COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

RECORDS 1959, No. 14.

PROGRESS REPORT ON GEOPHYSICAL SURVEY AT TENNANT CREEK, 1957

by

M. J. O'CONNOR, R. J. GOODCHILD and J. DALY

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ABSTRACT.

This report deals mainly with detailed ground magnetic surveys over two areas near Tennant Creek. The areas were selected from the results of aeromagnetic surveys and the main purpose of the ground surveys was to obtain data for use in the interpretation of the aeromagnetic results.

The results of the aeromagnetic surveys are discussed. In the ground magnetic surveys, two type of anomalies were observed and are classified as major and regional. A procedure is used for the interpretation of major-type anomalies, based mainly on profiles of the horizontal component. Comparisons are shown of observed profiles with profiles calculated for spherical bodies magnetised by induction.

Gravity measurements were made in several areas and the results for two areas are shown as relative Bouguer anomaly profiles. Comparison is made of the results of gravity and magnetic surveys in the Black Angel area.

A recommendation is made for the location of a drill hole site to test a regional type anomaly. Targets are also given for testing two major-type anomalies.

1. INTRODUCTION

The magnetic method of geophysical prospecting was first applied in the Tennant Creek field by the Aerial Geological and Geophysical Survey of Northern Australia, during 1935-37. The results of this work have been described by Daly (1957a), Rayner and Nye (1936), and Richardson, Rayner and Nye (1937), and show clearly that the magnetic method is particularly well suited to the geological conditions on the field. Several anomalies were observed, due to pipe-like ironstone bodies similar to the outcropping ones. Also, evidence was obtained of the presence of regional anomalies. It was considered that these regional anomalies, if properly delineated, would provide useful information on the structure of the field generally.

An aeromagnetic survey, covering the area of the field as known from workings, was performed by the Bureau of Mineral Resources during 1956. The results of this survey have been published as contour maps of total magnetic intensity. Some general remarks on these results are presented in a later section.

The purpose of the survey described in the present report was to carry out detailed ground magnetic surveys over areas selected from the aeromagnetic results, primarily in order to obtain data for use in the interpretation of these results. The geophysical party consisted of M.J.O'Connor (party leader), R.J. Goodchild, E.Sedmik (part of time) and M.B. McGirr (part of time). Two surveyors were made available by the Department of Interior for the necessary surveying work. Operations lasted from August to November, 1957, during which period approximately half of the proposed programme was completed. The survey is being resumed during the 1958 season.

During the season, the opportunity arose to perform a limited amount of gravity work. This was commenced by R.Underwood and completed by M.J.O'Connor. The results were of considerable interest, and it is desirable that more gravity work be performed.

2. GEOLOGY

The only comprehensive description of the geology of the Tennant Creek field is that by Ivanac (1954). A brief summary of this report, in so far as it concerns the interpretation of magnetic surveys, is given by Daly (1957a), and is not repeated here.

It is generally agreed that a re-examination of the regional geology is desirable for the following reasons:-

(i) The regional mapping of Ivanac was incidental to the main purpose of his report, which was directed to the potentialities of the field as a gold producer.

(ii) The mapping was based on air photos of inferior quality.

(iii) Regional mapping in the Tennant Creek area is very difficult, owing to the scarcity of outcrops. Under such conditions, information obtained from underground exploration by mine workings and diamond drilling is of great importance. A considerable amount of exploration of this type has been performed since the date of Ivanac's report.

(iv) Certain possibilities suggested by the aeromagnetic results should be borne in mind in further regional work. For example, it appears that the area of possible interest extends much further to the west than was previously supposed. Also, it seems possible that some rock units of major significance have no surface expression.

3. RESULTS OF AIRBORNE SURVEYS.

The area covered by aeromagnetic survey includes the Tennant Creek and Mount Woodcock one-mile sheets, the eastern half of the Red Bluff and Marion Ross sheets, and small areas of the one-mile sheets surrounding those named. Contours of total intensity over the Tennant Creek, Mount Woodcock, Red Bluff and Marion Ross sheets at a scale of one mile to the inch, and a single map of the whole surveyed area, at a scale of two miles to the inch have been published. Detailed interpretation on the basis of present geological knowledge would be premature. The following remarks are in the nature of preliminary suggestions, based to some extent on comparison of aeromagnetic results with the results of previous ground surveys.

It is apparent that two types of anomaly are present on the aeromagnetic maps.

One type corresponds to that classified as regional anomalies in the reports on ground surveys. Previous work was on too small a scale to delineate these anomalies completely. On the aeromagnetic maps, they appear as zones of high magnetic intensity, whose width may be up to a few miles, and whose strike length may be many miles. Superimposed on these are several of the so-called major anomalies. From the economic point of view, discovering major anomalies is the prime object of geophysical exploration on the field. Anomalies such as the Black Angel, Peko No.1 and the Golden Forty anomalies are clearly visible. However, the major-type anomalies of smaller amplitude tend to be obscured by the regional anomalies, and although most of the major-type anomalies located on the ground can be associated with magnetic highs of small dimensions on the aeromagnetic maps, these highs are indistinguishable from a large number of others which are not connected with any major-type anomaly. It appears that any magnetically high area, even of very small dimensions, is worthy of prospecting for the presence of major-type anomalies.

The results published cover a rectangular area measuring about 45 miles by 30 miles. A symmetrical division of this area into quarters by a north-south line through Mt.Samuel, and an east-west line through the Black Angel, also corresponds roughly with a division on the basis of magnetic intensity. In the north-eastern and south-western quarters, the magnetic intensity is uniformly low, in the south-eastern quarter it is higher, and in the north-western quarter it is considerably higher still. Indications are that the intensity is beginning to increase at the southern boundary of the area.

Superimposed on this general magnetic pattern are two magnetic features of considerable extent, which may be associated with major structural features.

(i) A magnetically high zone of width up to several miles commences quite suddenly at the south-eastern corner of the Tennant Creek sheet and proceeds in a direction about W20ON to the western edge of the surveyed area. A concentration of known mines and the largest of the known major-type anomalies appear to be associated with this feature. They occur, not at the magnetically highest points, but generally down the slope of the regional anomaly. Thus the Golden Forty - Peko line occurs on the south flank, and the Nobles Nob - Eldorado - Mt. Samuel line further down the southern slope. On the northern flank there are several workings of minor importance such as the Lone Star. The Black Angel anomaly may occupy a similar position, and a previously unknown major body of dimensions comparable with the Peko appears on the same strike at the extreme western edge of the area surveyed. This association is by no means exclusive. Important producers such as the Whippet and the Northern Star occur in areas of low magnetic intensity and are apparently unconnected with any regional magnetic feature.

(ii) A zone of sharply defined anomalies, both positive and negative, follows a sinuous but generally easterly course, along the northern edge of the surveyed area. This feature lies close to the contact between the Warramunga Group and the Ashburton Sandstone, as mapped by Ivanac. According to Ivanac, the contact is gradational and the Ashburton Sandstone is unmineralised. The magnetic results suggest, however, that either the Ashburton rocks may contain deposits of magnetic minerals or the contact may not be gradational but may be governed by a tectonic feature of major importance.

It is apparent that complete delineation of the magnetic pattern will require extension of the aeromagnetic survey to the west, and possibly to the north. Attempts to account for the regional anomalies on the basis of present geological knowledge would be merely guesswork. However, it is appropriate to list some possibilities and to draw attention to some difficulties which are obvious at present.

The problem of accounting for the magnetic anomalies is rendered particularly difficult by the fact, established by previous ground surveys, that the anomalies are caused in general by material below water level, which, on the Tennant Creek field, is at least 250 feet below surface. However, although the magnetic properties of outcropping rocks have not been systematically studied, it may reasonably be stated that there is no rock type outcropping which could account, for example, for the magnetically high zone in the southern portion of the surveyed area. Two possibilities might be suggested.

(i) The anomaly is due to a rock type which is not represented in outcrop.

(ii) The rocks causing the anomaly are basically similar to outcropping rocks of the Warramunga Group but have been affected by tectonic movements and rendered liable to impregnation of magnetic minerals in restricted zones.

The first possibility is suggested by a similar situation which obtains near Rum Jungle. Attention has been drawn previously to the remarkable series of magnetic anomalies around the Rum Jungle and Brock's Creek granites (Daly, 1957b). Drilling carried out by Territory Enterprises Pty.Ltd. in the areas south-west of Brown's workings has proved that magnetic anomalies in this area, and presumably others around the Rum Jungle granite, are caused by rocks which do not crop out anywhere in the area. The drilling has disclosed the presence of formations of varying types, which have been grouped under the field name of "amphibolite". The rocks have not been studied petrologically, nor is their structure fully known, but they include strongly magnetic formations. It has been stated that rocks described as amphibolites have been intersected at many places in drilling in the Tennant Creek field. However, this statement has not been based on a sound geological assessment of the drilling evidence.

Useful information in this connection could be obtained if the cores obtained from drilling performed by National Lead Co. in the New Hope area were available for magnetic measurements and petrological study. This area is located on a high point of the regional magnetic anomaly. The drilling was unsatisfactory from the Company's point of view, in that no massive ironstone was encountered, but from the regional anomaly aspect, the cores would be more interesting for that reason. If these cores are not available, it is suggested that valuable information would be obtained by drilling a vertical hole to a depth of 1,000 feet at point 015370 on the Tennant Creek one-mile map, with the object of sampling the rock formations at this point for petrological study and measurement of magnetic susceptibility.

