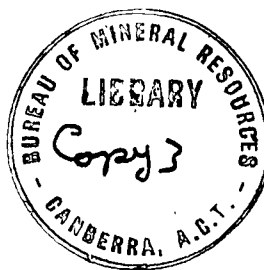(a) MINING ENGINEER

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DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORDS 1951 No. 56

GEOPHYSICAL SURVEY OF THE RUM JUNGLE

URANIUM FIELD, N.T. 1950

by

M.G. Allen

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FOREWORD

In 1949 the first discovery of uranium minerals was made in the Rum Jungle area. As copper and silver lead had been worked to a small extent many years earlier, it was decided that the exploration programme carried out by the Bureau in the area should include geophysical surveys by electrical methods, to test for the possible presence of sulphide deposits. This report deals with the first test survey, which was performed during October and November 1950. Largely due to the successful results of this survey, similar surveys on a much larger scale have since been made.

A report on the survey was prepared by the party leader, M.G. Allen, but, although the results of the survey have been used in later work, the report has not been issued. When the report was written, the only geological information available was that derived from preliminary surface mapping by geologists of the Bureau. Since that time, the area has been extensively investigated by mining and drilling, and the geology is much better known. However, as this survey was the pioneer geophysical work in a district which has proved particularly well suited to the use of geophysical methods, and as it has been frequently referred to in later geophysical reports, it is considered desirable that the results of the survey be placed on record.

March, 1960.

ILLUSTRATIONS

ABSTRACT

A geophysical survey was made in the Rum Jungle district in
October and November, 1950, using self-potential and potential-ratio methods.
This investigation formed part of a larger programme of geological and geo-
physical exploration for uranium minerals.

Self-potential surveys were made over three areas, namely:

(i)   Brown's Copper Mine Area;

(ii)   Intermediate Area;

(iii)   White's Area,

and a potential-ratio survey was made over only the first of these. Two out-
standing self-potential anomalies were revealed at Brown's Copper Mine area and
an analysis of the results suggests that each anomaly may be due to two
sulphide bodies. Four diamond drill holes are recommended to test this
conclusion.

An S.P. anomaly in the Intermediate area is possibly caused
by sulphides or graphitic schist but no recommendation is made for drilling
at this stage. The S.P. anomalies recorded at White's Area do not appear
to coincide with known sulphideors deposits. The results of further drilling
and exploration in that area are awaited.

The potential-ratio survey at Brown's Copper Mine Area does
not give confirmation of the sulphide bodies indicated by the self-potential
survey, but the results are of assistance in determining geological boundaries.

1. INTRODUCTION

The geophysical work described in this report was carried out in October and November 1950, and formed part of a larger programme of geological and geophysical exploration for uranium minerals in the Rum Jungle district.

The Rum Jungle siding is $56\frac{1}{2}$ miles south of Darwin and 5 miles north of Batchelor siding on the Darwin-Birdum railway line. The region surveyed, comprising Brown's Copper Mine Area, White's Area, and Intermediate Area, lies approximately 2 miles north-east of the Rum Jungle siding. The tracks to these areas are shown in the locality plan (Plate 1.).

A bush track leads from the Rum Jungle siding for a distance of 3 miles south-east to the intersection of the railway line with the Batchelor road and provides the best access to the areas by road. Approximately 8 miles from the railway line, the Batchelor road joins the Stuart Highway at a point $54\frac{1}{2}$ miles south of Darwin.

The earliest record of copper ore in the Rum Jungle district appears in a report by the Surveyor-General, G.W. Goyder (1869). Later, Parkes (1892) reported a small silver-copper show $1\frac{1}{2}$ miles south-east of the Rum Jungle siding and Brown (1895) mentioned an abandoned copper-lead show at Rum Jungle. Brown (1906) described Clarke's Mine, $2\frac{1}{2}$ miles north of Rum Jungle. By 1906, 40 tons of ore assaying about 11 per cent copper had been extracted from this mine. The Rum Jungle Copper Mines described by Jensen (1915) probably include Clarke's Mine. The area in which these workings occur has been called Brown's Copper Mine Area in this report.

In 1949 the discovery of uranium minerals in an area now known as White's area was confirmed by geological and radiometric examinations by officers of the Bureau of Mineral Resources (Townley, 1950; Ward, 1950). The Bureau has since begun an extensive investigation of the Rum Jungle district consisting of detailed and regional geological and radiometric surveys, with diamond drilling, costeaning, and shaft-sinking in the more promising areas.

2. GEOLOGY AND NATURE OF THE PROBLEM

Rum Jungle mining field is an area of mature topography with low rounded hills drained by an eastern branch of the Finniss River, which in the dry season forms a series of long waterholes winding through the area.

Granite crops out over much of the area. The sedimentary rocks are chiefly quartzites, crystalline limestones, slates, and schists of the Brocks Creek Group of lower Proterozoic age (Noakes, 1947). A ferruginous laterite of Tertiary age forms a residual capping over many of the rocks in the area.

From the regional mapping it has been inferred that several major faults striking approximately north-west cross the area.

In White's Area and Brown's Copper Mine Area the uranium minerals are associated with sulphides, and at the time this survey began the geologists considered that a method of outlining the extent of these sulphide deposits would assist in assessing the possibilities of the areas. Hence the purpose of the geophysical surveys was principally to investigate the known sulphide deposits, and to locate any concealed sulphide bodies that may be in the area. Information on the presence of sulphide bodies should form a useful supplement to the results of the radiometric surveys, which are restricted to the detection of radioactivity

originating from minerals within a few inches of the surface. However, more recent geological field work has shown that the uranium minerals do not necessarily occur with sulphides, and that their occurrence together at Brown's Copper Mine Area and White's Area may be fortuitous.

3. GEOPHYSICAL METHODS USED

Two electrical methods of prospecting for sulphides were employed on the field. The self-potential method was used on White's Area, the Intermediate Area, and Brown's Copper Mine Area, and a potential-ratio survey was made over Brown's Copper Mine area.

(A) Self-Potential Method.

A sulphide ore-body with its upper end in a state of active oxidation will give rise to a difference of potential between the sulphides in acid solution in the zone of oxidation and the sulphides in comparatively alkaline solution well below the water table. An electric current will therefore flow from one end of the sulphide body to the other, and the return current flowing through the surrounding rocks produces a negative potential centre above the upper end of the ore-body. This negative centre is observed by potential measurements made between points on the surface of the ground.

Similar electro-chemical processes can be expected where there are beds of oxidising graphitic schists. The graphitic schists should form a reasonably good conductor between the acid solutions of the oxidising zone and the comparatively alkaline solutions at depth. Thus electric currents will flow in the graphitic schist and surrounding rocks, and a potential anomaly can be expected over the upper end of the body of graphitic schist. Field experience has shown that oxidising graphitic schists normally produce negative potential anomalies.

Graphitic schists and carbonaceous rocks crop out on White's Area, Intermediate Area, and Brown's Copper Mine Area. Their presence adds a considerable complication to the problem of interpreting self-potential and other electrical prospecting methods (Edge and Laby, 1931; Dessau, 1950; Heiland, 1946; Kelly, 1945).

The equipment and technique used in self-potential surveys are described in the Appendix to this report.

(B) Potential-Ratio Method.

The potential-ratio method provides an electrical means of locating good conducting bodies or good insulating bodies within a medium of intermediate conductivity.

In this method alternating current of 500 c.p.s. is passed into the ground through two power electrodes, one of which, the near electrode, is 200 feet from the beginning of a traverse line. The other is so far away (generally over 3,000 feet) as to be virtually at infinity. With this arrangements the near electrode may be considered as an "isolated" power electrode and the electric field over the area being surveyed can be considered as entirely due to the near electrode. For example, in Brown's Copper Mine Area (Plate 2), traverses 17E, 19E and 21E were surveyed with the near power electrode at 15E/8N.

To measure the surface potentials, contact is made with the ground with steel probe electrodes, which are equally spaced along the traverses being surveyed and are connected to a high impedance ratiometer. The ratiometer readings give the ratio of, and the phase difference between, the potentials across successive intervals along the traverses. In this survey, electrode separations of 25 feet or 50 feet were used, and the readings were taken at every 25 feet or 50 feet.

The results are presented as :-

(i) Potential-ratio profiles, in which the potential ratio for each position of the three electrodes is plotted at the centre electrode position.

(ii) Phase-angle profiles, in which the phase difference measured for each position of the three electrodes is plotted at the centre electrode position.

The presence of a narrow conducting body or a narrow insulating body in an otherwise homogeneous medium, is indicated by a definite type of anomaly in both the potential-ratio and phase-angle profiles. The contact between two formations of different conductivity is indicated by a different type of anomaly in the potential-ratio and phase-angle curves (Heiland, 1946, p.750).

The method is sensitive to horizontal conductivity variations and considerable anomalies are produced by small changes in the composition and structure of the surface layers. This is a disadvantage that can largely be overcome by using the "return survey" technique. The line being surveyed is traversed in the reverse direction with the near power electrode in a corresponding position at the opposite end of the traverse. The mean of the original profile and the profile resulting from the return survey, should show only the effects due to deeper bodies.

4. AREAS SURVEYED

(A) Brown's Copper Mine Area.

The position of Brown's Copper Mine Area is shown in the locality plan (Plate 1). Plate 2 is a general plan of the area and shows the geology, the positions of two boreholes Nos.1 and 2 described by Jensen (1915) and the geophysical grid.

A geophysical grid measuring 2,100 feet x 400 feet, with the base line bearing 247° (magnetic), had been set out earlier in the year by the party carrying out radiometric surveys. This grid was extended 400 feet north and 400 feet south and taken 1,000 feet farther west to make a grid 3,100 feet x 1,200 feet which was used in the self-potential and potential-ratio surveys. The traverses surveyed were 200 feet apart, except traverses 12E to 17E which were 100 feet apart, and covered the area outlined by the contours of high surface radioactivity.

A shaft 35 feet deep, at 14.8E/1.2S on the geophysical grid, is situated in the area of highest radioactivity. A large heap of mullock near the geophysical baseline at 9E came from a shaft shown as 60 feet deep in Jensen's sketch plan, (1915), but the shaft has now completely fallen in. Both these shafts and the many costeans were probably made before 1905 and, apart from the diamond drill holes put down by Jensen in 1913 or 1914, no work was done in the area since that time until the discovery of uranium minerals.

Coarsely crystalline. limestone and silicified limestone form scattered outcrops through the brown soil which covers much of the northern,portion of the area.   Metamorphosed slates and schists, some of which are graphitic, occur over the southern portion, and, in general, these beds dip at 55° to 75° to the south and east.   Small residual deposits of Tertiary laterite cover some of the rocks,and a relatively large area in the south-west is capped by ferruginous laterite.

The ore occurs in slates and schists and in many places these rocks are copper-stained on the surface.

(B) Intermediate Area.

The Intermediate Area, which lies approximately 1,000 feet east of Brown's Copper Mine Area is shown in the locality plan, Plate 1. The principal rocks, which are crystalline limestones and graphitic slates and schists, belong to the same formations and have the same general easterly trend as those which crop out on Brown's Copper Mine Area.   Most of the Intermediate Area is covered by alluvium from the Finniss River or by brown soil.   There is some evidence of copper mineralization and several prospecting costeans were made many years ago. A small portion of the area is radioactive.   Geological mapping suggests that a fault striking north-north-west crosses the area in the position shown in Plate 6.

(C) White's Area.

White's Area is shown in the locality plan, Plate 1.   The uranium-bearing minerals at Rum Jungle were first discovered in White's Area and three prospecting shafts were sunk and a number of costeans made by the end of 1950, The positions of the shafts and costeans and the geology are shown in the plan of the area, Plate 8.   Graphitic schists, carbonaceous slates and a quartzite breccia form the principal outcrops; the uranium mineralisation is confined to the graphitic schists and carbonaceous|slates.   The beds have a general easterly trend and are nearly vertical or dip steeply to the south.   There is evidence of some faulting and folding.

5. RESULTS AND THEIR INTERPRETATION

(A) Brown's Copper Mine Area.

(i) Self-potential survey.

Potential readings were taken at 25-feét intervals along north-south traverses and the results are shown as profiles on Plate 3 and as equipotential contours, at 20-millivolt intervals, on Plate 2.   Two outstanding negative anomalies with minima of about -250 millivolts were recorded with centres at about 14E and 0, and in the following discussion these are referred to as the eastern anomaly and the western anomaly respectively.

Eastern Anomaly. The eastern anomaly lies between traverses 6E and 19E. A pronounced feature of the anomaly is the presence of two well-defined troughs about 130 to 140 feet apart. The northern trough is the more intense and extends from traverse 7E to 19E and the southern trough extends from traverse 9E to 17E.

