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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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SOME EXAMPLES OF SELF-POTENTIAL SURVEYS

by

J. Daly

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ABSTRACT

The mechanism by which ore-bodies generate electric potentials is imperfectly understood. This Record gives several examples of the results of self-potential surveys in Australia; some of the results are consistent with existing theory, but others are not. It is shown that striking variations in both amplitude and form of self-potential anomalies can occur during the wet season in northern Australia.

1. INTRODUCTION

The self-potential method has been used for many years as one of the standard geophysical methods of prospecting for metalliferous deposits. Many examples of successful results obtained by this method are quoted in geophysical literature. However, interpretation of the results of self-potential surveys has been purely empirical, owing to the very unsatisfactory state of the theory of the generation of such potentials.

The difficulty arises primarily from the fact that a number of electrochemical processes capable of producing potentials can be present in the ground, and these in general are not well understood. The problem is complicated by the fact that it is very difficult to obtain direct evidence. Exploration of a mineralised body by diamond drilling does not provide detailed information on the shape of the body, nor allow of access for the measurements necessary to test theories of the generation of self-potentials. If mining openings are available, information on details of shape is considerably more complete, and the body is accessible for any measurements which may be required, but it can no longer be assumed that the results of the measurements can be considered as representative of the undisturbed body. Although it is well established empirically that bodies containing graphitic or sulphide mineralisation, lying partly above ground water level, can often cause self-potential anomalies of a characteristic type, it is equally a fact that they do not always do so.

There are examples of bodies that cause self-potential anomalies despite the absence of some conditions that are normally required. On the other hand, other bodies have been encountered which cause no anomalies, although they appear to possess all the characteristics that are generally supposed to give rise to anomalies of the standard type.

There have been various attempts to elucidate the mechanisms by which sulphide or graphitic bodies give rise to self-potentials. The most recent is by Sato and Mooney (1960), which gives references to earlier work. Criticism of the processes suggested is a matter for specialists in electrochemistry. However, the main test of any such theory is that it should fit results obtained in the field. The Bureau of Mineral Resources has had occasion, in the course of its work, to make many self-potential surveys. Generally, these surveys were made for economic reasons, and no attempt was made to study anomalies from the theoretical aspect. The purpose of the present Record is to present the results of some selected surveys, which appear to possess special interest from the theoretical point of view. They bear mainly on the influence of ground water-level. Most of the surveys quoted were made in the Rum Jungle district, but one example from Mt Lyell is also given.

The results of the various surveys are discussed below under the two areas.

2. SURVEYS IN THE RUM JUNGLE DISTRICT

General

The Rum Jungle mining district is in the Northern Territory, about 50 miles south of Darwin. A sketch map of the district, showing the location of the surveys discussed, is shown on Plate 1.

The main geological feature of the Rum Jungle field is a compound dome, the cores of which are formed by the Rum Jungle and Waterhouse granite bodies. The doming is reflected through 8000 ft or more of sediments. Amongst these sediments is a formation about 6000 ft thick, consisting mainly of quartz siltstone and carbonaceous siltstone. Sulphide mineralisation occurs in carbonaceous portions of this formation.

The mineralisation is typically very fine grained, and probably of syngenetic origin. The intensity of mineralisation varies greatly from place to place. In some places it forms sulphide bodies of considerable length; in others, mineralisation consists only of very thin films of pyrite. The experience of a considerable number of surveys using electrical methods, and laboratory tests of samples, suggest that the unmineralised carbonaceous siltstone is not a very good electrical conductor, but that a small amount of pyrite mineralisation is sufficient to make the conductivity extremely high. Sulphide mineralisation is therefore readily detectable by electrical methods of survey, but it is impossible to form any estimate of the degree of mineralisation from the survey results.

The district is particularly well suited to obtaining information on the effect of ground water conditions. The depth to ground water-level in different areas ranges from 6 ft in swampy areas to 100 ft or more on higher ground. Also, the rainfall is relatively high (50 in. or more per annum) and falls usually in heavy storms mainly between November and May. During the wet season, therefore, it may be expected that water-level, in some areas at least, will be subject to considerable variations.

Results of particular surveys which appear to bear on this problem are discussed briefly below.