It seems very likely that some of the main mines on the field are directly associated with this particular magnetic feature. However, the investigation of regional anomalies of this type cannot be expected to disclose the full control of mineralisation. This is clearly shown by the situation at the Northern Star. This mine has been a significant gold producer. It occurs on an aeromagnetic high of very limited extent. On the ground, this appears as two small anomalies of the major type, which have been interpreted as due to pipe-like ironstone bodies at considerable depth. Drilling carried out by Peko Mines N.L. has encountered massive ironstone, carrying low-grade copper mineralisation at depths of the order of 900 feet. The site is in an area of low magnetic intensity, and far removed from any major magnetic feature.

4. SELECTION OF AREAS FOR GROUND PROSPECTING.

(A) Magnetic.

Inspection of the results of the aeromagnetic survey indicates that there are many areas on the Tennant Creek field worthy of prospecting for major-type anomalies. The areas for the present survey were chosen on the following criteria:-

(1) They should be located so as to cover a reasonable sample of the regional anomalies, so that the results would be of value in the interpretation of the results of the aeromagnetic survey.

(2) They should be remote from present mining or prospecting activities.

In the first instance, four areas were selected, as follows:-

Area No.1. A strip on the Mt. Woodcock sheet, centred approximately at the Flynn memorial. This area covers a regional high of moderate intensity, on which no prospecting or mining has yet been done.

Area No.2. A relatively small area, near the southern boundary of the Marion Ross sheet. This covers a very strong anomaly of relatively small area.

Area No.3. An area near the south-western corner of the surveyed area on the Red Bluff sheet. This covers a regional high of moderate extent, but considerably disturbed.

Area No.4. A strip lying south and east of the Trump Mine. This was selected as it is easily accessible and covers what appears to be a fairly typical section of the long regional high on the Tennant Creek sheet.

Arrangements were made with the Director of Mines, Northern Territory, to have Areas 1 and 3 reserved from the provisions of the Mining Ordinance for the period of the survey. It was discovered that Area No.2 was largely covered by existing mining tenements, and this area was therefore excluded from the survey. Although no mining operations were in progress on Area No.4, it covers the positions of a number of old leases. In order to avoid possible administrative complications, no reservation was applied for over this area.

The survey was begun on Area No.4 and by the end of the field season, Area No.4 and about two-thirds of Area No.1 had been surveyed.

(B) Gravity.

During the season, the Bureau undertook a limited amount of gravity work at the request of National Lead Pty.Ltd. Advantage was taken of the availability of the gravity meter to run some traverses in connection with the Bureau's operations. The following traverses were selected:-

(1) Three short traverses at the Black Angel, to check the gravity anomaly caused by a large concealed body located during 1937.

(2) Two of the surveyed traverses on Area No.4 were read with the gravity meter to test possible gravity effects associated with a regional-type magnetic anomaly.

5. TECHNICAL MATTERS.

(A) Surveying.

The baselines for Areas No.1 and 4 were laid out due east (magnetic), using compass and theodolite. True bearings for these baselines were also observed. Traverses were run on the magnetic north bearing using theodolite and chain.

In general, traverses were 400 feet apart and pegs were put in every 200 feet along the traverses to denote the magnetometer stations. In two sections of Area No.1, viz. 2,200E - 2,800E / 1,800S - 3,800S and 12,000E - 12,600E / 3,000S - 5,600S, traverses were 100 feet apart and pegs every 50 feet along the traverse.

The origin of the geophysical grid for Area No.1 was approximately 50 feet south-east of the Flynn Memorial, which is situated at the junction of the Stuart and Barkly Highways. The baseline was extended 15,600 feet east and 20,000 feet west of this origin. There were 90 traverses each 13,200 feet long. At the eastern end of the area, traverse 15,600E extends 4,400 feet north of the baseline and 8,800 feet south of the baseline. Traverse 20,000W extends from 2,400 feet north to 10,800 feet south of the baseline. The baseline must be extended a further 14,000 feet to the west before the Reserved Area No.1 can be completed. The bearing of the baseline was 274°47' true. The north-eastern and south-eastern corners of the reserved area were surveyed in and marked by steel pipes 8 feet high.

Origin of the geophysical grid for Area No.4 was the north-western corner of the area. There were 76 traverses, ranging in length from 5,600 feet to 11,400 feet, with an average length of 8,150 feet. The gravity stations were precisely levelled.

(B) Magnetic.

Instruments used for the magnetic survey were magnetic variometers of the Schmidt type. Three variometers were used - one manufactured by E.R. Watts and Sons Ltd. (Serial No.85999) and two by Askania-Werke (Serial Nos.521633 and 541479). The Watts variometer was used for measuring the vertical magnetic force and the Askania variometers were used for measuring both vertical and horizontal magnetic force.

The scale values of the vertical magnetic systems were of the order of 30 gammas per scale division, and those of the horizontal systems were approximately 15 and 25 gammas per scale division. Scale values of the instruments were checked several times during the survey by means of Helmholtz coils and calibrating instruments.

The magnetic systems for the Askania variometers were adjusted for latitude and temperature compensation for the Tennant Creek area before the party left Melbourne. Similar adjustments for the Watts variometer were made at Tennant Creek. For each area, a base station was established and readings were made there, at the beginning and end of every day's field work, with every instrument used during that day. Readings made in the field were referred to these base station readings as zero. A check was kept on the diurnal variation by repeating readings at certain field stations at intervals of approximately two hours.

In addition copies of magnetic records were obtained from Darwin magnetic observatory for particularly disturbed days. Corrections for diurnal variation were then made to the observed readings. The period of the survey coincided with a period of marked sunspot activity and the diurnal variations were found to be large and irregular. Diurnal variations of the order of 100 gammas in the vertical force were quite common, whilst in the horizontal component, variations as large as 500 gammas were measured. The results obtained on one day had to be repeated because of the effect of a magnetic storm of unusually large and erratic magnitude. The vertical magnetic force was measured on all traverses. The horizontal magnetic force was measured on every third traverse (except for the eastern section of No.4 area) and over the central traverses covering some of the better defined anomalies in the vertical force. Each variometer was operated by a geophysicist, assisted by a survey hand who carried the instrument and recorded the readings.

(C) Gravity.

Gravity measurements were made by a geophysicist using Worden gravimeter No.61. Scale value of the meter was 0.08895 milligal/scale division. Readings were corrected for instrumental drift by making repeat readings at certain stations every hour.

Gravity ties were made between Pendulum Station No.34 at the Tennant Creek Aerodrome and the areas where the gravity readings were made. This was done at the request of the regional gravity group of the Bureau. The levels were connected by means of micro-barometers.

Measurements were made at the following stations:-

Area	Traverse No.	Length (ft)	Station Interval (ft)	No. of Stations
Black Angel	200E	3600	100 & 300	21
	0	3600	100 & 300	21
	200W	3600	100 & 300	20
Area No. 4	1600E	8200	200	42
	3200E	8200	200	42

6. RESULTS

(A) Magnetic.

Area No.1.

The results of the reconnaissance survey over Area No.1 are shown as contours of vertical intensity on Plate 2. Detailed surveys were performed over two small areas, referred to on Plate 2 as Areas 1A and 1B. The results obtained in Areas 1A and 1B are shown as vertical intensity contours on Plates 3 and 4 respectively. Selected profiles

from these areas are compared with theoretical profiles on Plates 6, 7 and 8.

Area No.4.

Results of the reconnaissance survey over Area No.4 are shown as contours of vertical intensity on Plate 5. Plate 9 shows observed and calculated profiles along traverse 13200E.

In addition to the above, the results of magnetic surveys carried out by National Lead Pty. Ltd. over certain areas have been made available by courtesy of Mr. R.D. Ellett, of that Company. These results will be of value in connection with the final report on the complete survey, but it is not considered necessary to reproduce them in the present progress report.

(B) Gravity.

Bouguer anomaly profiles on the Black Angel area, and on traverses 1600E and 3200E in Area 4, are shown on Plates 10 and 11 respectively. The results of the gravity work performed for National Lead Pty.Ltd. are not reproduced here, as they contain no information which would be of value to this report.

7. DISCUSSION OF RESULTS

(A) Magnetic.

Neglecting minor-type anomalies due to near-surface material of erratic magnetism, the anomalies discovered in the ground surveys performed by the A.G.G.S.N.A. were classified in two types, described by Daly (1957a) as follows:-

Major-Type Anomalies: These are large regular anomalies of considerable extent, obviously arising from magnetic bodies at depth.

Regional-Type Anomalies: These are broad regular anomalies showing comparatively small variations in magnetic intensity over large areas.

The primary purpose of this classification was to distinguish anomalies which could reasonably be attributed to pipe-like bodies of ironstone similar to the outcropping bodies from anomalies due to any other cause. Major-type anomalies could be of immediate economic interest, whereas the cause of anomalies of other types is uncertain at present. In previous surveys, the description given above was sufficient to differentiate the anomalies, as the areas covered by the surveys were not large enough to delineate the regional-type anomalies completely. In the present survey this is not so, and a more precise means of classification is necessary. It is proposed that the terms "major-type anomaly" and "regional-type anomaly" be retained, and that they be defined as follows:-

Major-Type Anomaly. A regular anomaly in total force or vertical component of roughly circular plan, which can be reasonably attributed to a pipe-like body at depth.

Regional-Type Anomaly. A regular anomaly which, due to its shape, cannot be caused by a pipe-like ironstone body.