The analysis of the eastern anomaly has been confined to the more intense part of the anomaly between traverses 10E and 17E.   The anomaly can be explained by assuming that there are two

steeply-dipping sheet-like bodies striking approximately west.
The positions of the bodies have been found by comparing calculated
profiles for the combined effect of two such bodies, with observed
profiles along the sections AA', BB', CC' (Plate 4). The closest
approach to the observed profiles is obtained by assuming :-

(i)   A depth of 25 feet to the upper edge of the bodies.
        This is approximately the depth to the water table.

(ii)   That the dimensions of each body are - length 400
        feet, slope depth 100 feet.

(iii)   That the bodies dip to the south at about 60°.

(iv)   That the bodies are approximately 150 feet apart.

(v)   That the northern body produces an effect about
        twice as great as the southern body.

The form of the profiles does not greatly depend
on the dimensions of the bodies. Assumption (v) is necessary to
match the observed and calculated profiles and is not unreasonable,
because differences in the composition of the two bodies, partic-
ularly the percentage of sulphides, could easily account for the
different intensities of the self-potential effects produced at the
surface by the two bodies.

Calculated and observed profiles are compared in
Fig.1, 2, and 3 of Plate 4. An appreciable divergence between the
observed and calculated curves occurs over the limestone, beginning
near the limestone/slate contact. Crystalline limestone has a
resistivity of 10^4 to 10^7 ohm-cms, compared with 10^3 to 10^5 ohm-cms.
for graphitic schists and slates. The potential-ratio survey, the
results of which are discussed below, shows a boundary, between a
poor and a good conducting medium, corresponding in position to
the limestone/slate contact. Hence an appreciable divergence from
the calculated curve, which assumes homogeneity of the surrounding
rocks, is to be expected, and the divergence immediately north of
the contact is consistent with this explanation.

The axes of the bodies shown on the plan are the
projections on to the surface, of a line through each body parallel
to, and 70 feet below, the surface.

Western Anomaly. The western anomaly extends in a south-
westerly direction from traverse 6E to 5W. Although this anomaly
does not show two distinct negative troughs its form is well-defined,
and it is necessary to assume that the anomaly is caused by two
sheet-like bodies, in order to match calculated profiles with the
observed profiles. The closest approach to the observed profiles
is obtained by assuming :-

(i)   A depth of 50 feet to the upper edge of the bodies.
        This is the approximate depth to the water table.

(ii)   That the dimensions of the bodies are - length 400
        feet, slope depth 100 feet.

(iii)   That the bodies are 120-140 feet apart.

(iv)   That the bodies are nearly vertical or dip steeply
        to the south.

(v)   That the northern body produces an effect about half
        as great as the southern body.

The dimensions of the bodies are not critical in
determining the form of the calculated profiles. The above inter-
pretation has been based on a comparison of observed and theoretical
profiles.

In Figs.4A, 5A, and 6A (Plate 4) a calculated profile is compared with observed profiles along sections DD', EE' and FF' respectively. The calculated profile is for two sheets 140 feet apart, dipping at 60° to the south, and it has been assumed that the effect of the northern body is half that of the southern body. The observed profiles along DD', EE' and FF' have also been compared in Figs.4B, 5B and 6B (Plate 4) with the calculated profile due to two vertical sheets 400 feet by 100 feet and 120 feet apart. The northern body has been assumed to produce an anomaly of half to three-quarters the intensity of the southern body.

Both theoretical profiles show a general agreement in form with the observed profiles although there are obvious departures in detail. A precise interpretation in terms of two simple bodies is not possible but there is justification for assuming that the anomaly is due essentially to two bodies, and a useful estimate of their positions can be made from a comparison of the observed and the theoretical profiles.

Nature of the bodies causing the self-potential anomalies

The axes of the anomalies are roughly parallel to the limestone/schist boundary. The anomalies follow the trend of the slates and schists and could be caused by the more highly graphitic beds or by sulphide bodies or by both. In the following paragraphs evidence is given to show that the anomalies are probably caused by sulphides.

Sulphides have been found in the 35 feet shaft at 14.8E/1.2S, and this shaft is about 30 feet north of the axis of the assumed northern body of the eastern anomaly. The collar of No.1 Borehole (Jensen, 1915) is located directly above the westerly extension of the same body and the drill should have passed through the upper part of this body about 50 feet along the drill hole. The drill log records from 1 per cent to 4.8 per cent copper as copper carbonate between 35 and 67 feet. This is good evidence for believing that the anomaly is caused by sulphides but the low percentage of copper in this zone does not offer much hope for a payable copper lode in the sulphide zone. Jensen's No.1 Borehole continues to an inclined depth of 320 feet but there is no other significant mineralisation. The drill log records mica schists, graphitic schists and limestones, with occasional pyrite veins and a minor occurrence of copper carbonate between 114 feet 10 inches and 120 feet 6 inches. No.1 Borehole does not adequately test the eastern anomaly, the form of which indicates the presence of two isolated bodies, and drilling should be carried out to test for both bodies.

No.2 Borehole is depressed at an angle approximately the same as the dip of the body assumed to cause the self-potential anomaly and is located about 200 feet north of the centre of the anomaly. The drill would therefore have passed well under the assumed body. Between 70 feet and 129 feet the drill log records "heavily mineralised graphitic schist" carrying an average of 0.1 per cent copper, the percentage decreasing with depth. From 160 feet to 168 feet the schist is "heavily mineralized" but little mineral is recorded for the rest of the bore. This drill hole provides evidence for the presence of sulphides, but its position is such that it probably would not intersect the body considered to be responsible for the self-potential anomaly.

Most of the area over which the western anomaly occurs is covered by a few feet of ferruginous laterite, and apart from some copper stains on the surface there is no direct evidence of the nature of the bodies causing the anomaly. The western anomaly is similar to the eastern anomaly in that the anomaly axes are roughly parallel to the limestone/schist boundary and 100 feet to 300 feet south of it.

The assumed bodies in both anomalies follow the trend of the schists and could be caused by mineralisation of the same two beds. The break between the eastern and western anomalies could be caused by a fault which may correspond to one of the faults inferred from the regional geological mapping.

Positive anomaly. A positive anomaly of 60 millivolts extends across the north-eastern part of the area. The anomaly is confined to an area in which limestones and silicified limestones crop out, but there is no obvious explanation of the anomaly. The anomaly is elongated and may give some indication of the strike of the rocks over which it occurs.

(ii) Potential-ratio survey

The potential-ratio method has been discussed earlier, and in the Appendix to this report the equipment and technique used are described.

The potential-ratio survey was carried out with the following aims :-

(i) To obtain additional information on the sulphide bodies indicated by the self-potential anomalies.

(ii) To obtain information which should help to determine the positions of faults inferred from the regional geological mapping.

The method gives sharp indications over vertical formation boundaries. It should therefore be applicable on Brown's Copper Mine Area where the beds are steeply dipping and the bodies responsible for the self-potential anomalies are probably nearly vertical or dip steeply to the south.

The geophysical grid set out for the self-potential survey was used in the potential-ratio survey, and the readings were taken along the N-S traverse lines. In the first part of the survey the electrodes were placed 25 feet apart, and stations were read every 25 feet; traverses 4E, 8E, 10E to 17E inclusive, 19E and 21E were completed in this way. The intervals were increased to 50 feet for the last 6 traverses completed (6E, 2E, 0, 2W, 4W and 6W), so that the area could be covered more quickly and because of difficulties mentioned in the Appendix.

The Rum Jungle camp closed at the beginning of the wet season, in November 1950, and there was not sufficient time to make the potential-ratio surveys as complete as could be desired.

The results of the survey are shown as potential-ratio profiles and phase angle profiles in Plate 5. The results are very irregular and effects due to surface formations cannot be distinguished from effects which may be due to deeper bodies.

Limestone/slate contact. The only prominent feature which is repeated on most traverse lines is a maximum on the phase-angle profiles and a corresponding minimum on the potential-ratio profiles. These maxima and minima indicate a boundary between a poorly conducting formation in the northern part of the area and a comparatively highly conducting formation in the southern part of the area. The line joining these points on each traverse has been plotted on the plan of Brown's Copper Mine Area, Plate 2. The line is roughly parallel to the limestone-slate contact, but is 100 to 300 feet south of it. This electrical boundary is due to the difference in the resistivities of the limestones and slates, and its southern displacement from the mapped limestone/slate contact is probably due to a southerly dip of the contact.

The distance between the mapped geological boundary and the observed electrical boundary depends on the depth to which the boundary extends and the angle of dip. In general the greater this distance the shallower is the angle of dip.

No.1 Borehole (Jensen, 1915) intersects the lime-stone at approximately 60 feet, indicating a southerly dip of approximately 50°, which is consistent with observed displacement.

Conducting zones. The form of the potential-ratio anomaly discussed above is such that the anomaly can only be interpreted as a boundary between a poor conductor and a good conductor and could not represent a narrow conducting body. The results give no indication of well-defined zones of high conductivity which could correspond to the assumed sulphide bodies producing the self-potential anomalies. This is probably not surprising as the anomaly caused by the limestone/slate contact could easily obscure the relatively small anomalies which would be expected from these bodies. However, there are features on the profiles which may be interpreted as being due to narrow conducting zones, and these are shown on Plate 2. One zone closely follows the southern negative axis of the eastern self-potential anomaly and another weaker zone lies about 100 feet further south. These zones of good conductivity may correspond to the presumed sulphide bodies. The same may be said about the weakly conducting zone between 2S and 4S on traverses 0 to 6E, though this zone appears to be dis-placed too far to the south to be associated with the bodies responsible for the self-potential anomaly.

Faults. The potential-ratio survey does not provide con-clusive evidence of the presence of faults crossing the area as inferred from the regional geological mapping. However, there is a marked change in the direction of the electrical boundary at 6E corresponding to a general change in the strike of the rocks, and this may be caused by a fault. The self-potential results also suggest a discontinuity in this vicinity. Small displace-ments of the electrical boundary which may correspond to minor faults occur between 0 and 2W, between 10E and 12E, and between 17E and 19E.

(B) Intermediate Area.

(i) Self-potential survey.

The survey was undertaken for two reasons :-

(a) To find out whether the self-potential survey would give some idea of the horizontal displacement of the fault by a shift of the negative potential centre expected over the graphitic schists. The displace-ment was thought to be several hundred feet.

(b) To detect any anomaly which may be due to sulphides.

Self-potential measurements were made along two traverses on the western side of the fault and two traverses on the eastern side.

(ii) Results.

The results are shown as profiles on Plate 7 and as contours on Plate 6 on which the geology is also shown.

The axis of a 100-millivolt anomaly lies about 100 to 200 feet south of the limestone/schist contact.

Thus the relationship between the self-potential results and the geology is similar to that observed on Brown's Copper Mine Area. The anomaly is probably associated with a bed of graphitic schist or a bed which has been partially replaced by sulphides.   In either case the self-potential results should reveal any large displacement along this fault.   However, the axis of the anomaly is very nearly a straight line and gives no evidence of any displacement.

(C) White's Area.

    (i) Self-potential survey.

        A small percentage of sulphide is associated with the uranium ore in No.2 shaft, and a self-potential survey was undertaken to help determine the extent of the sulphide deposit.

        The geophysical grid used for the radiometric survey of the area was extended 300 feet north and 300 feet south and the self-potential survey was made over an area 1,000 feet x 900 feet, surrounding the deposit.

    (ii) Results.

        The results are shown as profiles in Plate 9 and as contours in Plate 8. Contrary to expectations no significant negative anomaly occurs over the known deposit and the mineralised area, in which graphitic schists also crop out, is at a small positive potential. The absence of a negative anomaly could be explained by assuming that very little sulphide is present, or that the sulphide is below the zone of oxidation, or that the sulphide does not occur as a continuous body. Originally, the first explanation seemed most likely, but is no longer tenable as later mining operations have shown that sulphide is present in considerable quantities.

        The negative trough between 3N and 4N extends from traverse 0 to traverse 6E, and coincides approximately with outcrops of carbonaceous slate and white spotted slate. This anomaly could be caused by the carbonaceous slates, but the question arises as to why an anomaly should be caused by the carbonaceous slates and not the graphitic schists.   Factors determining the magnitude of a self-potential anomaly are :-

    (a) The conductivity of the body.

    (b) The degree of active oxidation.

    (c) To a limited extent the depth of the body; the body
         must extend well below the zone of oxidation to
         produce a large anomaly.

