-44.2	19.7	3.00	
1012	23°20.15'	130°17.95'	Granitoid	Ehrenberg Metm.	W	20	35 200	-	-	-	-	2.81	
1013	23°20.33'	130°18.70'	Dolerite	Ehrenberg Dolerite	D	0	2 600	9 700	14.4	26.2	87.2	3.10	
1014	23°20.50'	130°18.75'	Granitoid	Ehrenberg Metm.	W	20	15 000	-	-	-	-	2.79	
1016	23°20.85'	130°17.60'	Hornblende Gneiss	Ehr. Hornb. Gneiss	H	40	2 300	-	-	-	-	2.80	
1017	23°20.95'	130°17.55'	?Amphibolite	"	H	40	1 260	-	-	-	-	2.81	
1018	23°20.75'	130°17.70'	Granitic Gneiss	Ehr. Gneiss	Ø	40	3 500	-	-	-	-	2.71	
1212	23°20.20'	130°18.85'	Granitoid	Ehrenberg Metm.	W	20	2 510	-	-	-	-	2.73	
							(AV = 17 073) excl. S0100					(AV = 2.79)	

* metm. = metamorphics

TABLE 3 (Continued)

Sample No.	Lat. (S)	Long. (E)	Rock Type	Rock Unit	Code (*)	Met. Grade Code (**)	Susceptibility (SI units X 10^{6})	REMANENT MAGNETISM				Specific Gravity	Comments
								Intensity (mA/m)	Decln. (Deg)	Incln. (Deg)	Q Ratio		
(b) MOUNT RUSSELL (T4, T5)													
1019	23°14.75'	130°21.65'	Felsic Gneiss	Ehrenberg metm.	F		3 000	-	-	-	-	2.61	
1020	23°14.05'	130°22.55'	Opx-granitoid	"	W		19 300	-	-	-	-	2.72	
1021	23°14.05'	130°22.55'	Alluvium	-	Y		177 000	-	-	-	-	-	Heavy Mineral (Magnetite) Sand
1022	23°14.75'	130°2[illegible].85'	Opx-granitoid	Ehrenberg metm.	W		32 200	-	-	-	-	2.76	
1023	23°14.65'	130°22.80'	Opx-granitoid	"	W		21 000	-	-	-	-	2.71	
1024	23°15.05'	130°22.95'	Opx-granitoid	"	W		25 800	-	-	-	-	2.74	
1025	23°15.15'	130°23.05'	Opx-granitoid	"	W		29 000	-	-	-	-	2.76	
1026	23°14.00'	130°22.50'	Opx-granitoid	"	W		21 400	-	-	-	-	2.70	
1027	23°13.05'	130°22.80'	Granitoid	"	W		20 100	-	-	-	-	2.74	
							(AV = 21 475) excl. S1021					(AV = 2.72)	
(c) EAST EHRENBERG RANGE (T15)													
1074	23°19.00'	130°23.90'	Migmatite	Migmatite	I	50	3 770	-	-	-	-	2.73	
1089	23°19.45'	130°22.50'	Granitoid		W	70	22 400	-	-	-	-	2.75	
1090	23°20.10'	130°22.65'	Granodiorite		Ø	50	14 000	-	-	-	-	2.73	
1091	23°20.11'	130°22.65'	Gneiss aplitic		8	60	4 400	-	-	-	-	2.63	
1092	23°20.05'	130°21.05'	Adamellitic Gneiss		Ø	50	9 200	-	-	-	-	2.78	
1094	23°18.97'	130°23.60'	Migmatite, (granitic)		I		21 700	-	-	-	-	2.77	
1095	23°18.95'	130°23.45'	Migmatite (granodioritic)		I	50	23 200	-	-	-	-	2.73	
1096	23°19.00'	130°23.70'	Migmatite		I	50	39 000	5 800	178.6	0.7	3.5	2.82	
1097	23°20.40'	130°27.50'	Mylonite		R	20	220	-	-	-	-	2.87	
1098	23°20.30'	130°28.00'	Gneiss, pelitic		B	50	25 000	17 000	121.5	30.7	15.9	2.76	
1100	23°20.50'	130°30.85'	Gneiss, biotite		B	50	11 000	-	-	-	-	2.74	
							(AV = 15 808)					(AV = 2.76)	

* see Table 1

** see Table 2

depth which produce aeromagnetic anomalies, since surface susceptibility values vary in accordance with the aeromagnetic highs and lows. The 23 samples of Ehrenberg pyroxene-bearing granitoids measured have uniformly high susceptibilities ranging from 2500 to 51 000 x 10^{-6} SI units (average 22 000 x 10^{-6} SI) suggesting that these rocks may be a cause of magnetic anomalies in the region. Dolerites from the Ehrenberg Range area have only moderate susceptibilities (2600 to 19 000 x 10^{-6} SI units). The widespread occurrence of highly metamorphosed rocks in Area 1 suggests that magnetite contents and hence susceptibilities of parent rock types may have changed markedly,thus causing difficulty in distinguishing individual rock types on the basis of their magnetic properties.

Specific gravities were similar to or slightly higher than the average specific gravity of rocks (2.74) in the region as a whole, the exception to this being the doleritic dykes which averaged 3.00 (see Table 3).

Ground Magnetics

The magnetic response along a 7 km traverse (T1) extending southwest from the 'Gunbarrel' road exhibits irregular short-wavelength (100 to 200 m) variations superimposed on a broader anomalous response. This broad response represents macroscopic changes in the main rock type at depth, as indicated by the variation in composition of the individual intrusive bodies from acid near the road to intermediate further south. The shorter wavelength variations may represent subtle changes in composition of the pyroxene-bearing granitoids (charno-enderbites). These changes may be interpreted as highly aluminous flows of acid to intermediate composition which have been metamorphosed to the upper amphibolite facies. Such flows would be expected to have irregular variation in magnetic response,with good continuity along strike. A traverse parallel to T1 (T3) over 700 m (Fig. 5), indicates that the strike of the main structures is close to east-west. The magnetic response on T1 indicates the presence of faults between different rock units, such as at 2750S, 4000S.

A short double traverse (T2 and 2A) over a dolerite dyke in the southern part of the Ehrenberg Range shows that there is an anomaly associated with the doleritic outcrop, but it may be reversely magnetised.

A sample of this rock (S1013) has only moderate susceptibility but moderate to high remanent magnetisation (Table 3).

A 5 km north-south traverse (T4) immediately west of Mount Russell shows no broad variation but only short-wavelength variations (again 100-200 m) in magnetic response. The rocks in the Mount Russell area are pyroxene-bearing granitoids (charno-enderbites) of substantially the same composition as those in the Ehrenberg Range, and hence give a similar local response (short-wavelength, small amplitude anomalies). However, the background level is approximately 800 nT higher in the Mount Russell area than to the south. This is also evident in the aeromagnetic data, where a broad magnetic high distinctly separates Mount Russell from the lower response (negative with respect to Mount Russell) of the rocks in the Ehrenberg Range to the south. In the northwest of the Mount Russell area, the pyroxene-bearing granitoids (charno-enderbites) are interlayered with felsic gneiss, a rock type which would be expected to be even less magnetic than the granitoids (charno-enderbites) which are typically of granodiorite and tonalitic composition. It is postulated that the regionally higher magnetic response is possibly due to underlying mafic granulites (high metamorphic grade) similar to those that crop out in HERMANNSBURG, or else magnetic hypersthene norites which are found only 80 km to the west in Area 2 (see below). Association between charnockites (pyroxene-bearing granites and granitoids) and granulite is common, good examples of which occur in the Musgrave Block (Major, 1973). The absence of underlying granulites or norites in the Ehrenberg Range would thus account for the marked contrast in aeromagnetic response.

The response recorded on T4 in general suggests that a structurally complex situation exists in the near-surface rocks, particularly south of 2000N along the western foothills of Mount Russell. Anomalies at 2700N and 3900N indicate faults or contacts within the sequence, the latter location being interpreted as the contact between pyroxene-bearing granitoids (charno-enderbites) and felsic gneisses to the south and chalcedonic limestone and calcrete to the north. The nature of the contact and relationship between the rock types is not known. A short traverse (T5) parallel to the northern end of T4 suggests this contact strikes approximately north-west.

The ground magnetic response over migmatitic biotite gneiss and migmatite in the eastern Ehrenberg Range (traverses T15 and 15A Figure 9) was locally quite anomalous, in particular giving a large anomaly to 2000 nT amplitude. A sample of massive migmatite on T15 (S1096) was shown to have a moderate remanent magnetism but high susceptibility (Table 3). A dyke of massive dolerite intersected by T15 and 15A has no particular magnetic anomaly associated with it, in accordance with susceptibility data for dolerites from Area 1. The overall magnetic response in the eastern Ehrenberg Range has a similar background value (total intensity) to the response further west, this being part of the broad magnetic low measured over the Ehrenberg Range in the 1965 aeromagnetic survey.

Radiometrics and Geochemistry

Scintillometer readings were unreliable along T1 owing to faulty equipment. Readings on T4 showed a general decrease in response from areas of suboutcrop to alluvium, but highest readings were generally less than twice background and did not reveal any diagnostic character of the rocks. However, gamma-ray spectrometry showed the granitoids to have a radioactivity in the range 10-16 μR/hr (micro-Röentgens per hour) with potassium and thorium the major contributors. Radioactivity over the limestone at the northern end of T4 was similar to background (i.e. about 8 μR/hr).

Gamma-ray spectrometer measurements were made over sites from which rock samples were collected. The multi-channel data were reduced using calibration constants which were not well defined at the time of the work as the instrument had not been used previously under survey conditions. The results of the radioelement determinations from the gamma-ray spectrometry compared with rock sample analyses are included in Appendix 1 (see also Wilkes, 1978).

5. AREA 2: SANDY BLIGHT NORTH

The MOUNT RENNIE geological map (Ranford, 1969) shows an extensive occurrence of Precambrian schists and amphibolites (p€s) north of the 'Gunbarrel' road in the vicinity of Sandy Blight Junction. Fifteen km northeast of this road junction a strong aeromagnetic feature of 1400 nT amplitude (Fig. 6) coincides with the crest of the 'Papunya Gravity High' (Lonsdale & Flavelle, 1963). Gravity modelling (Mathur, 1976; Anfiloff & Shaw, 1973; Wellman, 1978) indicates that high density rocks may be present close to the surface, and hence rocks other than those mapped "p€s" should be encountered.

Two areas were examined, the first on the flanks of the aeromagnetic feature and including traverses T6 and T7, and the second some 5 km further west in a magnetically quieter area (T8). Fourteen observations on rock outcrop were recorded in the first area, and 5 in the second, the location of these being shown in Figure 6.

Geology

The eastern area (traverses T6 and T7) consists mainly of a recrystallised hypersthene norite (S1037, 1038) consisting of euhedral phenocrysts of hypersthene and rare olivine set in a very fine-grained matrix which contains small amounts of clinopyroxene and olivine in addition to hypersthene (60 percent) and plagioclase. Just south of this body of hypersthene norite, and probably overlying it, is a body of hypersthene-plagioclase-cordierite granofels containing numerous angular fragments of plagioclase and plagioclase-spinel rock. This metavolcanic appears to contain 0.5 percent magnetite, and may represent metasediment partly altered by the norite as it contained grains of zoned plagioclase and hypersthene with exsolution lamellae. Except for its unusually high quartz content, this presumed metavolcanic is petrographically similar to the pyroxene-bearing granitoids (charno-enderbites) of the Ehrenberg Range and Mount Russell area.

A small body of fine-grained meta-gabbro (S1030) occurs on the sand plain immediately to the southwest of the norites and presumed metavolcanic rocks. The meta-gabbro contains a small amount of clino-

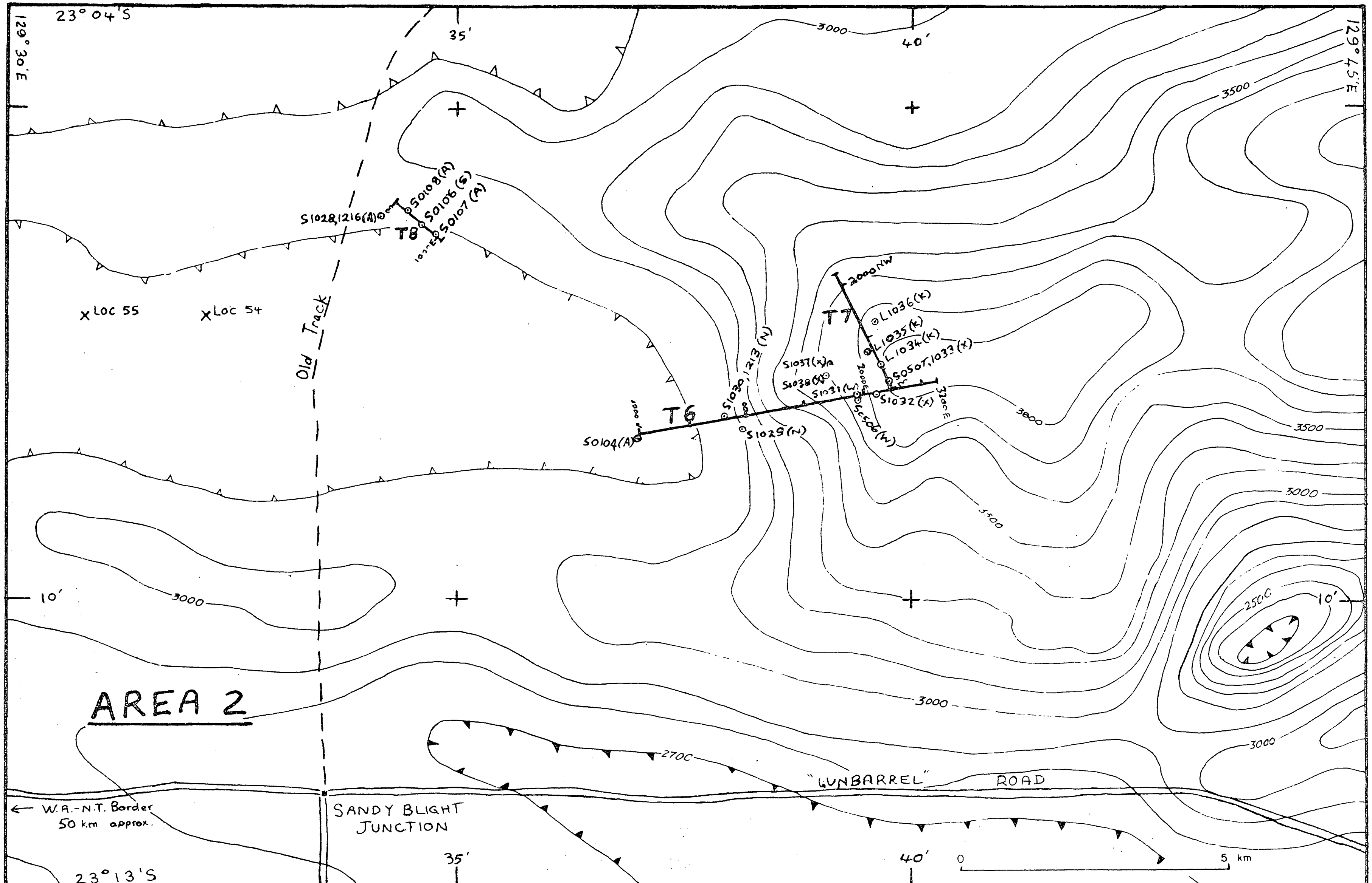

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Fig.6 Area 2-Sandy Blight North, showing aeromagnetic contours and sample and traverse locations (refer to Fig.4 for locality map)

TABLE 4. PHYSICAL PROPERTIES OF ROCKS - AREA 2, SANDY BLIGHT NORTH

Sample No.	Lat. (S)	Long. (E)	Rock Type	Rock Unit	Code (*)	Met. Grade Code (**)	Susceptibility (SI units X 10^6)	Intensity (mA/m)	Decln. (Deg)	Incln. (Deg)	Q Ratio	Specific Gravity	Comments
0104	23°8.35'	129°37.00'	Amphibolite	Dufaur Schist	A	30	99	-	-	-	-	3.04	
0106	23°6.20'	129°34.60'	Schist	" "	S	30	125	-	-	-	-	2.72	
0108	23°6.05'	129°34.45'	Amphibolite	" "	A	20	1 200	-	-	-	-	3.18	
0506	23°7.95'	129°39.40'	Opx-cordierite granofels	Granofels	7		60 300	-	-	-	-	2.76	
0507	23°7.75'	129°39.75'	Opx-norite	Lindsay Metanorite	X	10	16 400	-	-	-	-	3.14	
1029	23°8.25'	129°38.15'	Gabbro	Lindsay Gabbro	N	10	830	2 900	237.5	70.7	81.7	3.02	
1030	23°8.15'	129°37.95'	Gabbro	" "	N	5	590	570	262.8	63.4	22.6	3.00	
1031	23°7.90'	129°39.40'	Cordieritic granofels	Granofels	7		21 000	33 000	158.1	77.2	36.7	2.87	
1032	23°7.90'	129°39.60'	Opx-norite (meta)	Lindsay Metanorite	X	10	15 000	-	-	-	-	3.19	
1033	23°7.75'	129°39.75'	Opx-norite (meta)	" "	X		18 800	-	-	-	-	3.17	
1037	23°7.60'	129°39.10'	Opx-norite (meta)	" "	X	10	3 900	9 600	6.0	19.3	57.5	3.16	
1038	23°7.70'	129°39.05'	Opx-norite (meta)	" "	X	10	3 000	-	-	-	-	3.14	
							(AV = 11 845)					(AV = 3.03)	

* See Table 1

** See Table 2

pyroxene and quartz in addition to both green and blue-green hornblende and plagioclase. The body is subdivided by a fault. ?Amphibolite (SO104) and schists were encountered at the western end of T6.

The western area (traverse T8) contains highly folded and steeply dipping quartz-chlorite-sericite-schist (SO106) and small amounts of actinolite-rich schist (?amphibolite) (SO107, 0108). The schist is probably metamorphosed siltstone and sandy siltstone. Quartz veins are very common in the schists. Similar rocks are widely distributed throughout the northern part of MOUNT RENNIE; less common rock types recorded by Wells & others (1965) include tourmaline-quartz-sericite schist and quartz amphibolite. Small bodies of white medium-grained aplitic granite and biotite granite accompany the schists and possibly intrude them.

Both outcrop areas are deeply weathered in places, particularly in the east. The deep weathering has resulted in laterite and ferruginous silcrete deposits (L1034). This weathering profile is overlain in places by thin deposits of calcrete. In other places the calcrete lies directly on schist.

Physical Properties

Twelve samples, covering all rock types excluding laterite and calcrete, were collected for measurement, and the results are shown in Table 4. Distinct physical differences are observed between the various rock types. The metavolcanics and norites recorded high susceptibilities (3000 to 60 000 x 10^{-6} SI units, whereas the gabbros, amphibolites and schists were relatively non-magnetic (average 700 x 10^{-6} SI units). Remanent intensities were found to be highest in the presumed metavolcanics and least in the gabbro. Specific gravites recorded for the norites (average 3.16) and amphibolites (3.11) were very high, gabbros (3.01) moderately high, and the ?metavolcanics and schists (2.72-2.87) were lower. These values suggest that a large body of norite could account for the positive Bouguer anomaly feature ('Papunya Gravity High') referred to above. The location of norite outcrop does, in fact, coincide with the western extent of this feature. Poor access prevented further investigation of the gravity anomaly.

Magnetics

On T6, amphibolites and schists between 1000W and 2000W give a flat magnetic response with only small variations of 20 to 50 nT. The meta-gabbro outcrop between 200W and 00 yields only a slight increase in total magnetic intensity with again a flat response. The contact between the gabbro and the hypersthene norite and hypersthene-cordierite granofels bodies appears to be near 500E on T6, as evidenced by the incoming of a strong positive anomaly (1000 nT amplitude) on the ground magnetic response. This location correlates closely with the steepest part of the gradient observed on the aeromagnetic contours (Fig. 6). T6 indicates that the magnetic rocks continue up to and probably beyond 3000E, which is in agreement with the aeromagnetic response. The response recorded on T7, approximately perpendicular to T6, did not define the northern limit of the magnetic body, but it did delineate a fault or similar structure at about 2000NW. The presence of ferruginous laterite along T7 and the eastern end of T6 has some effect on the response, giving short-wavelength, small-amplitude anomalies in general.

It is considered that the main peak of the positive magnetic anomaly observed on T6 and the aeromagnetic pattern can be related directly to the occurrence of high-susceptibility, intrusive hypersthene norite. Because the hypersthene-cordierite granofels is so like the pyroxene-bearing granitoids (charno-enderbites) of Area 1, the overall broad magnetic ridge may again be due to underlying granulites which could be expected to be associated with the charnockitic rocks. The similarity between the magnetic response here and at Mount Russell is not so apparent, owing, presumably, to the differing effects on each response of near-surface material.

On T8 the actinolite-amphibolite is surprisingly non-magnetic, probably because it is a metamorphosed calcareous sediment, and hence it is magnetically indistinguishable from the sericite schists with which it is interlayered. The aeromagnetic low (Fig. 6), over which T8 and the western end of T6 are located, thus appears to represent broad areas of this sequence of schists and amphibolites. Similar rocks have been found to crop out at Mount Lindsay and the Dufaur Hills some 10 km to the west of T8 as noted by Wells & others (1965) at localities 54 and 55 in MOUNT RENNIE (Ranford, 1968).

Radiometrics and Geochemistry

Scintillometer readings on both T6 and T7 did not exceed background levels (5-7 μR/hr) despite the variation in rock types. In particular the laterite encountered on T7 did not have any effect on the response.

6. AREA 3: KINTORE RANGE

Situated in the west of MOUNT RENNIE, this area (Fig. 7) is dominated by the imposing northeast-southwest trending Kintore Range containing the prominent peaks of Mount Strickland and Mount Leisler, the latter rising over 400 m above the surounding plains. A graded road runs southwest from Sandy Blight Junction down the eastern side of the range. Existing geological mapping shows this road to separate predominately Precambrian granite to the east from intermediate and basic volcanics to the west. The volcanics are unconformably overlain by Upper Proterozoic Heavitree Quartzite (Euh) which dips gently to the west and forms a sharp escarpment at its eastern edge near the contact with the volcanic rocks. This escarpment forms the main ridge of the Kintore Range. Other rocks on the existing map include low hills of Precambrian quartzite immediately southwest of Sandy Blight Junction. A large portion of the area is covered by Tertiary conglomerate (Tc), sand and alluvium.