The second part of the anomalous zone east of the highway extends from 8,000E to 14,000E approximately and appears to be due to several pipe-like bodies. Portion of this zone has been covered by detailed survey (Area 1B), the results of which are shown on Plate 4. Inspection of the profiles shows that the main anomaly is due to two separate bodies at different depths. Plate 7 shows the observed vertical and horizontal component profiles along Traverse 12,300E, compared with profiles calculated for two spherical bodies, one centred at 4,240S, at a depth of 390 feet and one centred at 4,660S, at a depth of 500 feet. Assuming a susceptibility of 0.1 c.g.s. unit, the radii of the bodies are 110 feet and 132 feet respectively. The fit could be improved by variation in details, but the general agreement in shape of the profiles shows that the assumed distribution of magnetic material is justified in general. Drill sites could be selected on this basis, if investigation of the bodies were considered desirable. The anomalous zone also shows effects due to at least four other small bodies at various depths.

Area No.4.

The results are shown in the form of a contour map on Plate 8. The map shows a continuing zone of regional anomaly, with a large number of high closures, generally elongated in a direction slightly south of east. There is no reason for supposing that any of these closures is due to a pipe-like magnetic body. Plate 9 shows the observed vertical and horizontal component profiles along Traverse 13,200E, compared with profiles calculated for a spherival body centred at 1,060N at a depth of 1,650 feet: It is apparent that the profiles are different in character and that the observed anomaly cannot be due to a discrete magnetic body. It seems more likely that the anomaly is due to the edge of a relatively flat-lying magnetic sheet, which extends for a considerable distance to the south. Further mathematical study of these anomalies is being undertaken and may lead to more definite conclusions.

(B) Gravity Results.

Black Angel Area. Three traverses were read over the Black Angel Area, in order to determine the form of the gravity anomaly over a large concealed body which had been detected by magnetic methods. It is obvious that, provided the body is magnetised by induction so that the anomaly due to it can be calculated by potential theory, and provided the magnetic and gravity anomalies are both caused by the same material, both methods of surveying must give the same information on the position and shape of the body. However, the gravity profile provides extra control on the dimensions and magnetic susceptibility of the body.

Plate 10 shows Bouguer anomaly profiles over the Black Angel area, reduced using a value of 2.5 for the surface density. Considering traverse Zero as typical, the profile contains three noticeable features:-

(1) a general decrease to the south along the profile,

(2) a smooth anomaly, centred at about 150S, and

(3) a sharp anomaly superimposed on (2), centred at zero.

The second feature may be attributed to the large buried body and the third to the outcropping ironstone.

The slope of the profile, referred to under (1), corresponds with the slope of the ground level. This suggests that the slope of the profile may merely reflect the fact that the assumed value of 2.5 for the surface density is too high. The justification for using this figure is that the densities of samples of slates and schists of the Warramunga Group are about 2.5 or a little higher and that it is generally considered that the thickness of surface soil over the field is likely to be fairly small. On the other hand, a value of 2.2 is generally considered a reasonable average for reducing results of regional gravity observations over large areas.

The presence of the three effects mentioned renders fitting of a calculated profile rather indefinite in detail. On Plate 10, the observed profile along traverse zero is compared with a profile for a spherical body centred at 140S at a depth of 475 feet. The degree of fit appears to be as good as is likely to be obtained by any other arrangement. From the magnetic results, the body causing the anomaly was estimated to be centred at 200S (on the present layout) at a depth of 475 feet. There is a distance of 60 feet between the position of the centre, according to the gravity profile and that determined from the magnetic profile.

The amplitude of the gravity anomaly enables some conclusions to be reached concerning the size and effective susceptibility of the body. Assuming the body to be composed of the usual ironstone, its density would be about 5.0 (as determined from tests on samples), and the density contrast between the body and the country rock would be about 2.5. Using a value of effective susceptibility of 0.1 c.g.s. units, which was chosen as a reasonable average value over the field, the magnetic body was calculated to be equivalent to a sphere of radius 300 feet. However, using the above figures for density contrast and depth, such a sphere would give a maximum gravity anomaly of about 2.5 mgals. The observed anomaly which can be attributed to the buried body is about half of this amount. This suggests that the size of the body is about half of that calculated from the magnetic results and that the effective susceptibility of this body is about 0.2 c.g.s. unit. This would involve reducing the linear dimensions of the body by a factor of 2 1/3 (= 1.26), so that its radius would become about 240 feet. On this basis, its minimum extent in vertical depth would be from 235 feet to 715 feet.

Area No.4.

Bouguer anomaly profiles along traverses 1,600E and 3,200E are shown on Plate II. These profiles show weakly-defined highs on the northern and southern halves of each profile, corresponding to magnetic highs. The most striking feature of the profiles, however, is the sharp negative anomaly at the centre of each traverse. The only possible explanation for this is that there is a very substantial mass deficiency at this point. However, it is impossible at present to suggest an explanation for this feature with confidence. One possibility is that the negative anomaly is due to a fissure in the bedrock, possibly due to a tectonic movement and filled with some material, such as "bull-dust", of low density. It would be of great interest to determine whether similar anomalies are present in other parts of the field.

Other Areas.

Profiles over areas surveyed on behalf of National Lead Pty.Ltd., show no features similar to those discussed above and do not call for further discussion at the present stage.

8. CONCLUSIONS AND RECOMMENDATIONS.

(1) At the present stage, it is not considered desirable to propose any conclusion with regard to the cause of the regional magnetic anomalies. It is hoped that the results of the 1958 season's field work, and further mathematical study, may provide a more solid basis.

(2) It is recommended that a vertical drill hole, 1,000 feet deep, be put down at point 015370 on the Tennant Creek one-mile sheet. The purpose of this hole is to sample the rocks at a point at which it may be assumed that whatever formations cause the regional anomaly approach closest to the surface.

(3) Anomalies caused by pipe-like magnetic bodies may occur in any area showing a regional magnetic high even of small dimensions. Unless these anomalies are strong, they may not be visible as such on any map showing the results of an aeromagnetic survey.

(4) At least two anomalies due to pipe-like bodies have been located on Area 1. These anomalies have been fitted by theoretical anomalies to a degree of accuracy sufficient for siting drill holes, if such are required.

(5) Detailed gravity work can provide information of great value, and more of this work is required. However, it is considered desirable to await the results of the 1958 season's geological and geophysical field work, before deciding on a programme of gravity work.

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10. APPENDIX 1

CALCULATION OF MAGNETIC ANOMALIES DUE TO EXTENDED BODIES

The methods of interpretation used on surveys at Tennant Creek are based on the comparison of observed anomalies with theoretical anomalies due to spherical bodies (Daly, 1957). From preliminary inspection of the aeromagnetic map it appeared possible that regional anomalies could be due to relatively flat lying bodies, possibly folded, and an attempt was made to adapt the calculations to enable this possibility to be checked. It cannot be claimed that the results are very convincing, but they are presented here for what they are worth.

The potential at the origin due to a dipole centred at the point (x, y, z) and polarised by induction in a field of inclination θ is given by -

$$P = \text{constant } X \frac{x \cos\theta + z \sin\theta}{(x^2 + y^2 + z^2)^{3/2}}$$

where the x axis is in the meridian, the y axis perpendicular to it, and the z axis vertically downwards.

It is assumed firstly that the magnetic formation extends to infinity in the east-west direction. This is roughly applicable for example, to the main regional anomaly on the Tennant Creek one-mile sheet. Taking the appropriate derivatives and integrating for y between $\pm\infty$, we obtain the following expressions for anomalies in the various components of the magnetic field.

$$\Delta H = C \frac{x^2 \cos\theta + 2 x z \sin\theta - z^2 \cos\theta}{(x^2 + z^2)^2}$$

$$\Delta Z = C \frac{z^2 \sin\theta + 2xz \cos\theta - x^2 \sin\theta}{(x^2 + z^2)^2}$$

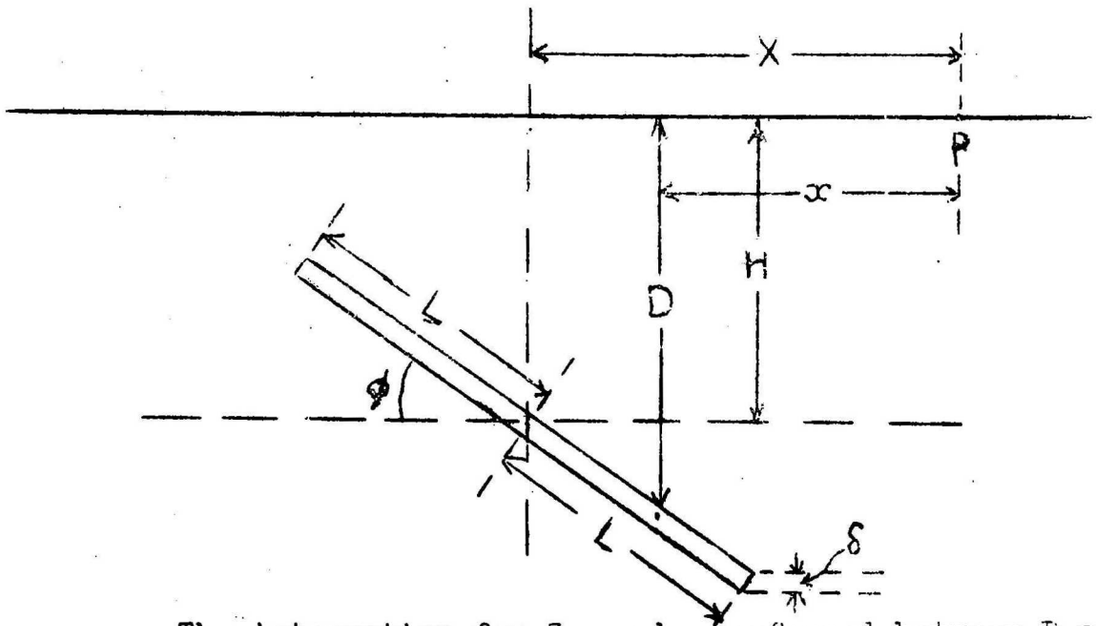
$$\Delta F(\text{Total force}) = C \frac{x^2 \cos 2\theta + xz \sin 2\theta - z^2 \cos 2\theta}{(x^2 + z^2)^2}$$

Where C is a constant involving the size and susceptibility of the body involved.