    (d) The depth of the soil cover. (Dessau, 1950, pp.711-
         712).

        The explanation in this case may be a higher percentage of carbon in the slates, which would influence factors (a) and (b).

        The -100-millivolt anomaly centred at 3.9N may be caused by a concentration of carbon in the slates in this region or it may be due to a small percentage of sulphide in the slates. The effect is shallow-seated and the depth to the centre of the body is probably no more than 30 feet and could be much less.

        The elongated -80-millivolt anomaly extending eastwards from 3E/1N, has the same easterly trend as the outcrops and is probably caused by beds of carbonaceous rocks. A similar anomaly in the south-west of the surveyed area may also be due to carbonaceous rocks and indicates a general south westerly trend of the under-lying rocks there.

6. CONCLUSIONS AND RECOMMENDATIONS

(A) Brown's Copper Mine Area.

(i) Summary of geophysical results

The self-potential survey of Brown's Copper Mine Area revealed two outstanding anomalies, and analysis of the results shows that each of the anomalies could be due to two sulphide bodies. At least four diamond drill holes are necessary to test these conclusions and the sites of four recommended diamond drill holes are given.

The potential-ratio survey did not provide confirmation of the presence of conducting bodies in the positions indicated by the self-potential survey, but on the other hand the survey results give no reason for doubting the interpretation of the self-potential survey.

A contact anomaly, corresponding to the limestone/slate contact, occurs several hundred feet south of the contact as mapped on the surface, and indicates that the contact dips to the south. This is consistent with the surface geological observations and the results of earlier drilling (Jensen, 1915).

The interpretation of several minor conducting zones is uncertain, but they probably correspond to the more highly conducting beds of graphitic schist or carbonaceous slate.

The positions of faults thought to cross the area cannot be reliably determined from the results of the survey.

(ii) Drilling recommendations

At least four drill holes are necessary to test the eastern and western anomalies.

Eastern Anomaly. The axes of the assumed eastern bodies shown in Plate 2 represent the drilling targets at a depth of 70 feet. Each recommended drill hole is expected to intersect the sulphide body between about 60 feet and 100 feet along the drill hole.

The recommended drill holes are :-

Position	Bearing	Depression
D.D.H.1. 1405'E/189'S	347° Magnetic	60°
D.D.H.2. 1380'E/335'S	347° Magnetic	60°

Western Anomaly. The axes of the assumed western bodies shown in Plate 2 represent the drilling targets at a depth of 100 feet. The estimated positions of the bodies are subject to considerable uncertainties and it is expected that each drill hole will intersect the sulphide body between about 60 feet and 160 feet along the drill hole. The recommended drill holes are :-

Position	Bearing	Depression
D.D.H.3. 130'E/188'S	313° Magnetic	60°
D.D.H.4. 80'E/80'S	313° Magnetic	60°

(B) Intermediate Area.

The self-potential survey over the Intermediate Area revealed a self-potential anomaly of approximately -100 millivolts

about 100 to 200 feet south of the limestone/schist contact. The
anomaly may be due to sulphides or graphitic schists but no drill-
ing recommendations have been given because none would be warranted
unless the results of drilling on Brown's Copper Mine are favourable.

The results do not confirm the displacement along a
north-south fault suggested by the geological mapping.

(C) White's Area.

Self-potential anomalies were observed on White's
Area but they do not correspond to the known occurrence of sulphide
ore. The anomalies are probably caused by carbonaceous slates,
and where the area is soil-covered the anomaly axes may indicate
the general trend of the carbonaceous rocks beneath.

(D) Future Surveys.

The value of the self-potential surveys in the Rum
Jungle district will be largely assessed on the results of the
drilling in Brown's Copper Mine Area. If the drilling proves the
sulphide ore bodies and radioactive minerals to be associated, then
further and more extensive surveys will be justified. Where the
anomalies are due to carbonaceous beds, as seems probable in White's
Area, the method may still be useful in tracing these beds in soil-
covered areas.

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A P P E N D I X

1. SELF-POTENTIAL METHOD

Theory

The theory of the method has been briefly discussed at the beginning of this report (Section 3(A)); the equipment and technique used to measure the self-potential voltages are discussed more fully below.

Equipment

The equipment consisted of a conventional D.C. potentiometer, non-polarising electrodes, and 1,000 feet of single-conductor cable. The D.C. potentiometer used a sensitive galvanometer as a "null" recorder. A voltmeter, reading from 0 to 1,000 millivolts on four ranges, gave a reading accuracy of better than 1 millivolt on the 0-50 and 0-100 millivolt ranges for normal ground contacts. Ground contacts were made with non-polarising electrodes consisting of a copper element in a porous pot containing a saturated solution of copper sulphate.

Corrections were made for the difference between the contact potentials of the electrodes, and this difference was checked at least every half-hour by reversing the electrodes at one station and taking the mean reading as correct.

Survey Technique

Readings were taken at 25-foot intervals along the north-south traverses using a cable more than 600 feet long so that all readings could be referred directly to a station on the baseline. Readings between adjacent traverses were made at three places, namely, between the baseline stations, between the northern ends of the traverse lines, and between the southern ends of the traverse lines. Closure corrections were then made for the circuits thus completed; in general the misclosure for each circuit was less than 10 millivolts. The largest misclosure was 34 millivolts in the circuit formed by the northern half of traverses 13E and 14E on Brown's Copper Mine Area.

2. POTENTIAL-RATIO METHOD

Theory and Technique

The potential ratio method has been outlined in the report (Section 3 (B)). Some instrumental details are given below and some difficulties encountered during the survey are described.

Equipment

The equipment consisted of (1) a 500 c.p.s. alternator rated at 1-3 amps., 150-200 volts, (2) 6,000 feet of single-conductor cable, (3) twenty-four bars of 1-inch steel pointed so that they could be driven into the ground, (4) three steel probe electrodes of 5/16" steel for use with the ratiometer, (5) a high impedance ratiometer.
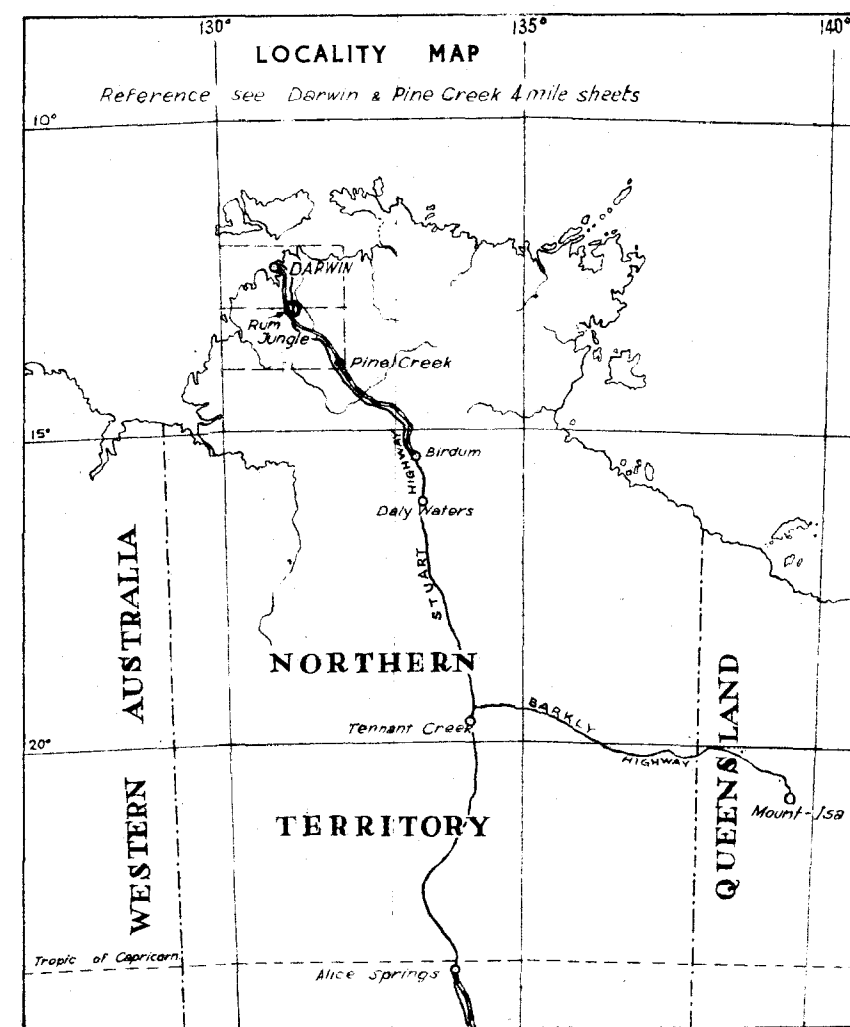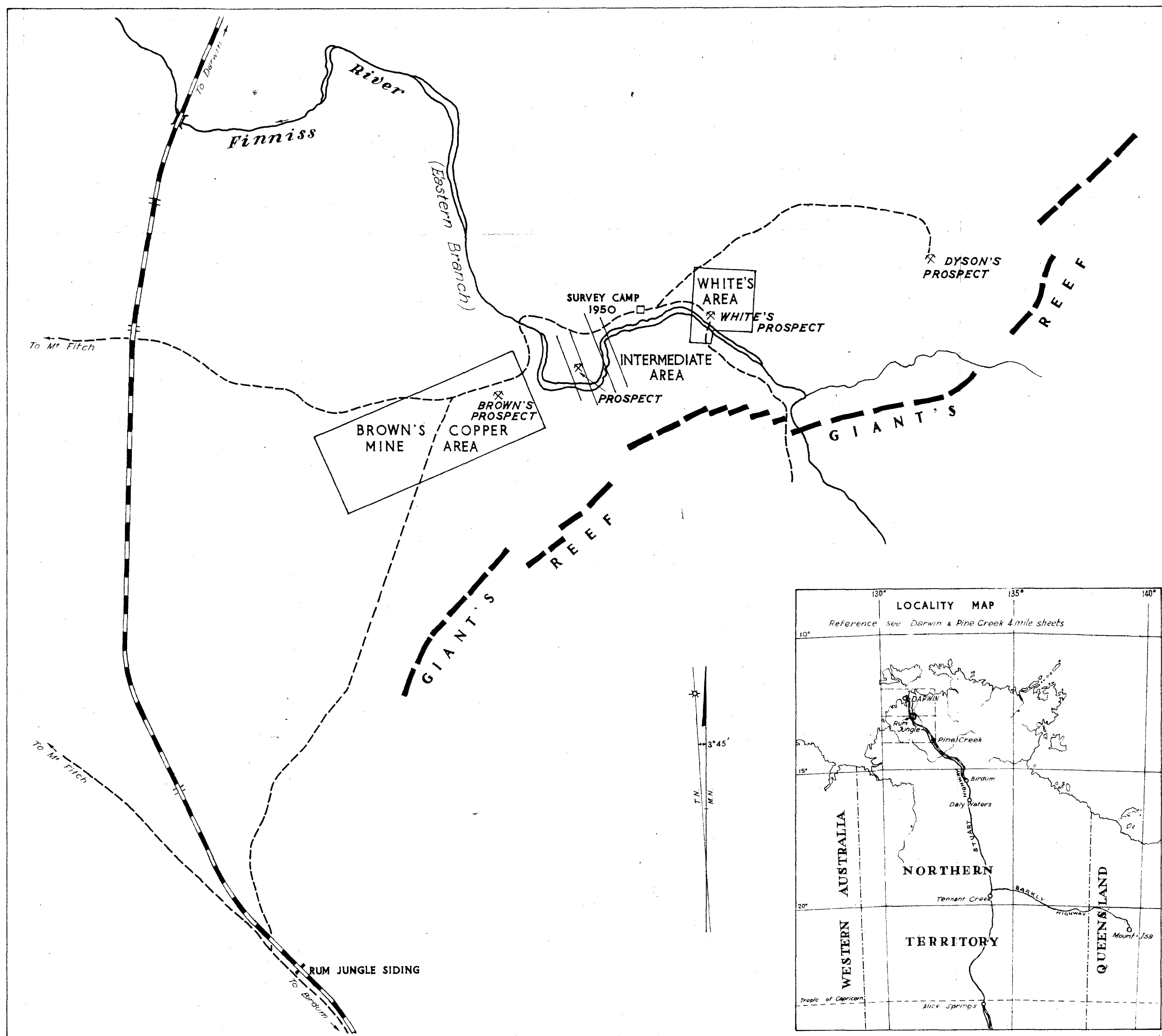
Each power electrode consisted of 8 or more steel bars driven about 2 feet into the ground and placed several feet apart. These were connected together by bare copper wire and a current of 0.5-2.0 amps was passed into the ground via these electrodes.

