DEPARTMENT OF MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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GROUND GEOPHYSICAL SURVEY, TENNANT CREEK, NORTHERN TERRITORY, 1972

by

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SUMMARY

In 1972 the Bureau of Mineral Resources made gravity and magnetic surveys in the Tennant Creek area to study the high-grade metamorphic rocks discovered in drill holes in BMR Area No. 3 and to study the Aeromagnetic Ridge. One east-west and three north-south traverses were surveyed; density, susceptibility, and magnetic remanence measurements were made on surface and drill-core samples.

The high-grade metamorphic rocks and associated minor basic intrusives at BMR Area No. 3 produced distinctive magnetic and gravity anomalies. This is consistent with susceptibility and density measurements made on drill core from the area; magnetite is considered to be a significant source of the high susceptibilities and densities. If the magnetite is syngenetic, the extent of metamorphic rocks can be determined with the magnetic method. If the magnetite has been introduced by basic intrusives, magnetic anomalies will not be a reliable guide for delineating the areas of metamorphic rocks, and the gravity method is a better method to use.

Granite masses in the Tennant Creek area produce low flat magnetic responses and gravity lows. The Warramunga Group sediments produce higher magnetic values with local anomalies, and gravity highs. The Quartz Hill/ Rocky Range Fault divides the sediments in the Tennant Creek area into magnetic sediments to the southwest and non-magnetic sediments to the northeast.

Comparison of susceptibility and density measurements on surface rocks with measurements on drill core showed that the physical properties of the surface rocks are markedly affected by weathering and that fresh rocks should be used.

1. INTRODUCTION

For many years the Bureau of Mineral Resources (BMR) has carried out ground geophysical work at Tennant Creek with surveys designed to yield basic information of significance to mineral exploration. This has necessitated extensive use of the magnetic method. In 1972 it was determined that joint gravity and magnetic surveys should be carried out with the objective of investigating more regional and fundamental questions concerning the mineral field. It was considered that this might lead to indirect economic benefits.

Three main investigations were undertaken:

(1) A study into the relation of the high-grade (possibly Archaean) metamorphic rocks discovered in drill holes in BMR Area No. 3 with the other rocks in the Tennant Creek field.

(2) An investigation into the structure of the Tennant Creek field, with particular reference to the significance of regional magnetic anomalies such as the Aeromagnetic Ridge.

(3) A study of physical rock properties to provide geological control of geophysical data.

To carry out these objectives, measurements were made on one east-west and three north-south traverses at 200-m station intervals using a gravity meter and vertical and total field magnetometers. The gravity survey results were reduced to the regional gravity network, enabling a more accurate regional gravity map to be produced for the south central region of the Tennant Creek area. Density, susceptibility, and in some cases magnetic remnant measurements were made on surface and drill core samples.

Field work was carried out from early August to late October by one geophysicist (I. Hone) and two field assistants supported by contract surveyors engaged by the Department of Interior.

A number of companies including Peko Wallsend Ltd., Australian Development, Inter Copper, and Australian Aquitaine Minerals have active exploration programs in the region. At times it was necessary to enter Authorities to Prospect held by these companies and their cooperation is gratefully acknowledged. The cooperation of officers of the Mines Branch, Northern Territory Administration is also gratefully acknowledged.

2. PREVIOUS GEOPHYSICAL INVESTIGATIONS

The first major geophysical investigation of the Tennant Creek area was carried out in 1935-1937 by the Aerial, Geological and Geophysical Survey of Northern Australia (AGGSNA). The magnetic results have been discussed in detail by Daly (1957).

In the period 1956 to 1960 the BMR covered the whole of the Tennant Creek Sheet area with aeromagnetic and airborne scintillometer surveys. Most subsequent geophysical investigations have been based on anomalies delineated by this work. Low-level aeromagnetic surveys have been flown over a number of selected areas (Milsom & Finney, 1965; Finney, 1967; Shelley & Browne-Cooper, 1967). The area has been covered in BMR's reconnaissance helicopter gravity survey, and the data in Plate 2 are based on results from the reconnaissance survey and from ground surveys.

Although almost every known geophysical method has been used in the field, the magnetic method has predominated. Except for groundwater investigations of Wiebenga & Dyson (1964) the BMR geophysical ground work was basically confined to magnetic surveys and gravity tests over significant magnetic targets. In 1969 Williams (in prep.) carried out gravity work in the Aeromagnetic Ridge area and the BMR Area No. 3. In 1971 Hone (1974) carried out additional gravity work over several magnetic anomalies, which demonstrated the usefulness of the method.

The 1972 traverses crossed many areas that had been surveyed previously by AGGSNA or by BMR. These include the Mount Samuel/Eldorado, Rising Sun, Joker, and Golden Forty areas surveyed by AGGSNA and described by Daly (1957), Area 4 (O'Connor, Goodchild, & Daly, 1959), BMR Area No. 3 (O'Connor & Daly, 1962), Golden Forty (Douglas, 1962) and the Cabbage Gum Basin (Wiebenga & Dyson, 1964). One traverse (Nobles Nob) crossed the westernmost part of the Aeromagnetic Ridge geochemical grid (Harding, 1965), an area covered by low-level aeromagnetic survey (Milsom & Finney, 1965). Other areas crossed which have similar low-level aeromagnetic coverage were Areas 1, 2, 3, and 7 (Finney, 1967).

3. GEOLOGY

The geology of the Tennant Creek mineral field has been described by Ivanac (1954), Crohn & Oldershaw (1965), Dunnet & Harding (1967), and Whittle (1966). A comprehensive summary is given by Crohn (1965). Mapping has been hampered by extensive alluvial cover and a deep zone of oxidation which commonly extends to over 60 m.

The Tennant Creek field is located near the centre of Tennant Creek Block of the North Australian Orogenic Province. In 1961-62, high-grade (almandine-amphibolite facies) metamorphic rocks were intersected by drill holes in BMR Area No. 3, 33 km west-southwest of Tennant Creek township. Schist and gneiss encountered were believed to be Archaean owing to their high metamorphic grade which far exceeds that of Proterozoic rocks found elsewhere in the Block.

Sediments of the Lower Proterozoic Warramunga Group contain all the known economic mineralization in the area. These extend from 54 km north of the Tennant Creek township to 57 km south. They are a eugeosynclinal sequence of greywacke, siltstone, shale, and interbedded volcanics with minor grit and pebble beds and contain ironstone (quartz-magnetite-hematite) bodies.

Unconformably overlying the Warramunga Group to the north and south are rocks of the Tomkinson Creek Group and the Hatches Creek Group respectively. These are regarded as one stratigraphic unit and consist of sandstone containing heavy minerals (tourmaline, zircon), minor grit, shale, and thin beds of basic and acidic lavas. Rocks of Cambrian age unconformably overlie the Warramunga Group to the east and west.