The variable part of each of these expressions is of the form -

$$\frac{Ax^2 + Bxz + Cz^2}{(x^2 + z^2)^2}$$

We assume, now, that a north-south section through the body consists of a succession of straight sections, inclined at various angles to the horizontal. The notation used is shown below -



The integration for Z may be performed between D and $(D + \delta)$ where δ is the thickness measured vertically and D is a function of the running co-ordinate x. (It should be noted that the fact that δ is measured vertically makes the formula meaningless for formations dipping very steeply).

Under suitable conditions on δ and D, the result of this integration is approximately

$$\delta.\left(\frac{Ax^2 + BxD + CD^2}{(x^2 + D^2)^2}\right)$$

This may be justified formally as follows. If f (x) and F(x) are functions of x such that $\int f(x)\,dx = F(x)$, then $\int_D^{D+\delta} f(x)\,dx$ $= F(D + \delta) - F(D)$. Expanding F $(D + \delta)$ in a Taylor series, the result follows, provided that the conditions are such that only the first two terms of the expansion need be taken.

For the integration with respect to x, we put $D = H + (X - x)\tan\phi$, and integrate for x, between limits $X \pm L\cos\phi$. The integration is elementary but tedious. The result is as follows:-

$$\text{Anomaly} = \text{Constant}\left[\frac{A + C}{2(H + x\tan\phi)}\ \text{artan}\ \frac{2L\cos^2\phi\,(H + X\tan\phi)}{(X^2 + H^2 - L^2)\cos\phi - 2HX\sin\phi}\right.$$

$$\left.\frac{+L\cos\phi\,L^2\cos^2\phi\,[(A-C)(\tan^2\phi - 1) + 2B\tan\phi] + 2BHX + (H^2 - X^2)(C-A)}{(X^2 + H^2 + L^2)^2 - 4L^2(X\cos\phi - H\sin\phi)^2}\right]$$

where the constant includes the factor δ, and A, B and C have the following values.

	A	B	C
ΔH	$\cos\theta$	$2\sin\theta$	$-\cos\theta$
ΔZ	$-\sin\theta$	$2\cos\theta$	$\sin\theta$
ΔF	$\cos 2\theta$	$\sin 2\theta$	$-\cos 2\theta$

In each case, A + C = 0, so that the first term vanishes. Taking H as the unit of length and replacing $\frac{X}{H}$ by X, and $\frac{L}{H}$ by L, we obtain -

$$\text{Anomaly} = \frac{\text{Constant}}{H}\left[\frac{L\cos\phi\{L^2\cos^2\phi[(A-C)(\tan^2\phi-1)+2B\tan\phi]+2BX+(1-X^2)(C-A)\}}{(X^2+L^2+1)^2-4L^2(X\cos\phi-\sin\phi)^2}\right]$$

It is apparent that this expression involves too many unknowns to be of any value for fitting to an observed curve Moreover its applicability is doubtful for the following reasons -

(1) the question of depolarising effects has been neglected completely.

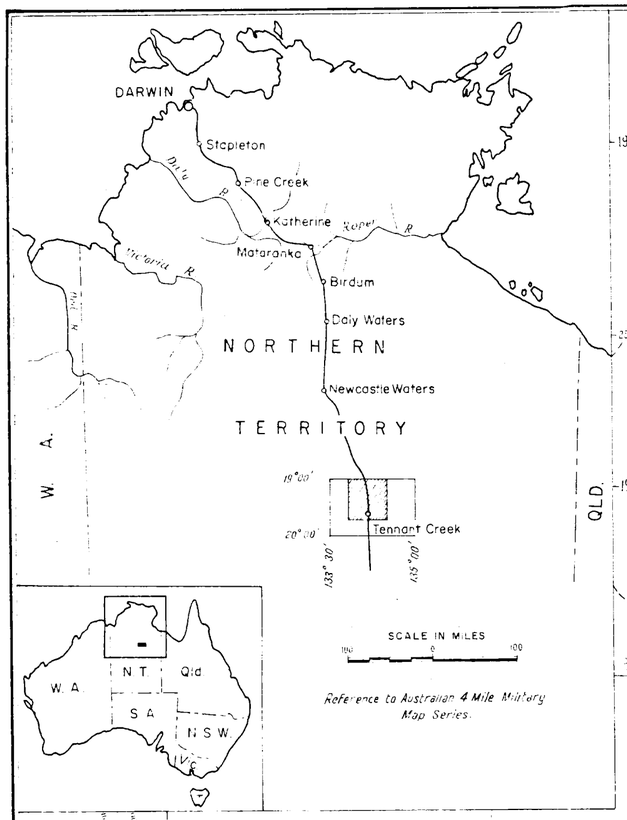
(2) the accuracy of the approximations involved in the integration with respect to z, has not been investigated; obviously, the formula is invalid for steeply dipping formations.

For the Taylor series expansion to be accurate enough it is probably necessary that δ and L be sufficiently small compared with H.

One of the main problems in interpreting anomalies of the type encountered at Tennant Creek is to distinguish between anomalies due to bodies which are magnetically equivalent to spheres and those due to flat lying bodies which may be considerably shallower. It is fundamental that the size and position of the body causing an anomaly cannot be uniquely determined from measurements of the potential due to the body, consequently, the fact that a body causes an anomaly indistinguishable from that due to a sphere, is not proof that the body in fact bears any resemblance to a sphere. However, it seems possible that if the body causes an anomaly which departs in some particular way from that due to a sphere giving the closest possible approximation this may be an indication that the body is actually flat lying and of small thickness.

As a test of this, horizontal and vertical component profiles have been calculated for a few cases, using the above formulas, and compared with profiles calculated for a sphere selected by fitting the turning points on the horizontal component profile as described by Daly (1957). The results are shown in Plate 12. No account has been taken of actual level of profiles, as this cannot be determined from field observations, but each profile has been matched by eye as well as possible. The divergences appear considerable, but the most spectacular occur where the body is steeply dipping and close to the surface, and it is most unlikely that the calculations can be trusted in such cases. The most consistent difference is in the vertical components, the amplitude of the anomaly calculated for a sphere being generally greater than that for the extended body. However it does not appear that this method can provide a sensitive test of the shape and aspect of the body.

PLATE 1



GROUND MAGNETIC SURVEY AT TENNANT CREEK, N.T. (1957)

LOCALITY MAP

(PORTION OF THE TENNANT CREEK (SPECIAL) MAP. G110-30)

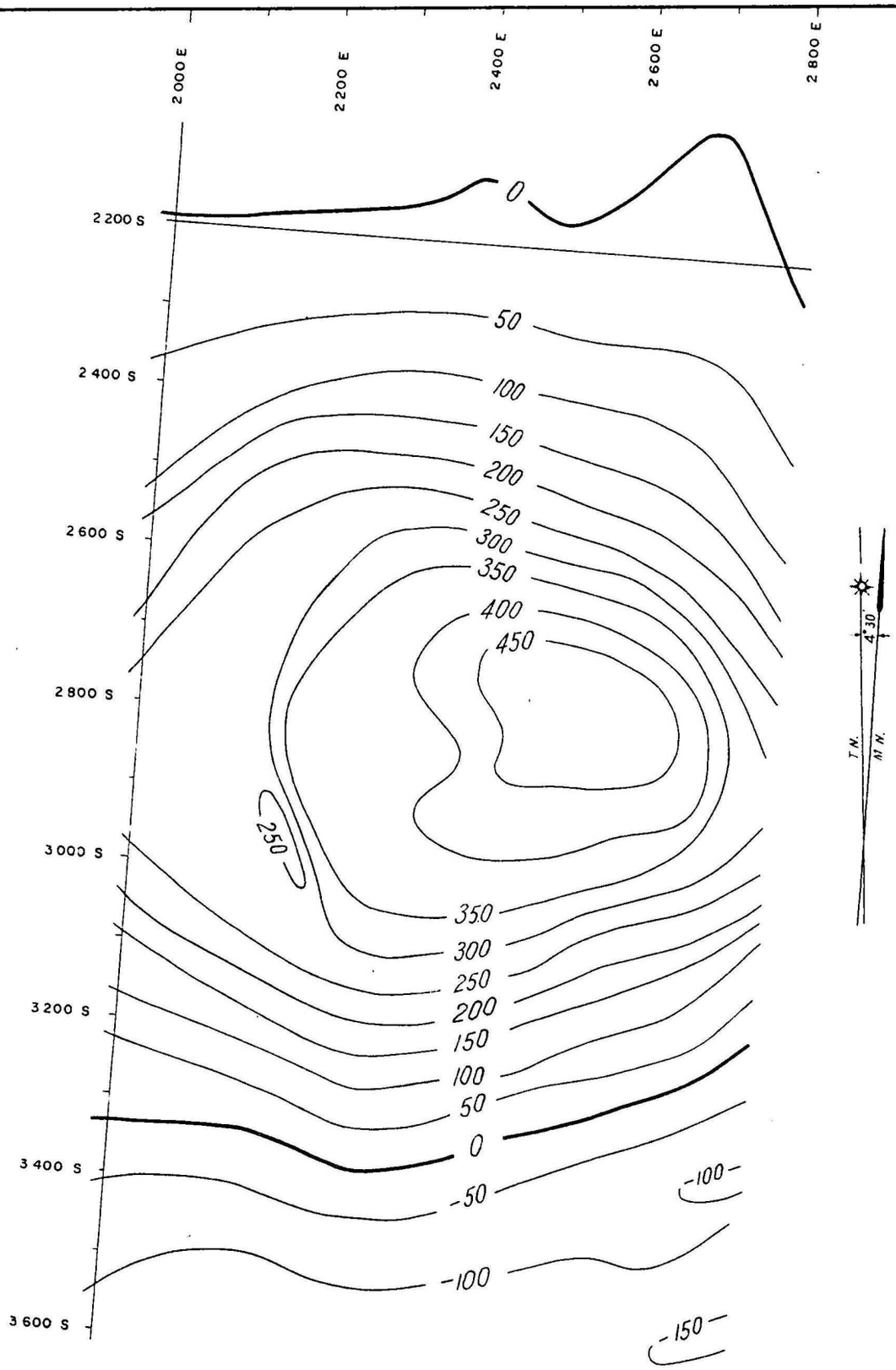
SCALE IN MILES

2 0 2 4 6

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics. G 110-31

To Accompany Records 1959. N°14

To Accompany Records 1959, No 14



GROUND MAGNETIC SURVEY AT TENNANT CREEK, N.T. (1957)