Geology

A traverse (T10) was located across outcrop forming low hills 3 km southwest of Sandy Blight Junction. Samples from 9 localities (S1039-1047) along this traverse showed the outcrop to be a uniform quartzite, being generally medium-grained (1-2 mm) in the north but fine-grained (less than 0.5 mm) south of 1300S. Coarse-grained (4 mm) feldspathic sandstone (S1040) is found in a small valley at 800S. Outcrops between 1500S and 2000S show iron-staining which may reflect a significant iron oxide content at depth. The small ridge further south at 2900S again consists of medium-grained quartizte. This quartzite unit is unlike the Heavitree Quartzite which occurs 20 km to the southwest, but is considered to be equivalent to the older Chewings Range Quartzite of

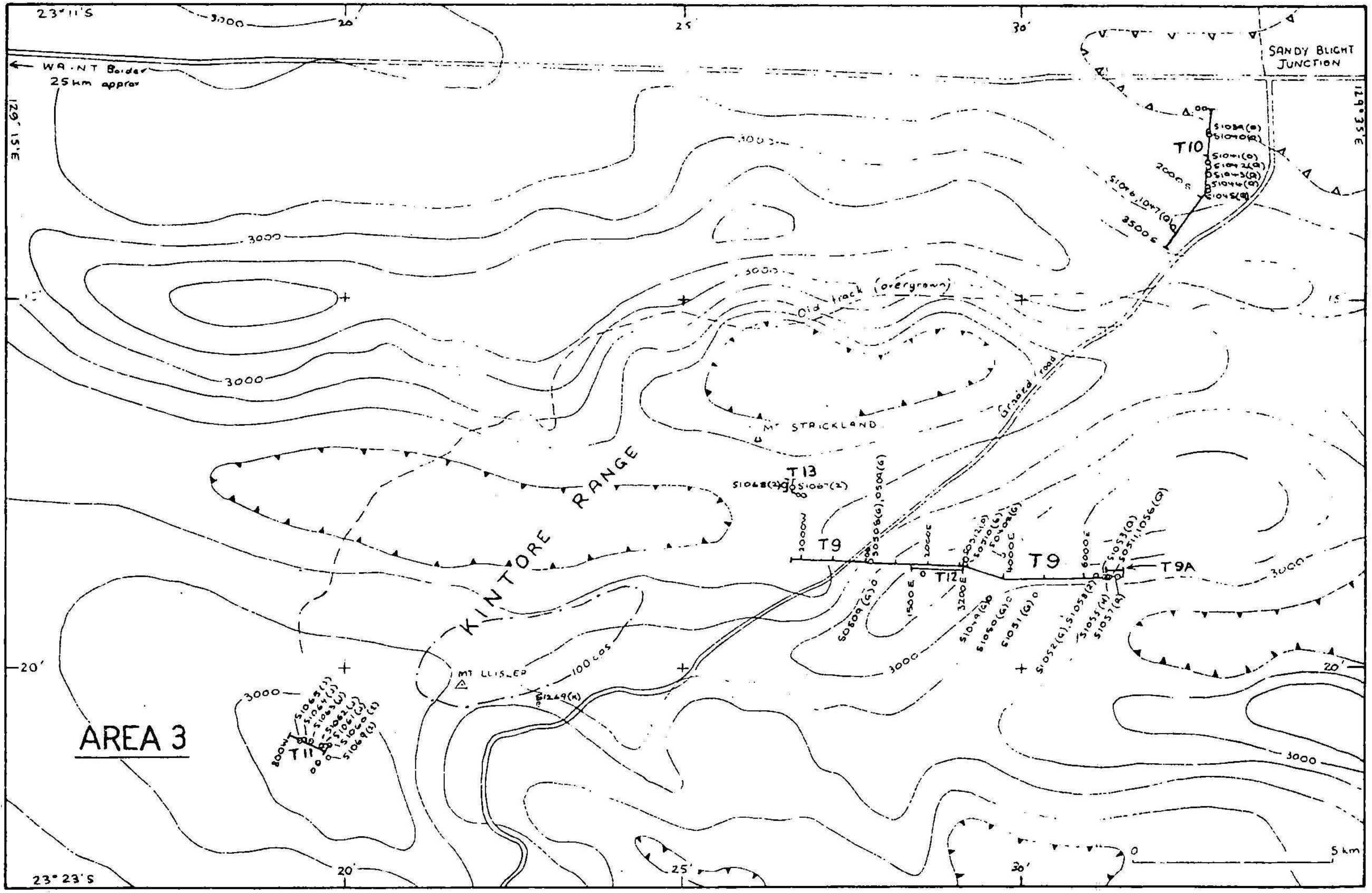

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Fig. 7 Area 3 Kintore Range, showing aeromagnetic contours and sample and traverse locations (refer to Fig. 4 for locality map)

TABLE 5. CHEMICAL ANALYSIS OF DACITE UNDERLYING HEAVITREE QUARTZITE IN THE KINTORE RANGE

	(1) 75091067	(2) Specimen from Lat. 23.2925^{o}E Long. 129.4433^{o}S
SiO_2	64.41	67.20
TiO_2	0.84	0.86
Al_2O_3	14.53	13.70
Fe_2O_3) FeO)	6.00	6.39
MnO	0.11	0.09
MgO	1.73	1.31
CaO	4.70	3.50
Na_2O	3.97	3.70
K_2O	2.41	2.80
P_2O_5	0.16	0.20
H_2O^+	-	0.29
H_2O^-	-	0.09
CO_2	-	0.02
TOTAL	99.25	99.80

(1) Job number AN 195/76. A.M.D.E.L. ANALYSES CODE H4 26-08-75

(2) Reference 28, Joplin, G.A. 1975 - Chemical Analyses of Australian Rocks. Part III: Igneous and Metamorphic, Supplement 1961-1969. Analysis by C.R. Edmond, A.M.D.E.L.

the Alice Springs area. One interbed contains diopside and microcline suggesting correlation with the actinolite and sericite schists in the area north of Sandy Blight Junction.

Precambrian granite (p€g) was found to be the predominant outcropping rock along traverse T9 for a distance of over 7 km east of the graded road. Most of the outcrops in this area (samples S0509, 0510, 1048-1052, 1059) consist of massive biotite adamellite and small amounts of granodiorite and granite which vary in grain size and biotite content (generally less than 10 percent, but as high as 27 percent at a few localities). Two (0509, 1051) contain traces of hornblende. Many of the adamellites contain hematite in addition to magnetite. The adamellites are intruded by very thin dolerite dykes (S0512) which are seldom more than 10 cm wide. Ferruginous fine-grained sandstone float (S1066) collected on the sandplain at 1650E on T12 (parallel to T9) is not Heavitree Quartzite as it contains biotite. A strike ridge at the eastern end of T9 consists of quartzite (S1053, 1056), thin lenses of which contain magnetite. The western part of the quartzite unit is quartz-rich whereas the eastern part is diopside-bearing and feldspathic. The quartzite is intruded by lensic units of meta-dolerite (S1055, 1057) and is itself an enclave in the granite, which was observed to crop out further east beyond this ridge.

On the eastern foothills of Mount Strickland to the west of the graded road, a short traverse (T13) was located to investigate the nature of the volcanics which underlie Heavitree Quartzite at this point. Outcrop examined here (S1067, 1068) suggests these rocks are mainly intermediate to acid in composition rather than basic as reported by Wells & others (1965). They are generally aphanitic, and exhibit a pale red-brown colour on weathering (unweathered colours are grey, green-grey and dark grey). Flow layering is evident, and Wells & others (1965) report amygdules and vesicles to be common. Two samples (S1067, and a specimen at lat. 23.2925^{o}S, long. 129.4433^{o}E (Joplin, 1975)) have been chemically analysed and indicate a dacite composition (Table 5).

A short traverse (T11) was located 4 km west of Mount Leisler, in the southern Kintore Range, to examine a sequence of shallow dipping Heavitree Quartzite. This unit is conglomeratic and feldspathic at the base (S1061, 1062) and gives way upwards to a medium-grained, fairly even-grained quartzose sandstone (?beach-sand) although repetitions of feldspathic sandstone (S1063-1065) occur. The conglomeratic member contains considerable feldspar derived from the underlying volcanic, indicating a local source. The whole unit is tentatively interpreted to be the upper and lower members of the Temple Bar Sandstone Member (Clarke, in Stewart & others, 1980) of the Heavitree Quartzite, although correlation with the Undoolya Siltstone cannot be discounted. The quartzite is overlain at the western end of T11 by highly iron-stained Tertiary conglomerates, which are in general common around the foothils of the Kintore Range (e.g. locality S1269 2 km east of Mount Leisler).

Physical Properties and Magnetics (Table 6)

Samples from 24 localities were measured for susceptibility and specific gravity values. The remanent magnetic properties of a dacitic rock (S1067) were also determined. These results are presented in Table 6.

The aeromagnetic pattern (Fig. 7) is only moderately disturbed compared with other areas to the east. The largest anomaly (an ENE trending high of 600 nT amplitude) northwest of the Kintore Range was not investigated owing to lack of outcrop and poor access. A magnetic low appears to coincide with the metavolcanics and younger sediments of the Kintore Range, whereas small amplitude anomalies (400 nT maximum) trending NE to E coincide with the granitic region to the east of the Range.

The ground magnetic response over Precambrian quartzites on T10 shows an unexpectedly large variation (up to 400 nT) considering the uniformity of the outcrop. However, surface iron staining in some places (S1044, 1045) suggests that iron oxide and perhaps other heavy mineral (in particular magnetite) concentrations may occur at different stratigraphic levels, thus explaining the irregular ground magnetic pattern. The aeromagnetic response is relatively undisturbed. Measurements made on samples S1044 and S1046 (Table 6) indicate very low susceptibilities and average specific gravities.

The magnetic response over Heavitree Quartzite (T11) drops gradually as the pebbly and feldspathic beds decrease in abundance up-section, but in general is undisturbed, except where the quartzite is overlain by Tertiary material which produces a slightly disturbed effect (200 nT) on the response west of 450W. Samples of Heavitree Quartzite (S1061-1064) proved to have very low susceptibilities (15 to 46 x 10^{-6} SI units) and low specific gravities (2.58 average).

Samples of the dacitic rock from T13 (S1067 and 1068) have moderate susceptibilities and average specific gravities as shown in Table 6. The variation in susceptibility between the two samples is in accord with the ground magnetic response, which was moderately disturbed (300 nT anomalies). This response may in part be due to structure, as there appears to be little compositional variation in the samples examined. An oriented specimen (S1067) of this volcanic rock indicates that remanent magnetism may not be significant in this case.

The ground magnetic response along T9 is variable. West of 1000E, the field is undisturbed, signifying the generally non-magnetic character of extensive granite outcrop in the vicinity. However, a sample of adamellite (S0509) 500 m south of 200E on T9 had a relatively high susceptibility (6000 x 10^{-6} SI units) suggesting that the composition and magnetic response of the granite in this area would be variable. This is seen between 1000E and 4500E on T9, where a magnetically anomalous zone contains little outcrop apart from small granitic bodies sometimes intruded by thin dolerite dykes. The major anomalies, up to 600 nT amplitude, are considered to be due to rafts of metasediments in or between the granitic plutons. The compositional variation of the granites themselves may also contribute to a lesser degree to the magnetic disturbance. The range in susceptibility of 8 samples of granite (Table 6) was 100 to 6000 SI units x 10^{-6} (average 1890 SI x 10^{-6}). Rocks close to the granite-adamellite transition have susceptibilities up to 700 x 10^{-6} SI and the other adamellites and one granodiorite had higher values. Specific gravities of these granites were uniform and typical of this rock type (average 2.66). The dolerite dyke rock had similar magnetic properties but was more dense. Between 6500E and 7000E on T9, a highly anomalous zone (1000 nT anomaly amplitude) coincides with the enclave of quartzite and meta-dolerite mentioned above. Table 6 indicates that the quartzite itself is non-magnetic (S1056) whereas the meta-dolerite (S1055) and another metabasic intrusive rock (S1058) have very high susceptibilities, and are thus considered to be the cause of the magnetic disturbance. The specific

TABLE 6. PHYSICAL PROPERTIES OF ROCKS - AREA 3, KINTORE RANGE

Sample No.	Lat. (S)	Long. (E)	Rock type	Rock Unit	Code (*)	Met.Grade Code (**)	Susceptibility (SI units x 10^6)	Specific Gravity	Comments
(a) SOUTHWEST OF SANDY BLIGHT JUNCTION (T10)									
1044	23°13.45'	129°32.70'	Quartzite	Chewings Qzite?	Q	20	60	2.64	Iron staining
1046	23°14.00'	129°32.20'	Quartzite	" "	Q	20	15	2.64	
							AV = 38	AV = 2.64	
(b) EAST OF GRADED ROAD (T9, T12)									
0509	23°18.85'	129°27.80'	Adamellite	Kintore Granite	G	10	6 000	2.68	
0510	23°18.55'	129°29.15'	Adamellite	" "	G	10	2 500	2.66	
0511	23°18.75'	129°31.40'	Quartzite	Lyell Qzite	Q	20	120	2.70	
0512	23°18.52'	129°29.15'	Dolerite	(intrudes Kintore Granite)	D	10	3 200	2.91	
1048	23°18.45'	129°29.70'	Adamellite	Kintore Granite	G	10	4 000	2.68	
1049	23°19.02'	129°29.55'	Adamellite	" "	G	10	100	2.64	
1050	23°19.07'	129°29.80'	Granite	" "	G	10	700	2.64	
1051	23°19.02'	129°30.20'	Granite	" "	G	10	600	2.62	
1052	23°18.75'	129°31.10'	Granodiorite	" "	G	10	1 100	2.67	
1054	23°18.75"	129°31.25'	Epidosite	Lyell Qzite	E	10	400	3.00	
1055	23°18.75'	129°31.27'	Amphibolite	" "	A	50	42 200	2.87	
1056	23°18.75'	129°31.40'	Quartzite	" "	Q	60	100	2.74	
1058	23°18.75'	129°31.10'	Igneous	(intrudes Kintore Granite)	2	10	20 100	3.06	

TABLE 6 (continued)

Sample No.	Lat. (S)	Long. (E)	Rock type	Rock Unit	Code (*)	Met. Grade Code (**)	Susceptibility (SI units x 10^6)	Specific Gravity	Comments
1059	$23^{\circ}18.55'$	$129^{\circ}27.75'$	Adamellite	Kintore Granite	G	10	125	2.67	
1066	$23^{\circ}18.70'$	$129^{\circ}28.55'$	Sandstone		J	10	600	2.66	Weathered - probable float
							AV = 5456	AV = 2.75)	
(c) KINTORE RANGE AREA. (T11, T13)									
1060	$23^{\circ}21.05'$	$129^{\circ}19.75'$	Altered, acid igneous rock	?Leisler Volcs	1	10	170	2.76	Position uncertain
1061	$23^{\circ}21.10'$	$129^{\circ}19.70'$	Conglomerate	Heavitree Qzite	J	10	-	2.56	
1062	$23^{\circ}21.10'$	$129^{\circ}19.65'$	Conglomerate	" "	J	10	46	2.52	
1063	$23^{\circ}21.03'$	$129^{\circ}19.50'$	Sandstone	" "	J	10	15	2.64	
1064	$23^{\circ}21.00'$	$129^{\circ}19.40'$	Sandstone	" "	J	10	40	2.59	
1067+	$23^{\circ}17.55'$	$129^{\circ}26.60'$	Dacite	Leisler Volcs	2	10	740	2.73	
1068	$23^{\circ}17.50'$	$129^{\circ}26.50'$	Dacite	" "	2	10	3800	2.77	
							(AV = 801)	(AV = 2.65)	

\+ Remanent Magnetic properties of S 1067:

Intensity = 220 mA/m Decln. = 153.7° Incln. = 4.2° Q ratio = 6.9

* See Table 1

** See Table 2

gravities of rocks on this strike ridge are also significantly higher (average 2.92) than the surrounding rocks. A short traverse (T9A) parallel to the eastern end of T9 emphasises the strong north-south lineation of the magnetic rocks. Another short traverse (T12) parallel to T9 between 1500E and 3300E also suggests that a north-south structural trend exists within the granite pluton. The contact between massive granite and a raft of metasediments is seen at 1600E on both T9 and T12.

Radiometrics and Geochemistry

Scintillometer readings over the quartzite on T10 gave consistently low values (5-6 μR/hr). The scintillometer was not used along other traverses in Area 3 owing to the large amount of sand and alluvium. Instead, the gamma-ray spectrometer was used to determine radioactivity levels at individual outcrops. These results showed the granites along T9 to be slightly radioactive (14-21 μR/hr).

The acid volcanics encountered on T13 had a radioactivity level of 13-15 μR/hr, which is more typical of acid rocks than of basic rocks as originally mapped (Ranford, 1968).

The spectrometer was also used on T11 to investigate the source of a small radiometric anomaly detected over Mount Leisler and the southern part of the Kintore Range in the airborne survey (Fig. 7). The ground readings showed a decrease in radioactivity going up the section from 18 to 4 μR/hr. The radioactivity is due to potassium and thorium, with only a low uranium content (less than 2 ppm). Even though the basal member of the Heavitree Quartzite is slightly more radioactive than surrounding rocks, it is believed that the airborne radiometric anomaly is more a reflection of topography than of geochemical variations.

7. AREA 4: WILLIE ROCKHOLE

Willie Rockhole is located in the centre of MOUNT RENNIE and approximately 20 km southeast of Sandy Blight Junction (Fig. 8). This area was chosen for several reasons:

(a) it coincides with a broad east-west trending aeromagnetic anomaly of 1400 nT amplitude;

(b) it has been mapped entirely as Precambrian granite similar to that east of the Kintore Range;

(c) it is located not far from the flight path of one of the north-south tie-lines (Tie 4N) in the 1965 airborne survey. (Tie-line data are considered to be of greater value than individual east-west flight line data in this case owing to the overall east-west trend of the geological structure).

Hence a good comparison between outcrop and airborne and ground geophysical response could be made, although areas of outcrop were in fact very few.

Geology

Very little outcrop is found owing to the presence of many longitudinal sand dunes in the area. The few outcrops encountered were flat-lying and partly sand covered. They occurred in the vicinity of Willie Rockhole (S1072, S1073) and some 4 km to the west (S1070, 1071, 1214) at the southern end of T14 (Fig. 8) and all contained granitic rock. No other outcrop was found north of these occurrences in this area.

These granites differ from those east of the Kintore Range in being coarser-grained and much more strongly foliated. They have a biotite content varying from 3 to 15 percent, an overall high colour index, and commonly contain porphyroblasts of potassium feldspar - a feature uncommon in the Kintore Range granites. The Willie granites range in composition from calc-alkaline granite to adamellite. Very small amounts (less than one percent) of hornblende and muscovite are rarely present. The strongly foliated granite has low magnetite content (0.01 to 0.03 percent) which shows alteration to hematite (S1070), but this alteration is absent in a more massive variety of the same granite (S1072).

Physical Properties and Magnetics (Table 9)

Owing to the scarcity of outcrop, only 3 samples were collected for measurement. These samples varied from massive granite (S1071, 1072)

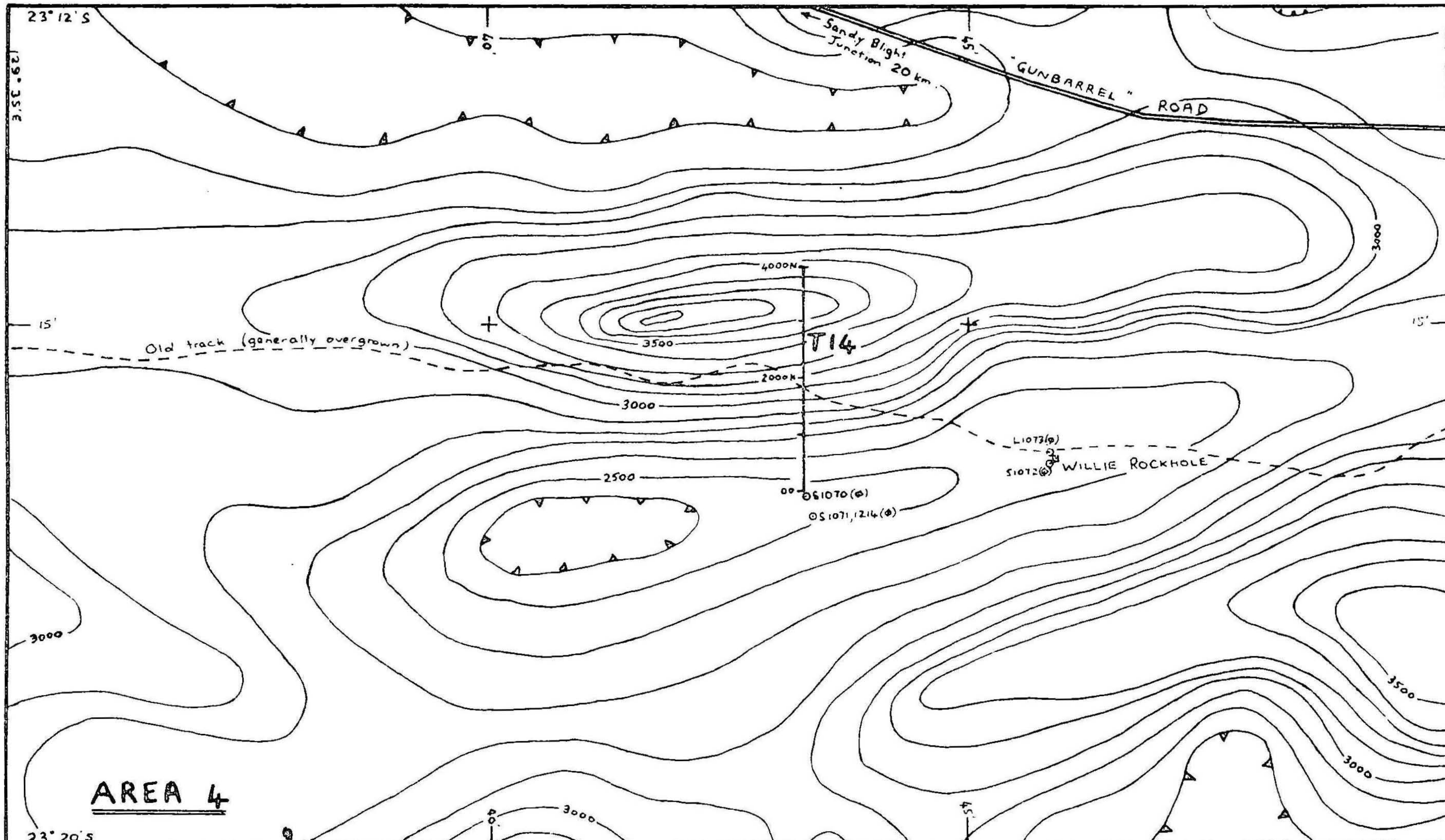

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Fig. 8 Area 4 - Willie Rockhole, showing aeromagnetic contours and sample and traverse locations (refer to Fig. 4 for locality map)

TABLE 7. PHYSICAL PROPERTIES OF ROCKS - AREA 4, WILLIE ROCKHOLE

Sample No.	Latitude (S)	Longitude (E)	Rock Type	Rock Unit	Code (*)	Met.Grade Code (**)	Susceptibility (SI units x 10^6)	Specific Gravity	Comments
1070	23°16.65'	129°43.32'	Granitic Gneiss	Willie Granite	G	10	1250	2.64	
1071	23°16.83'	129°43.38'	Granite	" "	G		20	2.57	
1072	23°16.35'	129°45.85'	Granite, massive	" "	G	10	300	2.61	
							AV = 523		

* See Table 1

** See Table 2

to foliated granitic gneiss (S1070), and are clearly shown to be weakly magnetic compared with rocks in other areas. This is consistent with the more acid, calc-alkaline composition of the Willie granites. The average susceptibility of these rocks is only 520 x 10^{-6} SI units, with the gneissic variety being the slightly more magnetic of the three. Specific gravities (average 2.61) are typical of granitic rocks.

