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GEOPHYSICAL SURVEY AT THE EVELYN MINE, PINE CREEK DISTRICT, NORTHERN TERRITORY

by

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ABSTRACT

In response to an application by Northern Mines Development N.L. in May, 1956, a geophysical survey was made by the Bureau of Mineral Resources at the Evelyn Silver-Lead Mine, about 30 miles north-east of Pine Creek, Northern Territory, during August, September and October, 1956. The object of the survey was to search for mineralisation additional to the limited known deposits.

The silver-lead lodes occur in limestones on the north-western flank of Pinnacle Hill, a quartz-ironstone-breccia outcrop of Proterozoic age.

The electromagnetic, magnetic and self-potential methods were used, and soil samples were taken for geochemical analyses for lead. The results of the geophysical methods show indications which are considered a useful guide to future prospecting in the area, but the extension of the known lodes appears to be limited.

Indications obtained by the electromagnetic method are thought to be due to various causes such as mineralised shears, beds of graphitic slates and lodes. The electromagnetic anomalies are important because the known lodes occur in tension fractures near their intersection with the main fault.

Some of the smaller self-potential indications may be associated with the sulphide ore bodies, but those of larger magnitude coincide with mineralised graphitic slates. The smaller indications are limited to the ore bodies and give no indication that the bodies extend beyond their known limits.

The magnetic anomalies are probably due to hematite associated with the lead lodes.

It is recommended that several of the electromagnetic anomalies be further investigated for possible sulphide mineralisation.

1. INTRODUCTION

The Evelyn silver-lead mine is situated about 30 miles north-east of Pine Creek at the junction of roads to Goodparla Station and the Northern Hercules gold mine. Pine Creek is linked to Darwin, 158 miles to the north, by the Stuart Highway and the Darwin-Birdum railway.

Following correspondence in 1954 and 1955 concerning a geophysical survey of the Evelyn Mine, a request to undertake the investigation was received by the Bureau of Mineral Resources from Northern Mines Development N.L. on 28th May, 1956. It was hoped the results of such an investigation would aid planned exploratory work by outlining possible extensions of the lodes.

The survey was carried out by officers of the Bureau during the period August to October, 1956, over an area measuring 3200 feet by 1500 feet around the old Evelyn mine.

Mining of the Evelyn lodes commenced prior to 1886, but the exact date is not known. During the period 1886-87, about 2,200 tons of ore were produced, realizing 600 tons of lead and 89,000 oz. of silver. The workings had reached the 130-foot level and most of the accessible ore had been removed when operations ceased in 1890. In 1924, the dumps were worked by the Silver Mountain Silver-Lead and Zinc Company and yielded 42 tons of silver-lead ore. A further 7 tons of concentrates were produced in 1947-8.

The current prospecting campaign was initiated by the company to investigate a 4-foot intersection of silver-lead-zinc ore revealed by a diamond drill hole put down by Zinc Corporation in 1955.

2. GEOLOGY

Only a limited amount of geological information on the mine is available. Hossfeld (1937) gives a brief description of the mine and its history, and Elliston (1954) reported briefly on the geology of the deposit. The following description is compiled from the above reports, from a report by Noakes (1949) on the regional geology, and from observations by the author. Geological mapping of the area, except near the main outcrops and costeans, was restricted by the lack of exposures due to extensive soil cover.

The geological environment comprises rocks of the Golden Dyke formation which is of the Lower Proterozoic Brocks Creek Group. The host rocks of the lead ore are crystalline and laminated limestone and calcareous slates which overly black carbonaceous slates and quartzites. About half-a-mile west of the Evelyn mine, the limestones abut the Cullen Granite, which is thought to be a Lower Proterozoic intrusive and the source of the mineralisation.

Black carbonaceous slates crop out as low ridges to the north and south of the area and, with the granite, form a shallow basin. Within this basin the dominant feature is Pinnacle Hill, a quartz-ironstone-breccia formation rising about 200 feet above the soil-covered flats.

Severe folding and contortion of the limestones is observed and also considerable faulting took place. An ironstone-quartz-breccia may be the result of a major east-west fault (Elliston, 1954); this is open to question, however, because of the large extent of the breccia. The breccia is not related to the mineralisation.