Surveys over the Waterhouse prospects

Surveys over several prospects in the Waterhouse area have been made by K.H. Tate. The results of two of these are of interest in the present connexion; they are the ones at Area 65, previously known as Waterhouse No. 1 prospect (Daly and Tate, 1958), and at Waterhouse No. 2 prospect (Daly and Tate, 1960).

The results of the surveys do not call for detailed discussion, as their bearing on the theory of self-potential effects is rather indirect. The geological settings of the prospects are very similar. Results obtained by electromagnetic surveys are also similar in that, at each prospect, there were intense anomalies due to narrow bodies of high conductivity. The results of self-potential surveys, however, are quite different. At Area 65, a strong self-potential anomaly was observed, coinciding in position with the electromagnetic anomaly. At Waterhouse No. 2 prospect, no self-potential anomaly was observed. The cause of the electromagnetic anomaly at Waterhouse No. 2 prospect has been tested by drilling; the anomaly is associated with a band of carbonaceous shale which contains very finely divided pyrite. It appears very likely that the similar anomaly at Area 65 is due to a similar cause although, as mentioned earlier, it cannot be assumed that the intensity of mineralisation in the two areas is similar.

The only obvious difference between the two prospects which could account for the difference in self-potential results is in the topography. Area 65 is on high ground and, by analogy with other parts of the district, it may be assumed confidently that water-level will be at least 70 ft below the surface. Waterhouse No. 2 prospect is on low-lying swampy ground, and water-level was encountered in exploratory costeans at 6 ft.

Until more accurate information on the cause of the anomalies at Area 65 is available, the evidence bearing on the self-potential anomalies is not conclusive. However, it is consistent with the general theory that a self-potential anomaly arises where a sulphide body has an oxidised portion above water-level, but that no anomaly is produced if the water-level is so high that the mineralised body is completely covered by the water.

Survey over Manton Dam No. 1 prospect

The Manton Dam area lies at the north-eastern corner of the Rum Jungle granite. The surveyed area lies within the catchment area surrounding Manton Dam, which is the water supply for the town of Darwin.

The survey was made at the request of the Northern Territory Administration, to determine whether there was any evidence of sufficient mineralisation to warrant making the reserved area available for mining operations. The rocks are carbonaceous shale similar to those in which mineralisation occurs south of the granite.

The results of the survey are described by Barlow (1956). Well-defined self-potential anomalies were observed. The results of the self-potential survey are shown as contours on Plate 2. One anomaly was tested by a diamond-drill hole, the position of which is shown on Plate 2. The results of the drilling are described by Dow (1955).

The evidence of the drill-hole is not conclusive with regard to the cause of the anomaly, owing to the very poor core recovery (about 10 per cent). However, a considerable amount of pyrite was observed in sludges and it appears reasonable to assume that the anomaly is due to a pyritic band of the carbonaceous shale. The drill-hole gave no reliable information on the mode of occurrence of the pyrite.

The effect of seasonal conditions in the area was studied by observations along Traverse 5800W at intervals ranging from one to two weeks during the 1957-58 wet season. The observations were made by B. Scriven and B.J. Bamber, and the results are shown on Plate 3. In general, measurements could be made without special preparation of the observation points, but on some occasions, when contacts were found to be poor, the observation points were watered about an hour before measurements were taken. Observations of rainfall were not made, but it may be assumed that many heavy storms occurred during the course of the measurements.

The main anomaly persisted during the whole series of tests, but with noticeable changes in maximum amplitude and distinct changes in the shape of the profiles, particularly on the northern side. In particular, there are changes in shape at 600N and 700N, which disappear and reappear at intervals over the series of tests.

However, the main theoretical problem with regard to this anomaly concerns the reason why it should occur at all. It seems that the ground-water regime in this area should have been changed radically by the building of the dam. The anomaly occurs on high ground. By analogy with other parts of the district it may be assumed that, prior to the building of the dam, a fairly static ground water-level would have existed, at a depth of about 100 ft. The anomaly area is only about 12 ft above the top of the dam wall and it appears that, under present conditions, water-level would be static at a depth not much greater than this. The conclusion that the ground is waterlogged at shallow depth is strongly supported by the extremely bad drilling conditions encountered in the drill-hole. The carbonaceous shales of the Rum Jungle area do not generally provide good drilling conditions, but core recoveries far better than those recorded in this hole are generally obtained without extreme precautions. The situation appears to be that a mineralised body, in which a regime of oxidation has been established with ground water-level static at about 100 ft, has had the static water-level suddenly raised by about 80 ft. On any simple theory, it would be expected that this would be sufficient to inhibit oxidation to a very large degree so that, as apparently occurs at Waterhouse No. 2 prospect, no self-potential anomaly would exist.