A traverse (T14) extending 4 km due north of sample location S1070 exhibited a non-magnetic response, as would be expected, over the outcropping granite. T14 traversed the magnetic high detected by the airborne survey, and the ground traverse clearly defined the boundaries between two main magnetic bodies and the granite. The most southern contact between the granite and a magnetic rock unit occurs near 500N, while a relatively sharp contact between this magnetic unit and a more magnetic unit occurs near 2200N. The northern extent of the main magnetic body would be close to 3800N. The magnetic anomaly produced has a maximum amplitude of about 2000 nT.

The only outcropping rocks in the area could not account for such an anomaly. It is suggested that a 3 km wide east-west striking belt of highly magnetic rock, similar to the hypersthene norites or mafic granulites interpreted as being the cause of the positive aeromagnetic anomaly in the Mount Russell and Sandy Blight North areas, is also the cause of this anomaly, even though there is no immediate evidence that rocks of this type occur in the vicinity. However, the fact that the northern extent of outcropping granite coincides approximately with the magnetic contact suggests that a different rock type (weathered to greater depths) occurs north of this contact. The depth to the magnetic body, as interpreted from the magnetic response, appears to be quite shallow (less than 100 m).

Radiometrics and Geochemistry

Scintillometer readings at the south of T14 indicate that the granites have above average radioactivity. Measurements over sand gave 7 μR/hr whereas over the granite the readings were up to 18 μR/hr. A corresponding high radiometric level was not detected by the earlier airborne survey owing presumably to the very small area of outcrop of granite, which is widely covered by a thin veneer of sand.

ARUNTA SURVEY 1975
TRAVERSE 15, 15A

PROTON MAGNETOMETER (8ft POLE)

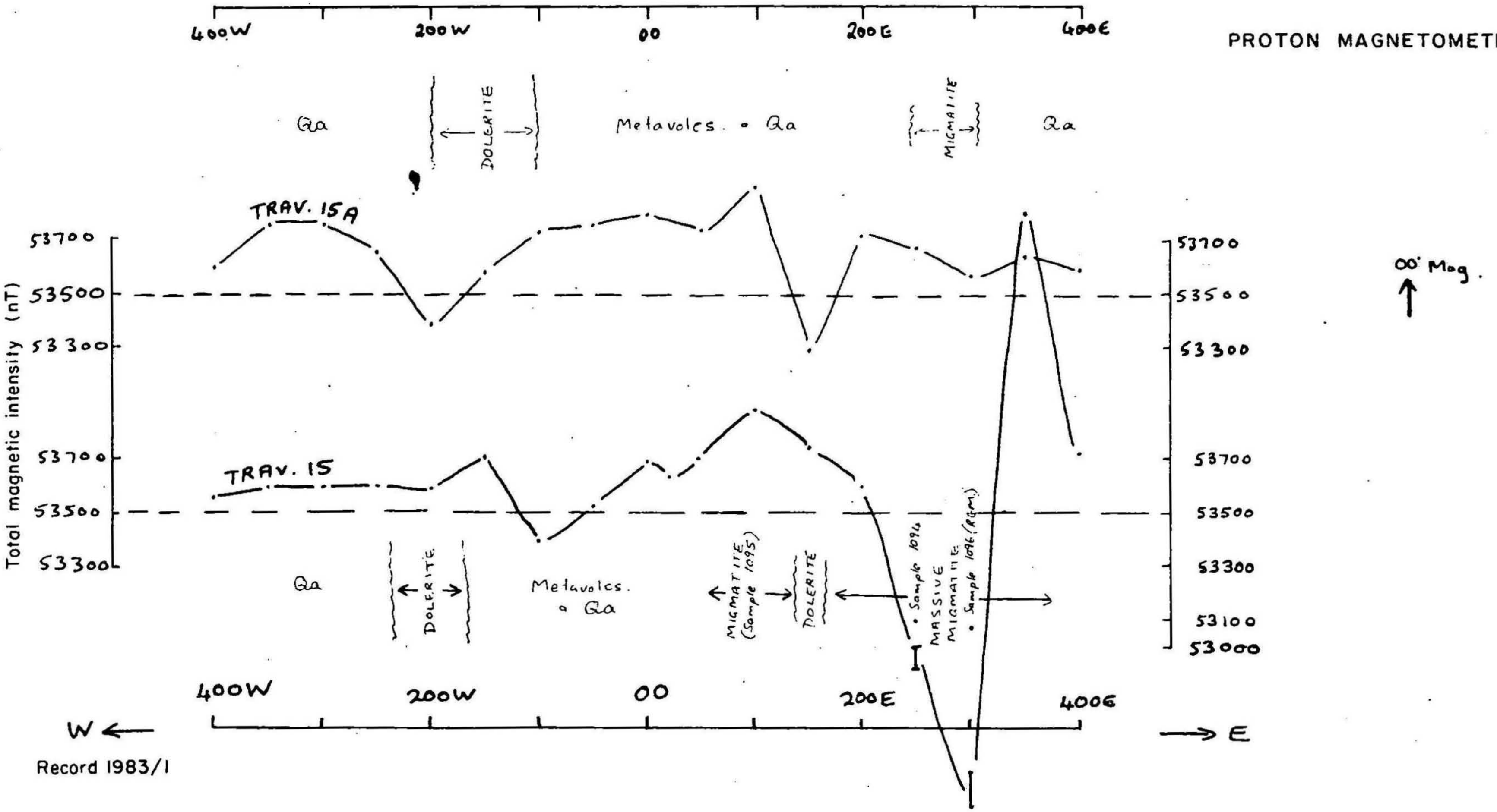

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Fig. 9 Profiles over dolerite dykes, Ehrenberg Range East area. Traverses 15, 15A. (see Area 1 for location)

16/F52/9

Gamma-ray spectrometer readings show the granite to be quite strongly radioactive (20-28 μR/hr); calculations indicate 3.5% potassium and 64 ppm thorium concentrations.

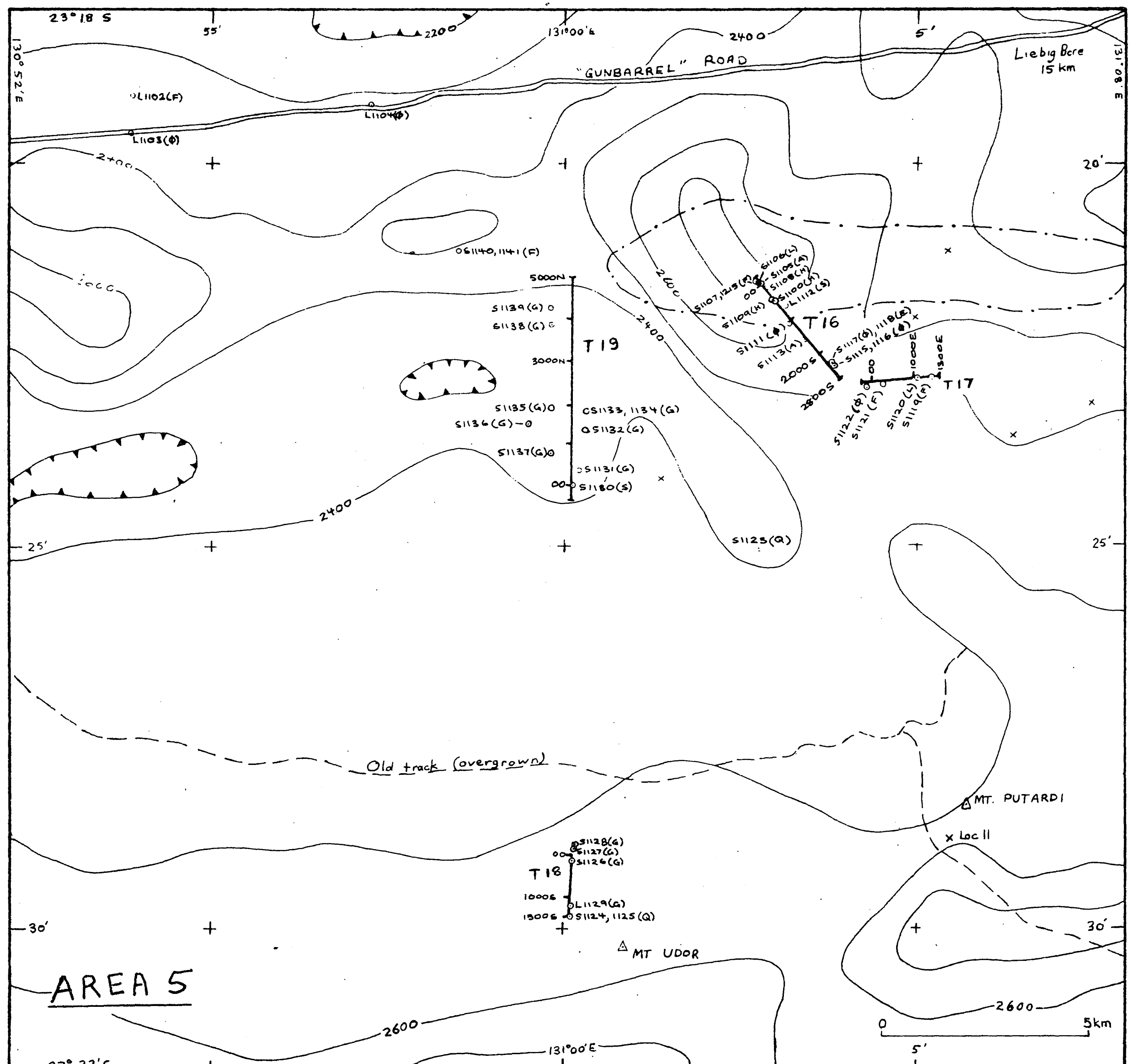
8. AREA 5: MOUNT PUTARDI-MOUNT UDOR

Prominent ridges of Precambrian quartzites and quartz-sericite schists in the central west of MOUNT LIEBIG (Ranford, 1969) form the southern boundary of the Arunta Block in this region. The peaks of Mount Udor and Mount Putardi occur along these ridges in the south and southeast respectively of this area. Further south of the ridges, younger meta-sediments (Upper Proterozoic to Lower Palaeozoic) crop out, forming the northern margins of the Amadeus Basin, while to the north, Precambrian granite has been mapped as cropping out over an extensive area.

The aeromagnetic response over this area (Figs 2 & 10) is relatively undisturbed apart from a mildly anomalous zone, immediately south of the "Gunbarrel" road, containing anomalies up to 400 nT amplitude and trending NW to SE in general. Hence, it was hoped to determine the source of these anomalies in an area exhibiting an otherwise "normal granite response" (i.e. magnetically undisturbed), and also to investigate the boundary between the granite and the quartzite ridge near Mount Udor. Outcrop and ground geophysical response were investigated along several traverses: T16 and T17 over the strongest aeromagnetic feature 10 km NNE of Mount Putardi; T18 on the northern foothills of Mount Udor; and T19 and 19A approximately 10 km due north of Mount Udor (Fig. 10).

Geology

In the vicinity of T16 and T17, granitic gneisses which vary widely in composition occupy low-lying ridges and are flanked to the north and east by a sequence of felsic and leucocratic biotite gneisses. The boundary between the granitic rocks (S1111, 1115) and gneisses (S1106-1110) occurs at approximately 1000S on T16 whilst on T17 this boundary is at 250E near S1121. The granitic gneiss to the south and west of these points respectively has been strongly deformed to produce a marked east-trending



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16/F52/10

Fig. 10 Area 5 - Mount Putardi - Mount Udor, showing aeromagnetic contours and sample and traverse locations (refer to Fig. 4 for locality map)

TABLE 8. PHYSICAL PROPERTIES OF ROCKS - AREA 5, MOUNT PUTARDI-MOUNT UDOR

Sample No.	Latitude (S)	Longitude (E)	Rock Type	Rock Unit	Code (*)	Met.Grade Code (**)	Susceptibility (SI units x 10^6)	Specific Gravity	Comments
(a) NORTH OF MOUNT PUTARDI (T16, T17)									
1105	23°21.59'	131°2.76'	Amphibolite		A	50	330	2.79	
1107	23°21.55'	131°2.70'	Felsic gneiss		F	50	270	2.63	
1108	23°21.63'	131°2.80'	Hornblende gneiss		H	50	1100	2.80	
1109	23°21.78'	131°2.93'	" "		H	50	300	2.77	
1110	23°21.81'	131°2.96'	" "		H	50	250	2.75	
1111	23°22.10'	131°3.17'	Orthogneiss		Ø	30	8600	2.71	
1122	23°22.92'	131°4.29'	Tonalite gneiss		Ø	20	4500	2.66	
							(AV = 2193)	(AV=2.73)	
(b) MOUNT UDOR (T18)									
1127	23°28.97'	131°0.15'	Granite		G	10	80	2.64	
1128	23°28.90'	131°0.15'	Granite		G	10	40	2.64	
							(AV = 60)	(AV=2.64)	
(c) NORHT OF MOUNT UDOR (T19)									
1131	23°24.00'	131°0.20'	Granodiorite		G	20	200	2.72	
1136	23°23.40'	130°59.50'	Leucogranite		G	10	400	2.61	
1140	23°21.15'	130°58.50'	Felsic gneiss		F	40	40	2.54	
							(AV = 213)	(AV=2.62)	

* See Table 1

** See Table 2

foliation. Quartz veins and less common epidosite veins (S1118) parallel the foliation. These granitic rocks show a wide variation in composition from tonalite in the north to calc-alkaline granite in the south. Calc-alkaline granite and adamellite compositions are the most common. The more basic varieties are hornblende-bearing. Amphibolite lenses (S1113) up to 2 m wide are occasionally present within the granitic gneisses. A few lenses of biotite schist (S1112) also occur in the unit.

The felsic and leucocratic gneisses form beds from 1 to 4 m wide and are interbedded with lesser amounts of biotite schist and amphibolite. The amphibolite is generally less than 20 percent of the sequence, but in the northwestern part of the outcrop area it is intercalated with hornblende biotite gneiss which together account for up to 40 percent of the sequence. The felsic gneisses (layered granitic gneisses) vary from calc-alkaline to adamellite in composition. The whole sequence is tightly folded into structures that plunge steeply and have east-trending axial planes.

The range that includes Mount Udor consists of medium to coarse-grained quartzite (S1124, 1125) which has been metamorphosed to the amphibolite facies. It is underlain by a muscovite-biotite leucocratic granite of uniform composition (S1126-1128) varying from adamellite to alkaline granite. Close to the quartzite range, the granite is strongly foliated (S1129) in a direction paralleling east-trending faults which are common in the quartzite range.

Approximately 10 m due north of Mount Udor, a low ridge of outcropping sericite-quartz-schist (S1130) striking east-west is prominent. Station 00 on T19, which extends 5 km due north and 0.5 km due south of this point, is located on this ridge. Granite similar to that found along T18 occurs on the southern slope of the schist ridge suggesting that this rock type occupies most of the region in between. Immediately to the north of the schist ridge, foliated biotite granodiorite (S1131, 1137) crops out, but this rock type rapidly gives way further north (1000N) to a calc-alkaline granite (S1134-1136) in which the biotite content is commonly less than 5 percent, seldom exceeding 10 percent. Up to 5 percent muscovite is commonly present, and biotite is retrogressed to chlorite in places. Muscovite aplite is present in small amounts, and small bodies of granodiorite (S1133) recur sporadically. The region is cut by numerous quartz-filled faults which trend about 070^{o}.

Just north of 4000N on T19, there is a sharp change from granites to a white, calc-alkaline to aplitic gneiss (S1140, 1141). These granitic gneisses are virtually devoid of mafic minerals, with the biotite content (in places a green variety) rarely exceeding 5 percent (more commonly it is absent). Garnet is confined to the rare granodiorite varieties which remain leucocratic. The gneiss is characterised by a lensic, well-developed gneissic foliation which is commonly folded. The white gneiss, which appears to continue northward at least as far as the road, is of uniform composition and lacks the schistose interbeds typical of the felsic gneiss north and east of T16 and T17.

Several isolated outcrops near the main road in the west of this area were also examined (S1102-1104). No samples were collected, but spot magnetic readings were taken. It appears that most outcrops are of migmatic biotite gneiss forming low hills and strike ridges (S1102). These gneisses are distinguished by their relatively high biotite content which varies between 25 and 35 percent. Further to the east, migmatic biotite gneiss is replaced by leucocratic granitic gneiss (S1104) containing only 3 to 7 percent biotite (at least one locality contained muscovite).

Physical Properties and Magnetics (Fig. 11 and Table 8)

Twelve samples from this area were collected for physical property measurements, the results being presented in Table 8.

The ground magnetic data on both T16 and T17 indicate a subtle but distinct difference in response between the granitic and felsic gneisses, the former in this case being the more magnetic. The granitic gneisses show a moderate level of local magnetic disturbance (anomalies with amplitudes commonly of 200 to 300 nT) although the average background level is low (53 500 nT). The local disturbance may be due to compositional variations in the granitic rocks, as well as the effect of east-west faulting. Measurements on two samples (S1111, 1122) of this rock type indicate moderate to high susceptibilities (average 6550 x 10^{-6} SI units) and typical granite specific gravities (2.69). On the other hand, ssmples of felsic gneiss (S1107-1110) had an average susceptibility of only 480 x 10^{-6} SI and specific gravity of 2.74 by comparison. These rocks in general yield a smooth ground magnetic response, with only minor disturbances up to 50 nT, consistent with their adamellitic composition. On T16, a uniform decrease of 100 nT per 250 m to the north over the felsic gneisses is believed to be related to a deeper structural component of the rock sequences rather than compositional variations within the gneisses. The marked change in this response at 50N on T16 is postulated as a fault within the gneissic sequence, although the aeromagnetic anomaly at this point suggests that a distinct variation in composition of the gneisses may occur to the north. It appears in this area that the magnetic disturbance varies as the biotite content of the gneisses varies.

On T18 near Mount Udor, the two-mica leucocratic granite north of the younger quartzite ridge produces an exceptionally smooth magnetic response. Neither variations in biotite content, or the change from massive to foliated granite, produce corresponding variations in the ground magnetics. Two samples of this granite (Table 8) had exceptionally low susceptibilities (average 60 x 10^{-6} SI) and average specific gravity (2.64). The contact between granite and quartzite did produce an immediate small variation in magnetic response, but evidence for a significant change in response over this boundary is inconclusive since rugged topography at the ridge prevented extension of the traverse further south. A regional increase on T18 of 100 nT from 00 to 1500S (also evident in the aeromagnetic data) is related to deep structure rather than near-surface compositional variations.

On T19, the magnetic response over and to the south of the low schist ridge at 00 is flat. This response, along with the aeromagnetic data, would confirm that uniform non-magnetic granite underlies the alluvium continuously between the northern end of T18 and southern end of T19. Granitic rocks north of 00 on T19 also produce a generally uniform, flat magnetic response, except between 1600N and 2000N where foliated leucogranite and the presence of quartz veins suggest an east-trending faulted deformed zone (exhibiting retrograde metamorphism) which yields a moderately disturbed magnetic response. In addition to this zone, a surprisingly large amplitude (800 nT) short-wavelength (200 m) anomaly at 200N occurs near some quartz float. This feature is postulated as a fault within the granitic rocks. A parallel traverse (T19A) 200 m to the west showed this feature to have a strike close to 070°. The fault appears to mark a change from biotite granodiorite on the south to strongly foliated biotite leucocratic granite, both of which are non-magnetic in themselves (average susceptibility of two samples - S1131, 1136 - is 300×10^{-6} SI units, as shown in Table 8). It appears that magnetic material as well as quartz has been mobilised along this fault, but the origin of this magnetic material is uncertain. Other faults in this area, evident on aerial photographs and by the presence of quartz veins, are not evident in the magnetic response, except possibly in the deformed zone (1600N to 2000N) mentioned above.

The incoming of the gneisses near 4000N on T19 corresponds to a sharp increase in the magnetic response of 250 nT (indicative of a faulted contact) and a change in magnetic character, to a moderately disturbed response north of this contact. Owing to poor outcrop, only one sample (S1140) of this gneiss was collected for physical property measurements (Table 8). This particular rock had a very low susceptibility.

Both the lithology and magnetic response of granites and gneisses near T19 appear to be quite different to that of similar rock types only 5 km to the east near T16. The aeromagnetic response suggests that a NW-SE trending fault may pass between these two traverses, separating rocks of different composition and metamorphic grade. In general, the aeromagnetic ridge extending east-west across the area coincides with outcrops of gneissic rocks in the west and granodiorites and tonalites in the east. The ground data indicate that granodiorites and tonalites are the most magnetic rocks in the area, with gneisses being less magnetic while leucocratic and biotite granites are non-magnetic. It appears therefore that the area of 'normal' granite outcrop, although extensive, is less than that postulated on the 1:250 000 geological map.