The limestones are highly silicified and are accompanied by numerous small quartz and quartz-hematite blows associated with the granite intrusion.

The limestone, with the granite blows, strikes approximately easterly and forms an asymmetric anticlinal structure with its axis parallel to the suspected fault (Plate 1). The graphitic slates also strike easterly and have a constant steep dip of 60° to the south. They are comparatively undisturbed over the whole northern portion and in the south-west, but show tight folding at their junction with the Pinnacle Hill breccia in the south-eastern part of the surveyed area.

The known silver-lead-zinc mineralisation is restricted to four small lodes in limestones on the north-western slopes of Pinnacle Hill (named No.1, No.2, No.3 and Main Lodes by the company's geologist), two smaller lodes to the south-east (No.2 and Murray's Lodes), and two smaller veins (the East and West Lodes) about 1,200 feet to the north of the main outcrop (Elliston, 1954).

At the main outcrop, the lodes are small tabular bodies situated en echelon with a northerly strike and easterly dip of 85°. The Main Lode is about 200 feet long and ranges in width from a few inches to several feet. Small fractures subsidiary to the main east-west fault are thought to have provided favourable channels for the ore solutions during the granite intrusion. All lodes terminate abruptly at the fault in the north and their extension to the south is limited by the Pinnacle Hill breccia.

Sphalerite was found to be the predominant mineral on the dumps. Gossan and leached boxworks are prominant. Secondary hydrozincite, aurichalcite and smithsonite, with cerussite and anglesite, occur in the oxidised zone. Galena and sphalerite predominate at depth.

The old workings (1886-7) reached a depth of 130 feet, which, although the workings are now inaccessible for examination, was probably the limit in depth of the enriched zone. Primary ore was found in the Main Lode at a depth of 250 feet in the diamond drill hole drilled by Zinc Corporation in 1955 (Plate 2). The hole intersected four feet of ore which assayed 20 per cent lead, 8 per cent zinc, 25ozs. of silver and 5dwts. of gold. At greater depth, the same hole disclosed about 7 feet of ore with 3 per cent lead and 7 per cent zinc. A shaft is being put down to investigate this ore shoot.

The dumps on the West Lode show galena, sphalerite, pyrite and chalcopyrite in limestones, but closely associated with hematite. The East Lode is mineralised to a lesser degree and the vein is only about one foot wide.

The graphitic slates and limestones surrounding the area covered by the geophysical survey revealed no traces of mineralisation.

3. PREVIOUS GEOPHYSICAL SURVEY.

A brief test survey, using potential ratio and self-potential methods, was made over the Evelyn mine area in 1937 by the Aerial, Geological and Geophysical Survey of Northern Australia (Rayner and Nye, 1937).

4. FIELD OPERATIONS AND METHODS USED.

(a) General.

The geophysical field work was conducted by geophysicists D.L. Rowston (party leader) and E. Sedmik, during the period 14th August to 14th October, 1956. J. Daly, Supervising Geophysicist, visited the party during the survey. E. Sedmik was recalled to Melbourne on 22nd September.

The topographic survey of the geophysical grid was carried out by Northern Hercules N.L., which also provided three field assistants. The existing mine co-ordinates were used for the geophysical grid. Surveying commenced on 16th August and initially covered the area from 4400N to 6600N and from 4200E to 5600E. The traverses, 200 feet apart, were pegged at 25-foot intervals and later some intermediate traverses were added. Extensions of this initial grid were subsequently surveyed and the whole area finally investigated, from 4100N to 7600N, is shown on Plate 2.

The survey pegs were originally numbered independently of the mine co-ordinates but were later altered to correspond with them. The key plan for the earlier numbering is held by the surveyor at the Northern Hercules Mine. Electromagnetic, magnetic and self-potential methods were used in the geophysical survey and soil samples were taken for geochemical analysis for lead.

(b) Electromagnetic.

The results of the earlier test survey using potential ratio and self-potential methods were poor and it seemed that the electromagnetic method would probably be more successful. The electromagnetic method is used to discriminate between zones of different electrical conductivity, which are related to the geology of the area.