Granite, adamellite, quartz porphyry, and quartz-feldspar porphyry intrude the Warramunga Group sediments. Granite has been intersected in water-bores in the Cabbage Gum Basin and crop out east (near Gosse River), 20 km north-east, and 10 km north of Tennant Creek, 100 km north-north-east of Tennant Creek, 2 km north of Red Bluff, and west and northwest of the Warrego Mine, which is 45 km west-northwest of Tennant Creek. Granitic dykes were intruded into the high-grade metamorphic rocks at BMR Area No. 3. The porphyry is believed to be genetically related to the granite. Diorite and rare dolerite sills and dykes abundantly intrude the lower parts of the Tomkinson Creek Group and the upper parts of the Warramunga Group. They also intrude the high-grade metamorphic rocks in BMR Area No. 3. The diorite/dolerite postdates major folding, faulting, and the acid intrusives.

The Warramunga Group occupies a broad anticlinorium which plunges west at a low angle. The rocks are not severely folded. The main structural features are strong shears and faults, some of which are filled with quartz. The dominant fault is the 74-km long northwest-trending Quartz Hill/Rocky Range Fault which approximately bisects the Tennant Creek one-mile Sheet. Northeast of this fault, folding is more open and to the southwest the sediments become more magnetic. A northwest-trending phase of folding and northwest and northeast shears accompany strong regional geological trends which in turn are reflected in Bouguer and aeromagnetic contour maps.

Gold and copper orebodies occur at Tennant Creek in close association with tabular and pipelike ironstone bodies of quartz, hematite, and magnetite in varying proportions, and in major shear zones cutting through rocks of the Warramunga Group. The major gold producers appear to be restricted to the vicinity of a hematite-shale marker bed, and the major copper produces appear to be at the intersections of a major shear zone with the Warramunga Group sediments. Minor lead and zinc mineralization is commonly associated with the copper ore bodies.

The granites have been suggested as the source of mineralization by Ivanac (1954) and Crohn & Oldershaw (1965), but Whittle (1966) and Dunnet and Harding (1967) have proposed the basic rocks (dolerite/diorite suite). Colloidal transfer of metal components in sediments followed by their subsequent concentration in preconsolidation slump structures has been suggested by Elliston (1966). Mendum & Tonkin (in prep.) have suggested that the gold was concentrated from underlying rocks and precipitated in the overlying greenschist rocks.

4. FIELD PROCEDURE

The locations of traverses surveyed and selected stations at 1-km interval are shown in Plate 1. Stations were pegged at 200-m intervals and levels taken to third-order accuracy and tied to bench-marks along the Stuart Highway and at the Peko road/Nobles Nob turnoff. To enable all gravity data to be reduced to a common datum, levels were established between the regional gravity network and the 1969 (Williams, in prep.), 1971 (Hone, 1974) and the present surveys. Key stations levelled were 20500°W/10000°N (BMR Area No. 3), 2000°E/5000°s, and 9600°E/8000°S.

Readings of gravity, total and vertical magnetic field were taken at each station. Base-station readings were obtained at intervals of one hour and every fifth or tenth station reread for instrument drift control.

The gravity meter used was a Master Worden (No. 260 A) with a scale value of 0.1094 mGal/scale division. In general this instrument performed well except when transported by vehicle over very rough ground. On such occasions irregular drifts were sometimes encountered.

For measurement of the vertical magnetic intensity an ABEM MZ-4 magnetometer which has a reading accuracy of 2 gammas was used. A Sander Proton Precession magnetometer, NPM - 3 was used for measurement of the total magnetic field. This has a digital readout and can be read to the nearest gamma.

Surface rock samples were collected for physical property measurements along the traverses as outcrop permitted. The BMR geochemical party (party leader S. Smith) collected additional surface and drill-hole samples more representative of the Tennant Creek field as a whole.

5. GEOPHYSICAL INTERPRETATION

First-order corrections made to all data were adequate to provide profiles of vertical and total magnetic intensity and Bouguer gravity as used in the main phase of interpretation. More accurate reduction was required for data entered in the ADP data bank which yielded the updated Bouguer anomaly contours shown in Plate 2. Owing to the wide separation of traverses, interpretation is qualitative rather than quantitative.

Table 1 documents rock properties measured in the laboratory, which have been used to assist interpretation.

Cabbage Gum North and South Traverses

Data recorded on the Cabbage Gum North (CGN) and the Cabbage Gum South (CGS) traverses are shown in Plate 3. Little geological information is available over these traverses other than rock units identified from drilling in BMR No. 3 Area and outcrops of porphyry and Warramunga Group sediments mapped near Red Bluff at the northern end of CGN (Mendum & Tonkin, in prep). Limited areas of Warramunga

Group sediments have also been mapped at the southern end of CGS and near OO. Granite and metamorphic rocks have also been reported from a water-bore at the latter locality. Sediments of the Hatches Creek Group have been mapped near the southern extremity of the traverse.

Three distinctive regions of gravity and magnetic anomalies are apparent on these traverses: approximately northwards from 27N, between 10.5N to 16.5N, and between 7S and 5N. For convenience these anomalous zones are designated A, B, and C respectively.

Referring to plates 1 and 3, it is apparent that Zone A is in a region of geological complexity where magnetic rock units with northeast and east-southeast orientation merge. The more prominent anomaly trend in this locality is that orientated northeast. This swings to the east at Red Bluff at a point where Warramunga Group sediments have been mapped.

Anomalies A_2 and A_3 which occur within this zone at 28.5N and 31.0N correspond to two east-southeast-trending magnetic units evident from the aeromagnetic contours. Both anomalies (Plate 3) are better resolved from magnetic than from gravity data. The plateau form of the gravity profile suggests a major influence from geology with northeast trend which parallels the traverse direction. Anomaly A_4 resolved solely from magnetic data is correlated to the iron-rich Warramunga Group sediments referred to above.

Zone B is contained within the BMR No. 3 Area. It is apparent from Plate 1 that the CGN traverse ran along the spine of the composite aeromagnetic anomaly, magnetic data being consistent with that previously obtained by O'Connor & Daly (1962). Anomalies B_1, B_2, and B_3 located at 11N, 13N, and 15.5N appear to be caused by the spherical bodies interpreted by O'Connor & Daly (1962). The better anomaly resolution evident from the magnetic data as compared with the gravity data is to be expected from potential theory. Drilling results indicate that amphibole gneiss (after Warramunga Group hematite-shale?) with density 3.1 g/cm^3 and susceptibility 72 x 10^{-3} c.g.s units (Table 1) is the probable source of both the gravity and magnetic anomalies.

Zone C represents the most outstanding gravity anomaly, yet has little associated magnetic expression. This anomaly is unquestionably related to the large regional feature to the west evident in the Bouguer anomaly map for Tennant Creek published in 1967 (E53/B2-14). Although the full expression of the anomaly is 38 km wide and it has an amplitude in excess of 24 mGal, it is important to note that the maximum anomaly gradients occur near 7.5S and 4.5N between which locations is a broad ill defined magnetic anomaly of 100 gammas amplitude.

This suggests that a common source accounts for both the gravity and magnetic anomalous responses, this source having high density but relatively low magnetic susceptibility. A major gabbroic intrusion is postulated as being the most likely rock unit to produce the anomalies observed; the intersection of dolerite in drill holes in the BMR No. 3 Area supports this hypothesis.