Radiometrics and Geochemistry (Fig. 11)

A weak airborne radiometric anomaly in the northeast of this area was investigated at the northern end of T16. Ground spectrometer readings (up to 13.5 μR/hr) were highest over felsic gneiss at the top of an east-west ridge about 200 m north of 200N on T16. Potassium and thorium appear to be the main contributors to the radioactivity. Spectrometer readings along

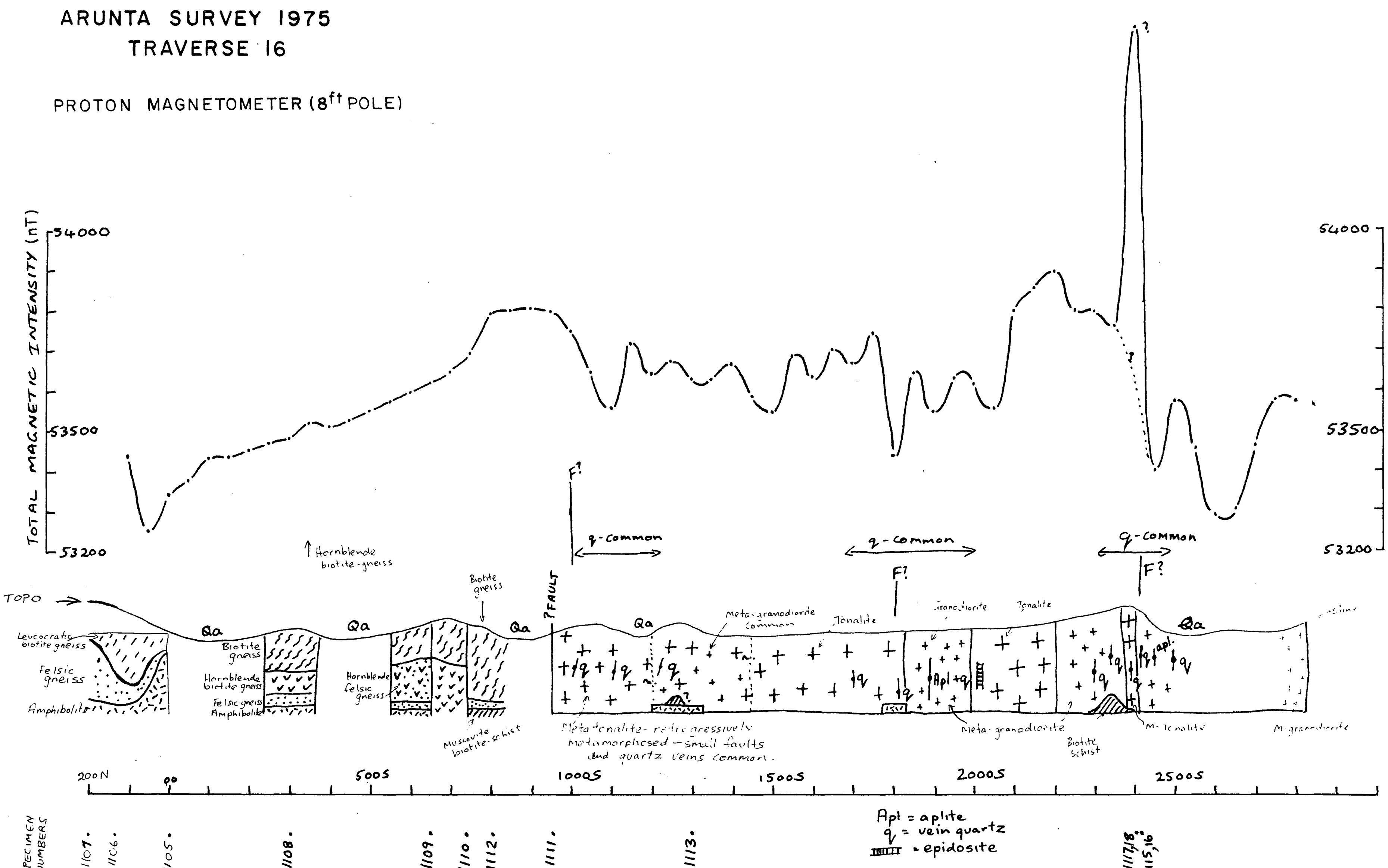

Fig. 11 Magnetic and radiometric profiles and related geological information for traverses 16, 17, 18, 19, 19A — Area 5 (Sheet 1 of 4) 16/F52/11

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TRAVERSE 17

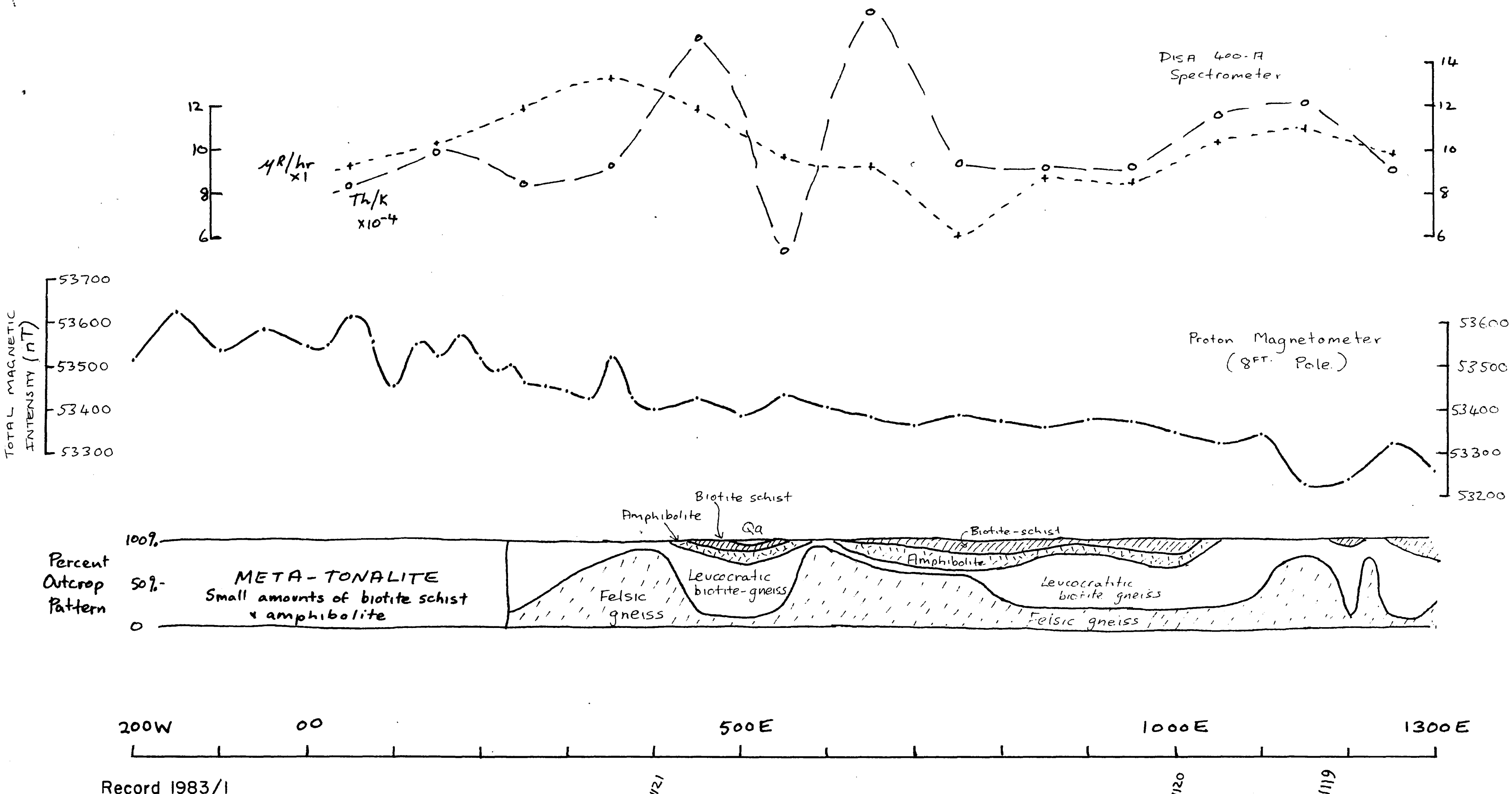

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Fig. 11

(Sheet 2 of 4) 16/52/11

ARUNTA SURVEY 1975
TRAVERSE 18

PROTON MAGNETOMETER (8^{ft} POLE)

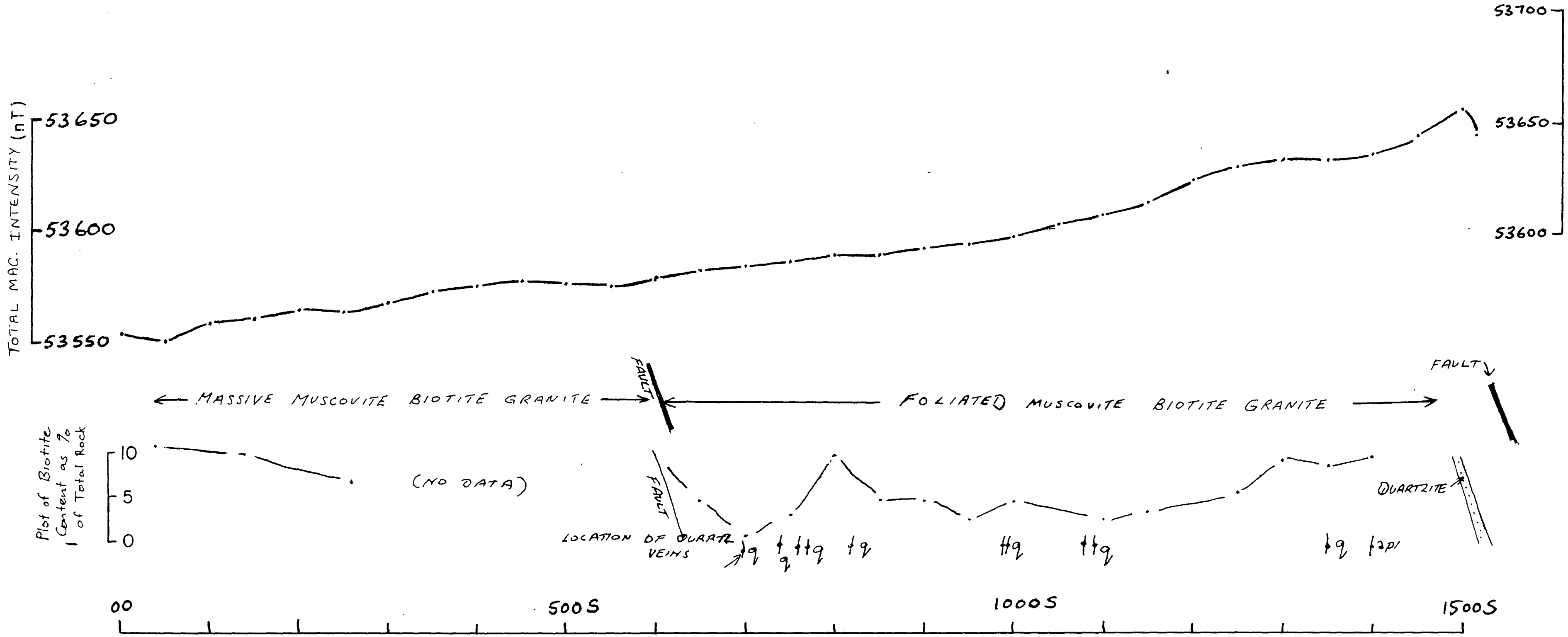

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Fig.11

(Sheet 3 of 4) 16/F52/11

ARUNTA SURVEY 1975
TRAVERSE 19, 19A

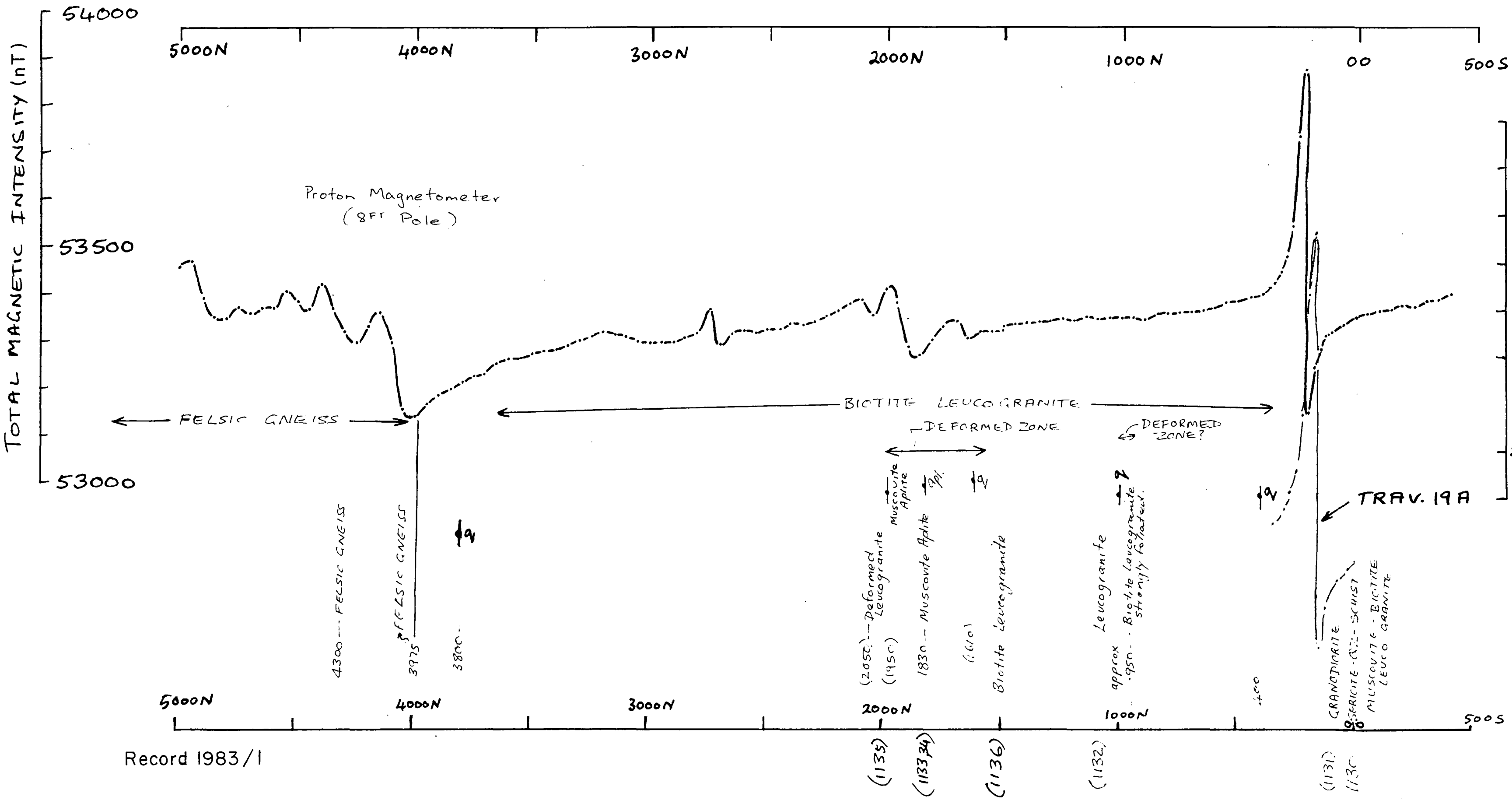

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Fig. 11

(Sheet 4 of 4) 16/F52/11

both T16 and T17 indicated slightly higher readings (8-12 μR/hr) over the tonalites and granodiorites compared with readings of 6-10 μR/hr over the gneisses.

The radioactivity associated with the granite north of Mount Udor is in the range 6-12 μR/hr, which is significantly lower than granitic rocks in MOUNT RENNIE. The quartzite at the south of T18 had a radioactivity of less than 6 μR/hr.

Radioactivity along T19 was in the range 7-11 μR/hr, except at 00 where the reading dropped to 4 μR/hr over sericite-quartz-schist outcrop.

9. AREA 6: YAYA CREEK

This area is located 30 km west of Papunya Settlement in the east of MOUNT LIEBIG (Fig. 12). It consists of numerous low hills and ridges forming the northern foothills of the Amunurunga Range, which contains the prominent peak of Mount Liebig. The Yaya Creek system rises in the Range and winds northwards through the foothills and out on to the sand plains near Ulumbara Bore (Fig. 12). Upper Proterozoic metasediments (mainly Heavitree Quartzite), forming the Range, unconformably overlie Arunta Block rocks in the foothills to the north. Previous mapping makes no differentiation of rock types within the basement complex.

The aeromagnetic pattern over these basement rocks is very disturbed (anomalies greater than 1000 nT amplitude are common), suggesting a complex geological situation. In particular, an intense magnetic low in the south of the area may be the result of one or more factors: overthrusting; retrograde metamorphism involving the alteration of primary magnetic minerals; granite intrusions; or strong remanent magnetism. Two traverses (T20 and T21) were located in the Yaya Creek area to investigate the source of these magnetic anomalies. As well, investigations were made to determine the source of several weak airborne radiometric anomalies which occur in this area.

Geology

At the northern end of T20 approximately 9 km south of Ulumbara Bore, migmatitic gneisses form low hills between east-trending strike ridges made up of generally more felsic gneisses. The northern ridge traversed (200N to 600N) included a high proportion of leucocratic biotite gneiss (S1151) of adamellite and calc-alkaline composition, and small amounts of granodiorite gneiss, amphibolite (S1149) and quartz-rich biotite gneiss (S1152). further north at 800N on T20, the biotite gneiss encountered is highly migmatitic and contains small amounts of garnet.

Between 200N and 1400S on T20, the traverse does not pass over any outcrop. Exposures of rock some hundreds of metres to the east and west of the traverse were examined. In general migmatised gneisses (S1153-1155) continue to about 500S and leucogneiss (S1162-1164) further south. South of 1400S another series of strike ridges is traversed. Rock types in these ridges at first consist of muscovite-bearing leucocratic and felsic gneisses (S1165-1169) which are typically calc-alkaline in composition and are commonly schistose. These muscovite-bearing rocks pass southwards into garnet-sillimanite-biotite gneiss (S1170, 1172). The presence of muscovite suggests that the rocks reached only the lower amphibolite facies whereas the rocks of the northern ridge are considered to be metamorphosed to the upper amphibolite facies. Muscovite is confined to the southern ridge south of a deformed zone (1450S to 1500S) suggesting post-metamorphic faulting along this zone.

Traverse T21 was located north and south of the headwaters of Yaya Creek within the aeromagnetic low referred to above. The rocks of this area are mainly metasediments interlayered with subordinate felsic and leucocratic gneisses, there being a far smaller proportion of such gneissic rocks than in the region 5 km to the north (T20). Metasediments include sillimanite-muscovite-biotite gneiss, quartzite and interlayered para-amphibolite; biotite gneiss which is commonly quartz-rich, and in places is garnet-bearing; and, further south, muscovite-biotite schist, muscovite-chlorite schistose gneiss, and muscovite quartzite (S1184-1187). North of 100S on T21, the felsic rocks (S1173-1176) are commonly quartz rich with minor mafic minerals, whereas south of this point the main felsic rock is a leucocratic biotite gneiss (S1177-1183) containing up to 15 percent each of muscovite and biotite. Muscovite occurs as coarse-

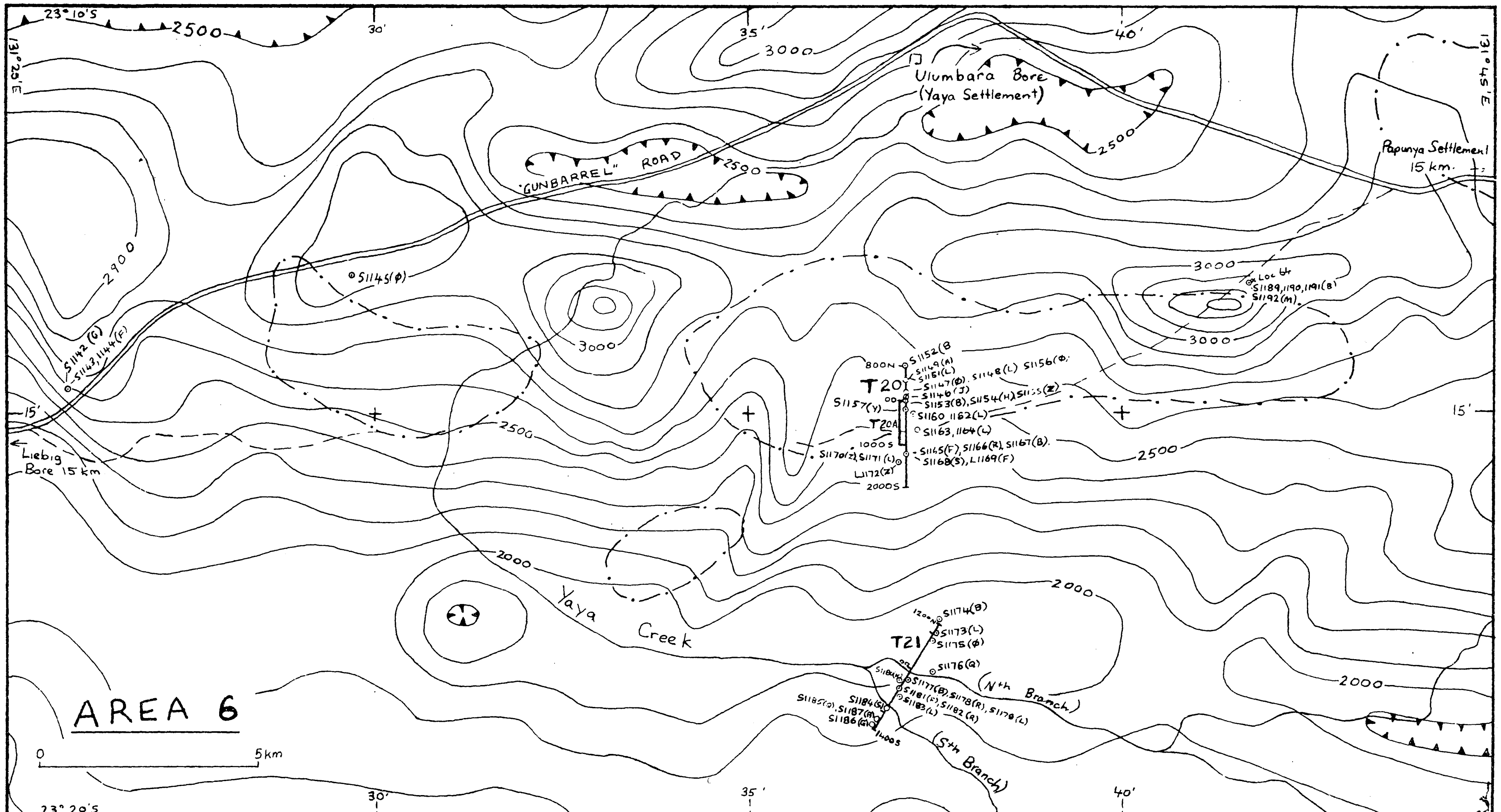

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Fig.12 Area 6-Yaya Creek, showing aeromagnetic contours and sample and traverse locations (refer to Fig. 4 for locality map)

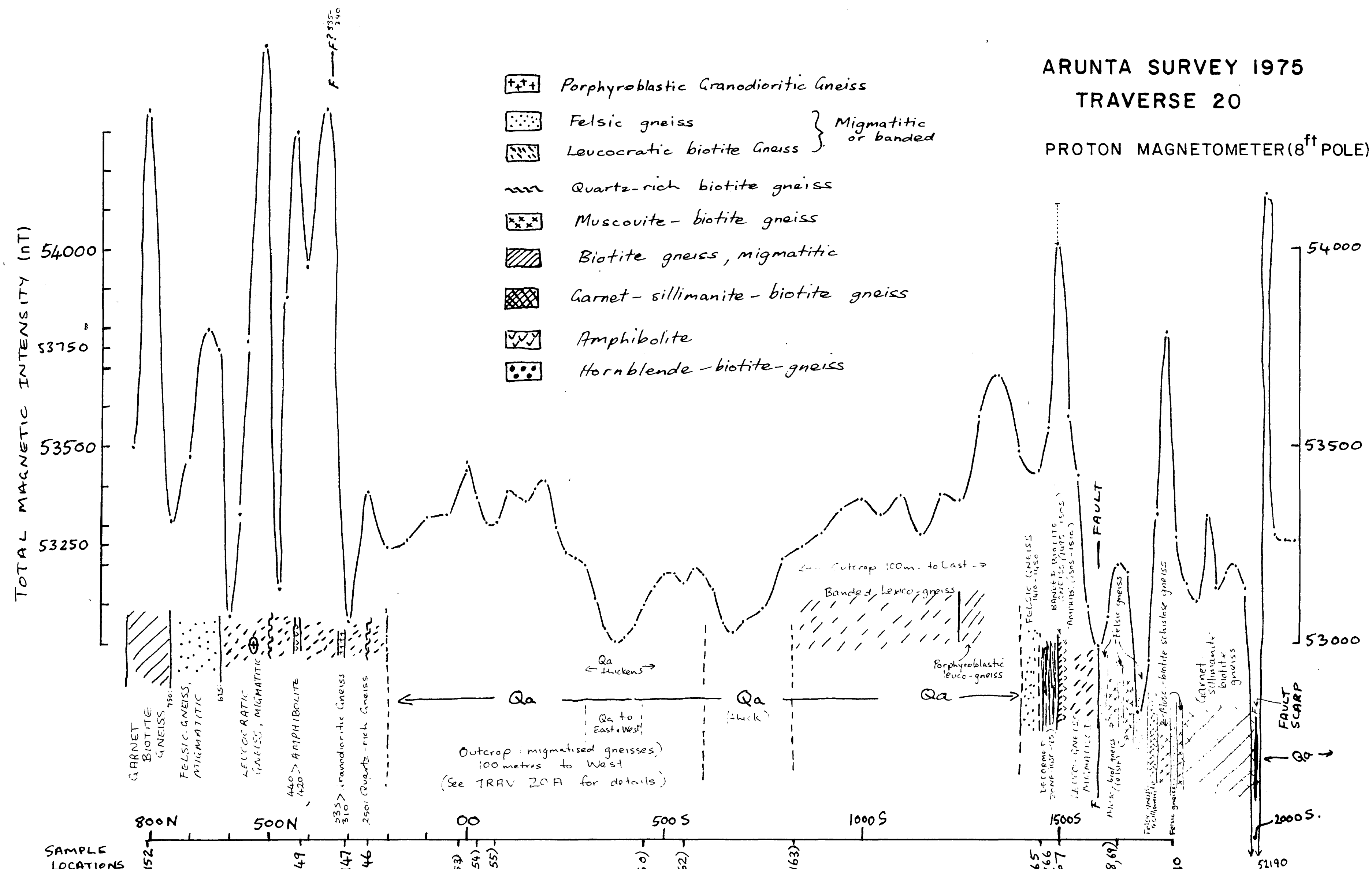

Fig 13 Magnetic profiles and geological information in Area 6 (Mt. Liebig–Yaya Creek). Traverses 20, 20A, 21 (Sheet 1 of 3) 16/F52/13