When an electromagnetic field is established in a homogeneous medium, a normal field distribution exists and can be calculated. The presence of subsurface features with different electrical characteristics causes distortions of the normal field, which can be found by measuring the components of the field at the surface. The observed field is a combination of the normal (primary) field and the effects of good electrical conductors causing a secondary field. By subtracting the theoretical (primary) component from the observed values of the total field, indications are obtained of the presence of a secondary field caused by good sub-surface conductors. Zones of higher conductivity can be due to sulphide bodies, shear zones, graphitic slates and ground water channels containing mineralised solutions.

Two parameters of the resultant field vector, the field intensity and the phase displacement, are observed when using the Turam equipment. The Turam equipment comprises two coils, an alternating current bridge network and detector. The relative intensity (Ratio) and phase difference (Phase) of the vertical component of the electromagnetic field at two points are read directly from the instrument.

The field at these points sets up electromotive forces in two electrically identical search coils connected to the measuring bridge. By taking successive readings along traverses laid at right angles to the strike of the mineralised zones, continuous profiles of Ratio and Phase are obtained (Plate 5). Zones of higher conductivity are indicated by an increase in the reduced ratio and by negative phase differences.

The primary field is established by means of a long straight insulated cable connected to an audio-frequency generator and earthed at each end.

The Turam cable was initially laid along 4200E and all traverses from 4400N to 7400N were surveyed with the cable in this position; the cable was later laid along 5800E. Test surveys using two frequencies, 440 and 880 cycles per second, and coil separations of 100 and 200 feet were made over the known ore bodies. Combinations of each frequency and coil-spacing showed good agreement but as no particular combination gave greater detail than any other the survey was continued using a frequency of 440 cycles per second and a coil-spacing of 100 feet.

The phase differences and relative intensity ratios were plotted as profiles, and a selection of these is shown on Plate 5. A phase difference contour map is shown on Plate 3 and the main electromagnetic indications are included on Plate 2.

(c) Magnetic.

Magnetic observations were made to determine local variations in the intensity of the vertical component of the earth's magnetic field. Such variations are due to concentrations of magnetic minerals and are sometimes associated with mineralisation.

The instrument was a Watts Vertical Variometer No.69107.

Readings were taken on all traverses at intervals of 25 or 50 feet. The readings were plotted as profiles with respect to the arbitary zero of base station 4750E/5200N. Typical profiles are shown on Plate 5, a magnetic contour map is shown on Plate 4 and the main magnetic indications are included on Plate 2.

(d) Self-Potential.

Sulphide bodies which are undergoing active oxidation above the ground water table frequently generate natural earth potentials and are usually characterised by a negative potential anomaly.

The sulphide mineralisation of the Evelyn lodes favoured the application of this method and the surface potential distribution was measured using a sensitive S.P. Meter. Copper electrodes in a concentrated copper sulphate solution were used to eliminate errors due to polarisation. Two measurements were made at each station to minimise local surface effects.

Observations were made mainly on traverses 200 feet apart from 4400N to 7600N with a 25-foot station interval, but additional traverses were surveyed over the mineralised zones and also south of Pinnacle Hill, because of an extensive indication there. Only very few self-potential anomalies were obtained.

The main indications are shown on Plate 2. Typical profiles, along traverses 5000N and 6400N over the lodes, are shown on Plate 5. The profiles are relative to the assumed zero of base station 4750E/5200N.

(e) Geochemical.

Geochemical prospecting is used to determine the presence of various elements by the chemical analysis of soil samples. The method is particularly applicable where extensive alluvium prevents a detailed geological examination. These conditions prevail near the Evelyn mine and as an aid to the interpretation of the geophysical results about 700 soil samples were taken.

The soil samples were dried, sieved and assayed for lead using the sensitive colorimetric dithizone method developed by the U.S. Geological Survey.

The purpose of the geochemical work is mainly to determine whether the geophysical indication is due to lead mineralisation or to some other source. The preschce of a nearby lead lode is indicated on the geochemical profiles by increased metal values at the respective sampling points. The results of the geochemical investigation have given considerable assistance in the interpretation of the results of the survey. Due to lack of facilities, however, only a small portion of the samples could be assayed.

5. DISCUSSION OF RESULTS

The geophysical methods used at the Evelyn Mine were successful in delineating numerous anomalous zones. It cannot be stated however, that any particular indication is definitely due to lead sulphide mineralisation. The origin of the indication must finally be ascertained by further investigations such as trenching and diamond drilling. Indications most probably associated with ore can, however, be inferred from a correlation of geophysical, geochemical and geological data.