The more sharply defined magnetic and gravity anomalies evident between 1.5S and 2.5N bear some resemblance to those recorded in Zone B. Reference to aeromagnetic contours about and to the west of 00 (No. 2 Bore) indicates anomaly forms in many respects similar to those evident at BMR Area No. 3. Warramunga Group sediments near No. 2 Bore are a probable source for the magnetic anomalies. Further detailed gravity and magnetic work to the west and west-northwest thus appears warranted.

In the region immediately south of 26N, the lowest Bouguer value was observed. It is probable that this locality is underlain by granite and furthermore that this rock type extends southwards as far as 18N.

Cabbage Gum West Traverse

Data recorded on the Cabbage Gum West (CGW) traverse are shown in Plate 4. Other than where CGW meets and CGN, the only additional geological information available is that at the eastern end of the traverse where Warramunga Group sediments are known to occur (Crohn, 1961; Mendum & Tonkin, in prep.) Wiebenga & Dyson (1964) carried out geophysical investigations in this area in 1958 to assist groundwater investigations of the Cabbage Gum Basin, drilling of which provides the main source of geological information referred to above.

The plateau evident in the Bouguer values east of 6.5W is very similar to that present in Zone A of CGN. In both places Warramunga Group sediments are known to occur. Although magnetic anomalies are apparent at both localities, those recorded at the eastern end of CGW indicate that Warramunga Group sediments have low susceptibility as anomaly amplitude is limited to 50 gammas. Reference to the aeromagnetic contours shown in Plate 1 indicates some similarity in anomalies evident at either end of the CGW traverse and at BMR No. 3 Area.

The very flat, low magnetic field between 6.5W and 22.5W coupled with the rapid change of Bouguer values at those two locations is interpreted as evidence for the presence of granite underlying this section of the traverse.

The gravity and magnetic anomalies evident to the west of 22.5W are expressions of the features already referred to in Zone C of CGN and CGS.

Stuart Highway Traverse

Results obtained from the Stuart Highway traverse are shown in Plate 5. Magnetic data are unreliable between 1N and 2S owing to the traverse passing through the township of Tennant Creek.

Geology is comparatively well known over the northern half of the traverse as shown by the Tennant Creek 1-mile geological Sheet. More recent mapping has been completed by Whittle (1966) and Mendum & Tonkin (in prep.).

For convenience, areas of gravity and magnetic anomalies located approximately between 10.5N and 13N, 7S and 8N, 11S and 14S and southwards from 19.5S are designated Zones D, E, F, and G respectively.

Warramunga Group sediments mapped to the east of Zone D are the most probable source of anomalies recorded at this locality; however, the significance of the Quartz Hill/Rocky Range fault which passes through the zone must not be overlooked. The low amplitude of the gravity anomaly is consistent with a minor occurrence of sediments enclosed within granite as mapped to the north of Zone E. Magnetic anomalies evident to the east of 11N and 12N in the aero-magnetic data are only barely resolved by the ground traverse.

Zone E is characterized by a Bouguer gravity plateau of approximately 8 mGal relief and a magnetic plateau, as seen in both total and vertical field components, of approximately 250 gammas relief. Only limited correspondence is present between distinct Bouguer and magnetic anomalies, e.g. at E_1, and E_4, the former representing the Mount Samuel line of ironstones. Anomalies E_2, E_3, E_6, and E_8 are resolved by the magnetics only, whereas E_5 and E_7 are seen as distinctive gravity features.

The gravity anomaly in Zone E exceeds that in Zone A of CGN or that present at the eastern extremity of CGW (cf Zone F). The individual magnetic anomalies in Zone A are much greater than those in Zone E. These factors suggest a difference in the hematite-magnetite content of the sediments between the localities mentioned above. In particular, hematite appears to be most abundant in Zone E as evidenced by the high gravity response coupled with the low correlation between individual magnetic and Bouguer anomalies.

Zone F appears to be defined by gravity data as extending from 14S to 11S whereas magnetic data suggests extension to at least 9S. Anomaly characteristics are similar to those of Zone D, source rocks being interpreted again as Warramunga Group sediments contained within granite. The granite is interpreted to extend intermittently from 7S to 19.5S. Westward extension of Zone F has already been established, by data recorded at the eastern end of CGW.

The high Bouguer values recorded in Zone G coupled with the regional contours shown in Plate 2 suggest a source in some way similar to that already proposed for Zone A on the CGN traverse. Hatches Creek Group sediments mapped near the southern end of the Stuart Highway traverse contain heavy minerals. It is likely that Zone G reflects these sediments. Anomalies G2 and G3 are of interest in terms of the positive magnetic anomaly coincident with a Bouguer anomaly of 1.5 mGal at G2 as compared to a negative magnetic anomaly coincident with a slightly smaller Bouguer anomaly at G3. It is possible that a single folded geological unit accounts for both anomalies, remanent magnetism accounting for the change in the sign of the magnetic anomaly.

Nobles Nob Traverse

Data recorded on the Nobles Nob (NN) traverse are shown in Plate 6. As with the Stuart Highway traverse, much of traverse NN lies within the Tennant Creek 1-mile geological Sheet, additional geological information being available from the mapping of Whittle (1966) and Mendum & Tonkin (in prep.).

It is apparent that the gravity and/or magnetic anomalies recorded over almost the entire traverse reflect simply physical rock property differences between Warramunga Group sediments and granite. In general the gravity data appear to be more valuable in differentiating between the two rock types, the rapid fall-off in Bouguer anomaly values at 14S and 18N clearly indicates the proximity of major low-density granite masses. From the high values recorded between 6S and 14S in a region of granite outcrops as mapped by Mendum & Tonkin, it is inferred that either the granite has no great depth extent or alternatively it contains large rafts of denser Warramunga Group sediments.

Between 4.5S and 9.5N distinctive magnetic anomalies are associated with Warramunga Group sediments. Five major anomalies (H1 to H5) are resolved at 3S, 1N, 3.5N, 6.5N, and 9N all of which have some associated local gravity anomaly. The form of the anomalies at 3.5N, 6.5N, and 9N indicate shallower-seated sources than those at 3S and 1N. For this reason it is possible that magnetic and gravity anomaly correspondence is better for the former group than for the latter.

The Quartz Hill/Rocky Range Fault intersects the traverse near 11N. The fault as mapped does in fact follow the northern boundary of the magnetically disturbed zone as shown in the aeromagnetic contours. As such it appears that distinctively less magnetic and, to a much smaller extent, less dense rocks of the Warramunga Group lie to the northeast of the fault. Crohn & Oldershaw (1965) consider that movement on the fault was northeast block down with a throw of at least 5000 ft. Although major differences are evident in rock units from the geophysical data, geological mapping does not reveal a significant difference in rock units on either side of the fault. Quite obviously magnetite content is more abundant to the southwest of the fault.

Owing to the prospective nature of the region surveyed with traverse NN it is appropriate to relate anomalies where possible to observed mineralization or features of economic interest.