CONTOURS OF VERTICAL MAGNETIC INTENSITY

AREA No 1A

SCALE IN FEET

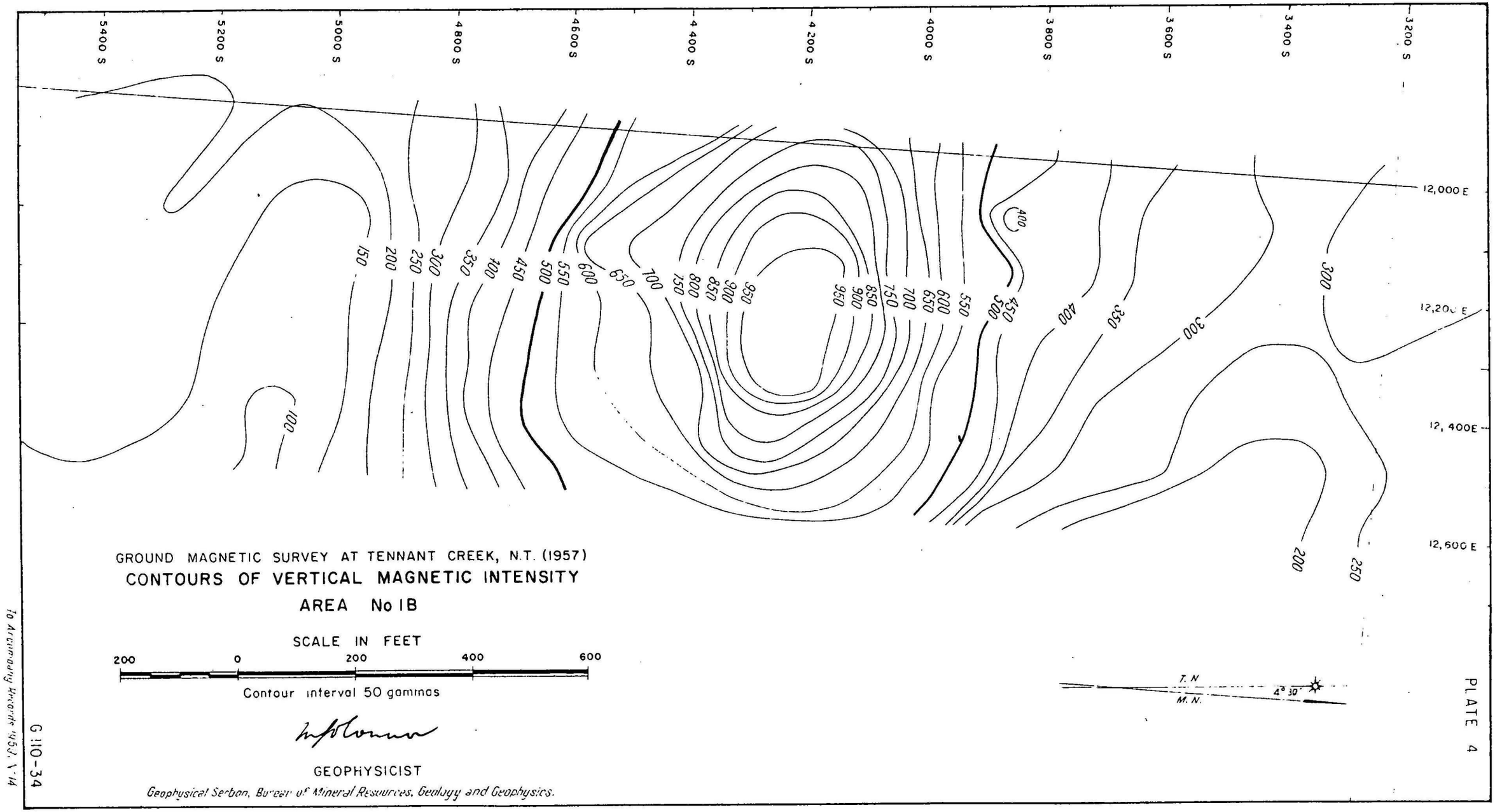
200 0 200 400 600

Contour interval 50 gammas

GEOPHYSICIST

Geophysical Section, Bureau of Mineral Resources, Geology & Geophysics. G 110 – 33

To Accompany Records 1959. N° 14



GROUND MAGNETIC SURVEY AT TENNANT CREEK, N.T. (1957)

CONTOURS OF VERTICAL MAGNETIC INTENSITY

AREA No 1B

SCALE IN FEET

200 0 200 400 600

Contour interval 50 gammas

GEOPHYSICIST

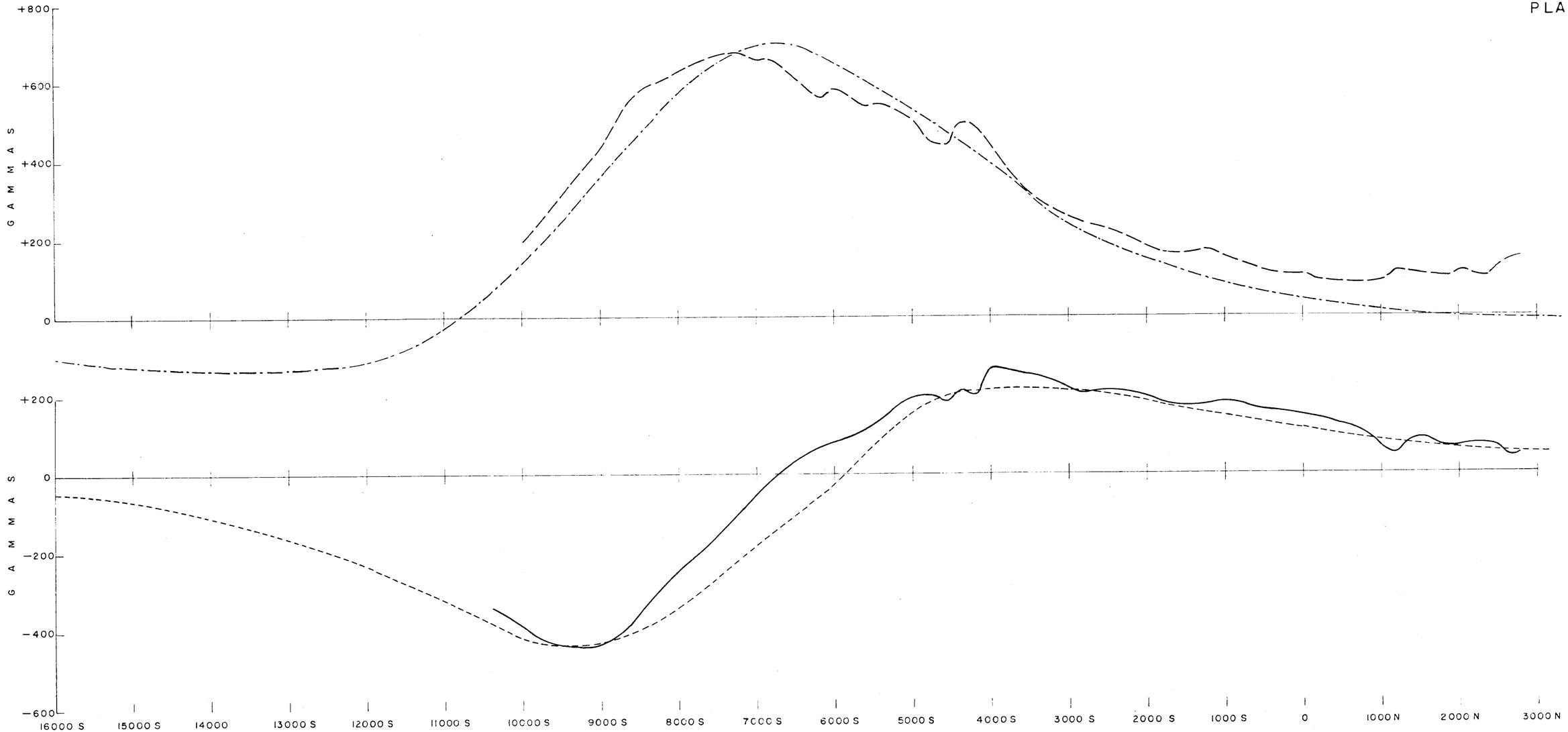
Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics.