(a) Electromagnetic.

The indications obtained by the Turam method are shown on Plates 2 and 3 and represent zones of higher conductivity. The indications have been classified as weak, medium and strong, but this classification does not necessarily denote their importance with regard to mineralisation. The most important indications have been numbered EMI to EM6 for discussion purposes.

The systematic pattern of the anomalies and their association with particular rock types indicate that they arise from two main sources:-

(i) Those in the limestone are probably due to channels containing mineralised water and representing a system of fractures and faults.

(ii) Zones of high conductivity, such as those found north of traverse 4600N, are due to the conducting nature of certain rock formations such as the graphitic slates.

The following discussion of the results is based on the above-mentioned premises.

Two main directions of strike predominate on the phase contour map, one to the west-north-west and the other approximately to the north. The indications with a consistent west-north-westerly strike form a broad zone about 350 feet wide which is probably associated with the major fault (Plate 1).

Less distinct west-north-west shears appear at the northern ends of indications EM2 and EM3.

The Turam indications striking approximately north and in close proximity to the fault zone, i.e. EM1, EM2 and EM3, are more intense than those which strike west-north-west, and are probably due to fractures developed by considerable movement along the fault plane. The anomalies further away from the fault are weaker and not as well defined.

Elliston (1956) shows an approximately north-south cross-fault on his geological map; this may be associated with indications EM5 and EM6, although the indications are further to the west than the fault shown by Elliston.

Two broad anomalies were recorded on traverse 4400N. Both are associated with ridges of graphitic slate and must be attributed to these rocks. The minus one degree contour (Plate 3) appears to demarcate approximately the limestone/slate contact in this section of the grid. Although soil conceals the rock type at the western end of traverse 4400N it is thought that a tongue of slate penetrates the limestone, giving rise to EM6.

At the northern end of the grid, an unusual positive phase indication on traverse 7600N coincides with the slate ridge which crops out from 5000E to 5600E. The ridge is almost parallel to the traverse, however, and could give an abnormal field distribution.

The known ore bodies are associated with weak electromagnetic anomalies.

The East and West Lodes occur at the junction of the minor west-north-west fault and the tension fractures associated with EM3 and EM4. The northern part of EM3, over the East Lode, is terminated by a fault striking north-west, but towards the south, indication EM3 continues to 5700N. Further investigation by shallow drilling or trenching is warranted on this indication. The limited extent of indication EM4 towards the north does not favour an extension of the West Lode beyond the exposures in the costean. Lead assays of soil samples showed high metal values over traverse 6400N (4650E to 4700E), but the anomalous values dropped sharply to 6600N/4625E.

Another well-defined indication (EM2) is centred at 5800N/5475E and has a similar structural environment to EM3.

The known Evelyn lodes are contained within a broad, weak electromagnetic anomaly (Plate 3) in which the individual ore bodies are not differentiated. The anomaly is terminated in the north by the extensive west-north-west trending indication of the fault zone, but continues south to 4800N. As the known ore bodies occur at the northern end of the good conducting zone, the southern section of this zone warrants re-examination of the old workings.

An interesting anomaly (EM1) centred at 4750E/5300N is parallel to the Evelyn lodes. This indication is somewhat similar to EM2 and EM3, and, because of its proximity to the main ore bodies, its origin should be investigated.

The strong indication (EM5) along 4300E, which is almost continuous over the length of the grid, is not associated with any known mineralisation. The length of the indication and its almost uniform intensity suggest that it is associated with a geological feature such as a band of graphitic schist rather than with lead ore mineralisation.

(b) Magnetic.

The area surveyed shows local magnetic variations, particularly near Pinnacle Hill and the lodes. Most of the variations recorded coincide with limonitic and hematitic outcrops. No magnetic anomalies were observed over the slates, except along 7400N, where quartz ironstones occur at the limestone/slate contact.

The area may be conveniently divided into the following four zones, each containing characteristic magnetic indications (see Plate 4):-

(i) a central zone comprising the complex magnetic indications of Pinnacle Hill and the fault zone.

(ii) a comparatively undisturbed area south-west of Pinnacle Hill.