The Power Plant anomaly

The Power Plant anomaly was selected for study, as it was known from earlier measurements that it was strongly affected by seasonal influences. Measurements were made by B. Scriven, and geological and drilling information was supplied by courtesy of Territory Enterprise Pty Ltd. The following information is presented:

Plate 4 showing the location of traverses and geology

Plate 5 showing the geological section

Plate 6 showing S-P. profiles over main anomaly at 12/12/58

Plate 7 showing S-P. profiles along Traverses 6600W and 6700W at intervals during the 1958-59 wet season.

Plate 6 shows that the anomaly is of considerable magnitude, but is irregular in shape, and that it has a limited length. From the geological information on Plate 5, it appears that the anomaly does not occur over the mudstone sequence, which might be considered a favourable environment for mineralisation, but is confined to limestone, which is not known to be favourable in the Rum Jungle district. Two diamond-drill holes put down by Territory Enterprises Pty Ltd showed no evidence of mineralisation. The cause of the anomaly is therefore uncertain, except that it seems most unlikely that it has any connexion with sulphide or graphitic mineralisation. However, the anomaly is of a type which, in the absence of other knowledge, could be associated with a body that contains sulphide or graphitic mineralisation. The logs of the drill-holes, supplied by courtesy of Territory Enterprises Pty Ltd, are attached as an appendix to this Record, for the convenience of anyone desiring to construct a theory of the cause of the anomaly.

Plate 7 shows clearly the very strong correlation between the intensity of the anomaly and the rainfall. The anomaly gradually disappears at the beginning of the wet season, then gradually reappears as the season progresses. It is particularly striking that the anomaly on Traverse 6600W reappears with the same shape even in minor details, with gradually increasing strength, until it is completely damped out again after the very heavy rains at the beginning of April 1959.

On Traverse 6700W, however, the onset of the wet season causes a complete change in the character of the anomaly. The original character had not reappeared at the time measurements were suspended, but there is no reason to suppose that it would not have done so later.

This effect may merely reflect the fact that the anomaly is not due to a mineralised body. However, the conclusion is unavoidable that, in a particular case, climatic conditions may have a very large influence on the results of self-potential surveys.

3. SURVEYS IN THE MT LYELL DISTRICT

The Mt Lyell district is on the west coast of Tasmania and is one of the most important copper mining areas of Australia. Many geophysical surveys have been made in the district, and the results are of considerable interest with regard to the theory of the generation of self-potentials.

The geology of the area is described in numerous publications; a convenient summary is by Edwards (1943). For the purpose of the present Record, it is sufficient to notice that the mineralisation occurs in Dundas slate, usually fairly close to its contact with the West Coast conglomerate. The mineralisation occurs as impregnations over large areas of slate, and is generally pyritic, though several zones contain sufficient chalcopyrite to form important ore-bodies. The topography is rugged, the West Coast conglomerate in particular outcropping as high bare hills with very steep slopes. Rainfall is heavy (about 100 in. per annum) and well distributed.

The points of interest in the present connexion are exemplified in Plate 8, which shows a profile taken from a survey described by Rowston (1957). This profile shows three anomalies; a wide one extending from about 1200 to 2200, a narrower one extending from about 2600 to 2900, and a very large and sharp anomaly appearing from about 3300 onwards. The first two anomalies are associated with mineralised zones in the slate. The third one occurs on the conglomerate, and there is no reason to expect that it has any connexion with mineralisation.

The main points of interest are the following:

(a) on the usual theory, it is somewhat surprising that the first two anomalies are present. As mentioned by Edwards, it is a feature of the Mt Lyell district that oxidation is practically non-existant. The workings are dry to considerable depths, so that the conditions usually associated with the generation of self-potential anomalies are absent.