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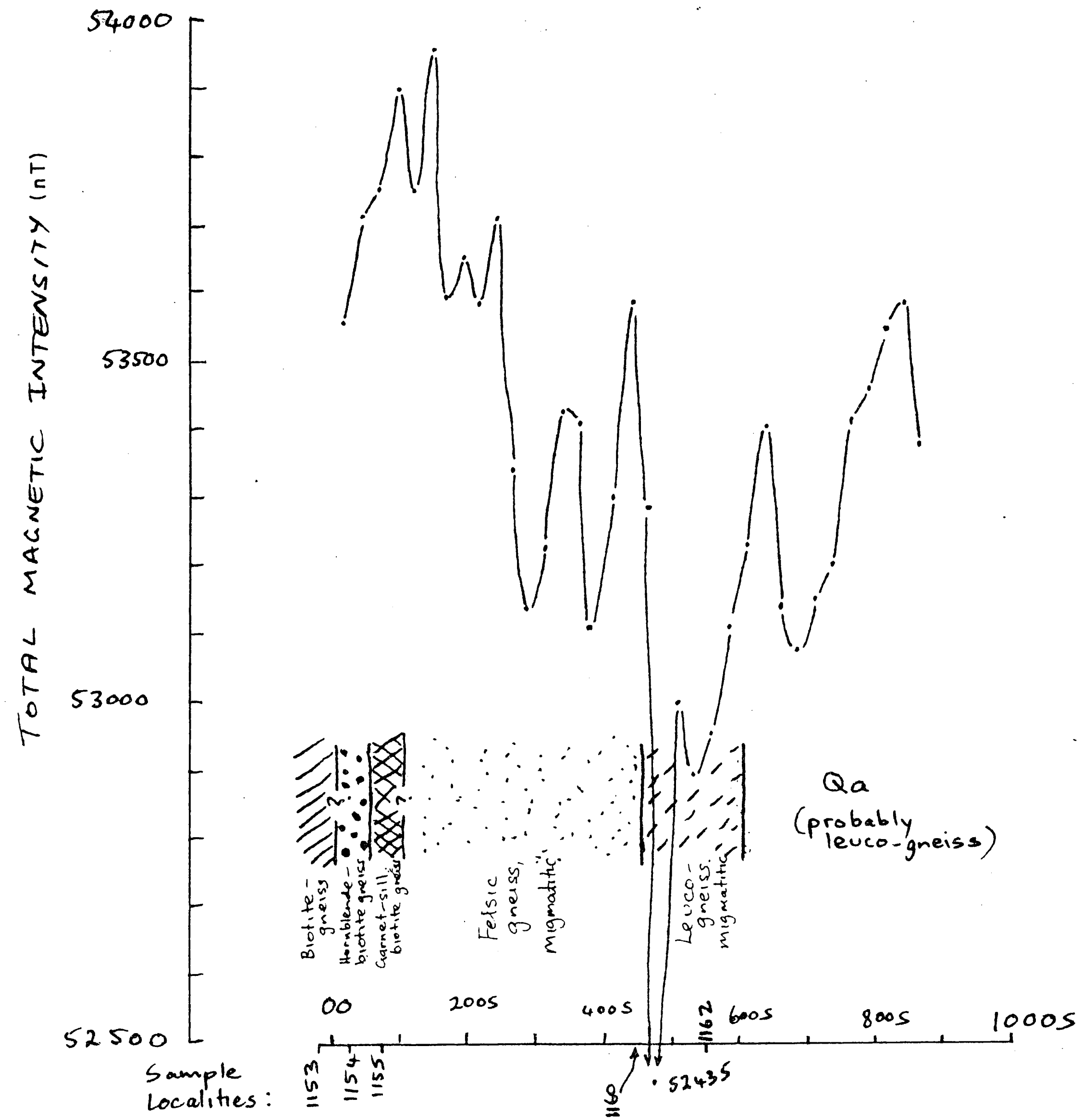
ARUNTA SURVEY 1975

TRAVERSE 20 A

PROTON MAGNETOMETER (8^{ft} POLE)



Outcrop
(see KEY TRAV 20)

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Fig. 13

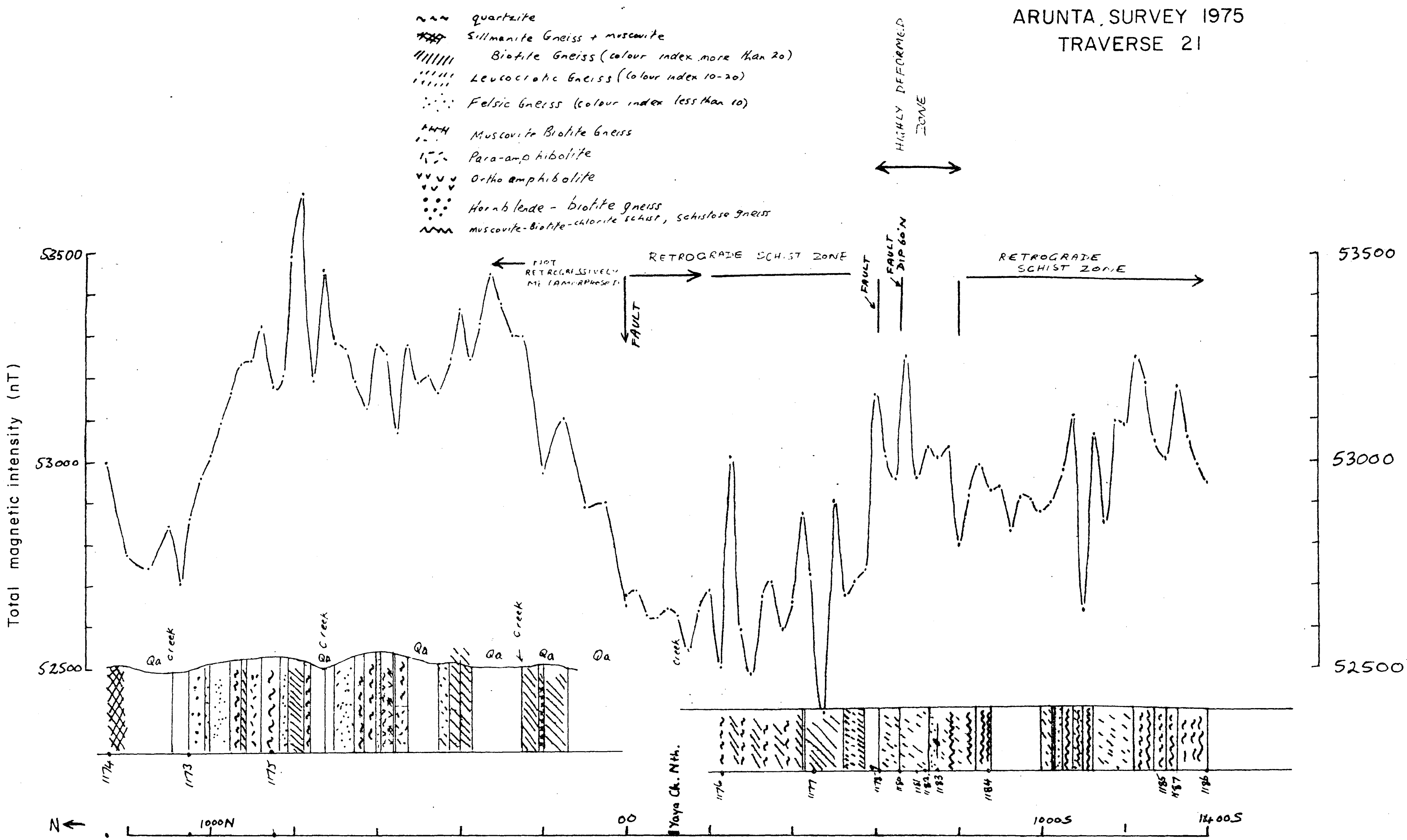

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Fig. 13

(Sheet 3 of 3) 16/F52/13

TABLE 9. PHYSICAL PROPERTIES OF ROCKS - AREA 6, YAYA CREEK

Sample No.	Lat. (S)	Long. (E)	Rock Type	Rock Unit	Code (*)	Met. Grade Code (**)	Susceptibility (SI units X 10^6)	Intensity (mA/m)	Decln. (Deg)	Incln. (Deg)	Q Ratio	Specific Gravity	Comments
(a) WEST OF YAYA CREEK													
1142	23°14.70'	131°25.80'	Tonalitic Gneiss		8	60	51 000	530	201.8	-7.4	0.2	2.81	
1144	23°14.70'	131°25.80'	Felsic Gneiss		F	50	2 200	120	19.9	-66.6	1.3	2.58	
1145	23°13.30'	131°29.70'	Tonalite Gneiss		Ø	80	13 000	46 000	81.7	-8.9	82.7	2.72	Migmatized
							(AV = 22 0670					(AV = 2.70)	
(b) EAST OF YAYA CREEK (T20)													
1147	23°14.75'	131°37.10'	Granitic Gneiss		Ø	60	33 300	-	-	-	-	2.74	
1148	23°14.75'	131°37.10'	Leucogneiss		L	60	20 500	-	-	-	-	2.59	
1149	23°14.60'	131°37.10'	Amphibolite		A	50	3 100	-	-	-	-	2.80	
1151	23°14.60'	131°37.10'	Leucogneiss		L	60	42 000	-	-	-	-	2.71	
1152	23°14.40'	131°37.10'	Biotite Gneiss		B	60	13 600	-	-	-	-	2.73	
1153	23°14.85'	131°37.10'	Biotite Gneiss		B	60	1 600	-	-	-	-	2.71	
1154	23°14.85'	131°37.10'	Hornblende Gneiss		H	60	5 500	-	-	-	-	2.74	
1156	23°14.75'	131°37.10'	Granitic gneiss		Ø	60	21 000	350	276.1	55.7	0.4	2.75	
1157	23°14.95'	131°37.10'	Soil, aeolian		Y	-	10 600	-	-	-	-	-	
1162	23°15,00'	131°37.20'	Leucogneiss		L	60	4 100	-	-	-	-	2.67	
1163	23°15.20'	131°37.25'	Leucogneiss		L	60	16 500	-	-	-	-	2.70	
1164	23°15,20'	131°37.25'	Leucogneiss		L	60	900	-	-	-	-	2.70	
1165	23°15.50'	131°37.10'	Felsic gneiss		F	60	33 500	-	-	-	-	2.71	
1166	23°15.50'	131°37.10'	Mylonite		R	30	3 700	-	-	-	-	2.67	Deformed
1167	23°15.50'	131°37.10'	Banded gneiss		B		33 000	-	-	-	-	2.73	
1168	23°15.50'	131°37.10'	Gneiss		S	50	18 700	-	-	-	-	2.74	
1170	23°15.60'	131°37.00'	Gneiss		Z	50	16 700	-	-	-	-	2.72	
1171	23°15.60'	131°37.00'	Leucogneiss		L	50	13 600	-	-	-	-	2.70	
							(AV = 16 546) excl. S1157					(AV = 2.71)	

TABLE 9 (Continued)

Sample No.	Lat. (S)	Long. (E)	Rock Type	Rock Unit	Code (*)	Met. Grade Code (**)	Susceptibility (SI units X 10^6)	REMANENT MAGNETISM Intensity (mA/m)	Decln. (Deg)	Incln. (Deg)	Q Ratio	Specific Gravity	Comments
(c) HEADWATERS OF YAYA CREEK (T21)													
1177	23°18.30'	131°37.10'	Biotite Gneiss		B	50	18 000	-	-	-	-	2.72	
1178	23°18.30'	131°37.10'	Fault Rock		R	30	11 400	-	-	-	-	2.78	
1180	23°18.30'	131°37.00'	Mylonite		R	20	4 400	-	-	-	-	2.73	Deformed rock
1183	23°18.50'	131°37.00'	Leucogneiss		L	20	24 000	-	-	-	-	2.70	
1184	23°18.65'	131°36.85'	Biotite schist		S	20	9 800	-	-	-	-	2.75	
1185	23°18.80'	131°36.70'	Quartzite		Q	30	30	-	-	-	-	2.68	
							(AV = 11 272)					(AV = 2.73)	
(d) NEAR 'LOC. 64'													
1189	23°13.40'	131°41.70'	Migmatite		B	60	150	76	163.4	58.3	11.8	2.66	
1190	23°13.40'	131°41.70'	Migmatite		B	60	5 400	100	62.3	-2.2	0.4	2.68	
1192	23°13.40'	131°41.70'	Mafic Granulite		M	65	1 300	6 700	57.5	22.4	120.5	3.09	
							(AV = 2 283)					(AV = 2.81)	

* See Table 1

** See Table 2

grained aggregates and, together with chlorite, is considered to be the product of retrograde metamorphism.

This metamorphism, reducing rocks from the middle amphibolite facies to the greenschist facies, becomes apparent at or just south of 00 on T21, through which point a fault is postulated. In this zone (00-600S) biotite gneisses become fine-grained, highly schistose and contain feldspar porphyroblasts. About 600S, the rocks are mainly leucocratic gneisses, are more obviously retrogressed, and contain abundant muscovite and chlorite, although the primary coarse-grain size is commonly maintained. In the region 600S to 900S several intensely deformed zones are present. This deformed region has undergone late stage folding about shallow plunging axes. Further south the rocks (S1184-1187) are less deformed and less intensely metamorphically retrogressed. In the retrograde zone on this traverse, hematite appears to be a common retrograde mineral owing to alteration of magnetite which is still present as relics, particularly in chlorite-bearing rocks. Ilmenite is also a common opaque mineral in these rocks.

Investigations were also made at several isolated outcrops in the west and east of the area. Felsic gneisses and tonalites (S1142-1145) were encountered at two locations adjacent to the main road in the west of the area. At the second of these locations (S1145), the outcrop was observed to be migmatitic and folded.

Several samples were collected from a prominent outcrop in the east of the area. This outcrop ('Loc 64') has been previously described by Wells & others (1965). Biotite migmatite (S1189-1191) was the main rock type; mafic granulite (S1192) was also present.

Physical Properties and Magnetics (Fig. 13 and Table 9)

North of 300N on T20, high-amplitude (up to 1500 nT), short-wavelength (less than 200 m) ground magnetic anomalies were recorded over what is essentially the same rock type throughout the traverse (i.e., migmatitic gneisses of granodiorite to calc-alkaline granite composition). Similar anomalies also occur over the southern ridges on the traverse, but in the intermediate region in which outcrop is masked by sand, only a moderate magnetic disturbance is observed. A traverse (T20A) parallel to this central part of T20 and some 150 m to the west over outcropping migmatised gneisses yielded again a highly disturbed response, suggesting that the high-amplitude anomalous response is related to very near surface features in the outcropping rocks, and hence their effect would be greatly attenuated when covered by even a small thickness of sand (increasing the distance between source and receiver). This problem makes the task of correlation of ground magnetics difficult, as can be seen by comparing T20 with T20A.

It is also apparent that the degree of migmatisation and deformation affects the magnetic response. Massive migmatites at the northern end of the traverse gave widely varying ($\pm$ 1000 nT) total intensity field values over a small area (10 m). Hence the true signal is masked by the near surface noise. Several faults were detected, particularly in the southern ridges, and these generally coincided with very sharp magnetic anomalies.

Samples of 17 metamorphosed, deformed and predominantly gneissic rocks collected along and near T20 were measured for physical property characteristics (Table 9). Susceptibilities were very high in general (average 16 546 x 10^{-6} SI units) but were quite variable from outcrop to outcrop or even within samples from the same locality. Specific gravities were only moderate for metamorphic rocks (2.71 average). It seems apparent that the higher degree of metamorphism or even the degree of migmatisation may cause an increase in magnetic material is this area. The relationship between metamorphic grade and susceptibility is illustrated in Figure 15. An oriented specimen (S1156) from T20 possessed only weak remanent magnetism, but this result is not considered to be typical of the response; more specimens are required. It is possible that remanent magnetism may be an important component in the magnetic response. It is not certain whether remanence effects are related to the migmatisation process, or are characteristic of rocks of upper amphibolite (or higher) metamorphic grade.

On T21, the ground magnetometer detected a marked magnetic low (500 to 1000 nT less than surrounding features) with local disturbances. This coincides almost precisely with the retrograde schist zone between

00 and 600S on this traverse. However, the negative aeromagnetic anomaly cannot be attributed directly to retrogressive metamorphism because only about 5 percent of the magnetite has broken down to hematite as a result of retrograde metamorphism (6 specimens examined in reflected light). The magnetic data along the traverse show a highly disturbed response with low-amplitude (200 nT), short-wavelength (100 m) anomalies. This apparent noisy response, as with T20, appears again to be related to the amount of structural deformation in the near-surface rocks.

The overall lower level of magnetic intensity (1000 nT less than T20) thus appears likely to be due to the relatively high proportion of metasediments in this area as compared with the proportion of felsic and leucocratic gneisses along T20 to the north. A component of the reduction in intensity may be due to remanent magnetism in a negative sense.

Physical property measurements on 6 samples collected along T21 indicate that these rocks possess significantly lower susceptibilities (average 11 272 x 10^{-6} SI units) than those to the north near T20. It is apparent that there is less magnetic material present in this retrogressed zone. The remanent magnetic properties of rocks in this zone unfortunately remain unknown, since suitable oriented samples could not be collected owing to the schistose nature of the rocks involved. Specific gravities in the southern areas are similar to those in the north, suggesting that detailed gravity data would not delineate the zone of metamorphic retrogression.

Measurements on samples from the two localities west of Yaya Creek indicate high to very high susceptibility and remanent magnetic properties of rocks in this area. Positive aeromagnetic anomalies occur in proximity to these sample locations, and it can thus be postulated that they represent broad areas of magnetic tonalite gneisses.

On the other hand, migmatites and mafic granulites collected from 'Loc 64' (Fig. 12) in the east of the area had significantly lower susceptibilities and remanent intensities (on the average), despite the proximity of this location to the crest of a 1200 nT aeromagnetic high (Fig. 12). The source of this anomaly thus remains unresolved, although the highly magnetic properties normally attributed to migmatites and granulites would suggest that a large area of such rocks will produce the observed anomaly. It is possible that weathering may have diminished the proportion of magnetic material present in this particular outcrop.

Radiometrics and Geochemistry

Several weak aero-radiometric anomalies were recorded in the Yaya Creek area, as shown in Figure 12. To the east of Yaya Creek, part of the anomaly covering the broadest area was traversed by T20. Ground gamma-ray spectrometer measurements along this traverse indicated radioactivity up to 26 μR/hr over ridges of gneissic and migmatitic rock. In particular, felsic gneiss outcrop appeared to be the most radioactive in the area. Radioactivity was reduced to about 10 μR/hr over alluvial areas.

Radiometric data (both scintillometer and gamma-ray spectrometer) indicated weaker levels of radioactivity over outcrop along T21, the highest readings being in the range 12-16 μR/hr. Lows of 8 μR/hr were recorded over sand and alluvial material in creek beds.

The western end of a small airborne anomaly in the west of the area was investigated near S1145. Radioactivity up to 16 μR/hr was detected over migmatised gneisses exposed in a hill 30-50 m high. Further west, measurements made over outcropping felsic gneisses (S1143, 1144) showed radioactivity up to 11.4 μR/hr only.

10. AREA 7: HAAST BLUFF

At the eastern edge of MOUNT LIEBIG, Upper Proterozoic quartzites forming the Belt Range unconformably overlie low hills of undifferentiated Precambrian Arunta Block to the north and south of the Range. The primary purpose for going into this area was to investigate the source of a broad aero-radiometric anomaly (the most significant anomaly recorded over MOUNT RENNIE and MOUNT LIEBIG) which occurs over outcropping basement rock immediately to the north of the Haast Bluff Settlement.

Two traverses (T22 and T23) were located approximately 5 km northwest of the Settlement (Fig. 14) to follow-up this anomaly and determine the nature of the surrounding basement rocks.

Whilst in this area, it was also decided to investigate the magnetic and radiometric characteristics of a small base metal prospect (known locally as "Nickel Hill") located near the main road about 11 km east of the Settlement (Fig. 14). This would help determine if other mineral occurrences in the Arunta Block may be detected using these techniques.

<u>North of Haast Bluff Settlement</u> (Table 10)

The main rock types encountered on T22 and T23 were found to be a sequence of felsic gneiss interlayered with subordinate amounts of quartzite and muscovite feldspar-quartz schist, and occasionally biotite gneiss and epidote biotite amphibolite. The felsic gneiss unit may contain up to 50 percent quartz, while muscovite accounts for up to 15 percent and is generally more abundant than biotite, which seldom accounts for more than 5 percent of the gneiss. Where the muscovite content is high, the gneiss is generally coarse-grained and pegmatitic.

The quartzite generally contains muscovite and also contains up to 15 percent feldspar in places, suggesting it is related to the felsic gneiss and hence the latter may represent a metamorphosed arkose. Both the felsic gneiss and quartzite contain up to 2 percent generally disseminated opaque grains in places. These rocks have probably been metamorphosed to the middle amphibolite facies, as a leucosome phase has developed which is cross-cutting in places.

Between 00 and 800W on T22, the felsic gneiss is overlain by tertiary gravels, and is generally deeply weathered and ferruginous. The gravels consist of rounded boulders, cobbles and pebbles of Heavitree Quartzite as well as up to 30 percent vein quartz in places.