H1 Deep-seated magnetic and gravity anomalies, source unknown.

H2 Deep-seated magnetic and gravity anomalies, main source unknown. The Rising Sun mine is located near 0.2S on the southern flank of this broad 350-gamma magnetic anomaly. A small Bouguer anomaly (1 mGal) occurs between 0.6S and 0.2N, in association with a sharp negative magnetic anomaly more apparent from vertical field measurement. Density and susceptibility measurements of 4.2 g/cm^3 and 0.17 x 10^{-3} c.g.s. units respectively were obtained for ironstones collected from the mine dump.

H3 At 3.6N the traverse passed approximately 100 m west of the Golden Forty mine shaft. Magnetic and gravity anomalies of 790 gammas and 1.2 mGal are centred at this locality, anomaly forms indicating relatively shallow sources.

<u>H4 and H5</u> To the north of the H3 (Golden Forty) anomaly are the smaller anomalies H4 and H5. The anomalies had been recorded previously in the low-level aeromagnetic work described by Milsom & Finney (1965), the anomalies being designated AR11 and AR12 respectively. These aeromagnetic data showed the AR11 anomaly forming part of a feature which is pronouncedly elongated in the east-west direction, the anomaly itself lying in the Peko shear zone as defined by Harding (1965). Ground magnetic surveys subsequently carried out by Williams (in prep.) yielded information which proved difficult to interpret by conventional curve-fitting methods. The most satisfactory interpretation yet achieved is one which involves a vertical dyke-like body 2000 ft wide located at 500 ft depth below 21200S on Williams' grid. This interpretation coupled with the recording of a gravity anomaly of 0.8 mGal at 6.2N on NN suggest that both the magnetic and gravity anomalies of H4 are due to a change in lithology rather than the presence of an ironstone body.

The H5 (AR12) anomaly as recorded at 8.0N on NN as a small 100-gammas magnetic high and as a gravity high of slightly less than 0.2 mGal from 7.4N like H4 does not suggest the presence of a large-near surface ironstone but rather a source which involves disseminated magnetite contained within Warramunga Group sediments.

<u>H6</u> Anomaly H6 at 8.8N constitutes coincident magnetic and gravity highs of 270 gammas and 0.2 mGals respectively. The low-level aeromagnetic contours of the Aeromagnetic Ridge (Milsom & Finney, 1965) indicate that the magnetic anomaly is part of an elongate east-west feature which peaks 0.7 km to the east of the NN traverse. The anomaly lies in Area 4, surveyed by ground magnetic methods in 1957 (O'Connor, Goodchild, & Daly, 1959). The aeromagnetic contours shown in Plate 1 indicate a northeasterly magnetic low trend which extends from Peko to intersect the east-west feature 1km to the west of H6.

O'Connor et al. (1959) concluded that no magnetic anomaly recorded in Area 4 could be attributed to a discrete ironstone body. The east-west feature referred to above was interpreted to be caused by a relatively flat-lying sheet of magnetic material which extended for a considerable distance to the south. The magnetic high recorded at 8.8N on NN represents a local high on this anomaly. Thus as in the cases of H4 and H5, the H6 anomalies are interpreted as due to a change in lithology.

<u>H7</u> A gravity anomaly of 0.8 mGal without a corresponding magnetic anomaly occurs at 10.4N where the hematite-rich Specific Horizon marker bed of the Warramunga Group Sediments has been mapped (Whittle, 1966). The Great Bear mine is located immediately west of this feature.

<u>H8</u> At 12.0N a magnetic high slightly in excess of 100 gammas coincides with an extremely small gravity anomaly. The Specific Horizon has been mapped near this locality and as such must be considered as the source of the anomalies.

6. PHYSICAL PROPERTIES OF SAMPLES

A summary of the measurements obtained during 1972 supplemented by previous work is given in Table 1. Little value can be placed on measurements from surface rock samples as these have undergone variable weathering and oxidation, in some cases intense. Magnetic measurements made on surface rock samples are particularly suspect and for other than crudely identifying magnetic rock units should be ignored. Remanent measurements made from samples of outcropping ironstones showed widely varying results consistent with lightning strike effects. Such a variable magnetic characteristic represents one of the major noise sources to ground magnetic surveys in this region.

Drill-hole samples from BMR Area No. 3 yield significantly higher densities than those obtained from typical Warramunga Group sediments and other rocks excluding ironstone. This at least in part accounts for the gravity high over BMR Area No. 3. The density contrast between surface samples of granite and other rock types corresponds to a condition which is expected to exist in fresh rock as evidenced by gravity lows over the granites.

TABLE 1

ROCK TYPE	NUMBER OF SAMPLES	AVERAGE DENSITY (g/cm^3)	AVERAGE SUSCEPTIBILITY*
DRILL-HOLE SAMPLES COLLECTED IN 1972			
Coarse sediment	9	2.75	0.342×10^{-3}
Fine sediment	8	2.75	0.378×10^{-3}
Hematite shale	2	2.65	0.023×10^{-3}
Lamprophyre	2	2.78	0.863×10^{-3}
Porphyry	2	2.68	0.084×10^{-3}
Ironstone	1	4.93	131×10^{-3}
BMR Area No. 3 samples	15	2.89	-
DRILL-HOLE SAMPLES PREVIOUSLY DETERMINED (BMR Area No. 3)			
Magnetite gneiss	8		53×10^{-3}
	7	3.16	
Garnet gneiss	13		1.59×10^{-3}
	10	3.03	
Amphibole gneiss	2		$.144 \times 10^{-3}$
	4	2.88	
Pyritic gneiss	1	2.83	
Schist	2	2.74	$.07 \times 10^{-3}$
Granitic gneiss	14		1.33×10^{-3}
	12	2.74	
Amphibolite	2	3.11	$.219 \times 10^{-3}$
Dolerite	2	3.12	8.94×10^{-3}
SURFACE SAMPLES COLLECTED IN 1972			
Coarse sediment	12	2.49	0.021×10^{-3}
Fine sediment	17	2.42	0.028×10^{-3}
Porphyry	3	2.29	0.009×10^{-3}
Ironstone	39	4.18	2.195×10^{-3}
Jasper	2	2.60	0.006×10^{-3}

TABLE 1. (cont.)

Granite	6	2.31	0.026×10^{-3}
Conglomerate	2	2.41	0.087×10^{-3}
Chalcedony	2	2.45	0.1×10^{-3}
Breccia	7	2.16	0.012×10^{-3}
Caprock	4	2.55	0.042×10^{-3}

20 ironstone samples gave an average remanence of $200{,}000 \times 10^{-6}$ and an average Q_n value of 390

Biotite magnetite amphibole gneiss from BMR No. 3 Area drill holes 158 and 161 (from BMR file B193/NT3, part 3, folio 104).

	Density (g/cm^3)	Susceptibility
10% magnetite with pink Pegmatization	3.14	77.7×10^{-3}
" " " "	3.15	101.8×10^{-3}
" " " "	3.02	49.6×10^{-3}
5% magnetite with 2-5% garnet	3.05	58.3×10^{-3}
Mean of a samples	3.1	72×10^{-3}

* Susceptibility and remanence measurements were made in the e.m.u.c.g.s. system.