The high impedance ratiometer is an a.c. bridge,
designed and calibrated for use at 500 c.p.s.; from the bridge
readings the ratio of, and phase difference between, the potentials
across successive intervals along the traverse can readily be
calculated.   The main scale reads from 0 to 1.40, and is calibrated
to show directly the voltage ratio between the "in-phase" components
of the bridge arms.   A calibrated variable reactance can be
switched into either arm of the bridge and is used to measure the
"out-of-phase" component.   From these two readings the true volt-
age ratio, and the phase relation between the two arms of the
bridge, are calculated.   The null point indicator consists of a
two-stage amplifier incorporated in the instrument, and a pair of
earphones.   The instrument is provided with four scale factors,
(0.5, 1, 2, and 10) so that a wide range of ratios may be measured.
The reading accuracy is within one per cent under normal operating
conditions.   The instrument design and method of operation is such
that the effect of contact resistance between the electrodes and the
ground is eliminated.

Surface effects and ratiometer performance

The results on traverses 8E, 6E and 4E (Brown's
Copper Mine Area) illustrate the sensitivity of the method to varia-
tions in the conductivity of the surface layers.   Traverse 8E was
surveyed on 9-11-50 and traverses 6E and 4E were surveyed on 13-11-50
following heavy rain on the night of 12-11-50.   The readings along
6E and 4E are highly irregular, particularly over the schists and
slates, some of which have apparently become saturated near the surface.
The readings became less irregular as the ground dried out in the
following days.

A feature of the readings made on the days following
the rain was that, on any one station, a readings made on the x1
scale was always higher than a reading on the x2 scale which was
higher than a reading on the x10 scale.   In general all the readings
were too high as can be shown by the steeply rising logpotential-
gradient curve for traverses 6E and 4E.   An investigation showed that
these abnormal effects can be explained by assuming a leakage resistance
of 0.5-2 megohms across the 100,000 ohm potentiometer on which the
ratio is read.   A leakage resistance of this value would not be
detected in the field inspection of the instrument made at the time.
The reason for the leakage is not definitely known but it was probably
caused in some way by the existing conditions of high humidity.   The
effect gradually disappeared during the following week.

PLATE 1

To Darwin

Finniss River

(Eastern Branch)

To Mt Fitch

REEF

DYSON'S PROSPECT

SURVEY CAMP 1950

WHITE'S AREA

WHITE'S PROSPECT

INTERMEDIATE AREA

PROSPECT

BROWN'S PROSPECT

BROWN'S MINE   COPPER AREA

GIANT'S REEF

GIANT'S REEF

To Mt Fitch

T.N   M.N
3°45'

RUM JUNGLE SIDING

To Birdum

LOCALITY MAP
Reference see Darwin & Pine Creek 4 mile sheets

130°   135°   140°

10°

DARWIN
Rum Jungle
Pine Creek

15°
Birdum
Daly Waters

AUSTRALIA

WESTERN AUSTRALIA

NORTHERN

TERRITORY

STUART HIGHWAY

Tennant Creek

BARKLY HIGHWAY

Mount Isa

QUEENSLAND

20°

Tropic of Capricorn

Alice Springs

LEGEND

━━━━━ Railway Line

‑ ‑ ‑ ‑ Vehicle track

∿∿∿ River

✕ Uranium prospect

SCALE
APPROX.

1200   0   1200   2400 FEET
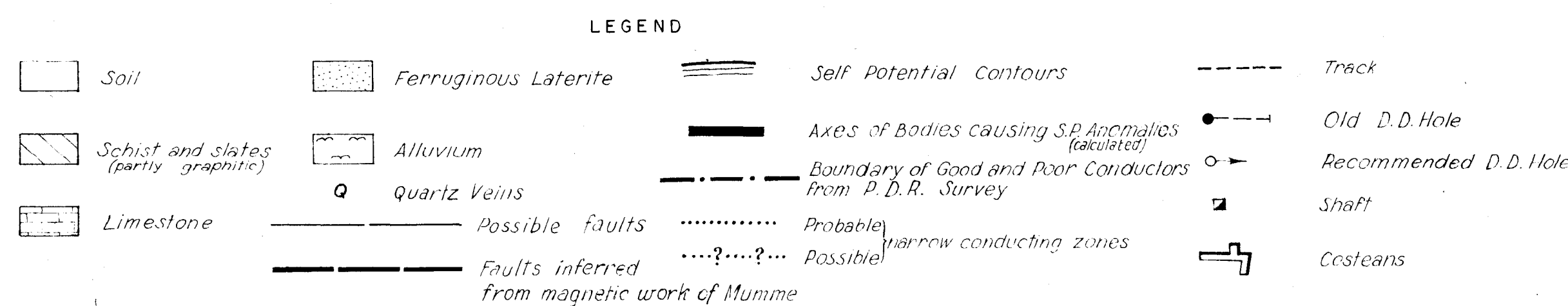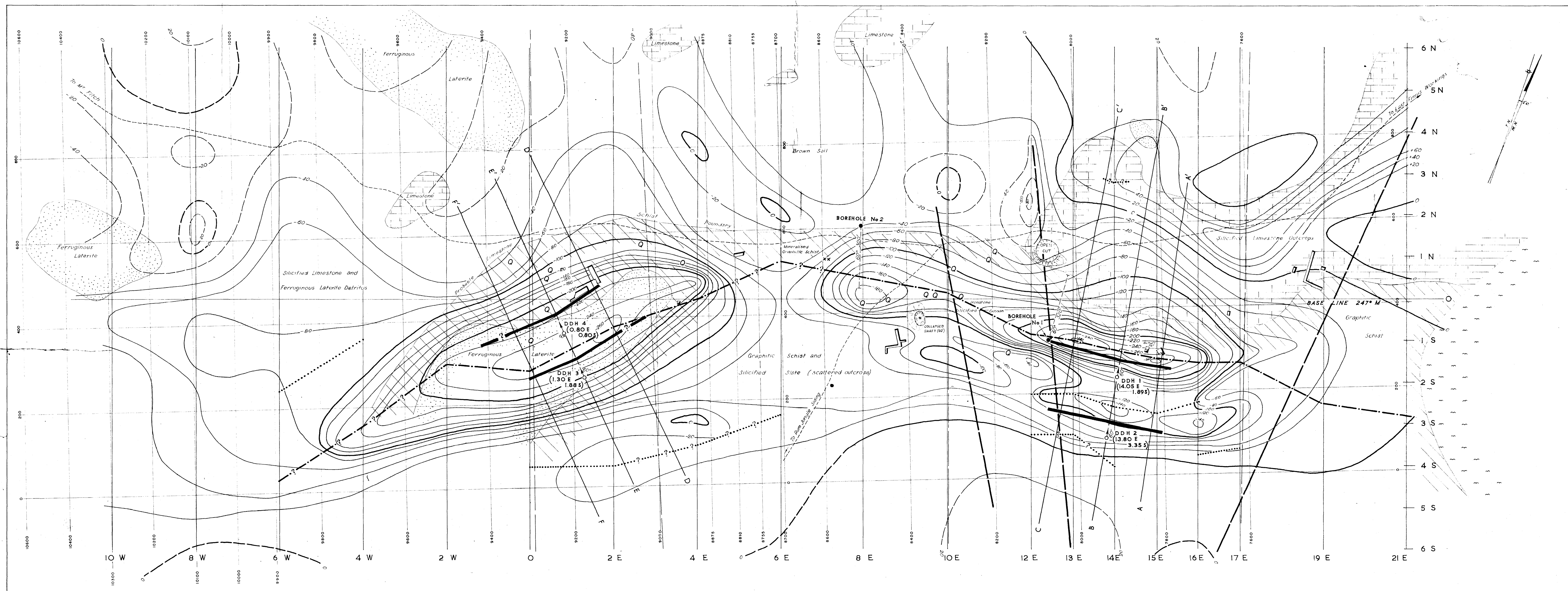
GEOPHYSICAL SURVEY AT RUM JUNGLE, N.T.

PLAN SHOWING

LOCATIONS OF AREAS SURVEYED

GEOPHYSICIST   Mr G Allen

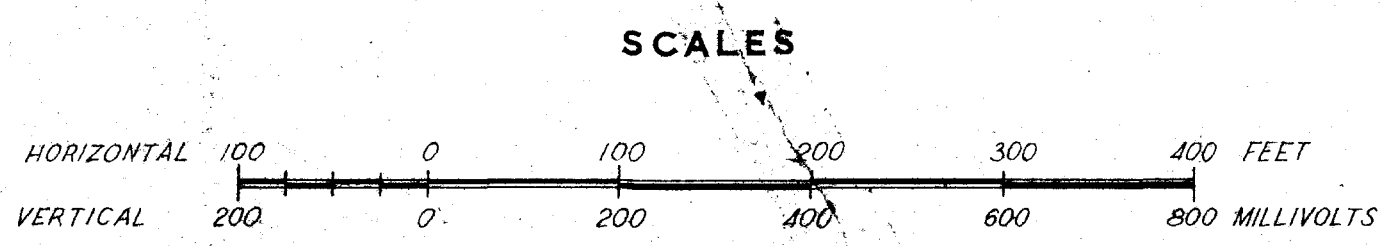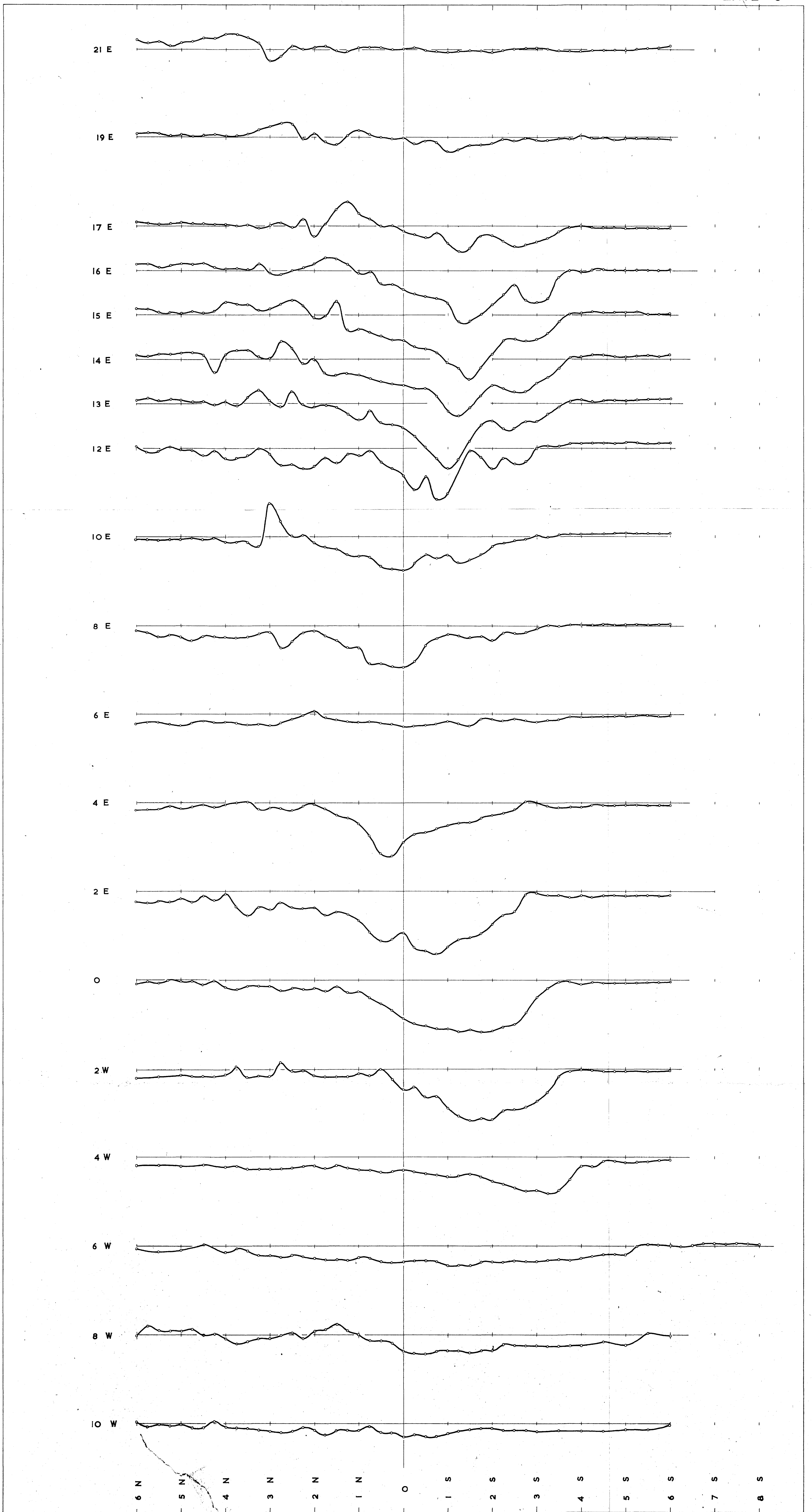G 71 - 16

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics
To accompany Records 1951, No 56

PLATE 52.