The magnetic response on both T22 and T23 was generally smooth, being only mildly disturbed over Tertiary gravels. A 200 nT anomaly at 250N on T23 possibly represents a small fault. The overall response of the felsic gneiss is in general similar to the response over gneisses in the Mount Putardi-Mount Udor area, but dissimilar to that in the Yaya Creek area. Physical property measurements (Table 10) on 2 samples (S1194, 1198) from this area indicate felsic gneiss to be non-magnetic while quartzite is slightly magnetic. Both had relatively low specific gravities.

On both traverses, the ground gamma-ray spectrometer data (which hopefully would delineate the source of the airborne radiometric anomaly) gave a maximum reading of 14 μR/hr and only limited areas above 10 μR/hr. The highest values were recorded over exposures of felsic gneiss. The surprisingly low measurements indicate that the zone does not appear particularly radioactive. By comparison with the northern end of T20 in Area 6, ground measurements should have indicated at least 20-25 μR/hr. The airborne data in this case appear to be incorrectly contoured, perhaps emphasising the dangers of contouring data from widely spaced (3km) lines.

"Nickel Hill" (Tables 10 & 11)

This minor mineral deposit, which crops out on both sides of the main road east of the Haast Bluff Settlement, consists of chalcopyrite, chalcocite and copper carbonates in a gossanous rock rich in tremolite and containing minor serpentinite. The mineralised rock contains antigorite-calcite ± dolomite lenses which dip 36-55^{o} northwards. Spectrochemical analysis of trace elements from the gossan are given in Table 11. Zinc and lead values generally exceed 1 percent whereas copper values are in the range 500-5000 ppm. The gossanous rock is unlikely to be a weathered basic or ultrabasic rock because the nickel values are very low (less than 5 ppm). On the footwall side, the country rocks consist of biotite-bearing felsic gneiss, (?)talc-quartz schist and muscovite-biotite-bearing felsic schist which all dip northwards at about 30^{o}. The country rock on the hanging wall is not well exposed. A swing in strike of the lode outcrop at its eastern end suggests folding, but the evidence is not clear. Samples S1199-1207 were collected from both gossanous outcrops.

About 2 km northwest of "Nickel Hill", Wells & others (1965) have noted a small deposit of malachite ('Loc 71' Fig. 14). This occurs in garnet amphibolite and appears to be unrelated to the above deposit. More extensive geological and geochemical work and some percussion drilling have been carried out on both these deposits by the Northern Territory Geological Survey (NTGS). The results of this work are summarised by Barraclough (1975).

Ground magnetic and radiometric readings were recorded over the "Nickel Hill" deposit along a previously established survey grid. For the present purpose, traverses on this grid are collectively referred to as T24 in Figure 14.

Magnetic results indicate a significant 300 nT amplitude anomaly over the centre of the main deposit (1040W on line 1030N). A similar amplitude anomaly was encountered at the edge of the northern outcrop (1300W on line 970N). Smaller amplitude anomalies (up to 150 nT) occur between the two deposits, but there is no evidence to suggest that these may be related to mineralisation. Also these data tend to indicate that the main body is quite small and does not continue under the alluvium for a great distance. There appears to be no magnetic continuity between the two gossanous outcrops.

Physical property measurements (Table 10) on 4 samples (S1199, 1202, 1206, 1207) from the mineral prospect indicate moderate to high susceptibilities in two gossanous samples (S1206, 1207) whilst the other samples (one gossan, one country rock) were non-magnetic. Both magnetic samples come from the gossan north of the road. These two samples had slightly higher specific gravities than the other two. However, it is believed that these results are not truly indicative of the situation since insufficient time prevented adequate sampling.

Ground gamma-ray spectrometer data were more definitive of the main mineralised body than the magnetic data. A distinct radiometric low (values less than 4 μR/hr) was recorded over the outcrop, with higher values (8-10 μR/hr) over the surrounding sand. Insufficient time prevented extension of this work, but from the results presented it appears that the radiometric method may be well suited to exploration for similar mineralisation in this geological environment.

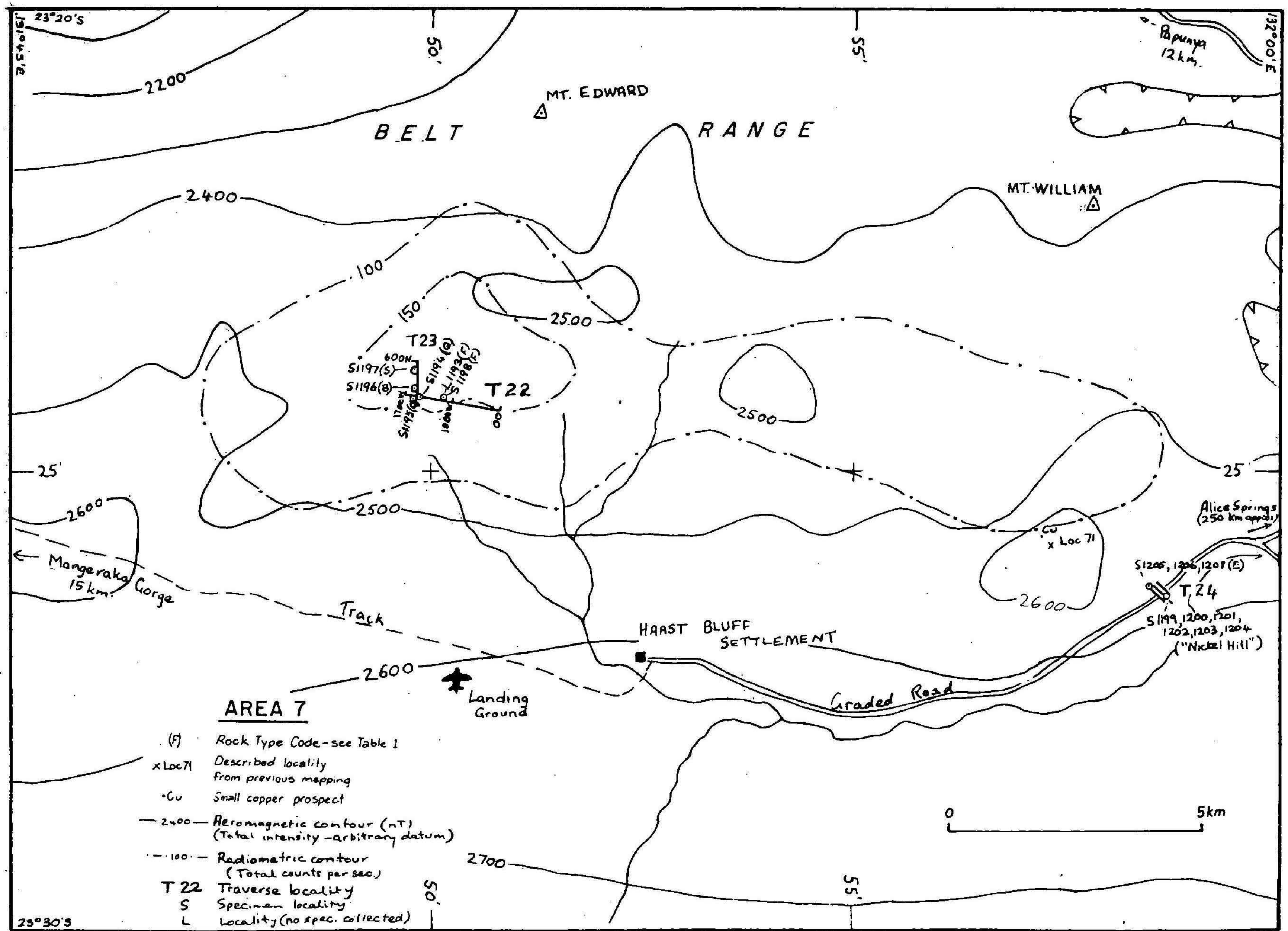

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Fig. 14 Area 7-Haast Bluff, showing aeromagnetic contours and sample and traverse locations (refer to Fig. 4 for locality map)

TABLE 10. PHYSICAL PROPERTIES OF ROCKS - AREA 7, HAAST BLUFF

Sample No.	Latitude (S)	Longitude (E)	Rock Unit	Formation	Code (*)	Met.Grade Code (**)	Susceptibility (SI units x 10^6)	Specific Gravity	Comments
(a) NORTH OF HAAST BLUFF SETTLEMENT (T22, T23)									
1194	23°24.20'	131°49.85'	Quartzite		Q	35	1700	2.64	
1198	23°24.20'	131°50.15'	Felsic Gneiss		F	40	50	2.57	
							(AV = 875)	(AV=2.61)	
(b) "NICKEL HILL" (T24)									
1199	23°26.40'	131°58.70'	Leucogneiss		?L		30	2.62	
1202	23°26.40'	131°58.70'	Gossan		E		80	2.30	?Weathered
1206	23°26.25'	131°58.50'	Gossan		E		3 900	2.73	
1207	23°26.25'	131°58.50'	Gossan		E		38 200	2.71	
							(AV = 10 552	(AV=2.59)	

* See Table 1

** See Table 2

TABLE 11. SEMI-QUANTITATIVE ANALYSIS OF TRACE ELEMENTS BY EMISSION SPECTROSCOPY

Specimen	Co	Cr	Mo	Ni	Zr	Ag	Bi	Cu	Pb	Zn	Au	Li	Rb	Sr	Ti
1200	5	20	3	5	X	80	1	2000	300	>1%	X	1	X	X	600
1202	X	X	X	X	X	80	20	5000	>1%	>1%	X	3	X	X	X
1203C	X	X	3	X	X	5	X	500	1000	>1%	X	5	10	X	100
1204	X	X	150	X	X	20	50	5000	>1%	>1%	X	3	X	X	100

X = not detected

TABLE 12

SUMMARY OF PHYSICAL PROPERTY MEASUREMENTS - SOUTHWEST ARUNTA BLOCK, N.T.

Group	Rock Types	No. of Samples	Specific Gravity Range (mean)	Susceptibility Range (mean) X 10^6 SI units	Remanent Intensities, mA/m (Q ratio)
Granite	Leucogranite, adamellite, granodiorite	16	2.57 - 2.72 (2.65)	20 - 6000 (1300)	NM (= Not measured)
Gneiss	Quartzofeldspathic	8	2.54 - 2.65 (2.61)	40 - 4500 (1800)	120 (1.3)
	Leucocratic	4	2.70 - 2.71 (2.70)	900 - 24000 (11800)	NM
	Biotite, hornblende	9	2.72 - 2.80 (2.76)	250 - 29000 (10200)	82000 (66)
Migmatite	Migmatitic gneiss	16	2.59 - 2.81 (2.72)	150 - 51000 (20300)	76(12), 100(0.4), 350(0.4), 530(0.2), 17000(16), 46000(83)
	Migmatite	4	2.73 - 2.82 (2.76)	3770 - 39000 (21900)	5800 (3.5)
Granitoid (Ehrenberg Range)	Granodiorite	12	2.71 - 2.78 (2.74)	2510 - 36000 (19100)	5300(4.1), 26000(28)
	Tonalite	12	2.70 - 2.81 (2.75)	15000 - 35200 (24800)	NM
Granulite	Mafic granulite	6	2.73 - 3.09 (3.00)	1300 - 38000 (23200)	730(0.5), 6700(120), 10000(123), 18000(13), 92000(57)
	Granofels	2	2.76 - 2.87 (2.82)	21000 - 60300 (40600)	33000(37)
	Hypersthene norite	5	3.14 - 3.19 (3.16)	3000 - 18800 (11400)	9600(58)
Metasediments	Quartzite	5	2.64 - 2.85 (2.72)	30 - 1700 (400)	NM
	Schist	3	2.62 - 2.75 (2.70)	30 - 9800 (3300)	NM
	Para-amphibolite	6	2.79 - 3.18 (2.91)	330 - 42200 (8200)	NM
Other Rock Types	Deformed schists & mylonite	5	2.67 - 2.98 (2.81)	220 - 11400 (4100)	6400 (258)
	Dolerite	32	2.91 - 3.10 (3.00)	2600 - 19000 (8300)	9700(87), 16000(20)
	Gabbro	2	3.00 - 3.02 (3.01)	590 - 830 (700)	570(23), 2900(82)
	Dacite	2	2.73 - 2.77 (2.75)	740 - 3800 (2300)	220 (7)
	Amadeus Basin sediments - quartzite, conglomerate	3	2.52 - 2.64 (2.58)	15 - 46 (30)	NM

11. SYNTHESIS OF PHYSICAL PROPERTY MEASUREMENTS

Overall, about 150 basement rock samples collected from the southwest Arunta Block were measured for magnetic susceptibility and specific gravity, and about 20 oriented samples were measured for remanent magnetic properties. A summary of the physical property results is presented in Table 12. As indicated, the rocks have been classified into several broad groupings based largely on composition and metamorphic grade.

Granitic Rocks

It is apparent from Table 12 that virtually no non-magnetic granites exist in the southwest Arunta Block. Many of the granitic rocks are, in fact, gneissic granite, adamellite, or granodiorite, and have low susceptibilities, generally less than 0.001 SI units. These weakly magnetic granites are restricted to a few localities. Other rocks previously mapped as granite have been reclassified on the basis of composition and metamorphic grade as gneiss, migmatite, granitoid or granulite. These rock types could, in a general sense, be regarded as granitic rocks, as they appear to be the product of complex metamorphism and migmatisation of older granite, adamellite and granodiorite or their extrusive equivalents.

Gneisses cover a broad range of metamorphosed rock types: from weakly magnetic quartzofeldspathic gneiss (average susceptibility 0.002 SI units), which appears to be equivalent to metamorphosed leucogranite, to moderately or strongly magnetic leucocratic and biotite gneisses (0.012 SI units), which may represent metamorphosed adamellite, granodiorite or tonalite. Specific gravities are commonly in the range 2.6 to 2.7 for the felsic gneisses, but are significantly higher for the biotite and hornblende-bearing granitic gneisses. Several biotite-rich types cannot be distinguished from pelitic metasediments. Remanent intensities of these gneissic rocks range from very low to very high, reflecting their diverse nature and complex history.

Migmatites, including migmatitic gneisses, are granitic rocks ranging in composition from granite to tonalite. They are characterised by high to very high magnetic susceptibilities (average 0.21 SI, with some samples up to 0.05). These high values, along with average specific gravities from 2.72 to 2.76, suggest that a high proportion of the migmatites are of tonalitic composition, which has been confirmed by petrographic examination. However, preliminary measurements of physical properties on migmatitic rocks from the Alice Springs area (unpublished data, R.D.S.) show that migmatites of all compositional types tend to have higher magnetic susceptibilities than their lower-grade equivalents.

Granitoids refer to the group of granitic rocks which are found in the Ehrenberg Range (Fig. 5). They are commonly pyroxene-bearing (charnockites), generally range in composition from granodiorite to tonalite, and are strongly magnetic, with susceptibilities commonly from 0.01 to 0.03 SI units. They have an average specific gravity of 2.74. The available data suggest also that these rocks have high remanent magnetism. Similar physical property results for charnockites (i.e. pyroxene granites and related gneisses) in India have been obtained by Aravamadhum (1974). The potassium percentage for all the rocks of this granitoid suite ranges from about 2.3 to 3.5 percent, which is similar to the range for migmatitic gneiss. The Ehrenberg Range granitoids appear to have undergone a complex history, possibly involving metamorphism at granulite facies, followed by a pervasive retrograde metamorphism to amphibolite facies.

Granulite refers to a broad group of rocks which includes mafic granulite, orthopyroxene-cordierite granofels, and hypersthene norite. All these rocks have consistently high to very high magnetic susceptibilites (up to 0.06 SI units) and high remanent intensities. Koenigsberger ratio (Q) values are commonly greater than 20 and in some cases exceed 100. Remanent directions vary widely. The specific gravity (commonly from 2.8 to 3.1) and the potassium percentage (less than 1% for the mafic granulites and less than 0.5% for the hypersthene norite) are distinctive features of this rock group. The hypersthene norite near Mount Lindsay (Area 2) contains a predominance of polygonal grains indicating considerable recrystallisation and may have been substantially equilibrated under granulite facies conditions. From the point of view of physical properties, this rock can be regarded as transitional between a norite and a mafic granulite.

Metasediments

Metamorphosed quartzites and calc-silicate rocks generally have magnetic susceptibilites less than 0.001 and rarely up to 0.002 SI units. On the other hand, pelitic rocks metamorphosed above the sillimanite, kyanite or cordierite isograds have magnetic susceptibilities in the range 0.002 to 0.02 SI units. The more common magnetic sediments - the para-amphibolites with susceptibilities up to 0.04 SI units - do not appear to be as widespread as the weakly magnetic quartzites and schists, and therefore would not have a major effect on the regional geophysical response.

Other Rock Types

Minor occurrences of dolerite, gabbro and dacite would also have little effect on the regional geophysical response. However, in a detailed survey, the dolerites in particular have an effect on the magnetic response as shown in the traverses over dolerites in the Ehrenberg Range area. These narrow dolerite dykes are moderately magnetic (average susceptibility 0.008 SI) and dense (average specific gravity 3.00). They are also characterised by high remanent intensities which again appear to have random directions. Several of the dolerites are associated with negative magnetic anomalies. It may be possible to use the remanent magnetism of these dykes to determine their age.

Acid volcanics in the Kintore Range area are by comparison weakly magnetic (0.002 SI) and have low remanent magnetism and specific gravity. Similarly, metagabbros in the Mount Lindsay area are virtually non-magnetic, but have a relatively high specific gravity. The zone of deformed schist and mylonite in the Yaya Creek area contains rocks of average specific gravity and moderately high susceptibility, but are characterised by their high remanent magnetism. If this zone is as widespread as predicted, it could possibly account for the intense negative magnetic anomalies observed in the original magnetic data in that area.

Metasediments forming the basal units of the Amadeus Basin sequence (Heavitree Quartzite) are virtually non-magnetic, have low specific gravity (less than 2.6) and would have little effect on the regional geophysical response.

Physical Property Analyses

For the granitic rocks - that is, the granites, gneisses, migmatites, granitoids and granulites - the magnetic susceptibility and specific gravity measurements have been compared with rock composition and magnetic grade. Figure 15 shows the relation between magnetic susceptibility and potassium content measured as K_2O by atomic absorption spectrometry. The potassium content can be regarded as an approximite measure of acidity of the rock. A distinction has been made between those rocks that are metamorphosed, and those that are not. It is apparent from Figure 15 that susceptibility may be a general guide to composition, in that the highest values are often associated with the most basic rocks. However, within a particular rock group, the susceptibility range is far too wide to be a distinctive characteristic of rock type.

A significant feature of Figure 15 is the suggestion that once the igneous rocks become metamorphosed their range of susceptibility may increase markedly. A similar observation on basement rocks was made by Lidiak (1974).

The relation between susceptibility and the characteristic secondary mineral present for each suite of granitic rocks is shown in Figure 16. This figure suggests that granitoids containing clinopyroxene have a higher susceptibility than granites of similar composition containing hornblende and biotite, which in turn have a higher susceptibility than those containing just biotite. Muscovite-bearing granites have the lowest susceptibilities.

The metamorphism of most igneous rocks appears to increase magnetic susceptibility markedly, but to change the specific gravity only slightly (Fig. 17). Because the specific gravity of igneous rocks depends on their composition, and is little affected by metamorphism at lower grades, it is considered that detailed gravity surveys produce a more diagnostic interpretation of compositional variations within the basement than do magnetic surveys, which reflect metamorphic as well as compositional changes. Classification of rock types in terms of composition and metamorphic grade may thus be possible from combined interpretations of both gravity and magnetic data.

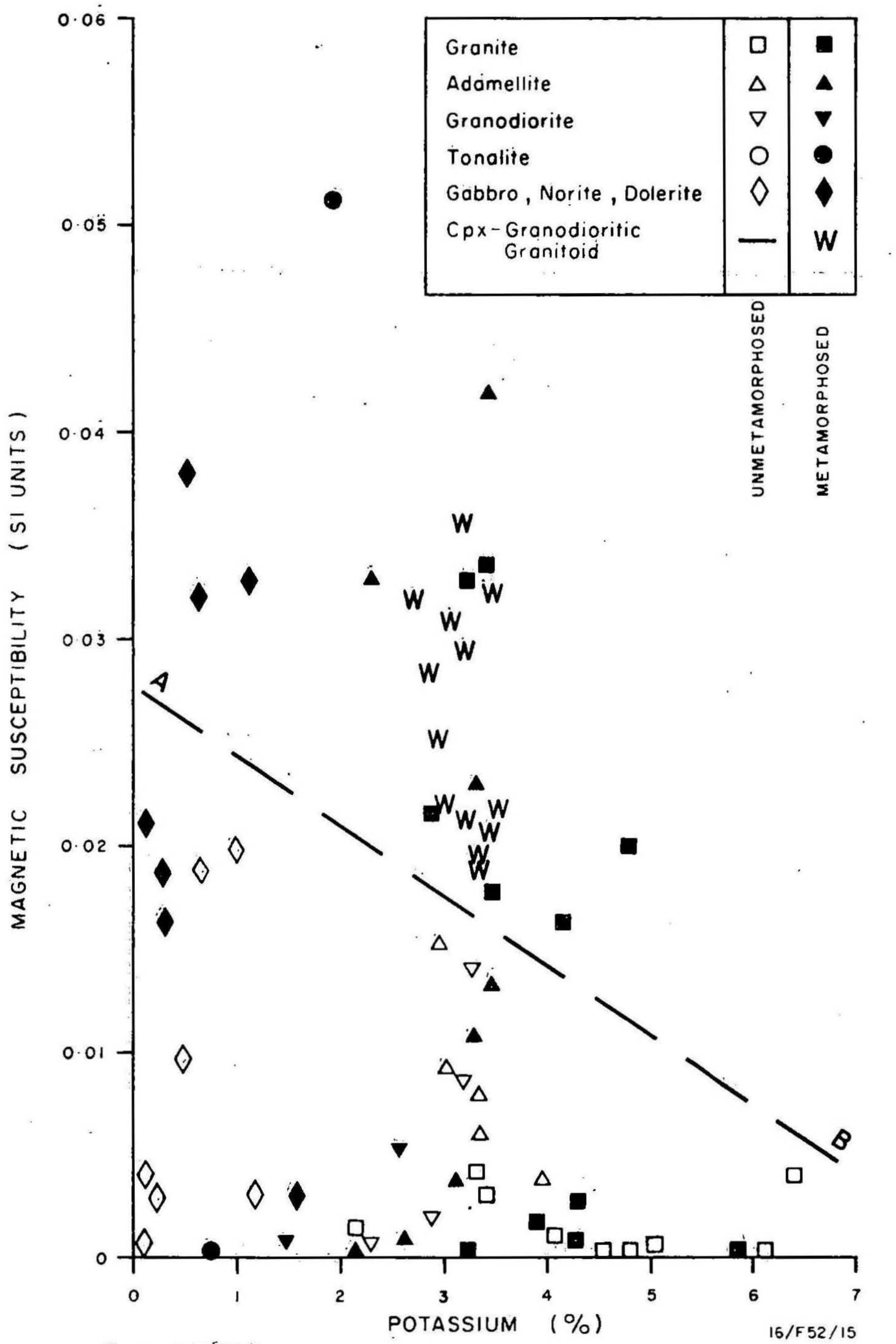

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Fig. 15 Relationship between magnetic susceptibility and potassium content for igneous and metamorphic rocks from SW Arunta Block