Q is Koenigsberger's ratio and is the ratio of a material's natural remanent (permanent) magnetization to the magnetization induced by the Earth's field at the sample location. Older rocks usually have smaller ratios than younger ones; the range of values is very large but is usually within the limits 0.1 Q 100. The high Q values indicate that the permanent magnetization completely dominates the induced magnetization.

7. CONCLUSIONS AND RECOMMENDATIONS

The known high-grade metamorphic rocks and associated minor basic intrusives produce distinctive magnetic and gravity anomalies at BMR Area No. 3. This is consistent with susceptibility and density measurements made on drill core obtained at this locality. Magnetite is considered to make a significant contributation to both the high susceptibilities and high densities observed. However it is not known whether it is syngenetic or has been introduced by basic intrusives.

If the magnetite is syngenetic, then the distribution of rocks similar to the high-grade metamorphics intersected in drill holes at BMR Area No. 3 will be limited to regions of magnetic anomalies which can be resolved from the high-level aeromagnetic data. Such regions could be evaluated in more detail by low-level aeromagnetic work before ground work need be done. If the magnetite is epigenetic, then the distribution of magnetic anomalies will no longer be a reliable guide for delineating areas of rocks similar to those at BMR Area No. 3. In this case, the gravity method would be better although much slower.

To delineate the gravity high over BMR Area No. 3, more traverses perpendicular to the local magnetic strike need to be read in the magnetically anomalous area. Interpretation of the magnetic and gravity data based on spherical and/or tabular models is recommended once adequate data are obtained.

If the magnetite in the known high-grade metamorphic rocks can be proved to be epigenetic, then selected highs on the Tennant Creek regional Bouguer gravity map should be further investigated by ground traverses or by helicopter work to obtain gravity stations no farther apart than 1 km to define additional areas of possibly similar rock type. Because of its proximity to BMR Area No. 3, the first gravity high to be investigated should be the one to the west of 1.2N on the CGN traverse.

The Quartz Hill/Rocky Range Fault divides the sediments of the Tennant Creek one-mile Sheet into magnetic sediments (i.e. sediments containing more magnetite-bearing layers) to the southwest, and non-magnetic sediments to the northeast. Magnetic traverses show low flat responses over large granite masses and higher values with more local anomaly relief over the iron-rich Warramunga Group sediments. A slight density difference produces gravity highs over the sedimentary rocks and lows over the granite.

Local gravity highs were recorded where traverses passed close to the Golden Forty, Rising Sun, and Great Bear mines. In the case of the largest mine (the Golden Forty) an associated magnetic anomaly was clearly resolved. Small gravity highs were found in the region of the hematite shale, but it is not known definitely whether these gravity highs were caused by the hematite shale or associated ironstone.

Gravity highs were recorded on Traverse NN associated with known linear aeromagnetic anomalies which include AR11 and AR12. The form of the gravity and magnetic anomalies suggests regional changes in lithology rather than discrete anomaly sources commonly associated with ironstones.

Weathering and oxidation have markedly affected near-surface rocks. It is essential that fresh rocks obtained from drill holes or mines be used for density or susceptibility determinations.

Most of the results obtained from this survey should be reviewed and combined with any additional data recorded to the south of Tennant Creek. Such work is necessary to form an optimum base for the quantitative interpretation of the gravity data which will meet both regional and local anomaly analysis.

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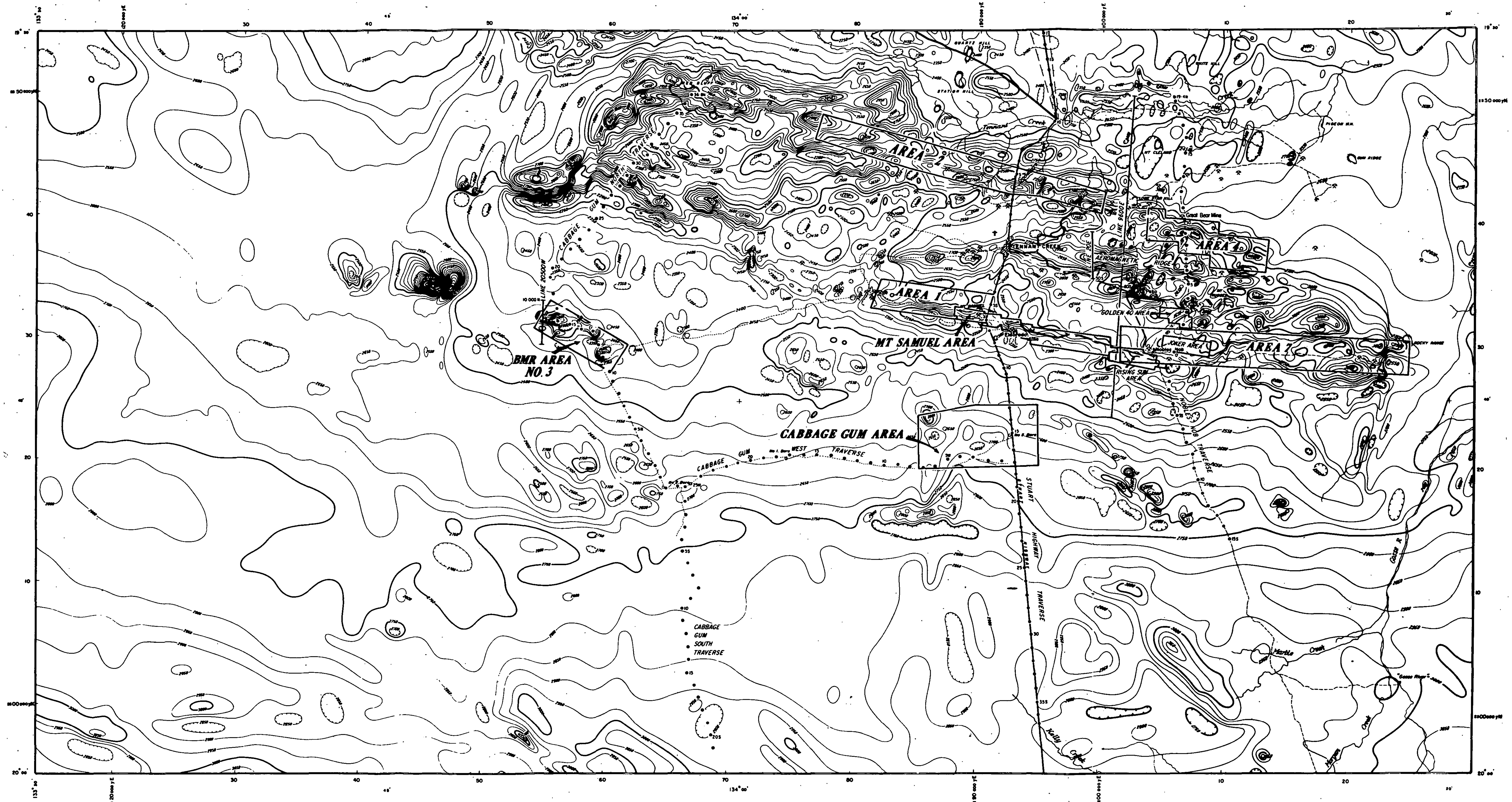
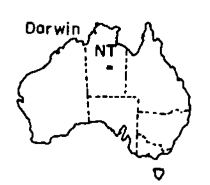
PLATE 1