(b) the third anomaly is a good example of the type of anomaly which has apparently no connexion with mineralisation. It was not explored completely, as it was obvious that it had no economic interest sufficient to warrant undertaking the difficult and dangerous operation of extending the survey up the precipitous slope of the conglomerate. Several examples of similar anomalies are recordedin the literature. It is reasonable to assume that they are related in some way to the topography, but no convincing mechanism has yet been suggested.

4. CONCLUSIONS

The only general conclusion which can be drawn from the examples presented is that no simple theory is likely to succeed in predicting the presence or absence of self-potential anomalies, even under well known geological conditions. Regardless of whatever detailed criticism could be made of the mechanism suggested by Sato and Mooney, the basic fact remains that self-potential anomalies do not behave as they would be expected to. The general theory of the production of self-potential anomalies by a body containing sulphide or graphitic mineralisation, lying partly above and partly below ground water-level, has been consistent with experience in a great many cases reported in the literature.

Some of the examples given support this theory strongly. In one case, it is quite a reasonable supposition that an anomaly would be observed except for the fact that ground water-level is almost at the surface; in another, the presence or absence of the anomaly is critically dependent on the position of water-level. On the other hand, a sudden recent rise in water-level has apparently had little effect on some well marked anomalies, and in yet another case, anomalies are present, although there is no oxidation, and water-level in the ordinary sense does not exist.

5. REFERENCES

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APPENDIX

POWER PLANT ANOMALY, RUM JUNGLE, N.T.

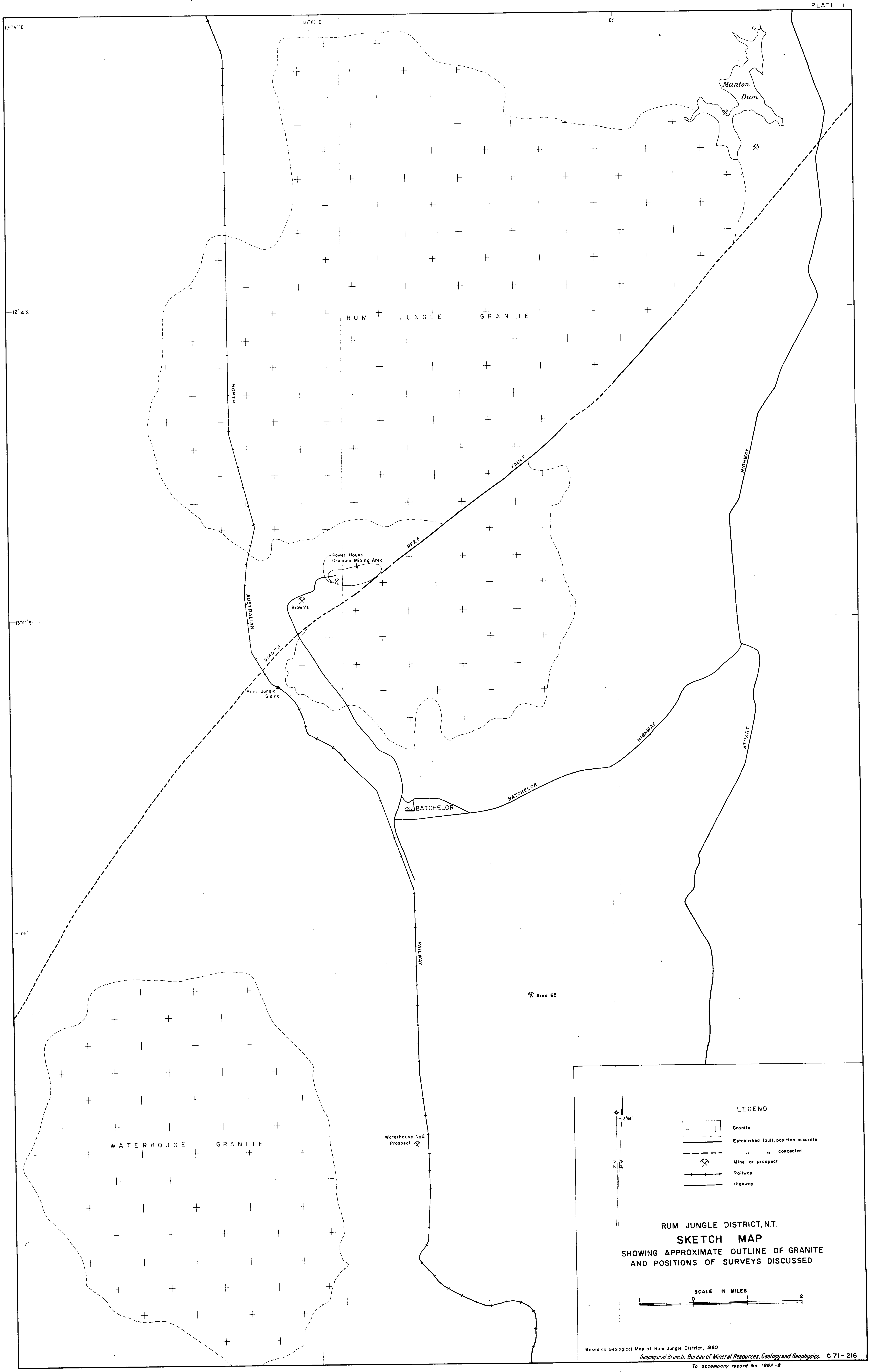
Logs of diamond-drill-holes supplied by Territory Enterprises Pty Ltd