(iii) a comparatively undisturbed area north of the fault zone.

(iv) a broad zone in the north-eastern portion of the surveyed area containing generally weak negative indications.

The indications over the quartz-ironstone-breccia of Pinnacle Hill exceed 400 gammas and have a northerly strike, i.e. parallel to the ore bodies. Although the ore bodies are reported to contain some magnetite there does not appear to be any definite spatial relationship between the magnetic indications and the lodes. A change in the direction of strike of the magnetic indications, similar to that in the electromagnetic results, occurs immediately to the north of the known lodes, thus confirming some major structural change; the magnetic indications in the fault zone have the same direction of strike as the electromagnetic indications.

The East and West Lodes lie within the comparatively undisturbed area north of the fault zone and coincide with some weak magnetic indications. The East Lode coincides with a broad, weak anomaly of only 100 gammas.

A regular, strong magnetic indication commences at the West Lode and continues with a north-westerly strike as far as traverse 7000N. This indication is probably associated with a dykelike hematite occurrence similar to those which crop out to the south-west on traverses 6100N and 6800N (Plate 2). A shallow trench which intersects the indication on 6800N shows no traces of mineralisation nor does it disclose the source of the magnetic indication. In the costeans at the West Lode however, the lead ore minerals seem intimately associated with hematite.

A broad zone of weak negative indications occurs north of 6800N. This zone strikes north-westerly, and appears to originate from a deeper source than the other magnetic anomalies. Two positive anomalies occur within the zone - the larger one at 5400E on 7400N, appears to be due to quartz-hematite rocks which crop out at the limestone/slate contact.

(c) Self-potential

The indications obtained by this method fall into two categories, namely those due to mineralisation and those due to graphitic slates.

Those in the first category are small but distinct, and are associated with the known ore bodies (Plates 2 and 5). Although the indications over the Evelyn mine strikes west-north-west, as compared with the northerly strike of the lodes, the maximum self-potential values coincide with the main workings. The indications do not continue towards the north beyond 5400N.

A small self-potential indication occurs over the West Lode, but is limited to the exposures of mineralisation in the costeans and gives no indication that the sulphides continue beyond these limits, thus confirming the conclusions drawn from the electromagnetic results. No indication was observed over the East Lode.

South of Pinnacle Hill, a broad self-potential anomaly of more than -400 millivolts was recorded over a ridge of graphitic slate adjoining the breccia. Self-potential indications are commonly associated with graphitic rocks.

The profiles in the north-eastern part of the area show a general negative trend which might be ascribed to the graphitic slates under a shallow limestone cover. The slates crop out along traverses 7400N and 7600N.

6. CONCLUSIONS AND RECOMMENDATIONS

The electromagnetic indications, although generally weak, are thought to be associated with the faults, shears and tension fractures near the mine. Because the known ore bodies are localised in tension fractures where they intersect shears striking west-north-west, the Turam results are important and are probably the best indications of possible sulphide concentrations.

Hematite deposits are associated with the known lodes, but whether mineralisation occurs without an associated magnetic anomaly is not known. A magnetic indication unaccompanied by a Turam indication is considered, however, to lack favourable environment for mineralisation.

Only the minor self-potential anomalies can be ascribed to the sulphide bodies and the self-potential indications are limited to the known lodes. No extension of these lodes is indicated by the self-potential anomalies. Large self-potential anomalies were located over graphitic slates which are not mineralised and are economically unimportant.

Several of the geophysical indications warrant further investigation and the following recommendations are made:-

(i) A detailed geological examination of the lease should be carried out prior to, or in conjunction with, the testing of the indications.

(ii) Turam Anomaly EM1, at 4750E/5300N, has a favourable structural environment and arises from a narrow vertical feature which extends for 400 feet and is parallel to the main lodes. It is recommended that this indication be tested initially by trenching to expose the limestone and facilitate geological examination. A suitable trench about fifty feet long, intersecting the indication at 4750E/5300N, is shown on Plate 2. A shallow diamond drill hole to prospect the indication at about 60 feet vertical depth is suggested at 4725E/5325N, bearing 115°, depression 50° and with an approximate length of 100 feet.

(iii) Main Evelyn Lodes Anomaly Zone (Plate 3).