LEGEND

Soil — Ferruginous Laterite — Self Potential Contours — Track

Schist and slates (partly graphitic) — Alluvium — Axes of Bodies causing S.P. Anomalies (calculated) — Old D.D. Hole

Limestone — Quartz Veins — Boundary of Good and Poor Conductors from P.D.R. Survey — Recommended D.D. Hole

Possible faults — Probable narrow conducting zones — Shaft

Faults inferred from magnetic work of Mumme — ....?....?.... Possible — Costeans — Geophysicist

SCALE IN FEET
100 0 100 200 300 400
Contour Interval 20 Millivolts

GEOPHYSICAL SURVEY AT BROWN'S PROSPECT,
RUM JUNGLE, N.T.

SELF-POTENTIAL CONTOURS AFTER ALLEN 1950
WITH FAULTS INFERRED FROM LATER MAGNETIC WORK

GEOLOGY FROM THE 100 FEET TO 1 INCH PLAN BY H.J. WARD
AND
ALSO THE 400 FEET TO 1 INCH PLAN BY D.J. GATES & N.J. MACKAY

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

To accompany Records 1951, No 56

G 71-17

BASE LINE 247° M

BOREHOLE No 2
BOREHOLE No 1

DDH 4 (0.80 E, 0.80 S)
DDH 3 (1.30 E, 1.88 S)
DDH 1 (14.05 E, 1.89 S)
DDH 2 (13.80 E, 3.35 S)

PLATE 3

SCALES

HORIZONTAL 100   0   100   200   300   400 FEET

VERTICAL 200   0   200   400   600   800 MILLIVOLTS

GEOPHYSICAL SURVEY AT RUM JUNGLE N.T.

BROWN'S COPPER MINE AREA

SELF-POTENTIAL PROFILES

Geophysicist

G 71-18

PLATE 4

SCALE

100   0   100   200   300   400 FEET

Note   Vertical spacing of profiles not to scale

LEGEND

⌐⌐⌐ Log Potential Ratio   ⌐⌐⌐ Phase Angle

GEOPHYSICAL SURVEY AT RUM JUNGLE N.T.

BROWN'S COPPER MINE AREA

POTENTIAL – RATIO AND
PHASE – ANGLE PROFILES

Geophysicist   M. G. allan

G 71 – 20

PLATE 5

EASTERN ANOMALY

SOUTH   PROFILE A-A'

Schist & Slate ↑ *Limestone*

150'
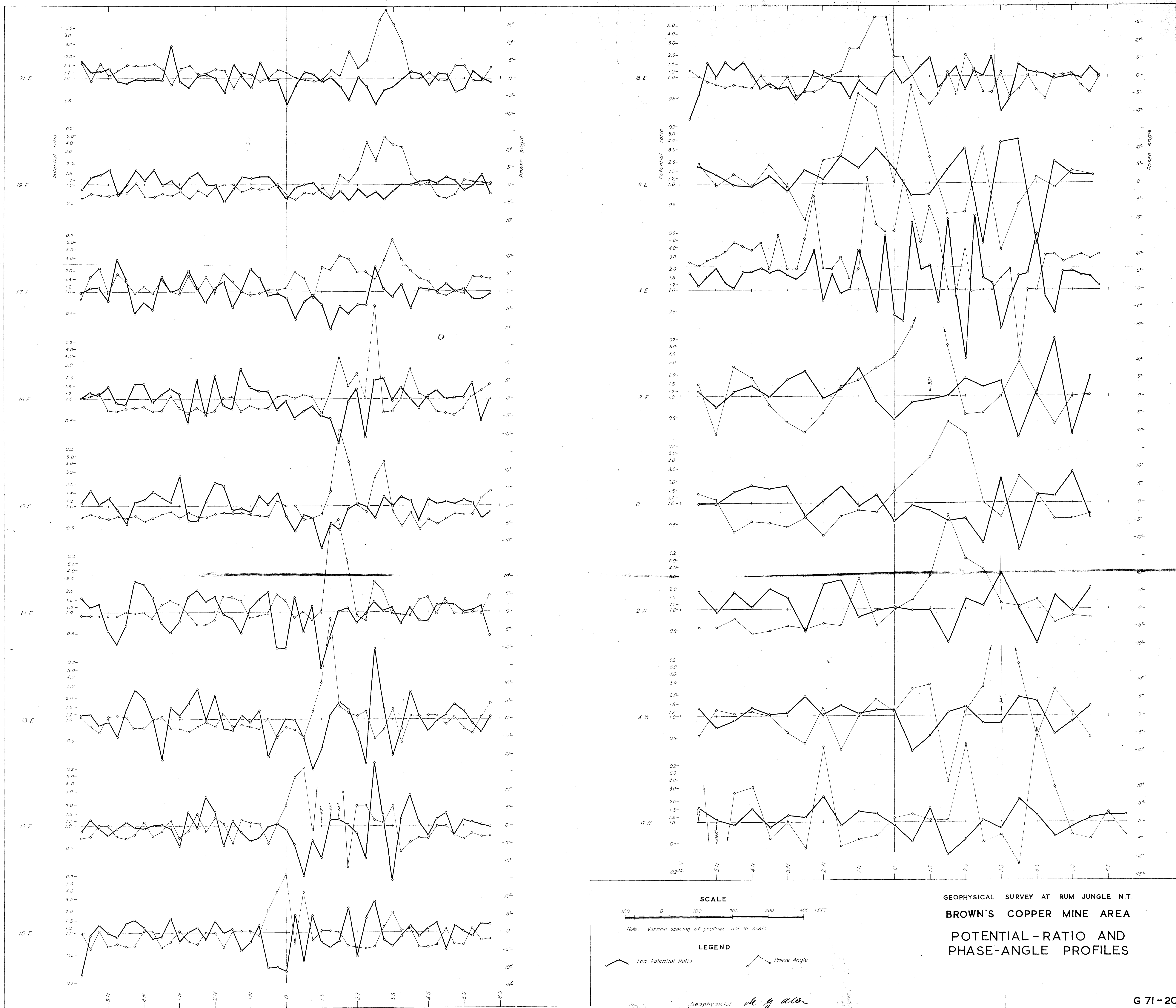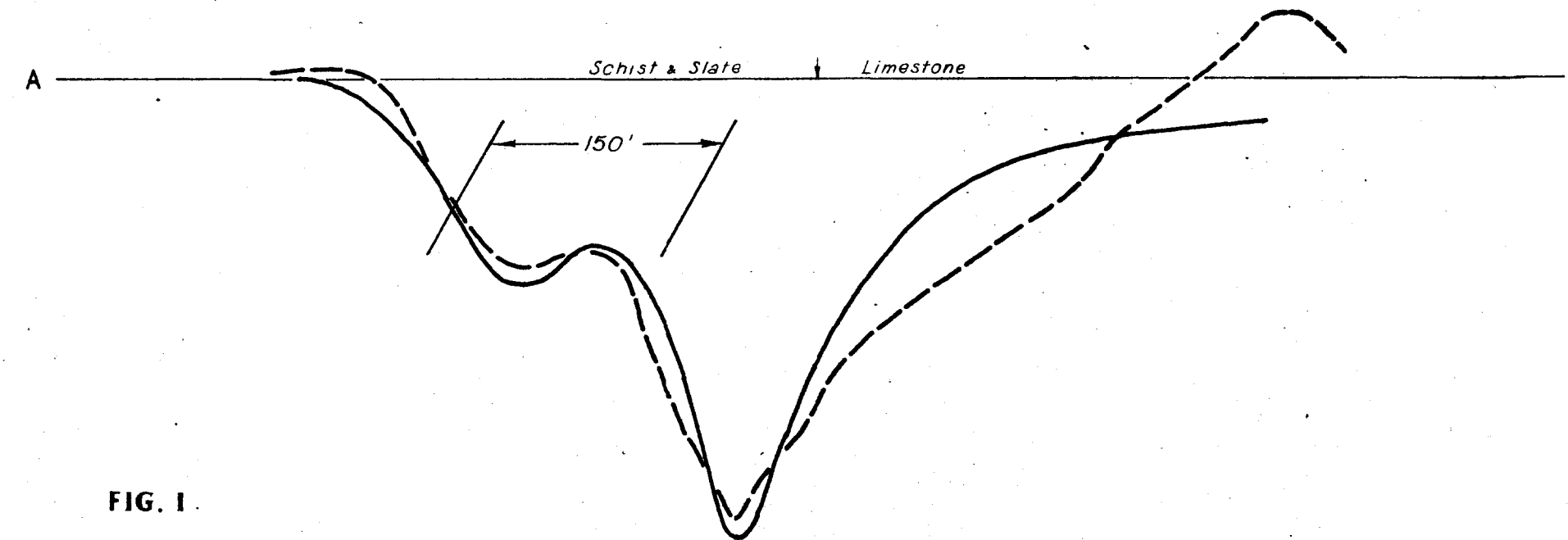
FIG. 1.
Calculated profile: Two sheets 400 feet long E-W × 100 feet
Dip 60°, 150 feet apart horizontal

PROFILE B-B'

Schist & Slate ↑ **Limestone**

150'
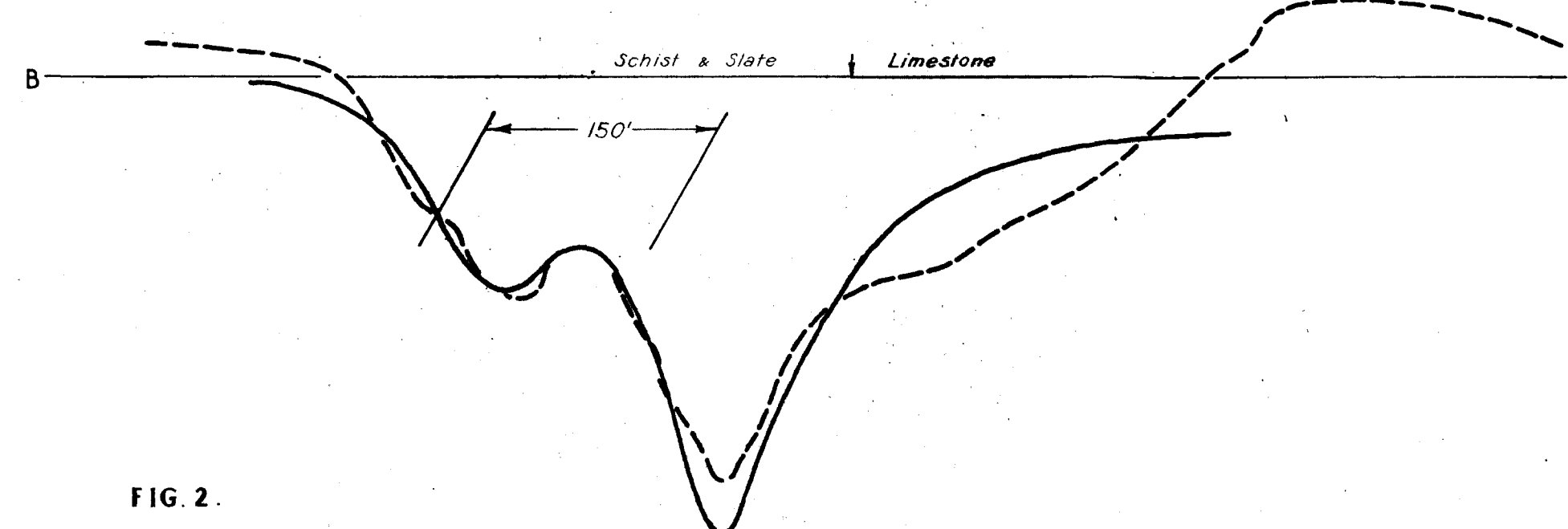
FIG. 2.
Calculated profile: Two sheets 400 feet long E-W × 100 feet
Dip 60°; 150 feet apart horizontal