DDH 342

0-19	Non core
40	Weathered red, brown, green mudstone
74	Red mudstone
76	Limestone
84	Brown clay
102	Limestone
	No sulphides seen

DDH 344A

0-50	Non core
71	Interbedded mudstone and quartzite breccia
186	Quartzite breccia
192.5	Mudstone
210	Crystalline dolomite in haematite sandy matrix
307	Quartzite breccia with minor quartzite and mudstone
326	Dolomite and mudstone
386	Limestone with interbedded mudstone (50% of each)
	No sulphides



To accompany record No. 1962-8

PLATE 2
MANTON DAM
MANTON DAM
DDH Bearing 100° Depression 70° Length 500 feet
A
B
C
D
E
F
GEOPHYSICAL SURVEY OF MANTON DAM CATCHMENT AREA, N.T.
SELF-POTENTIAL CONTOURS
Scale in feet
200 0 200 400 600 800 1000 1200
Contour interval 20 millivolts
Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.
G 185-5-1
To accompany record No. 1962-8

PLATE 3

MANTON DAM AREA, N.T.

NOV. 1957 TO MAY. 1958

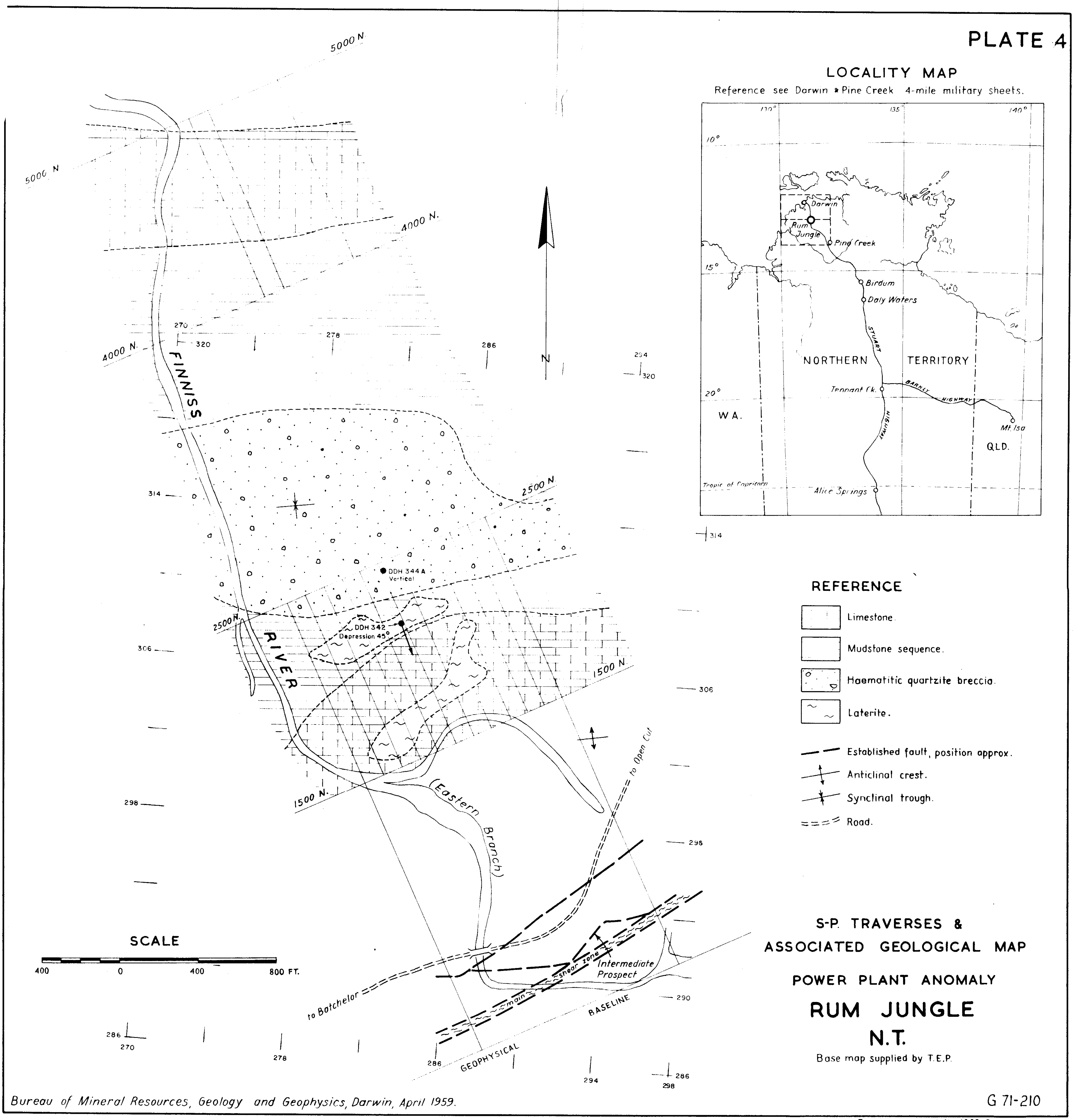
SELF-POTENTIAL RESULTS

TRAVERSE 5600 W

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

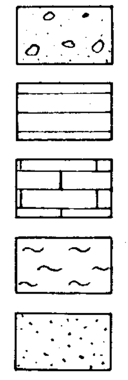
TO ACCOMPANY RECORD No. 1962-8

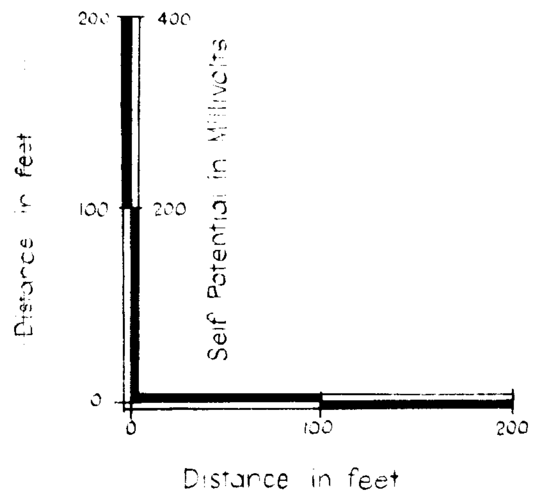
G 185-8



To accompany record No. 1962-8

REFERENCE





GENERALISED GEOLOGICAL CROSS-SECTIONS

AND CORRESPONDING S-P. PROFILES

ALONG TRAVERSE 6600 W.

POWER PLANT ANOMALY
RUM JUNGLE, N.T.