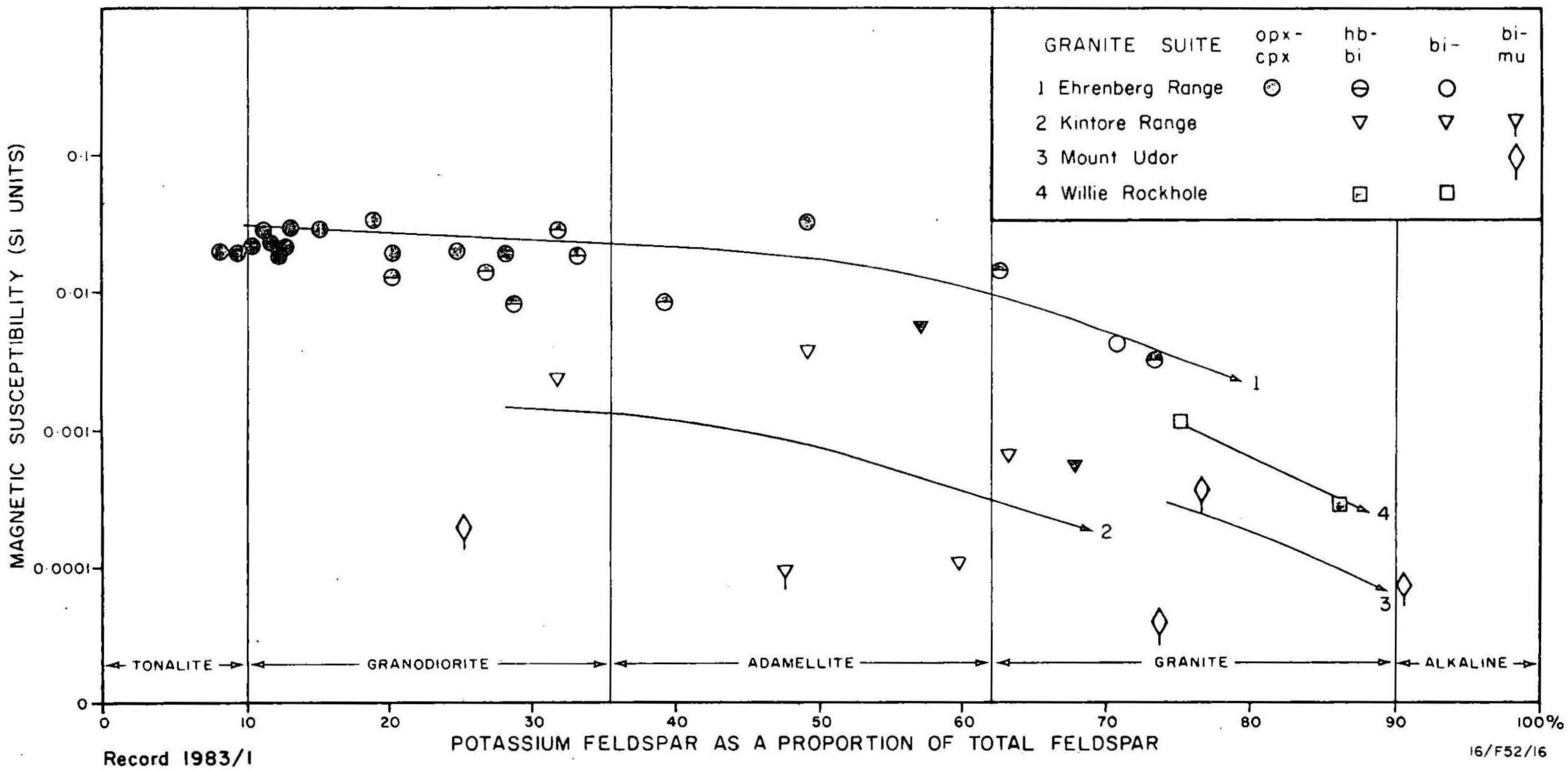

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Fig. 16 Variation in magnetic susceptibility for granitic rocks, SW Arunta Block, illustrating the significance of secondary mineral components.

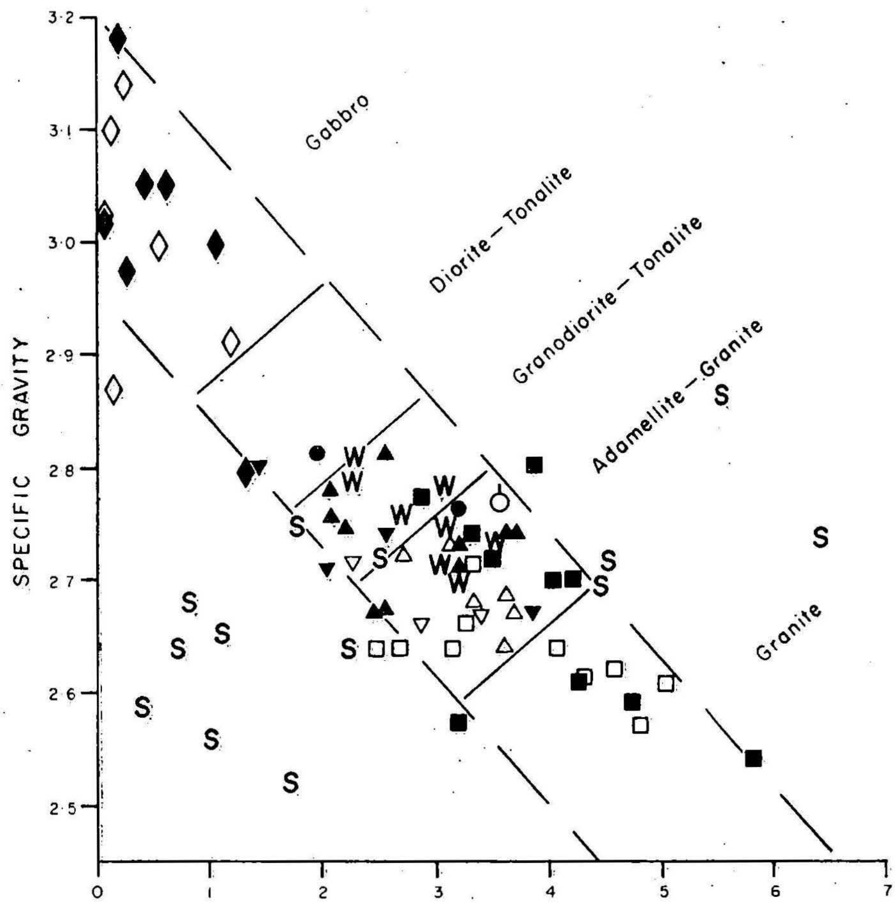

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Fig. 17 Relationship between specific gravity and potassium content for rocks from SW Arunta Block (S=Arunta Block metasediments and younger sediments overlying basement. All other symbols as defined in Fig. 15)

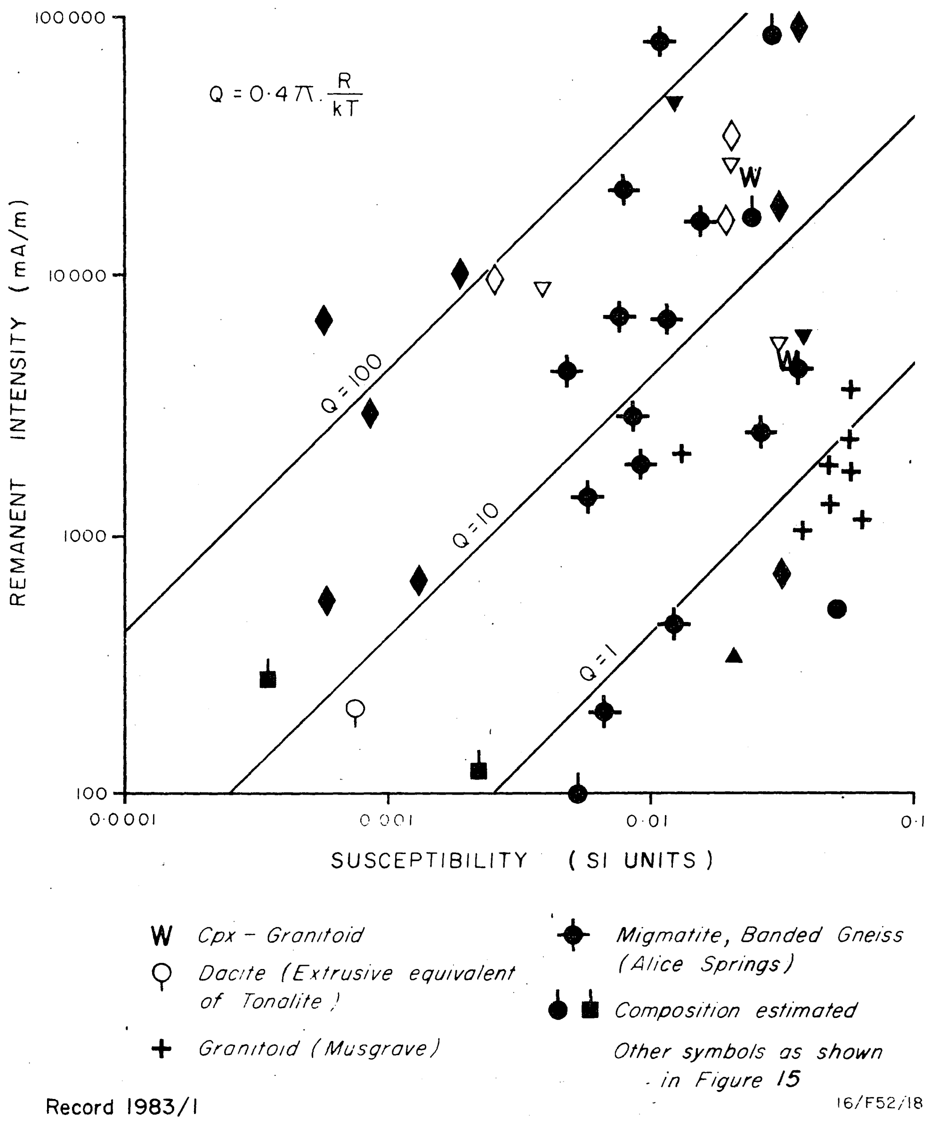

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Fig. 18 Relationships between magnetic susceptibility and remanent intensity, showing variations of the Koenisberger ratio (Q) for granitic rocks from the SW Arunta Block, migmatites from the Alice Springs area, and granitoids from the Musgrave Ranges. (R = remanent intensity, mA/m; k = susceptibility, SI; T = total field intensity, nT).

In Figure 18, the values of remanent magnetic intensity of the 20 oriented samples measured for remanent properties are plotted against magnetic susceptibility. The results of measurements on samples from the Alice Springs area and the Musgrave Ranges (several hundred kilometres to the south) are also included in Figure 18 to show that a similar range of values applies to similar migmatites and granulites from other basement areas in central Australia.

There appears to be no clear relation between remanent intensity and metamorphism, although the highest-grade rocks - mafic granulites, pyroxene-bearing granitoids, and migmatitic gneisses - commonly have high Koenigsberger ratios (Q), generally greater than 10. By contrast, the Musgrave Ranges granitoids have relatively low Q values. Lidiak (1974) records high Q values for high-grade metamorphic rocks from a basement terrain similar to the Arunta Block.

Remanent inclinations and declinations were also measured, but the values appear to be random despite magnetic cleaning of several samples to remove any soft magnetisation caused by lightning strikes. No firm conclusions can be drawn from so few samples, but it is probably significant that more than half of the samples measured have remanent inclinations reversed to that of the Earth's present field. This is believed to be partially responsible for the zones of intensely negative magnetic anomalies which occur across the area.

This cursory examination of remanent magnetic properties indicates the significance of remanence in basement terrains. It is suggested that more detailed sampling of rocks for their remanent properties should provide important information for the interpretation of the complex magnetic patterns generally observed in these areas. The variability of all magnetic properties highlights the need to determine the physical properties of substantial numbers of samples in each area where a magnetic interpretation is attempted.

The measured physical properties of basement rock samples collected from MOUNT RENNIE and MOUNT LIEBIG indicate that the magnetic properties of the rocks depend only in a general sense on composition.

They also appear to depend on the degree of metamorphism, and other geological processes that affect the total iron content and oxygen fugacity of the rocks. These processes are not always reflected in the geological classification of the rocks.

12. REGIONAL INTERPRETATION

An interpretation of the regional aeromagnetic data for MOUNT RENNIE and MOUNT LIEBIG has been controlled largely by the measurements of the magnetic properties of the most widely occurring groups of rocks, namely granite, metasediments, gneiss, migmatite (including migmatitic gneiss), granitoid (including tonalite and granodiorite), and granulite (which includes granofels, norite, and mafic granulite). Additionally, deformed schistose rocks which occur in narrow, east-trending zones near the southern margin of the Arunta Block, are included as an important rock type because they appear to be related to the region of intense negative magnetic anomalies which cross the area.

It is clear from the physical property data that the weakest magnetic anomalies should be associated with granites and metasediments, the more disturbed magnetic zones should correlate with gneisses, and the most disturbed zones with the strongest magnetic anomalies should correlate with migmatites, granitoids, and granulites. Remanent effects should be more apparent for the granulite group than for other rock groups.

A semi-quantitative interpretation of the southwest Arunta Block, presented in Figures 19 and 20 was made by computer modelling of selected regional aeromagnetic profiles, and extrapolation of these models by reference to the aeromagnetic contours. The magnetic susceptibilities of the sampled rock types were used as the primary guide for determining the lithological classification of the causative bodies.

Three north-south aeromagnetic traverses shown in Figure 19 were modelled using a forward-modelling computer program which calculates the magnetic anomaly for an array of two-dimensional bodies of arbitrary shape and magnetisation. The program is based on formulae presented by

Sharma (1966). In Figure 19 the traverse numbers (4N, 8S, 12N) refer to actual tie-line numbers flown in the 1965 BMR airborne survey of the Amadeus Basin (Young & Shelley, 1977). These lines represent north-south profiles along $129^{\circ}45'$E (4N), $130^{\circ}45'$E (8S), and $131^{\circ}45'$E (12N) from 23°S to approximately $23^{\circ}30'$S, and are normal to the major strike direction and hence traverse most of the rock types encountered in the southwest Arunta Block.

Traverse 4N

Outcrop geology along this traverse, the most westerly of the lines modelled, consists of weakly magnetic granite, schist, and amphibolite. It is clear that neither the susceptibilities nor the specific gravities of such rocks could produce the magnetic and gravity responses observed. The anomalies, particularly in the northern half of the traverse (north of Willie Rockhole), must be caused by much denser, magnetic rocks at comparatively shallow depths. The available gravity data, from the 1962 BMR reconnaissance survey (Lonsdale & Flavelle, 1963), are not detailed enough for modelling bodies in the upper crust. Recent interpretations of this regional gravity data (Anfiloff & Shaw, 1973; Mathur, 1976; Wellman, 1978) have been aimed at modelling variations in deep crustal thickness and shape; those interpretations have little bearing on the present investigation.

In the interpretation of the aeromagnetic data, two constraints - limited depth extent and induced magnetisation - are placed on the models. Modelling using the available remanent magnetic data was not successful, perhaps because of the paucity of samples measured. Modelling of induced magnetic bodies, on the other hand, revealed a consistent discrepancy as seen by comparing Figure 19 with Table 12, between measured susceptibility and model susceptibility, the latter generally being about 20 percent higher, particularly for the more magnetic rock units. The higher model values can be explained by:

(a) magnetisation due to remanence. The remanence component, which as noted is a significant factor in most of the granitic rocks, would tend to increase the total magnetisation of the rocks if the remanent inclinations add to the induced magnetisation of the Earth's present field. Under these circumstances the apparent susceptibility would be greater than the measured susceptibility.

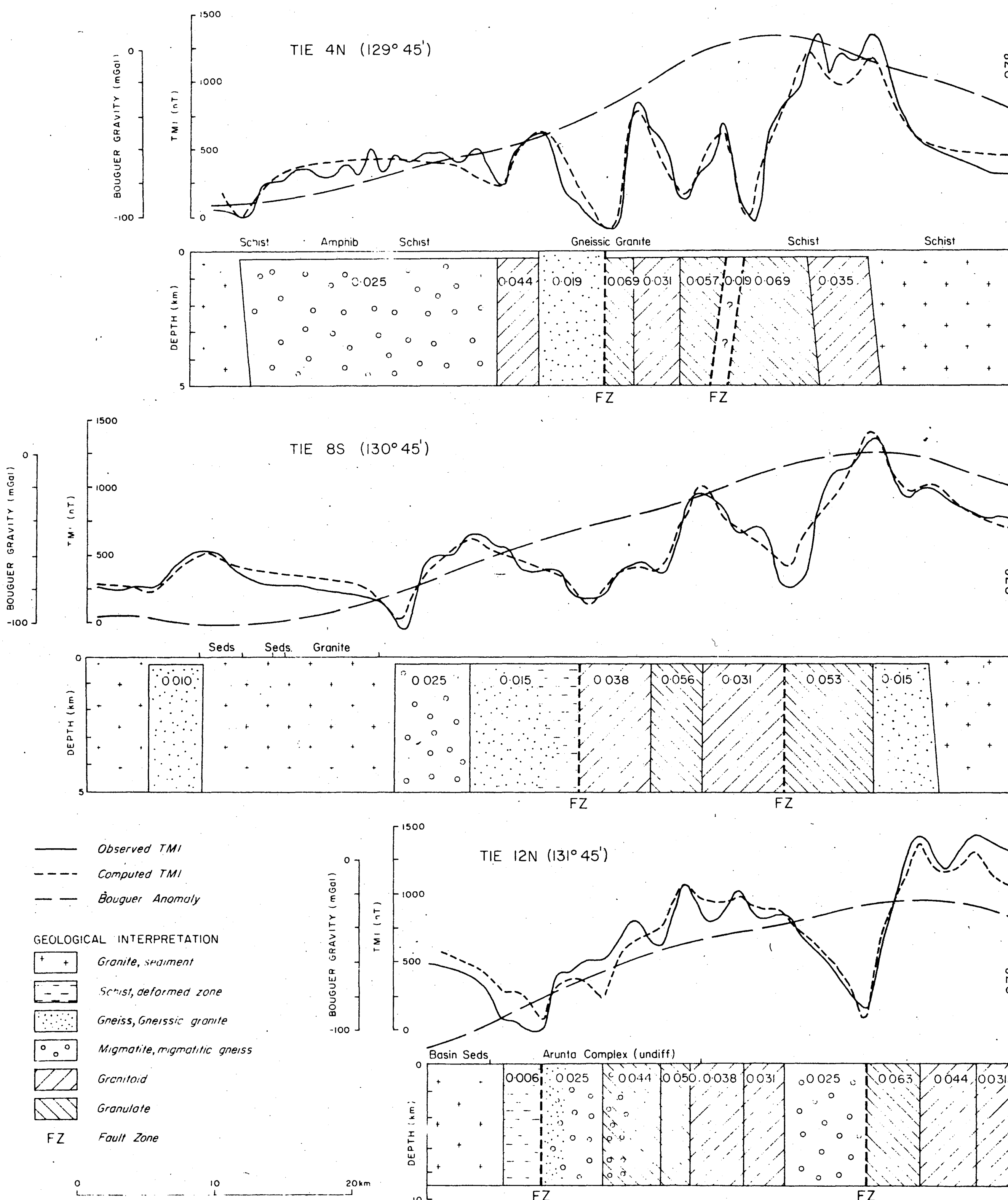

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Fig.19 Modelling and interpretation of N-S aeromagnetic profiles, SW Arunta Block.

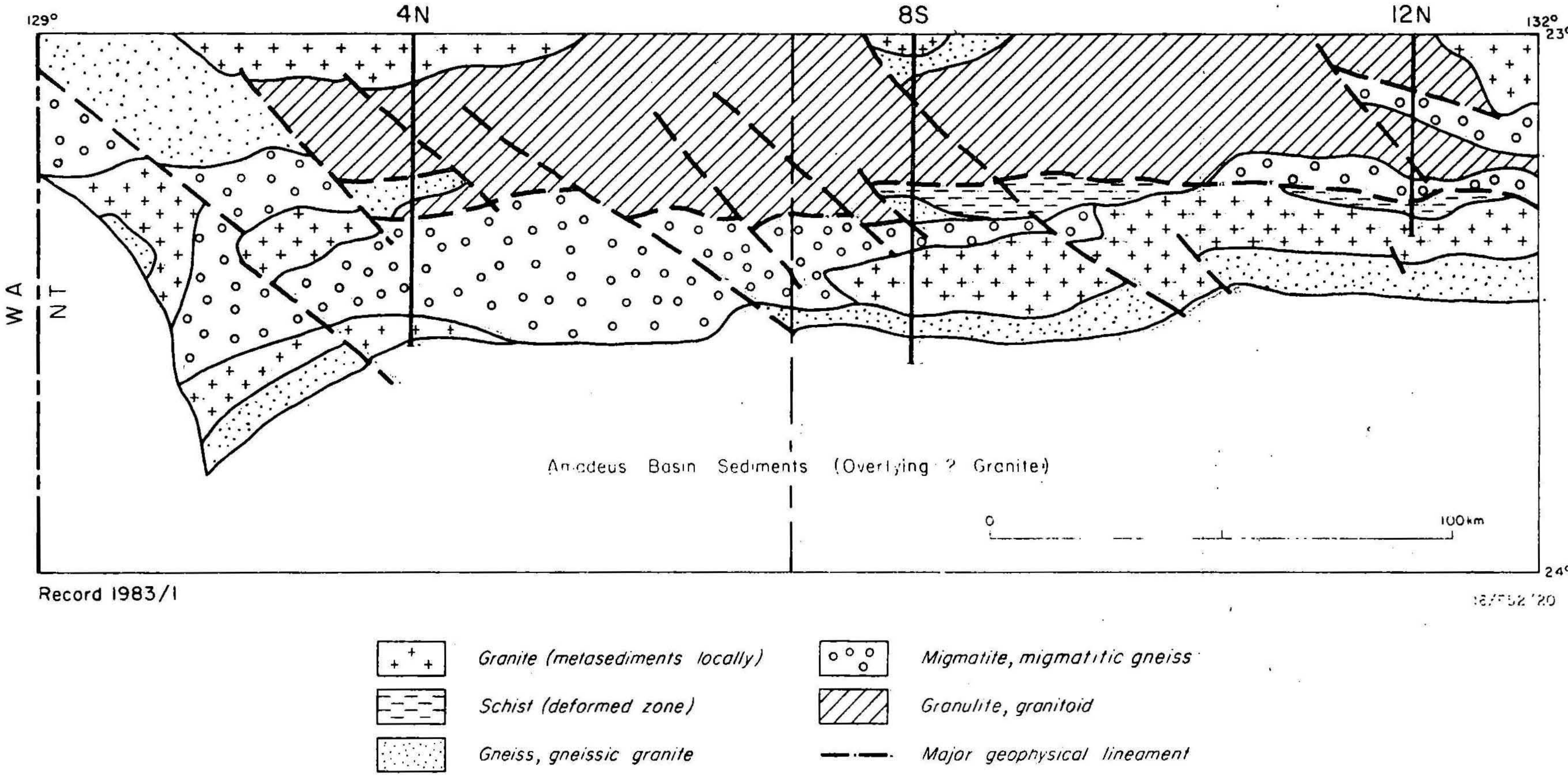

Fig. 20 Solid geology interpretation of aeromagnetic results, SW Arunta Block.