PLATE 4

G 110-34

To Accompany Records 1957, No. 14

PLATE 5



LEGEND

——— H OBSERVED

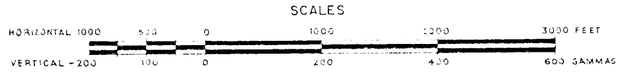
- - - - - - - H CALCULATED

— — — Z OBSERVED

—·—·— Z CALCULATED

The calculated profiles of H and Z are for a spherical magnetite body of 1480 feet radius and depth to centre 5450 feet below grid position 7780 S.

SCALES



GEOPHYSICIST

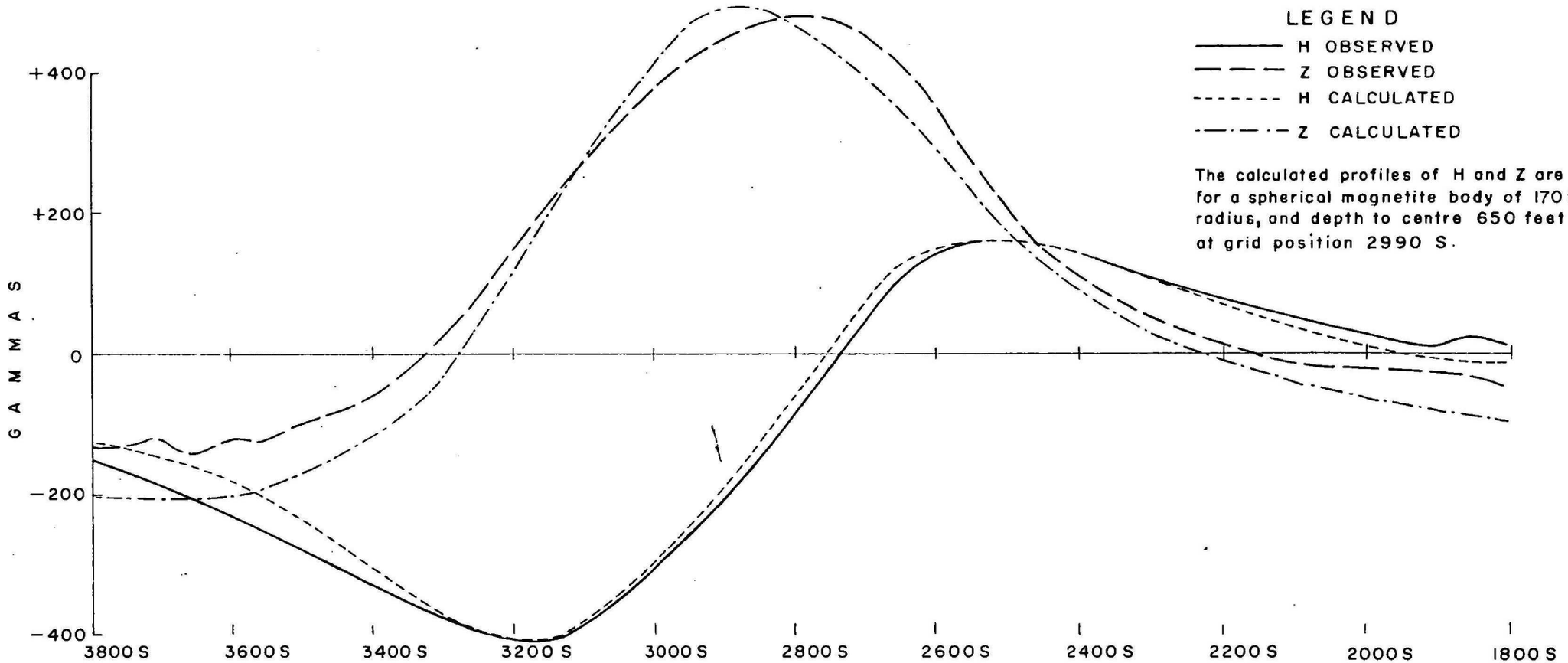
GROUND MAGNETIC SURVEY AT TENNANT CREEK, N.T. (1957)

AREA Nº 1

OBSERVED AND CALCULATED PROFILES OF VERTICAL Z AND HORIZONTAL H MAGNETIC INTENSITY ALONG TRAVERSE 12000 W.

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics G 110 – 36

To accompany Records 1959. No. 4



SCALES

HORIZONTAL 200 0 200 400 600 FEET

VERTICAL −200 0 200 400 600 GAMMAS

GEOPHYSICIST

GROUND MAGNETIC SURVEY AT TENNANT CREEK, N.T. (1957)

AREA Nº 1A

OBSERVED AND CALCULATED PROFILES OF VERTICAL Z AND HORIZONTAL H MAGNETIC INTENSITY ALONG TRAVERSE 2500 E.

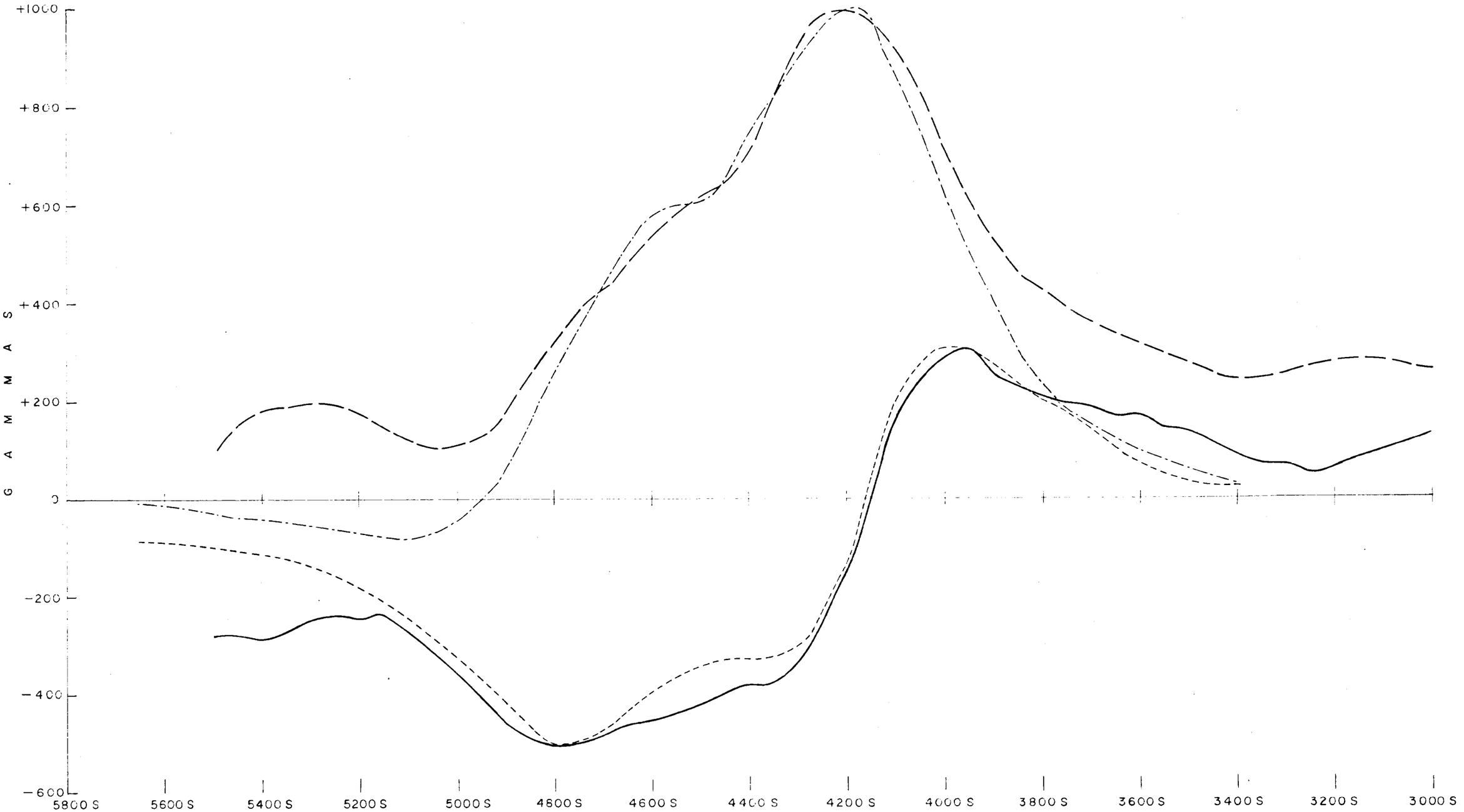
PLATE 6

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics

To Accompany Records 1958, Nº 14

G 110-37

PLATE 7



LEGEND

H OBSERVED

Z OBSERVED

H CALCULATED

Z CALCULATED

The calculated profiles for H and Z are for two separate spherical magnetite bodies as tabulated below.

Grid position	4240 S	4660 S
Depth to centre	390 ft.	500 ft.
Radius	110 ft.	132 ft.