PROFILE C-C'   NORTH

Schist & Slate ↑ *Limestone*

150'
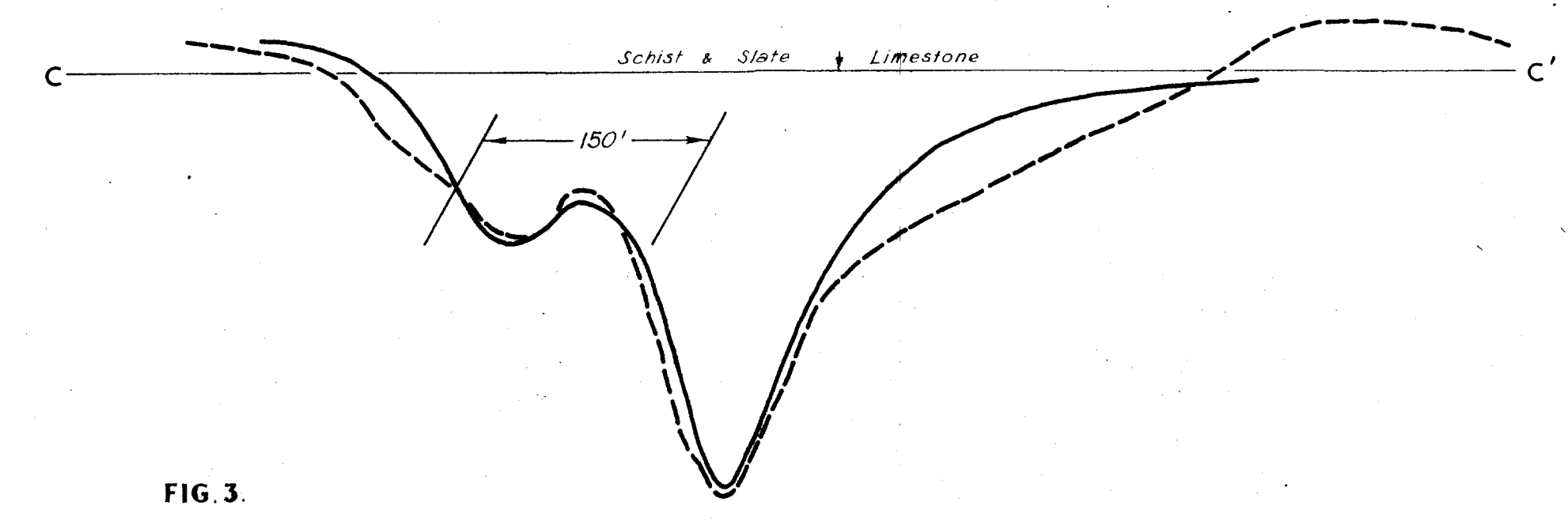
FIG. 3.
Calculated profile: Two sheets 400 feet long E-W × 100 feet
Dip 60°; 150 feet apart horizontal

WESTERN ANOMALY

SOUTH   PROFILE D-D'

140'
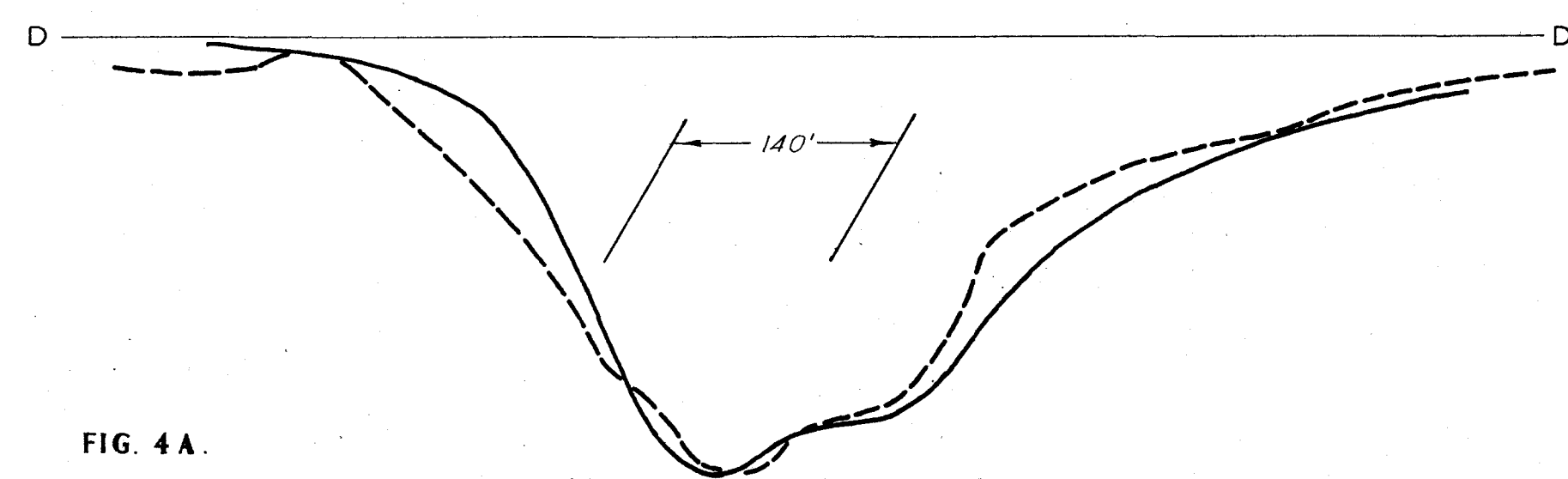
FIG. 4A.
Calculated profile: Two sheets 400 feet long E-W × 100 feet
Dip 60°; 140 feet apart horizontal

PROFILE E-E'

140'
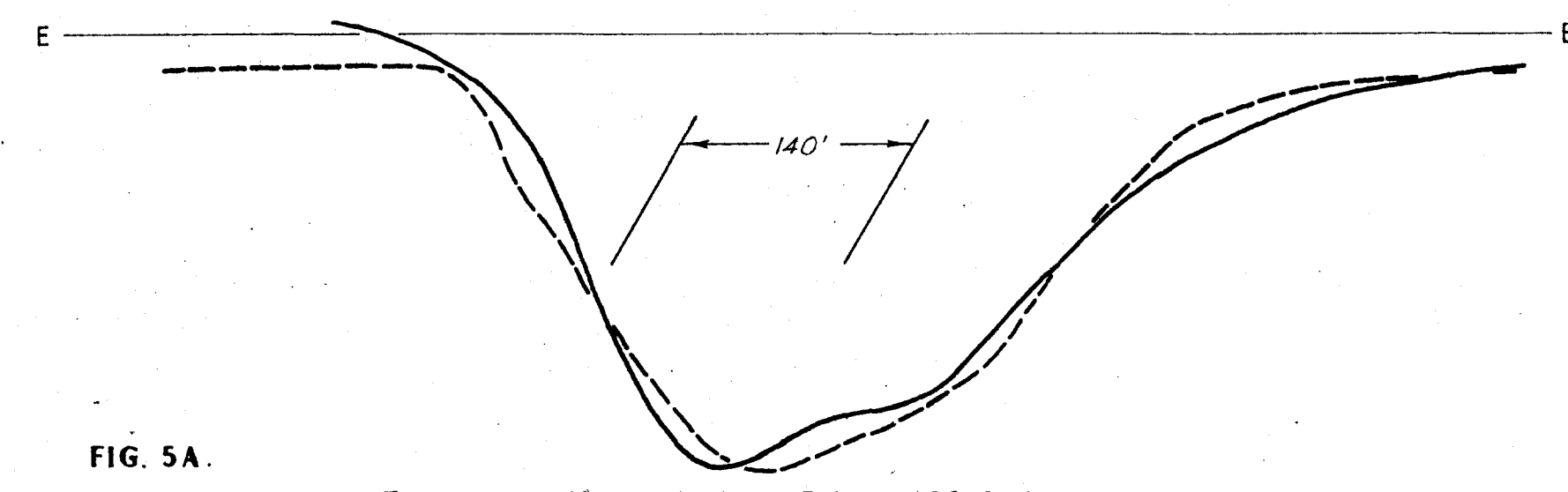
FIG. 5A.
Calculated profile: Two sheets 400 feet long E-W × 100 feet
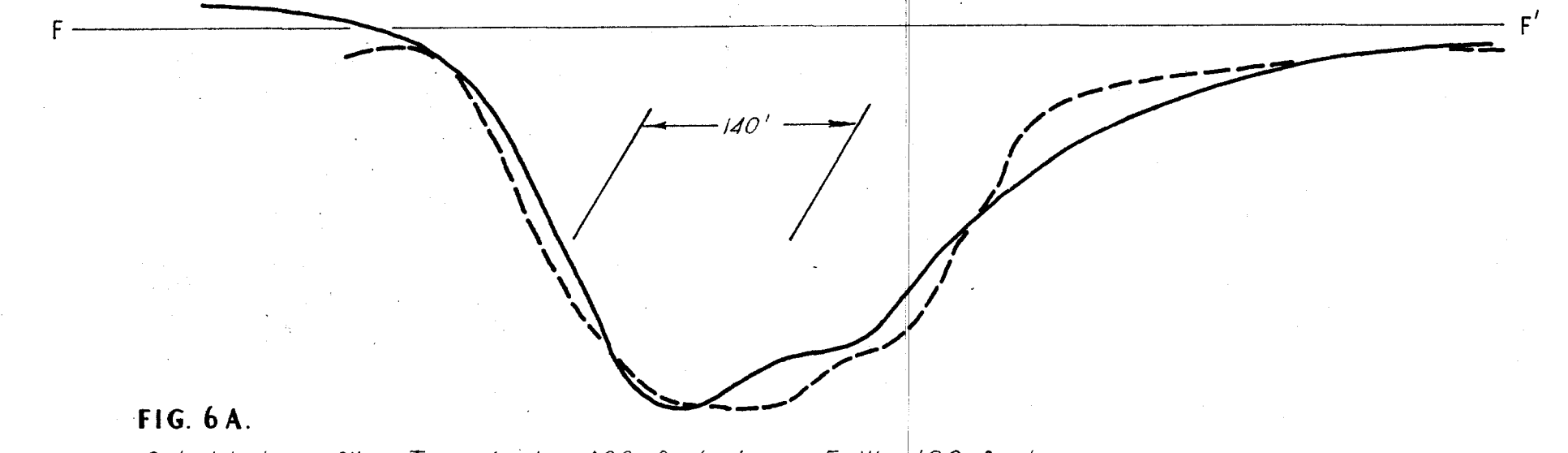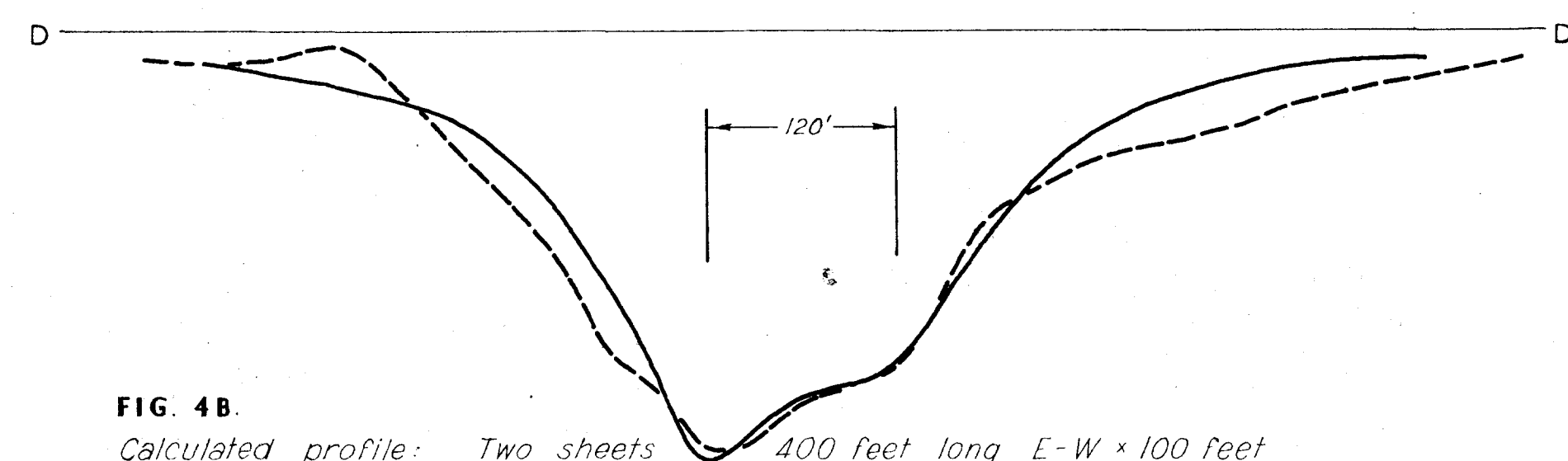*Dip 60°; 140 feet apart horizontal*