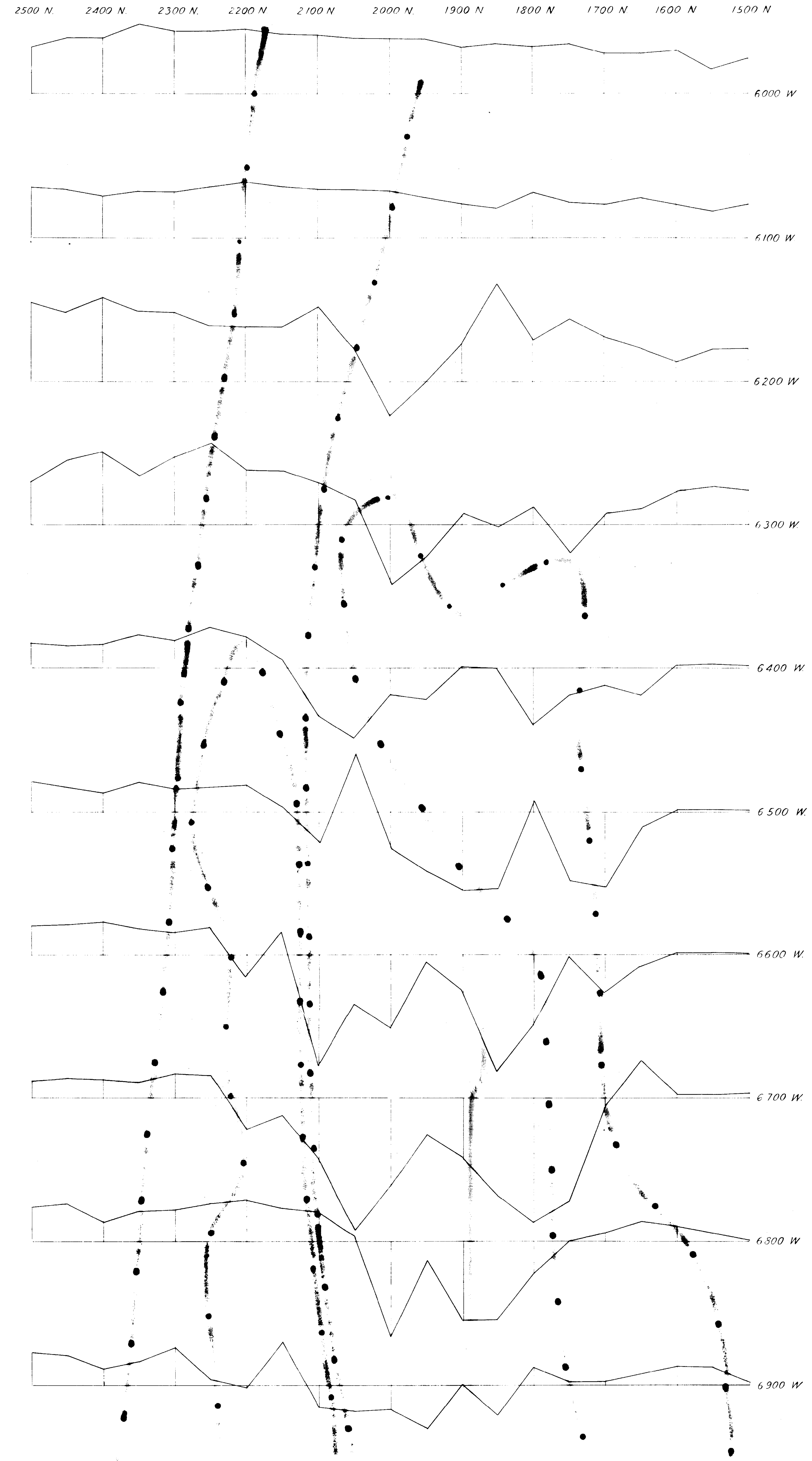
THE GEOLOGICAL CROSS-SECTION HAS BEEN INTERPOLATED FROM THE SECTION ALONG TRAVERSE 7800 W. SUPPLIED BY T.E.P. GEOLOGICAL SECTION.

Bureau of Mineral Resources, Geology and Geophysics, Darwin, April 1959.

G.71-214

TO ACCOMPANY RECORD No. 1962-8

PLATE 6



S-P. PROFILES
AT 12-12-58

POWER PLANT ANOMALY
RUM JUNGLE, N.T.

SCALES

horizontal 100 0 100 200 feet

vertical 200 0 200 400 millivolts

Bureau of Mineral Resources, Geology and Geophysics, Darwin, April 1959

G. 71-211

To accompany record No 1962-8

PLATE 7

RUM JUNGLE N.T.