(b) as the models represent buried rock units, the susceptibility could be greater at depth than in the surface samples; weathering effects commonly deplete the magnetite content near the surface.

Although the resultant model for this traverse is a simplification of an obviously complex geometry, a clear grouping of the major rock types is observed. A 20-km belt of mainly granulitic rock, which may be a combination of mafic granulite, granitoid, norite, and possibly gabbro, occurs immediately south of a non-magnetic block, which is interpreted as granite underlying metasediments. The gneissic granite cropping out at Willie Rockhole appears to be significantly more magnetic at depth. This may suggest that the granitic rocks are underlain by gneisses and migmatites. A small magnetic body immediately south may be a basic intrusive, such as gabbro. Its susceptibility would suggest that it is related to the granulitic rocks. The large body in the south of the traverse which is interpreted as migmatitic gneiss probably contains a complex array of gneisses and metasediments. Weakly magnetic schists and minor amphibolites exposed above this magnetic body are most likely related to a widespread but relatively thin unit present throughout much of the Arunta Block (Division 3 of Shaw & Stewart, 1975; Stewart & Warren, 1977). At the southern end of the traverse, granite possibly underlies the non-magnetic sediments of the Amadeus Basin.

The intense magnetic lows in the centre of the traverse coincide with the largest susceptibility contrasts. These may indicate major fault zones, particularly the low-susceptibility zone within the granulite block. Rocks within these zones may have been subjected to retrograde metamorphism.

<u>Traverse 8S</u>

This traverse is approximately 100 km to the east of 4N, but it is clear from Figure 19 that a broadly similar model is suggested by the interpretation. Again, a 20-km belt of strongly magnetic granulites and granitoids in the north of the area is bounded to the north and south by gneisses, migmatites, and, furthest away, granites. The boundaries may represent major fault zones. A large area of weakly magnetic rocks in the south of the traverse is interpreted as granite, but may well represent metasediments overlying granitic basement.

The southern boundary of the Arunta Block is marked by a narrow belt of moderately magnetic rock (susceptibility 0.01 SI units), which may be granodiorite or gneiss. Interpretations of the regional gravity data suggest overthrusting of the Amadeus Basin by the Arunta Block in a major east-trending zone in the vicinity of this magnetic unit. Non-magnetic basal sediments of the Amadeus Basin cropping out immediately north of this gneissic unit may thus represent remnants of the basin sequence exposed as a result of overthrusting. The interpretation of a high-angle overthrust at this point is supported by depth-to-basement contours of the Amadeus Basin given by Young & Shelley (1977). These regional contours show an abrupt thinning of the sedimentary sequence from depths in excess of 10 km to zero in this region.

Traverse 12

Occurring in the east of the survey area, this traverse was the most difficult to model. In fact it was necessary to increase the depth extent of the model to help accommodate an increase in the apparent susceptibility of the rock mass. This increase is most likely due to higher susceptibilities and remanent magnetisation in an area where metamorphic grade implies that the rocks have been thrust up from greater depths compared with rock units to the west. The total magnetisation at these greater depths would likely be enhanced by thermo-remanent or viscous magnetisation effects (Nagata, 1961; Coles & Currie, 1977) owing to the increase in pressure and temperature at such depths.

The overall pattern again emerges of a thick belt of highly magnetic granulite, granitoid, and migmatite bounded to the south by less magnetic gneiss, metasediments, and granite. However, on this traverse, some unusual features are seen, in particular the intense magnetic lows in the centre and south of the traverse. The first of these possibly represents a major fault zone, whereas the second appears to correlate with a zone of deformed schistose rocks which exhibit retrograde metamorphism. Modelling this second anomaly assuming only induced magnetisation proved difficult, and it is believed that in this zone of deformed rock, reverse remanent magnetism is possibly the dominant contributing factor to the total magnetisation of the rocks. A sample of deformed rock collected east of this zone (1086 in HERMANNSBURG) had a high remanent intensity and Koenigsberger ratio (6400 mA/m, Q = 258) and a reverse remanent inclination, but a relatively low susceptibility of 580 x 10^{-6} SI units.

Solid geology interpretation

The model results for the interpreted traverses were extrapolated to interpret the aeromagnetic data for the entire area, and so produce a solid geology interpretation for the southwest Arunta Block. This interpretation is presented in Figure 20. Non-magnetic sediments overlying basement rocks are excluded from this interpretation. The areas shown as granite present areas of non-magnetic basement, and therefore may equally represent thick sequences of metasediments, particularly in the south of the area, where sediments of the Amadeus Basin crop out. The nature of the basement beneath these sediments is not certain.

It is evident that the extent of non-magnetic granite within the southwest Arunta Block is much less than suggested by regional mapping. However, it must be emphasised that the moderately to strongly magnetised rocks (gneiss, migmatite, granitoid, and granulite) may include rocks of broadly granitic composition.

An important result to emerge from this study is the presence in the upper crust of the vast belt of strongly magnetic and dense granulite, representing rocks of very high metamorphic grade. It is possible that these rocks have been thrust up from the lower crust to form the elongate belt which occupies much of the northern part of the area. The regional gravity data support this broad interpretation. The gravity profiles shown in Figure 19 clearly indicate a close correspondence between the Bouguer anomaly high and the dense rocks of the granulite belt. The gravity lows correspond to zones of granite and Amadeus Basin sediments. The rocks of intermediate density - migmatite, gneiss, and schists - coincide with the main gravity gradient on each profile. Metamorphism and migmatisation of granites and metasediments in the region may have been associated with the upthrusting of the dense granulites. Major NE-SW lineaments are probably related to shearing and faulting of the main rock units following their formation.

The deformed schists, which occur in an extended east-west zone near the southern margin of the Arunta Block, may be related to overthrusting along major east-trending faults. Similar faulting further east has been related to tectonic activity associated with the Alice Springs Orogeny (400-300 m.y.) (Forman & Shaw, 1973).

13. CONCLUSIONS

The results of geological and ground geophysical investigations in the southwest Arunta Block have demonstrated the need for good data on the physical properties of rocks cropping out in the area in order to be able to interpret geophysical maps in relation to the regional geology. The complex magnetic patterns observed in MOUNT RENNIE and MOUNT LIEBIG could not be explained in terms of the lithological descriptions provided by the existing 1:250 000 geological maps. However, a meaningful interpretation of the regional aeromagnetic data from these areas has been achieved only by making use of physical property data from about 200 rock samples collected in the areas.

The ground gamma-ray spectrometer gave an inaccurate indication of K, U, and Th measurements (70 to 50 percent too low) when checked against chemically determined values (see Appendix 1). There are problems of calibration with this instrument. The regional airborne radiometric response seems to be related more to topographic variations than to variations in radiometric levels of the rocks, possibly because of the small crystal used in the survey.

Magnetic anomaly modelling, based on the properties of the most widespread rock units, was followed by qualitative zonal interpretations based on these models to produce a solid geology map of the Precambrian basement. Further refinements of this interpretation could be produced using the available regional gravity data in conjunction with the specific gravity measurements on the samples collected.

The main conclusions that can be drawn from the results of the work in MOUNT RENNIE and MOUNT LIEBIG are:

(i) the occurrence of non or weakly magnetic granite, including gneissic granite, adamellite and granodiorite, is restricted in these areas to very few localities (e.g. east of Kintore Range and at Willie Rockhole). This would resolve the apparent discrepancy between the complex magnetic patterns observed in the aeromagnetic data, and the regional 1:250 000 geological maps which show large areas of granite.

(ii) many of the rocks mapped as granite include rocks which in a general sense can be regarded as granitic since they represent the products of complex metamorphism and migmatisation of older granites, adamellites, granodiorites and tonalites. These granitic rocks can be reclassified on the basis of composition and metamorphic grade as gneiss, migmatite, granitoid or granulite, all of which can be moderately to very strongly magnetic.

(iii) metasediments which are in general weakly magnetic, and the less extensive occurrences of amphibolite, dolerite, gabbro and dacite, do not appear to have a major influence on the regional magnetic response.

(iv) analysis of the physical properties of the major rock types indicates that, in general, the magnetic properties of the rocks depend in a general sense on composition, but also on the degree of metamorphism and other geological processes (not always reflected in the geological classification of the rocks) which affect the total iron content and oxygen fugacity of the rocks. Specific gravity on the other hand is more closely related to the rock composition and is little affected by metamorphism at lower grades. It would appear therefore that classification of rock types in terms of composition and metamorphic grade may be possible from combined interpretations of both gravity and magnetic data.

(v) there appears to be no clear relationship between remanent magnetic properties and metamorphic grade, although the highest grade rocks commonly have high Koenigsberger ratios. Measurements of remanent inclinations and declinations gave results which were too random for quantitative assessment (possibly owing to poor sampling techniques), but it could be significant that more than half of the samples measured had remanent inclinations reversed to that of the Earth's present field. This may explain the occurrence of zones of intensely negative magnetic anomalies which are prominent in the southwest Arunta Block.

(vi) very little was achieved with respect to gamma-ray spectrometer measurements owing to inadequate understanding of the instrumentation at the time of the work. From the results presented, it is clear that more careful calibration of the instrument will give results on the radioelement content of the rocks which can be related directly in the field to composition and other physical properties of the rocks. However the gamma-ray spectrometer was able to give an immediate solution to the source of airborne scintillometer anomalies detected during the 1965 survey. These appear in some areas to be a reflection of topographic features rather than of geochemical variations (e.g. over Mount Leisler in the Kintore Range), and in other areas the anomalies reflect broad exposures of felsic gneiss.

(vii) ground magnetic data provided immediate information on subtle variations in the chemistry or lithology of the underlying rocks but, in the context of the regional interpretation, are of limited usefulness.

(viii) to obtain the best solution to the regional geological interpretation of this region, it would be necessary to carry out an airborne magnetic survey with north-south lines spaced at most 1.5 km apart, in conjunction with a gravity survey consisting of several north-south traverses across the basement with stations about 500 m apart.

In general, much useful data were generated from this field work carried out over a period of about 20 days in an area of poor access and poorly known geology. On the basis of ground geophysical surveys, geological mapping and physical property and geochemical analyses of numerous samples collected from the area, and in combination with modelling of previous geophysical data, it has been possible to produce a solid geology interpretation of the southwest Arunta Block which is by no means final but provides a basis for future geological work in the area, as well as for interpretation of magnetic and gravity survey data from other parts of the Arunta Block.

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APPENDIX 1. Ground gamma-ray spectrometer results

The table shows the results of potassium, uranium and thorium determinations obtained by ground gamma-ray spectrometry, and by laboratory analysis of rock samples from the sites where spectrometry was done. The spectrometry used counting times of 3 or 4 minutes. Error figures quoted correspond to $\pm$ 1 standard deviation based on errors from counting statistics and the stripping process. No allowance has been made for inaccuracies in the knowledge of background levels or in stripping ratios and sensitivity figures. Study of the tabulated results shows that :-

1. The ground spectrometer measurements for potassium have under-estimated the potassium concentration. On average the values derived from spectrometry are 70 percent of the values derived from atomic absorption analysis on rock samples.
2. About 70 percent of the uranium measurements agree within $\pm$ 2 ppm. However it should be noted that the range of uranium concentrations is very restricted.
3. About 53 percent of the thorium analyses agree within $\pm$ 20 percent.

In most cases only one sample was analysed per spectrometer site hence some of the differences between laboratory measurements and ground spectrometry are due to inadequate sampling.

The calibration constants used in the processing of the raw radiometric data were :-

Background value

ch2 = 105 ch3 = 19 ch4 = 12

Stripping Ratios

α = 0.57 β = 0.83 γ = 1.46

Sensitivity constants

SK = 212 cpm/%k SU = 14.1 cpm/ppm eU STh = 8.7 cpm/ppm eTh

RADIOELEMENT ANALYSES FROM GROUND GAMMA-RAY SPECTROMETRY AND LABORATORY ANALYSIS

Sample Number	Rock Type	Lab. analyses			Ground spectrometry		
		K %	U ppm	Th ppm	K %	U ppm	Th ppm
1000	granite	3.06	4	22	1.52 ± 0.07	2.1 ± 0.4	21.5 ± 0.8
1003	granodiorite	3.15	4	23	2.68 ± 0.09	0.6 ± 0.5	23.0 ± 1.0
1004	granodiorite	3.18	3	20	2.64 ± 0.09	1.7 ± 0.5	23.5 ± 1.0
1005	granodiorite	3.28	4	20	2.58 ± 0.09	3.1 ± 0.5	19.6 ± 0.9
1006	granodiorite	3.12	ND	11	1.98 ± 0.09	2.3 ± 0.5	20.4 ± 0.9
1007	sandstone	ND	2	18	0.0 ± 0.08	5.0 ± 0.6	28.3 ± 1.1
1008	granodiorite	3.16	4	21	2.35 ± 0.09	1.6 ± 0.4	17.6 ± 0.9
1011	dolerite	0.58	ND	ND	1.13 ± 0.07	0.6 ± 0.4	11.5 ± 0.7
1012	tonalite	2.29	ND	ND	1.67 ± 0.09	1.4 ± 0.5	13.0 ± 0.9
1016	gneiss	3.90	ND	25	2.23 ± 0.08	1.5 ± 0.4	11.3 ± 0.7
1017	amphibolite	2.59	4	16	1.57 ± 0.08	1.4 ± 0.4	14.5 ± 0.8
1018	granite	3.31	4	17	2.50 ± 0.16	4.2 ± 0.9	19.3 ± 1.6
1019	gneiss	4.29	6	21	1.92 ± 0.08	1.7 ± 0.4	16.4 ± 0.9
1022	tonalite	2.71	ND	13	2.06 ± 0.08	2.6 ± 0.5	15.8 ± 0.8
1023	tonalite	3.30	ND	19	2.39 ± 0.09	1.3 ± 0.5	21.1 ± 1.0
1024	tonalite	2.94	4	14	2.54 ± 0.09	1.9 ± 0.5	19.0 ± 0.9
1025	tonalite	2.81	ND	15	2.75 ± 0.09	1.3 ± 0.5	19.1 ± 0.9
1026	tonalite	3.22	3	19	2.29 ± 0.09	1.4 ± 0.5	21.1 ± 1.10
1027	granodiorite	2.96	4	16	2.16 ± 0.08	1.6 ± 0.4	17.3 ± 0.9
1030	gabbro	0.07	ND	ND	0.01 ± 0.05	0.0 ± 0.3	4.1 ± 0.6
1031	hornfels	0.16	ND	7	0.31 ± 0.05	0.0 ± 0.3	5.6 ± 0.5
1032	hypersthene norite	0.13	ND	ND	0.08 ± 0.04	0.0 ± 0.2	2.0 ± 0.4
1037	hypersthene norite	0.11	ND	ND	0.0 ± 0.04	0.5 ± 0.2	2.7 ± 0.4
1062	conglomerate	1.74	ND	8	2.53 ± 0.08	2.2 ± 0.4	23.2 ± 0.9
1063	sandstone	0.75	ND	4	0.32 ± 0.05	0.3 ± 0.3	4.5 ± 0.5
1067	dacite	2.11	4	17	2.18 ± 0.09	3.8 ± 0.5	18.2 ± 0.9
1070	gneiss	4.08	8	36	2.70 ± 0.11	1.8 ± 0.7	49.1 ± 1.4
1071	granite	4.83	10	41	3.32 ± 0.12	4.4 ± 0.8	54.4 ± 1.5
1072	granite	4.26	7	37	2.82 ± 0.13	5.4 ± 0.8	38.2 ± 1.6
1090	granodiorite	3.25	3	23	2.19 ± 0.09	3.9 ± 0.5	22.7 ± 1.0

ND: non-detectable; detection limits 2 ppm for uranium and thorium, 0.01% for potassium

Sample Number	Rock Type	Lab. analyses			Ground spectrometry		
		K %	U ppm	Th ppm	K %	U ppm	Th ppm
1091	gneiss	6.40	9	100	3.24 ± 0.12	3.2 ± 0.8	63.4 ± 1.6
1092	adamellite	3.06	2	21	2.01 ± 0.08	2.2 ± 0.5	18.3 ± 0.9
1094	granite	2.91	4	23	2.26 ± 0.09	3.5 ± 0.5	19.6 ± 0.9
1095	granodiorite	3.33	ND	10	2.70 ± 0.16	3.1 ± 0.9	20.6 ± 1.6
1100	gneiss	3.27	3	21	2.57 ± 0.08	3.3 ± 0.4	21.1 ± 0.8
1107	gneiss	0.73	ND	15	0.26 ± 0.06	1.1 ± 0.4	16.3 ± 0.9
1136	granite	5.04	4	28	3.37 ± 0.11	3.4 ± 0.6	30.6 ± 1.1
1140	gneiss	5.84	3	12	2.16 ± 0.09	0.9 ± 0.4	6.8 ± 0.7
1142	gneiss	1.97	ND	13	1.44 ± 0.08	1.9 ± 0.4	15.0 ± 0.8
1145	gneiss	2.75	ND	18	2.67 ± 0.09	0.9 ± 0.5	24.6 ± 1.0
1148	gneiss	4.75	2	40	3.28 ± 0.12	4.2 ± 0.7	46.4 ± 1.4
1151	gneiss	3.40	ND	12	2.30 ± 0.09	1.7 ± 0.5	27.2 ± 1.1
1152	gneiss	3.40	ND	23	1.99 ± 0.11	0.0 ± 0.7	59.4 ± 1.6
1157	soil	2.15	ND	12	1.69 ± 0.12	1.1 ± 0.6	8.9 ± 1.1
1163	gneiss	4.11	2	32	2.61 ± 0.12	1.2 ± 0.7	30.0 ± 1.4
1164	gneiss	4.18	3	27	2.71 ± 0.17	0.9 ± 1.0	32.8 ± 2.0
1165	gneiss	3.43	ND	18	2.75 ± 0.10	1.3 ± 0.6	37.3 ± 1.3
1166	mylonite	2.47	3	21	1.72 ± 0.09	1.5 ± 0.6	34.1 ± 1.2
1168	gneiss	3.67	8	45	2.67 ± 0.13	3.5 ± 0.8	42.7 ± 1.6
1184	schist	3.75	ND	18	2.13 ± 0.10	1.3 ± 0.5	18.0 ± 1.1
1185	quartzite	0.81	ND	6	0.98 ± 0.07	1.3 ± 0.4	11.2 ± 0.7
1189	migmatite	4.16	3	24	3.08 ± 0.10	1.2 ± 0.5	24.7 ± 1.0
1198	gneiss	3.23	ND	8	3.39 ± 0.15	0.8 ± 0.6	11.3 ± 1.2
0100	sand	2.38	2	10	1.82 ± 0.09	1.1 ± 0.4	8.8 ± 0.8
0501	tonalite	3.50	5	26	2.52 ± 0.09	2.3 ± 0.5	18.9 ± 0.9
0509	adamellite	3.35	3	15	2.61 ± 0.09	0.3 ± 0.4	19.8 ± 0.9
0510	adamellite	2.89	4	24	2.65 ± 0.09	3.4 ± 0.5	22.0 ± 1.0
0511	quartzite	4.55	ND	7	2.15 ± 0.08	1.5 ± 0.4	16.2 ± 0.8

ND: non-detectable; detection limits 2 ppm for uranium and thorium, 0.01% for potassium

APPENDIX 2. Table of chemical analysis of granites

Specimen No. (Prefix 7509-)	1000	1018	1048	1090	1092	1111	1127
Rock Type	Grano-dioritic Granitoid	Granitic Gneiss	Adamellite	Grano-diorite	Grano-diorite	Adamell-itic Gneiss	Granite
Area	Kintore	Ehrenberg	Kintore	Ehrenberg	Ehrenberg	Putardi	Mt Udor
SiO_2	66.29	66.98	70.47	66.32	64.81	68.01	73.48
TiO_2	0.92	0.83	0.33	0.88	1.03	0.55	0.13
Al_2O_3	13.53	13.49	14.53	13.65	13.33	14.43	14.44
Fe_2O_3	1.95	1.75	1.01	2.11	2.05	1.89	0.57
FeO	4.40	4.00	0.95	3.75	5.15	2.65	0.80
MnO	0.13	0.11	0.06	0.11	0.14	0.13	0.11
MgO	1.42	1.17	0.61	1.33	1.32	1.13	0.51
CaO	3.66	3.15	2.33	3.37	3.81	2.53	1.82
Na_2O	2.86	2.86	3.60	2.82	2.88	3.08	3.14
K_2O	3.66	3.88	4.25	3.87	3.65	4.03	3.77
P_2O_5	0.22	0.20	0.07	0.19	0.25	0.16	0.13
H_2O+	0.42	1.08	0.83	0.87	1.03	1.20	1.07
H_2O-	0.04	0.06	0.03	0.03	0.03	0.02	0.01
CO_2	0.05	0.05	0.25	0.05	0.05	0.05	0.15
SO_3	0.09	0.02	*0.01	0.01	0.04	0.01	*0.01
TOTAL	99.59	99.63	99.32	99.35	99.57	99.86	100.12

* = less than

Trace elements in ppm; * = less than

Ni	15	10	4	12	9	9	5
Co	15	12	3	13	16	9	3
Zn	120	120	53	92	132	80	55
Li	14	34	9	14	16	11	19
Ba	700	660	880	680	820	800	920
Rb	180	210	180	190	180	180	130
Sn	4	6	4	4	4	4	4
Sr	150	140	290	150	150	160	310
Th	20	16	18	22	18	12	14
U	4	6	6	4	6	*4	*4
Y	36	38	26	42	48	28	14
W	*10	*10	*10	*10	*10	*10	*10
F	700	750	820	820	750	660	430
B	30	40	10	35	15	5	5
Be	2	2	1	2	3	2	1

Note on granite analyses: Major elements analysed by code H3 (i.e. by combination of X-ray fluorescence and chemical methods). Ni, Co, Zn and Li analysed by Code C4 (i.e. Atomic absorption using hydrofluoric and digestion). Ba, Rb, Sn, Sr, Th, U, Y, W analysed by Code B1 (i.e. X-ray fluorescence, accuracy ± 5%). F, B, Be analysed by Code 02 (i.e. high quality analysis).

Table of visually estimated modes of analysed granitic rocks (%).

	1000	1018	1048	1090	1092	1111	1127
Quartz	28	11.0	25	27	29	30	40
Plagioclase	39	35.0	30	40	30	28	5
K-feldspar	5	30.0	29	10	21	28	48
Biotite	5	10.0	3	10	10	8	1.5
Hornblende	14	7.0		10	10		
Clinopyroxene	3						
Orthopyroxene	4						
Garnet		1					
Opaque grains	0.8	0.1	0.2	1.0	0.2	0.3	
White mica		2	4.0				5.5
Epidote/clinozoisite) chlorite)		3	6.0			5	
Other			1.0	2.0			
Possible opaque	mt	mt/Il	mt	mt/Il	mt	mt	-
Sphene		x				x	

x = accessory