PROFILE F-F'   NORTH

140'

FIG. 6A.
Calculated profile: Two sheets 400 feet long E-W × 100 feet
Dip 60°; 140 feet apart horizontal

PROFILE D-D'

120'

FIG. 4B.
Calculated profile: Two sheets 400 feet long E-W × 100 feet
Dip 90°; 120 feet apart horizontal
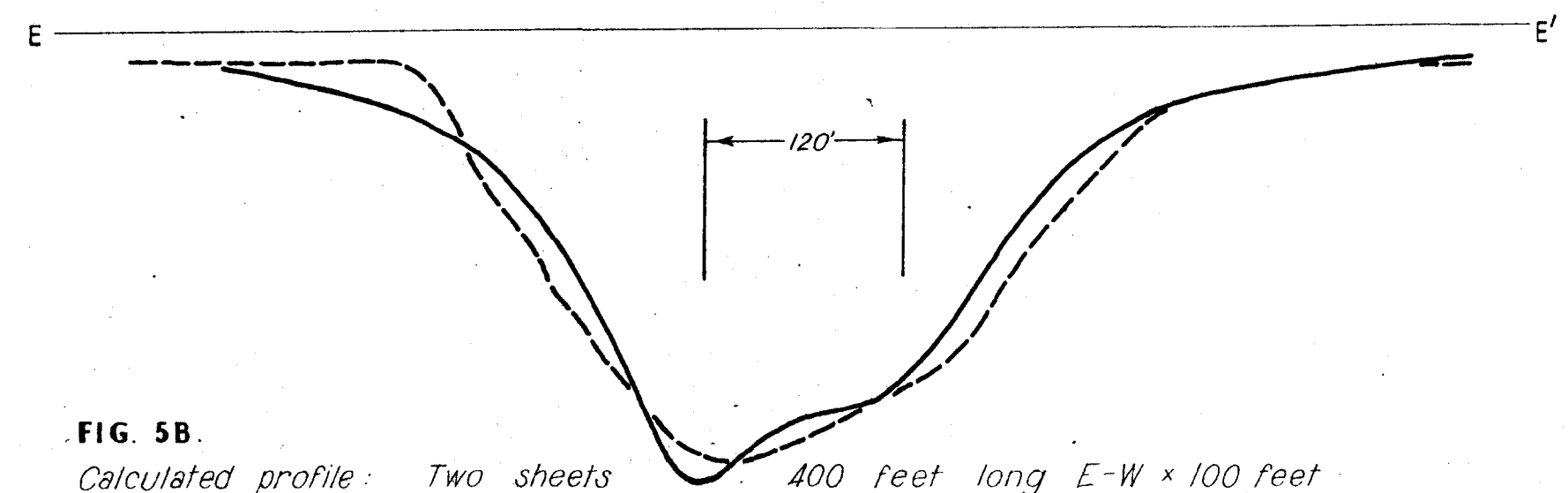
PROFILE E-E'

120'

FIG. 5B.
Calculated profile: Two sheets 400 feet long E-W × 100 feet
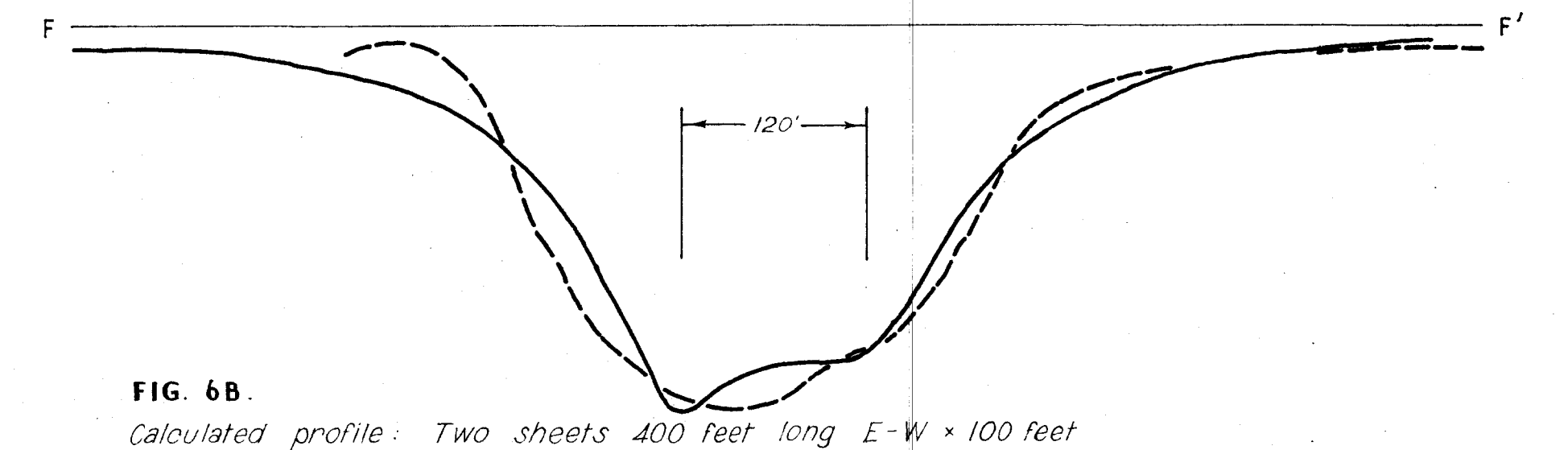*Dip 90°; 120 feet apart horizontal*

PROFILE F-F'

120'

FIG. 6B.
Calculated profile: Two sheets 400 feet long E-W × 100 feet
Dip 90°; 120 feet apart horizontal

SCALES

HORIZONTAL 100   0   100   200   300   400 FEET
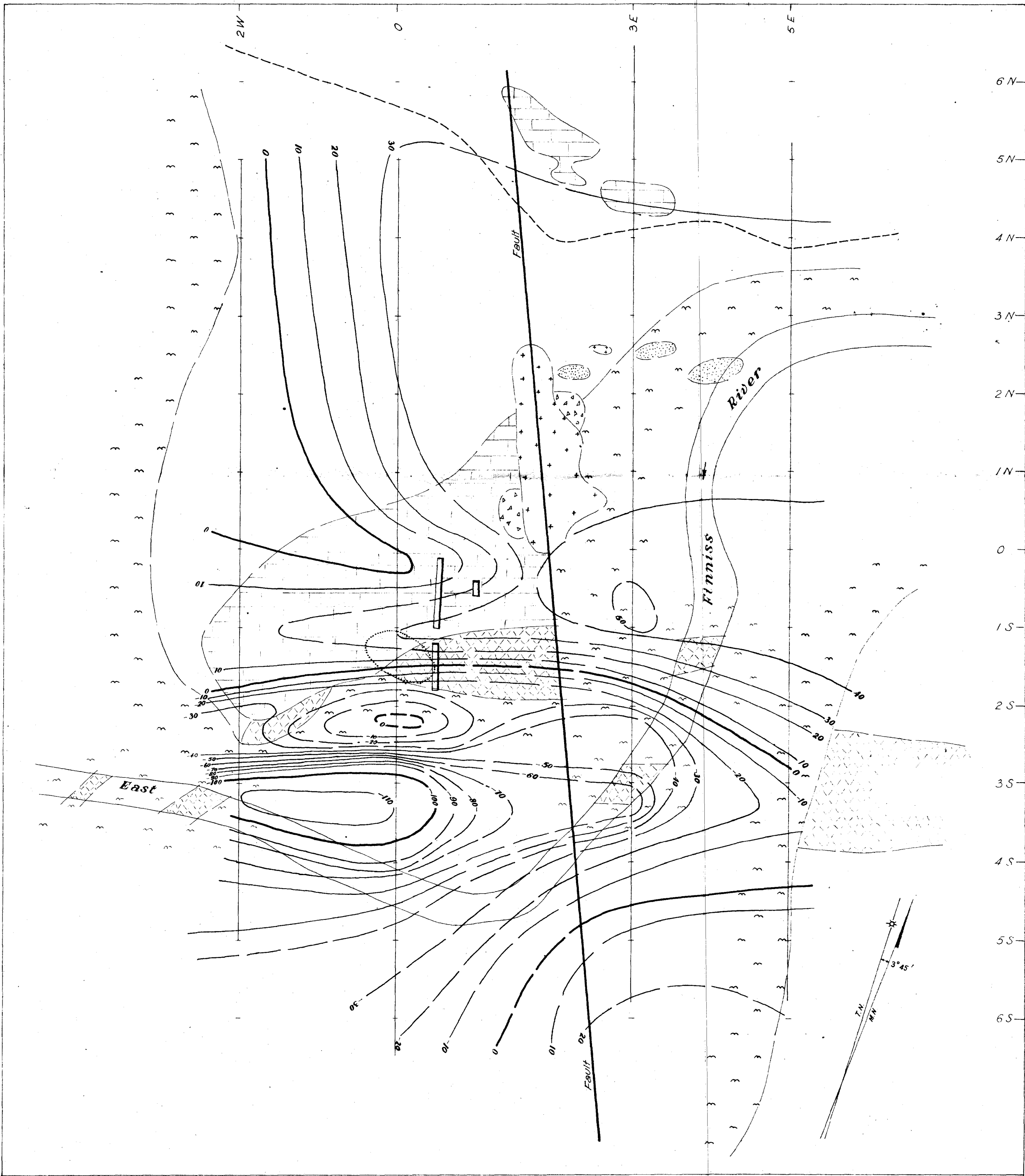VERTICAL 100   0   100   200   300   400 MILLIVOLTS

LEGEND

—— Calculated Profile
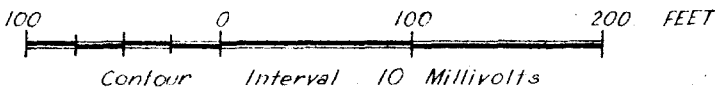
‒ ‒ ‒ Observed Profile

GEOPHYSICAL SURVEY AT RUM JUNGLE N.T.

BROWN'S COPPER MINE AREA
OBSERVED AND CALCULATED PROFILES
FOR EASTERN AND WESTERN S.P. ANOMALIES

Geophysicist

G 71 - 19

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

To accompany Records 1951, No 56

PLATE 6

2W 0 3E 5E

6 N
5 N
4 N
3 N
2 N
1 N
0
1 S
2 S
3 S
4 S
5 S
6 S

Fault

River

Finniss

East

Fault

3°45'

T.N   M.N

SCALE

100   0   100   200   FEET

Contour   Interval   10 Millivolts

GEOPHYSICAL   SURVEY   AT   RUM   JUNGLE   N.T.

INTERMEDIATE   AREA

PLAN SHOWING

SELF-POTENTIAL   CONTOURS   AND   GEOLOGY

(GEOLOGY FROM THE 400 FEET TO 1 INCH PLAN BY D.J.GATES & N.J.MACKAY)

LEGEND

Soil	Laterite
Alluvium	Self Potential Contours
Graphitic Schist and Slate	Geological Boundaries
Limestone	Geiger Müller Contour (2x Background)
Quartz	Costean
Quartz Breccia	Fault

Geophysicist   M G Allen

G 71 - 23

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To accompany Records 1951, No 56.