SCALES

HORIZONTAL 200 0 200 400 600 FEET

VERTICAL -200 0 200 400 600 GAMMAS

GEOPHYSICIST

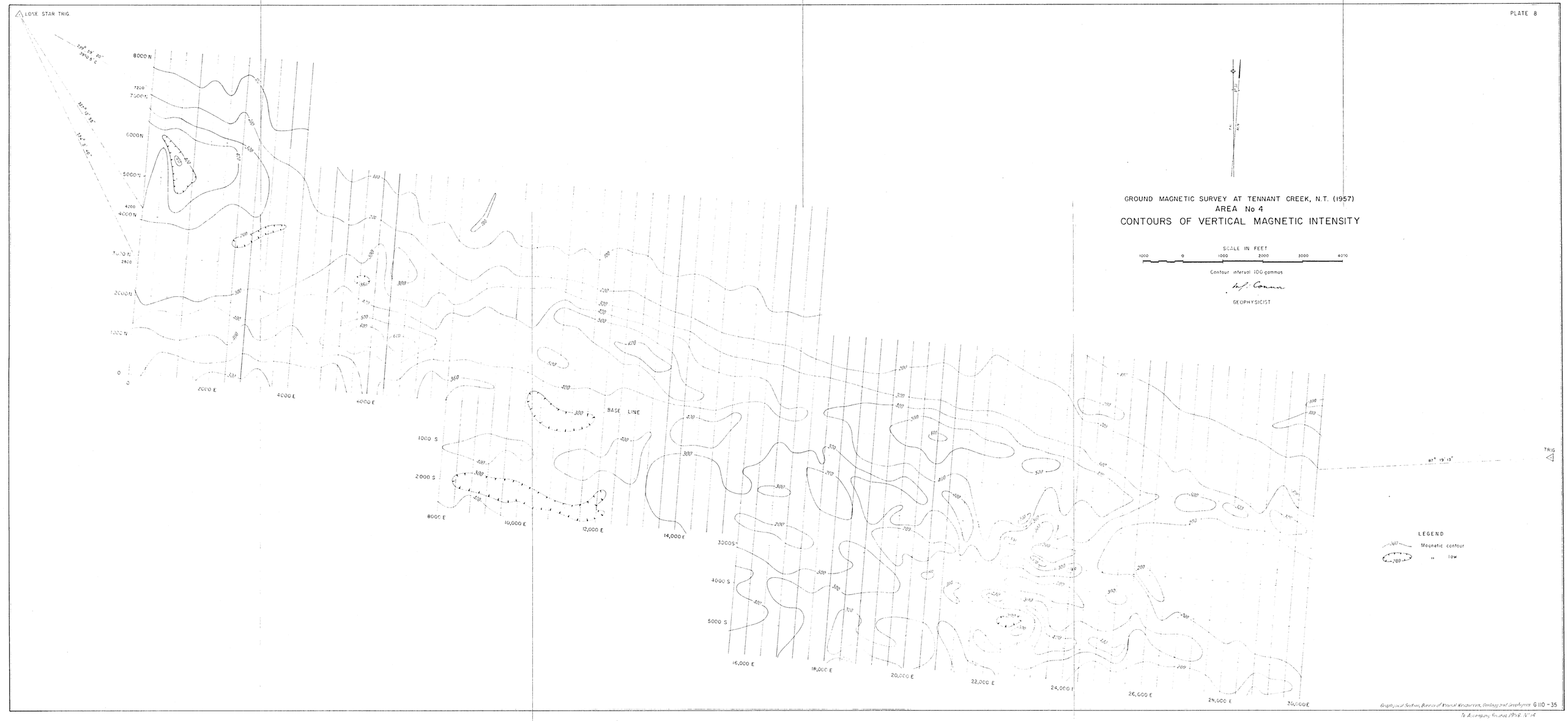
GROUND MAGNETIC SURVEY AT TENNANT CREEK, N.T. (1957)

AREA No. 1B

OBSERVED AND CALCULATED PROFILES OF VERTICAL Z AND HORIZONTAL H MAGNETIC INTENSITY ALONG TRAVERSE 12300E

Geophysical Section Bureau of Mineral Resources, Geology and Geophysics G 110 — 38

To Accompany Records 1959, No. 14



GROUND MAGNETIC SURVEY AT TENNANT CREEK, N.T. (1957)

AREA No 4

CONTOURS OF VERTICAL MAGNETIC INTENSITY

SCALE IN FEET

1000 0 1000 2000 3000 4000

Contour interval 100 gammas

W. J. Connor

GEOPHYSICIST

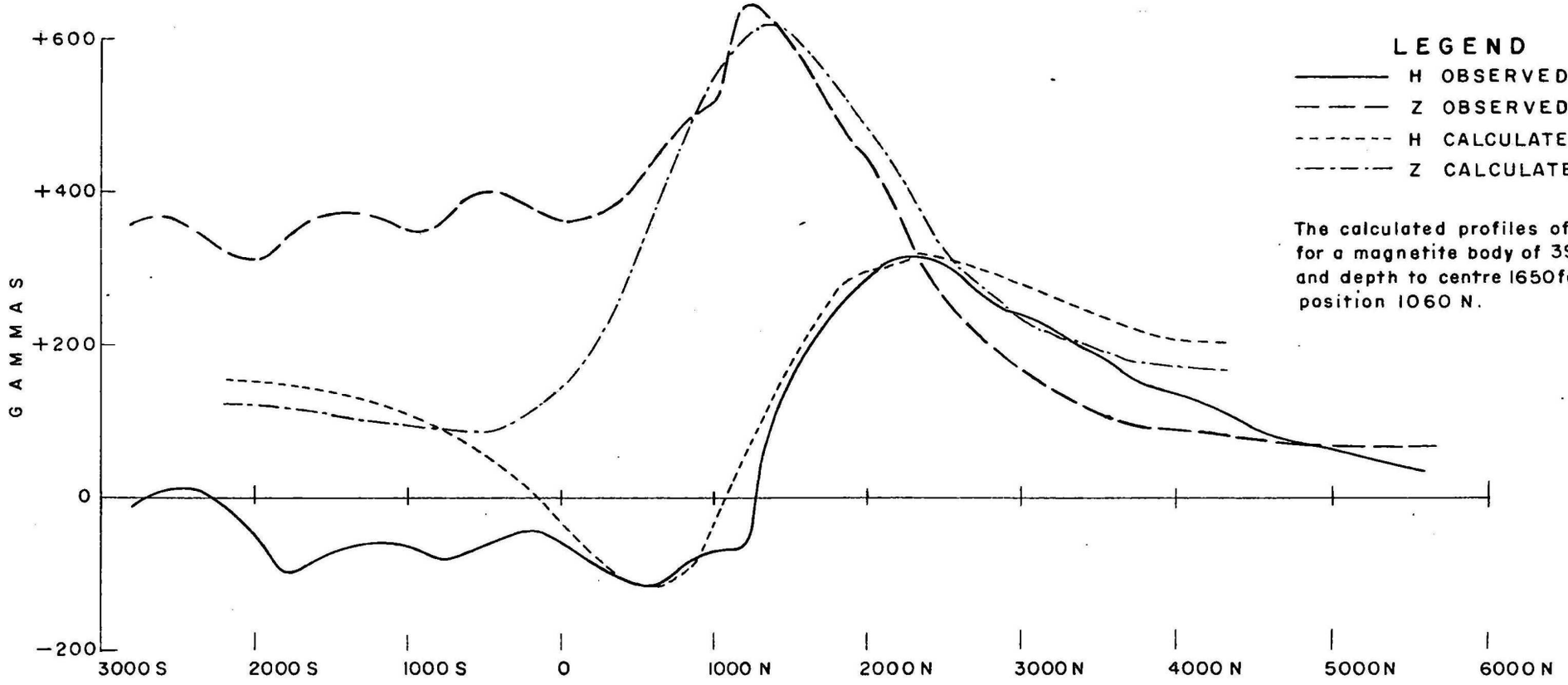
LEGEND

300 Magnetic contour

200 " low

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics G 110 - 35

To Accompany Record 1958/ No 14



SCALES

HORIZONTAL 1000 0 1000 2000 3000 FEET

VERTICAL −200 0 200 400 600 GAMMAS

GEOPHYSICIST

GROUND MAGNETIC SURVEY AT TENNANT CREEK, N.T. (1957)