LOCATION DIAGRAM



5 0 5 10 km

MAGNETIC CONTOUR INTERVAL 50 GAMMAS

2000
1900
Magnetic contours

Magnetic 'Low'

Stations located at 1km intervals in 1972 survey

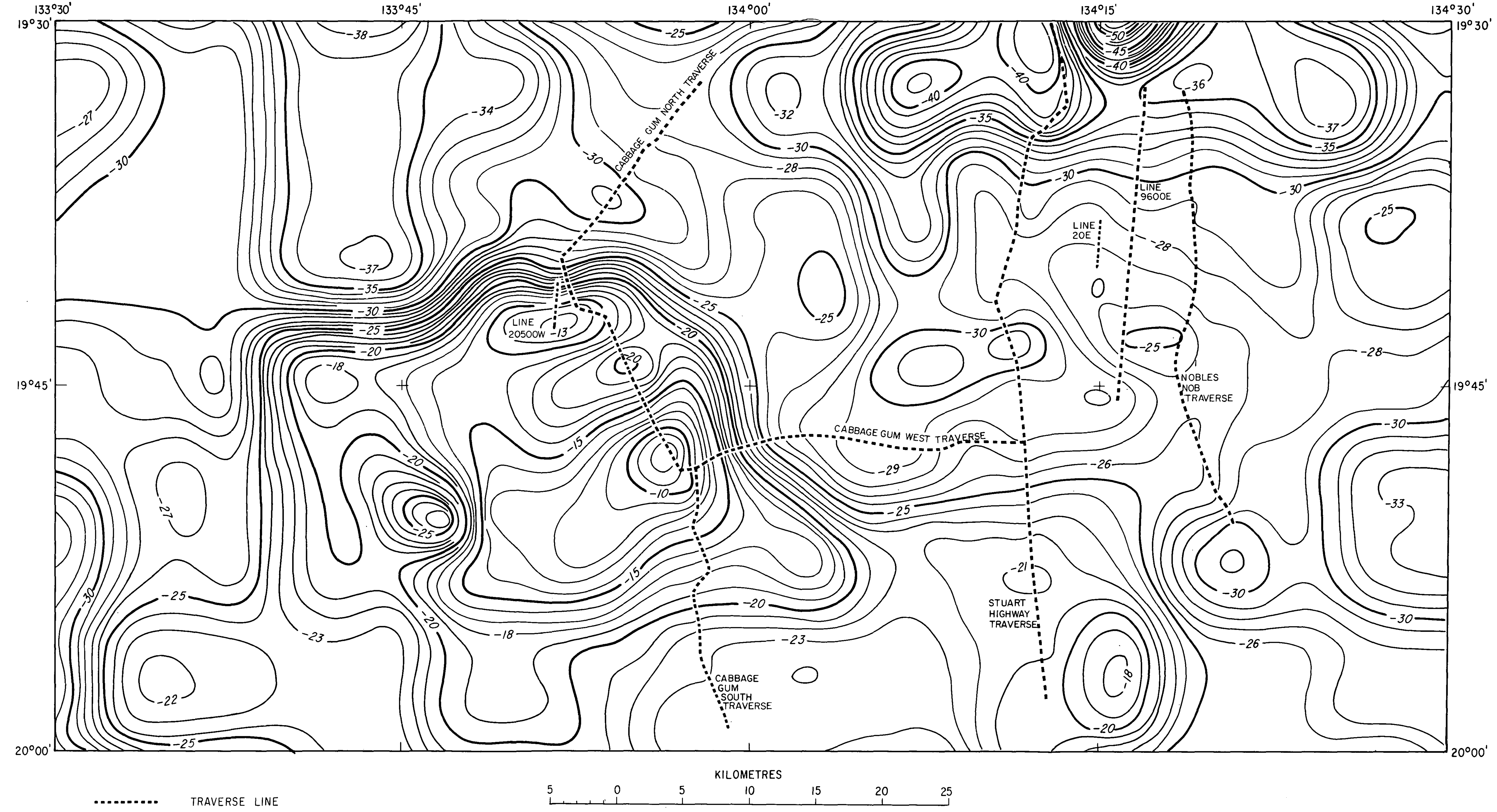
LOCALITY MAP SHOWING TRAVERSE PLAN AND AEROMAGNETIC CONTOURS

TENNANT CREEK 1972

Record No.1974/171

E53/B7-167R

PLATE 2



TRAVERSE LINE

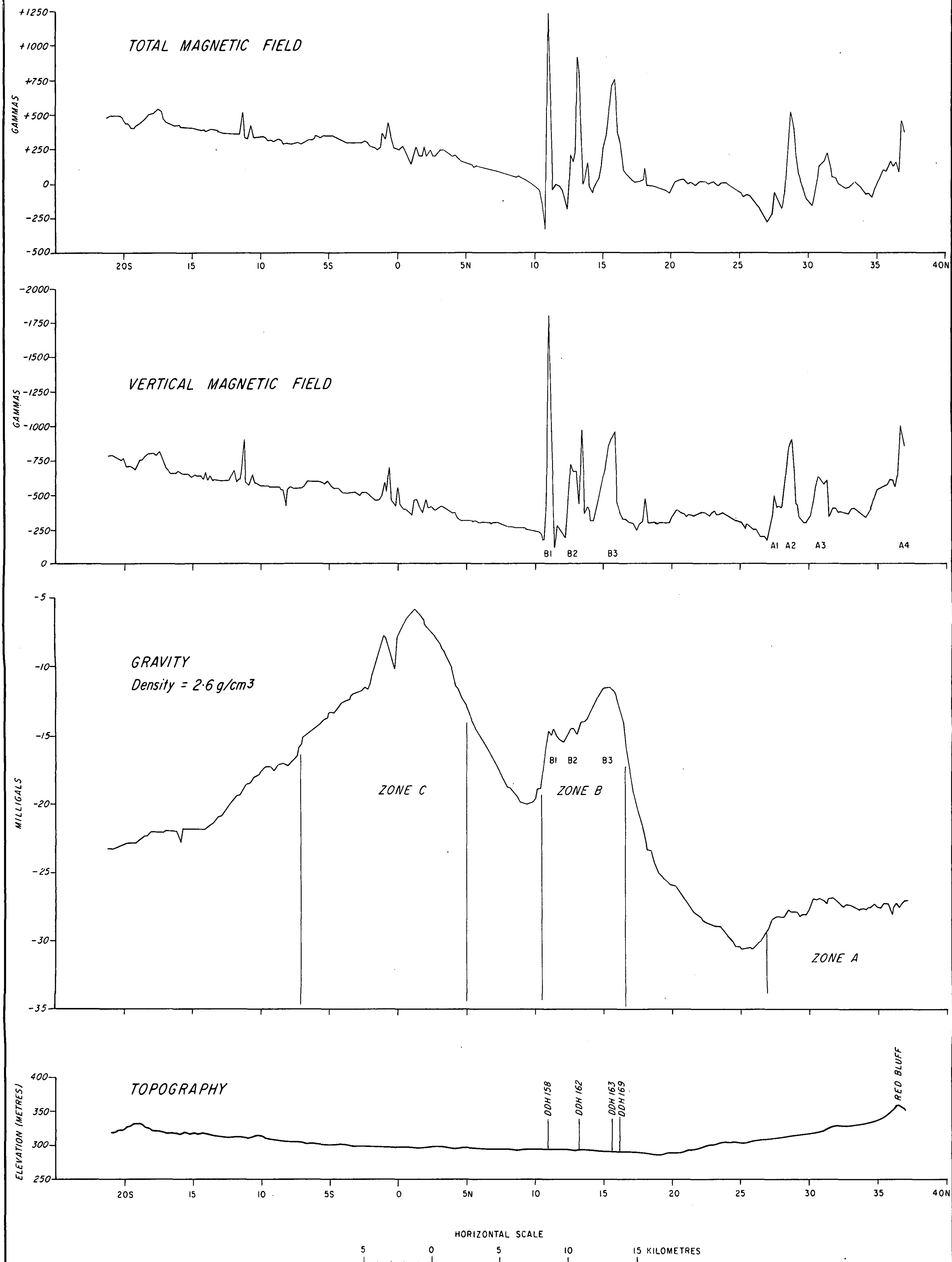
BOUGUER ANOMALY CONTOURS (interval = 1 mGal). Data from BMR reconnaissance helicopter survey and ground surveys