Although the extensive electromagnetic anomaly, which includes the old workings in its northern section, is weak, the section south to traverse 4800N should be re-examined by a careful study of the shafts and potholes. The geophysical results show no particular targets within the broad zone. Geochemical assays for lead were carried out on samples from traverses 5100N and 5200N. On both traverses a zone about 500 feet wide showed very high lead values between 4950E and 5400E. A diamond drill hole at 4900N/5000E, depressed at 30° on a bearing of 78° and approximately 400 feet long, should terminate in the Pinnacle Hill breccia after intersecting any existing lodes in the limestones.

(iv) Turam anomaly EM2, centred 5475E/5750N, has no surface evidence of mineralisation, but its magnitude and proximity to the East and West Lodes warrant investigation by trenching and drilling, the latter being conditional on favourable results from the trenching. A trench at 5850N would test the flexure of the indication and one at 5700N would test the maximum value of the indication.

(v) The Eastern Branch of the Fork-shaped Turam Anomaly EM3, centred at 5130E/5800N, is intersected by an old costean at 5860N, which should suffice for a superficial examination of the possibility of the East Lode continuing in a southerly direction. Another short trench is suggested at 5025E/5800N to investigate the branch of the indication which strikes west-north-west. A trench is also suggested at the junction, 5150E/5700N. Both branches of the indication are thought to be due to narrow vertical shear zones.

(vi) Turam anomalies EM5 and EM6. Alluvium covers the greater part of these indications and their origin is not known. In view of their magnitude and continuity however, their origin should be investigated. The soil along traverse 5000N is shallow and a long bulldozed trench from 4200E to 4500E, with emphasis on the portion between 4350E and 4450E, should be relatively easy to undertake. There is little hope that this indication is due to lead mineralisation.