AREA Nº 4

OBSERVED AND CALCULATED PROFILES OF VERTICAL Z AND HORIZONTAL H MAGNETIC INTENSITY ALONG TRAVERSE 13200 E

PLATE 9

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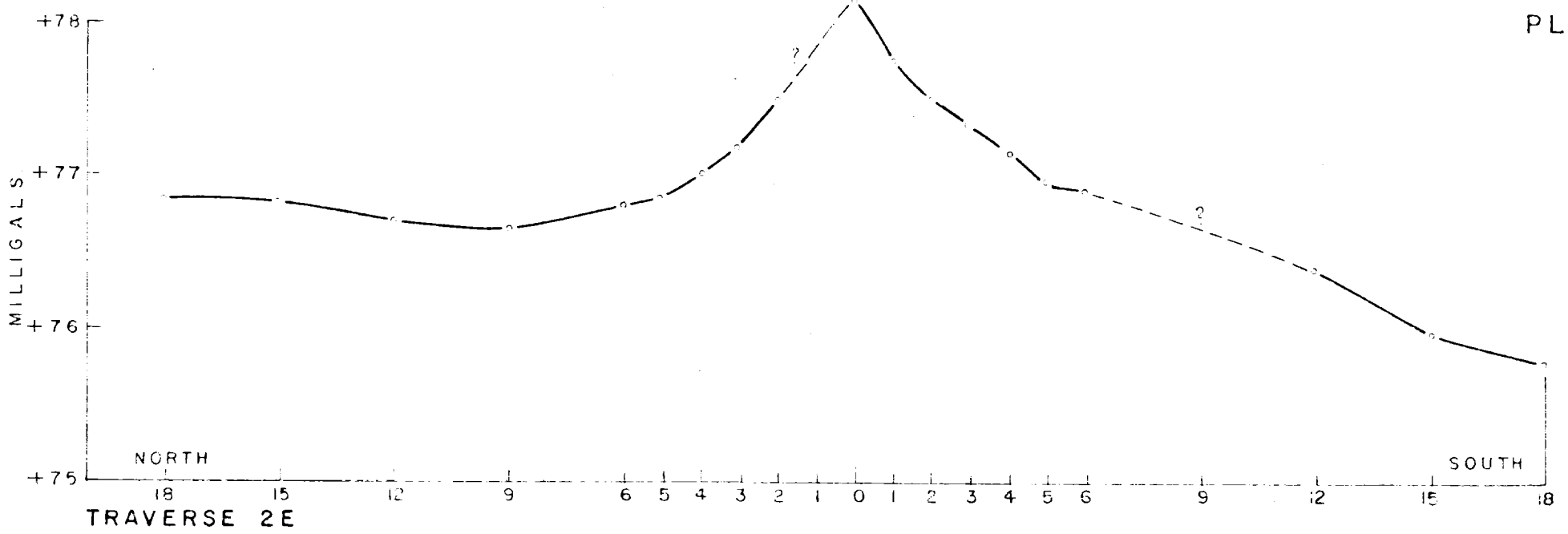
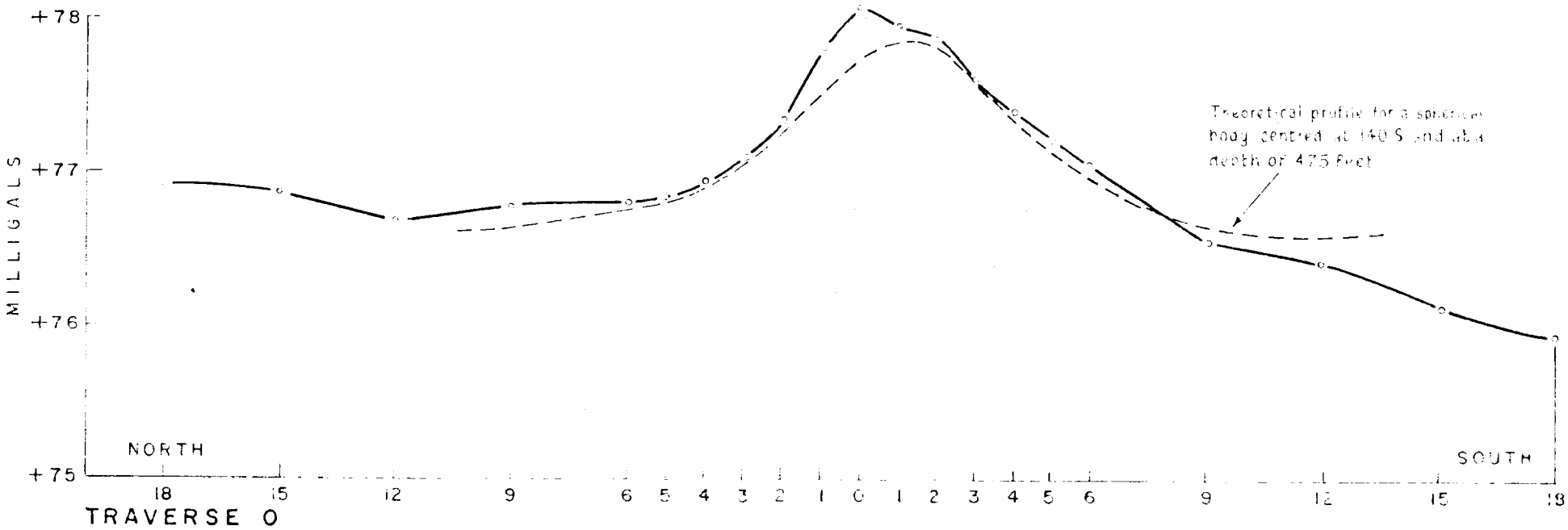
To Accompany Records 1959, N° 14

G 110 – 39

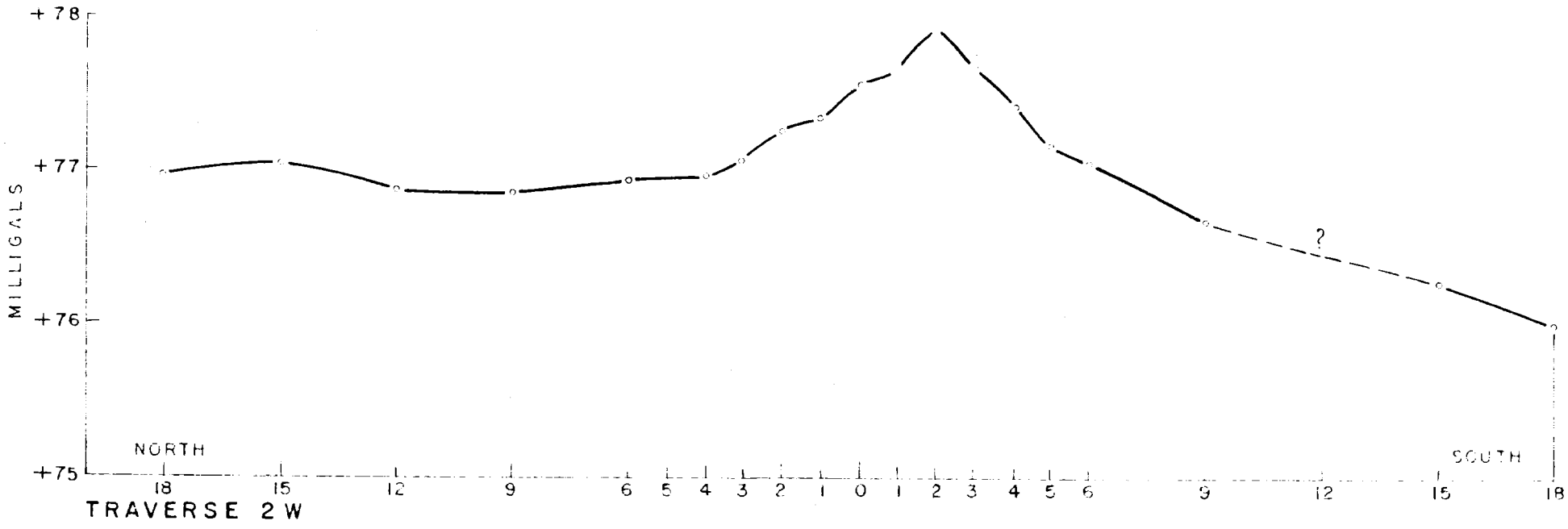
PLATE 10



TRAVERSE 2E



TRAVERSE 0



TRAVERSE 2W

SCALES

HORIZONTAL 400 300 200 100 0 400 800 1200 FEET

VERTICAL 0 1 2 3 MILLIGALS

GEOPHYSICIST

DETAILED GRAVITY SURVEY AT TENNANT CREEK, N.T. (1957)

BLACK ANGEL AREA

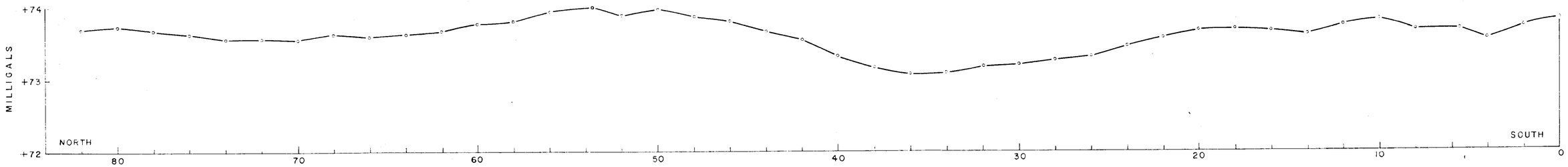
RELATIVE BOUGUER ANOMALY PROFILES

(ARBITRARY DATUM)

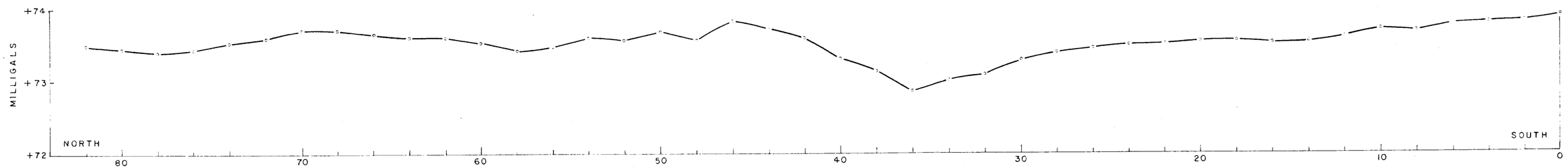
G 110-40

Bureau of Mineral Resources, Geology and Geophysics

To accompany Record 1958, No. 4

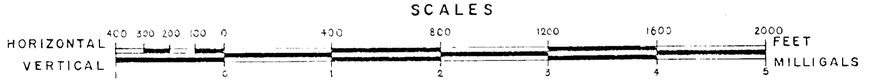


TRAVERSE 32 E



TRAVERSE 16 E

SCALES



GEOPHYSICIST

DETAILED GRAVITY SURVEY AT TENNANT CREEK, N.T. (1957)

AREA No. 4

RELATIVE BOUGUER ANOMALY PROFILES
(ARBITRARY DATUM)

Geophysical Section, Bureau of Mineral Resources Geology and Geophysics. G 110 — 41

To Accompany Records 1959, No. 14

PLATE 12

GROUND MAGNETIC SURVEY
AT TENNANT CREEK, N.T. (1957)

COMPARISON OF CALCULATED PROFILES FOR THIN MAGNETIC SHEETS AND FOR SPHERES

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics G 110 - 42

To Accompany Records 1959, N°14