POWER PLANT ANOMALY

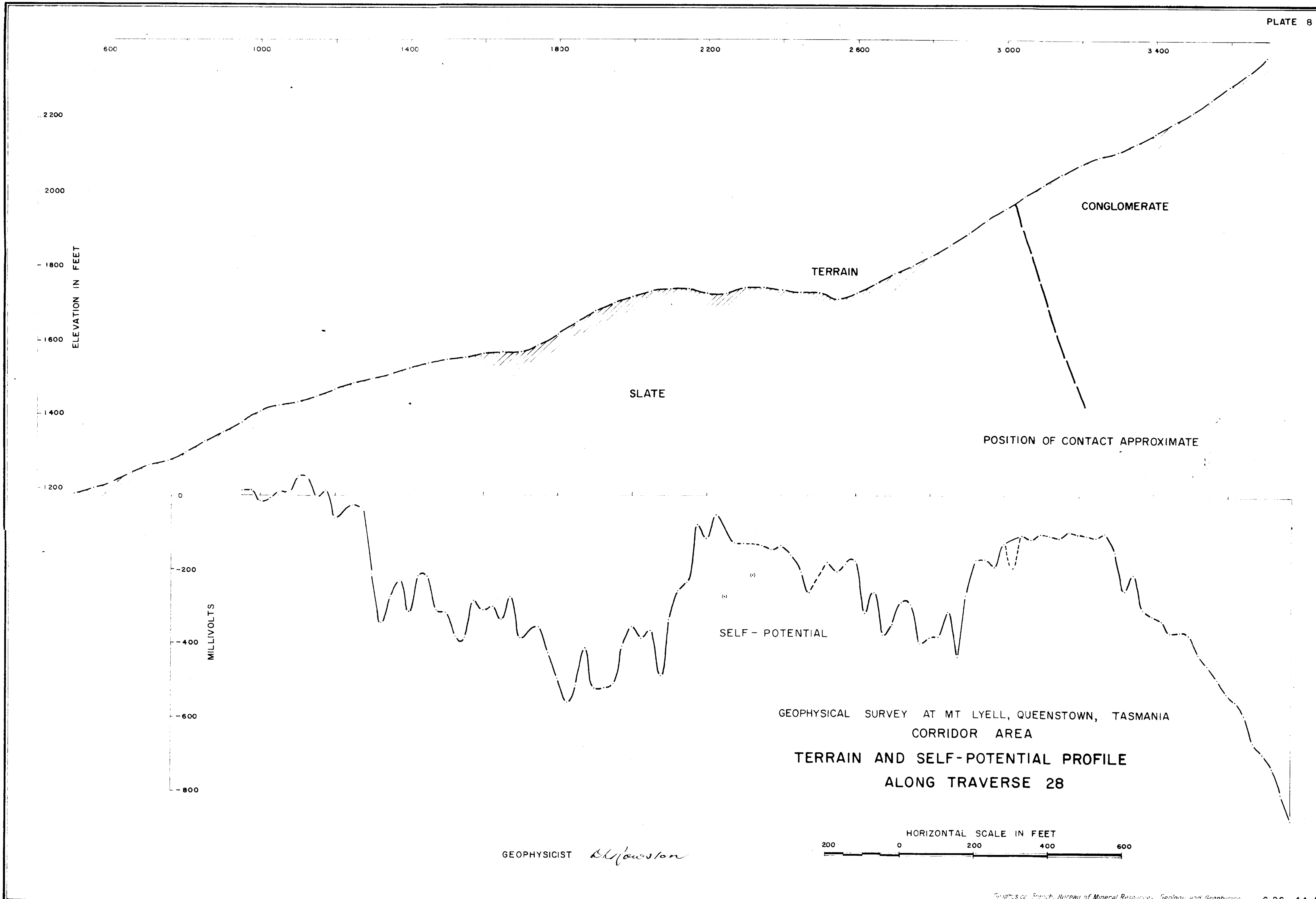
SELF-POTENTIAL PROFILES SHOWING EFFECT OF WET SEASON CONDITIONS

RAINFALL SHOWN AS AVERAGE POINTS PER DAY SINCE DATE OF PREVIOUS MEASUREMENT

Bureau of Mineral Resources, Geology and Geophysics, Darwin, April 1959.

G.71-215

To accompany record No. 1962-8



To accompany record No. 1962-8