7. REFERENCES

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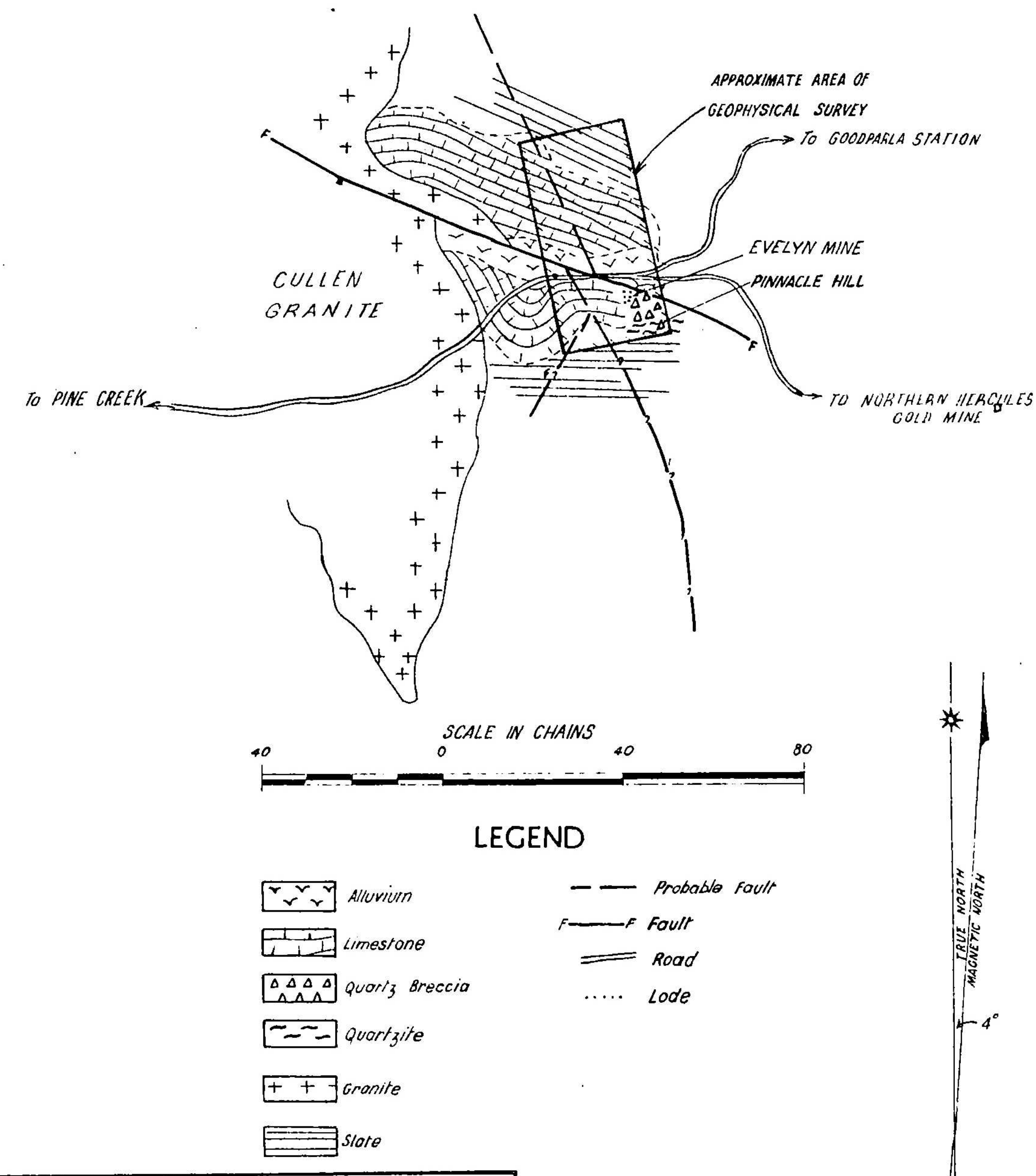
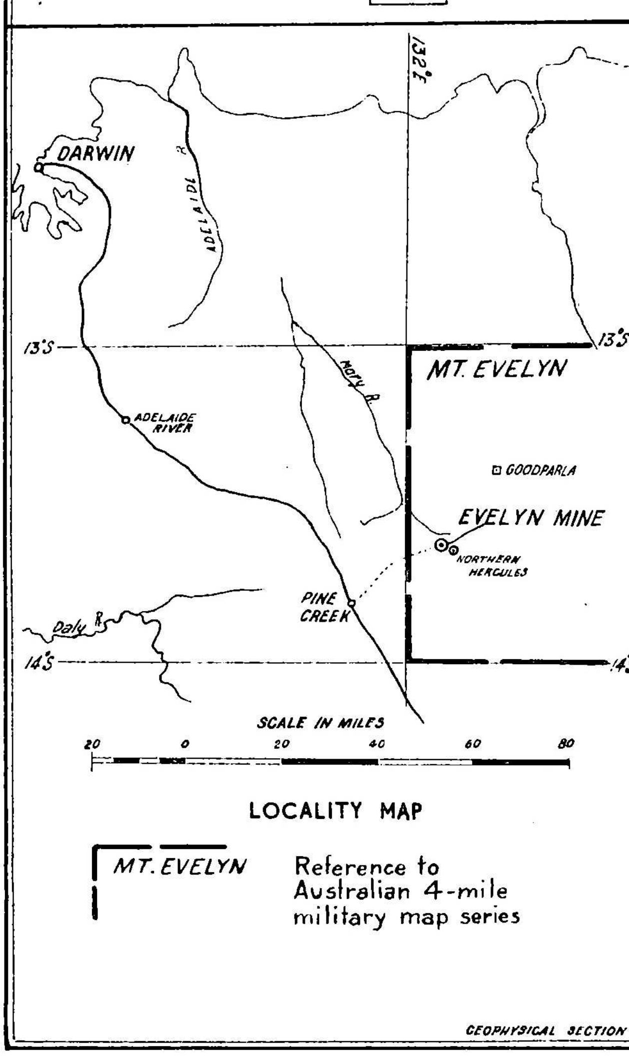
Rayner, J.M. and Nye, P.B.- 1937 The Evelyn Silver-Lead Mine, Pine Creek District - Geophysical Report. A.G.G.S.N.A. Rep. N.T. 26(b).

PLATE I





GEOPHYSICAL SURVEY AT THE EVELYN MINE,

PINE CREEK DISTRICT, N.T.