For the calculation of Bouguer anomalies, 2·67g/cm³ has been adopted as an average rock density

BOUGUER ANOMALY CONTOURS

Record No.1974/171

E53/B7-168

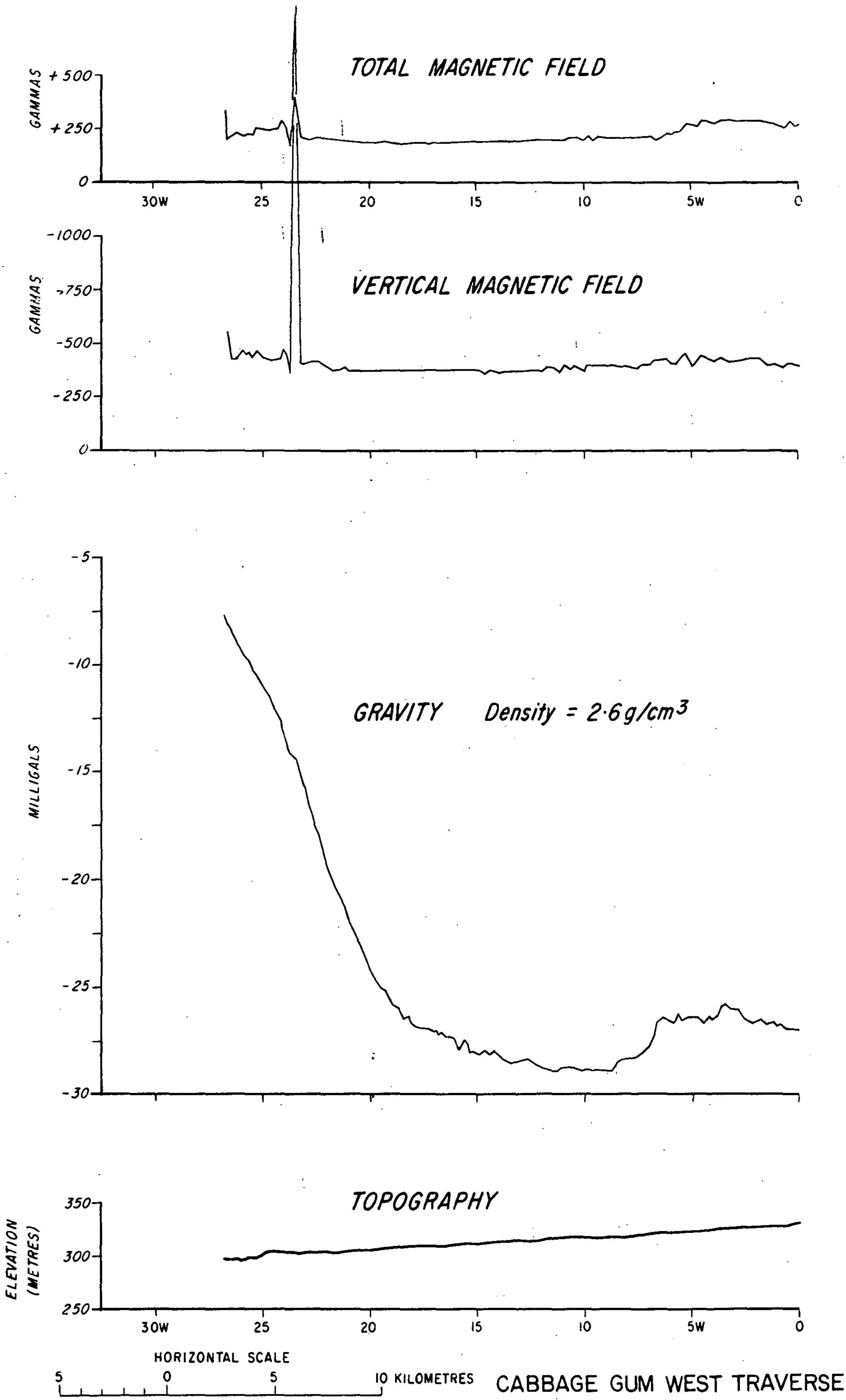


CABBAGE GUM NORTH AND SOUTH TRAVERSES

PLATE 3