PLATE 7

SCALES

HORIZONTAL 100   0   100   200   FEET

VERTICAL   100   0   100   200   MILLIVOLTS

Geophysicist *M G Allen*
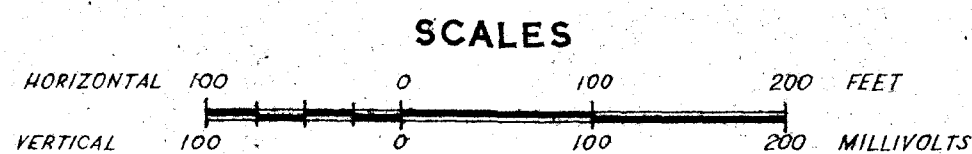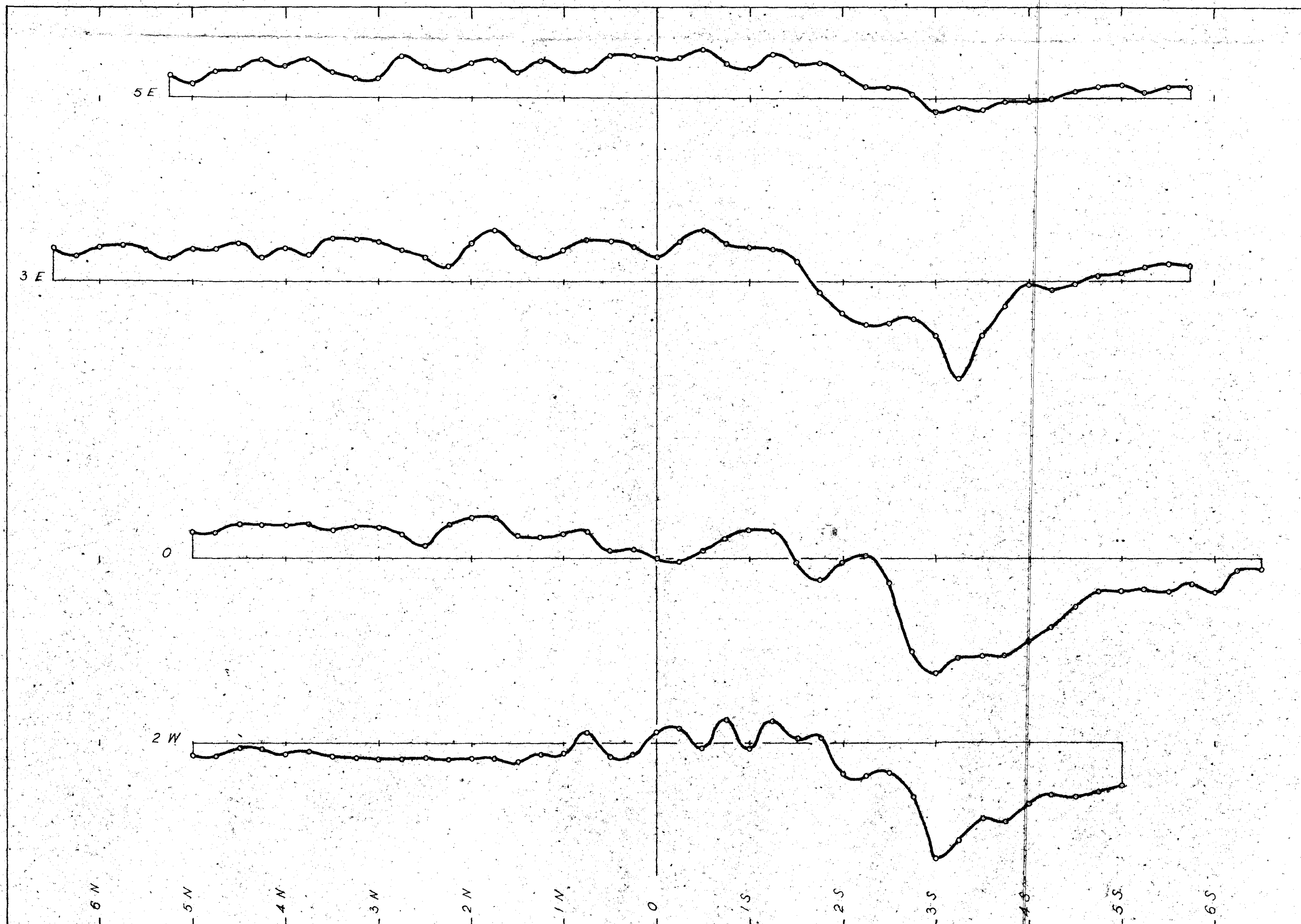
GEOPHYSICAL SURVEY AT RUM JUNGLE N.T.

INTERMEDIATE AREA

SELF-POTENTIAL PROFILES

G 71 – 24

PLATE 8
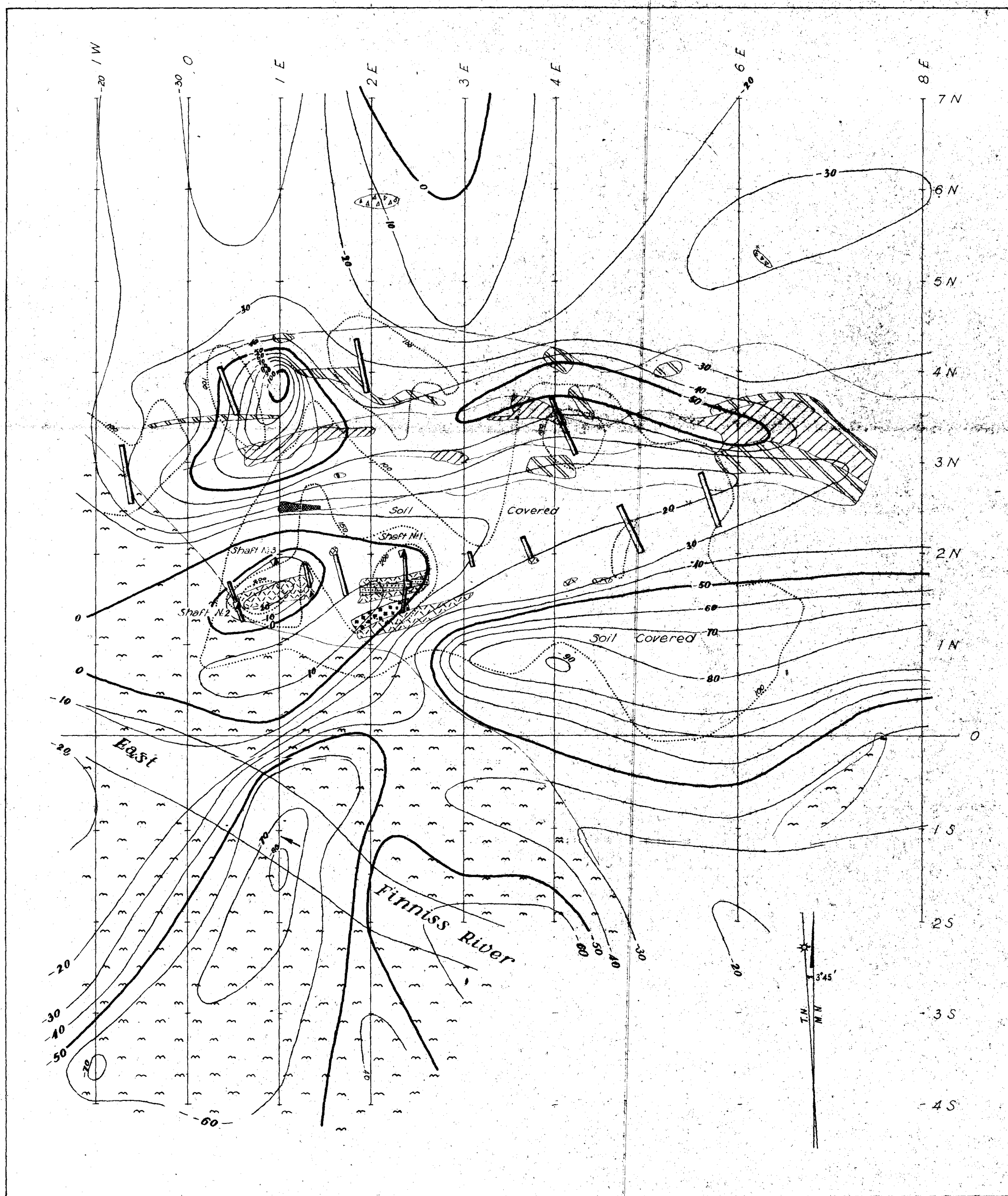
SCALE

100   0   100   200 FEET

Contour Interval 10 Millivolts

LEGEND

Soil	Self Potential Contours
Alluvium	Geiger Muller Contours (Counts per Minute)
Carbonaceous Slate	Approx. or assumed geological boundaries
White-spotted Slate	Costeans
Weathered Felspathic Slate	Accessible Shaft
Graphitic Schist	Inaccessible Shaft
Red Shale	
Micaceous Schist	
Quartz Breccia	

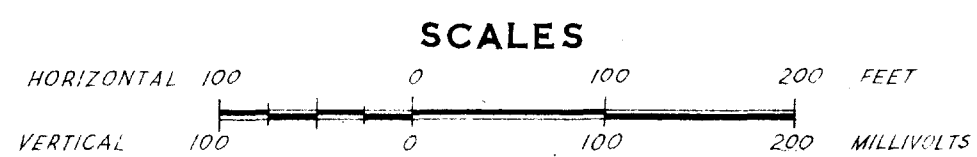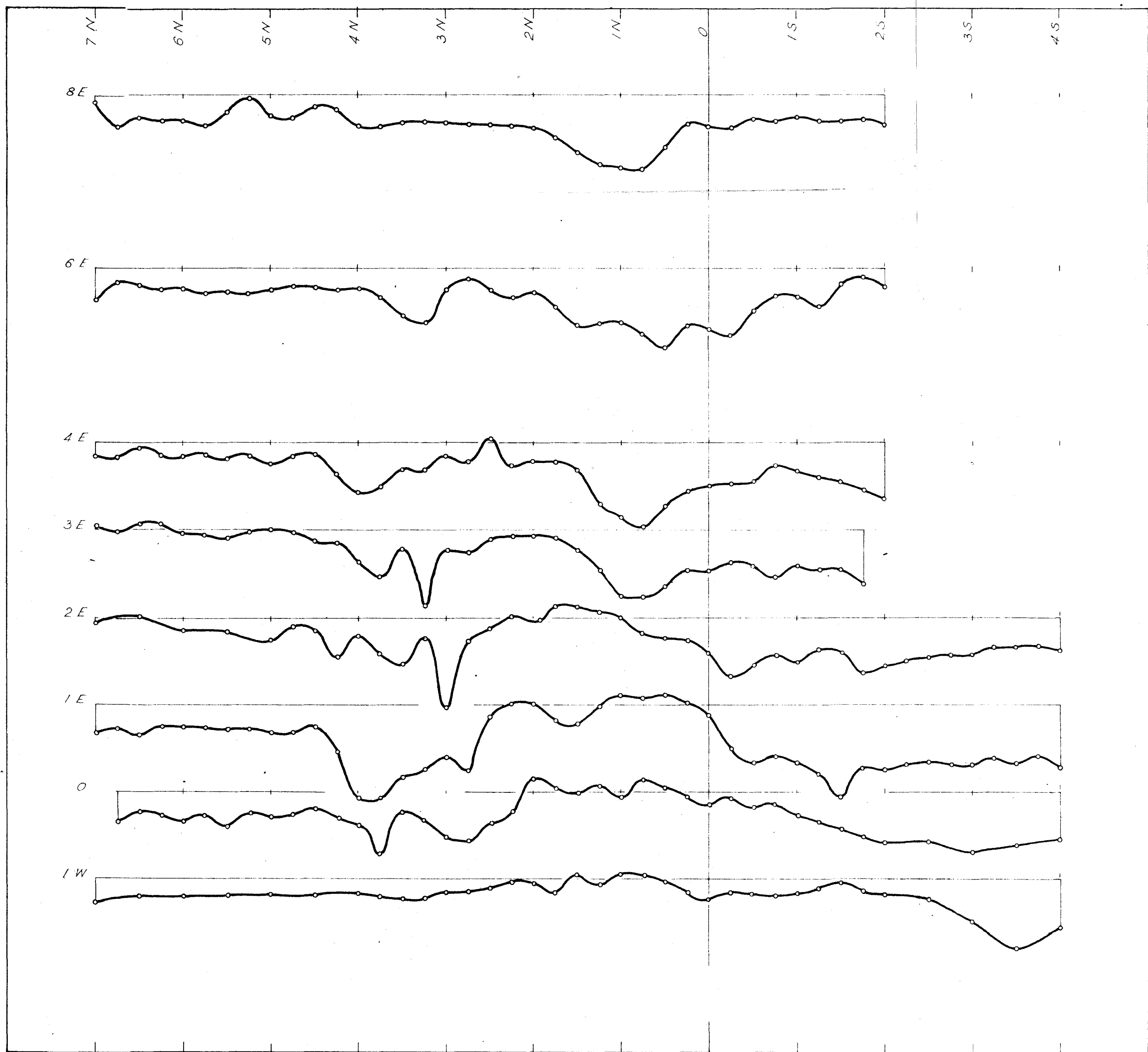GEOPHYSICAL SURVEY AT RUM JUNGLE N.T.

WHITE'S AREA
SELF-POTENTIAL CONTOURS
AND GEOLOGY

(GEOLOGY AFTER H.J. WARD)

Geophysicist

G 71 - 21

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

To accompany Records 1951, No 56.

PLATE 9

SCALES

HORIZONTAL	100	0	100	200 FEET
VERTICAL	100	0	100	200 MILLIVOLTS

GEOPHYSICAL SURVEY AT RUM JUNGLE N.T.

WHITE'S AREA

SELF-POTENTIAL PROFILES

Geophysicist M. G. allen

G 71-22