GEOLOGICAL MAP

(AFTER ELLISTON-AIR PHOTO SKETCH MAP)

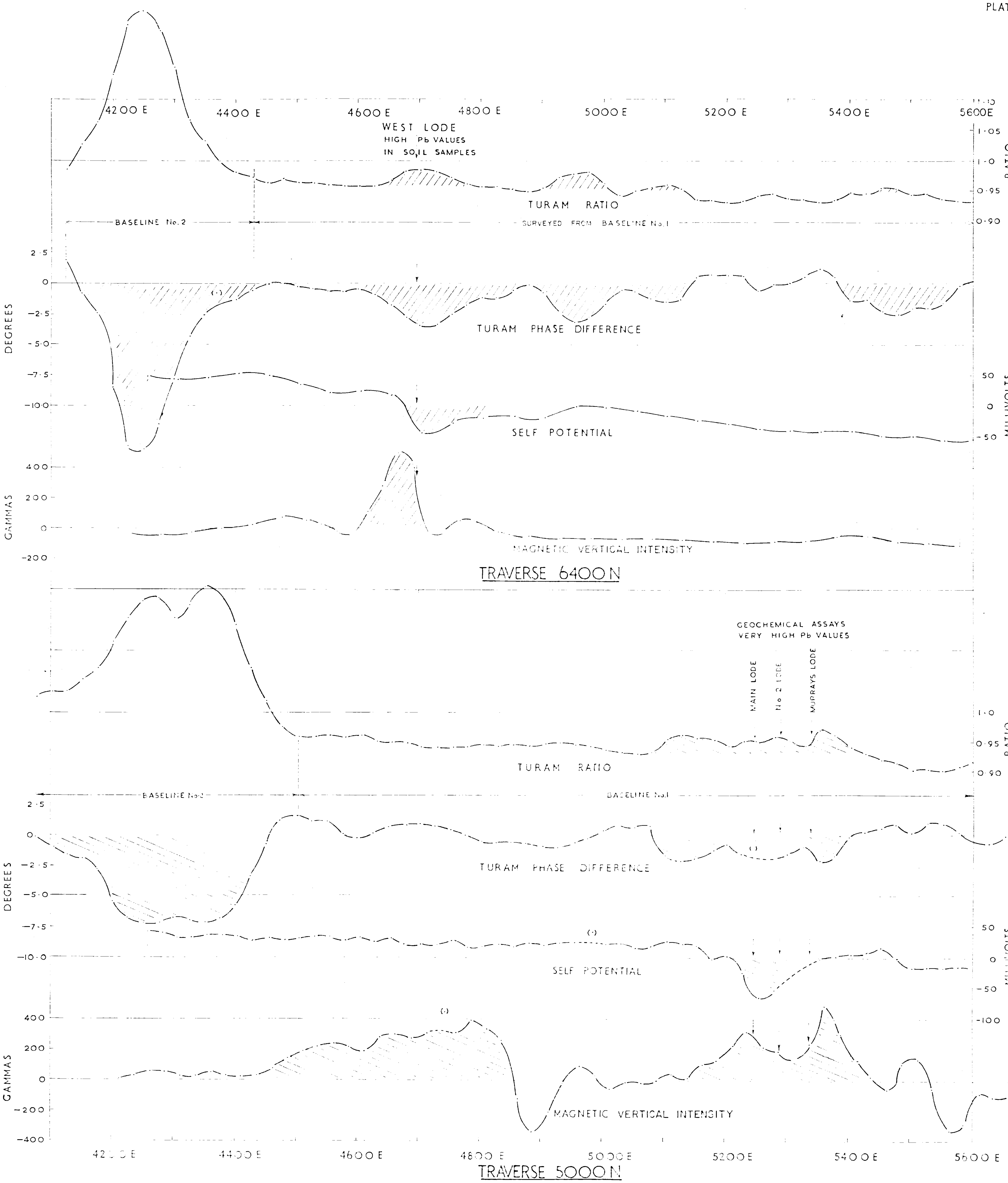
GEOPHYSICAL SECTION BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS. G282-2

To accompany Records 1957 No 101

GEOPHYSICAL SURVEY AT THE EVELYN MINE,
PINE CREEK DISTRICT N.T.

GEOPHYSICAL GRID, INDICATIONS AND WORKINGS

G 282-3



GEOPHYSICAL SURVEY AT THE EVELYN MINE,
PINE CREEK DISTRICT, N.T.

SELECTED TURAM, SELF-POTENTIAL AND MAGNETIC PROFILES

G 282-6