E53/B7-169
Record No. 1974/171

PLATE 4

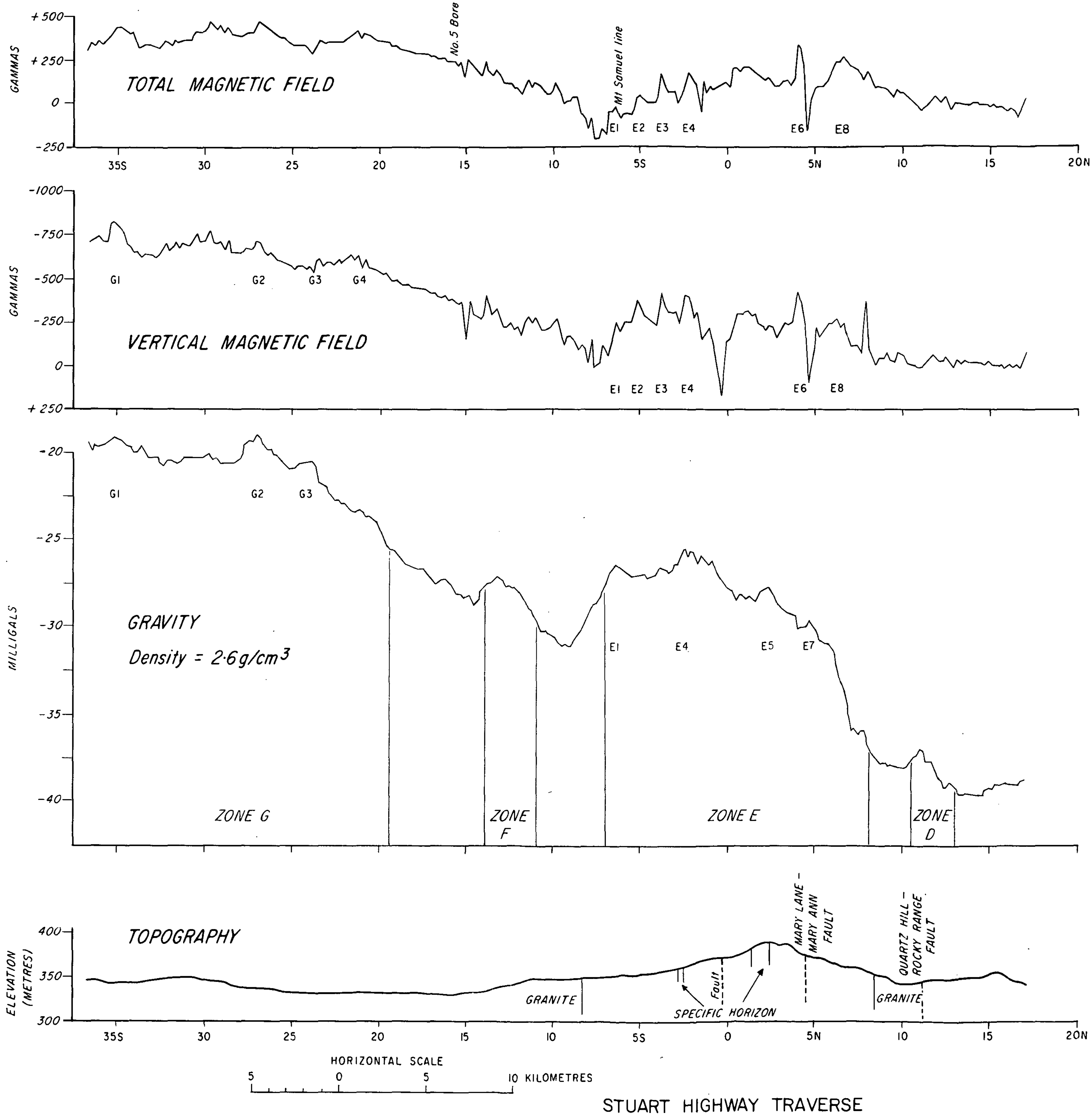


CABBAGE GUM WEST TRAVERSE

Record No. 1974/171

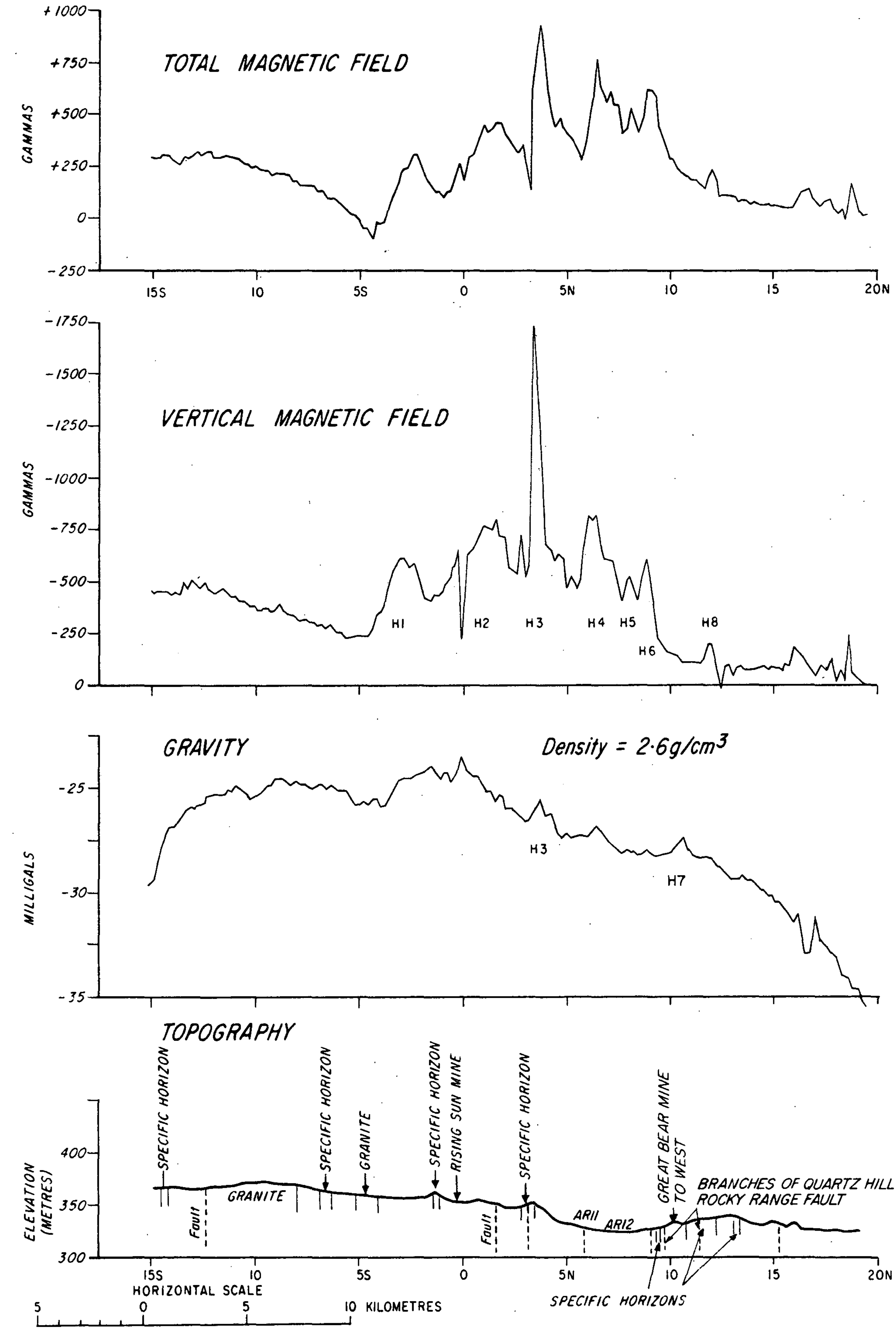
E53/B7-170A

PLATE 5



STUART HIGHWAY TRAVERSE

PLATE 6



NOBLES NOB TRAVERSE