COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1967/79

Mc ARTHUR RIVER INDUCED POLARISATION TEST SURVEY,

NORTHERN TERRITORY 1966

by

E.C.E. SEDMIK

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SUMMARY

An induced polarisation test survey was conducted in the McArthur River area, over traverses previously surveyed by Carpentaria Exploration Company Pty Ltd, to compare field techniques and results obtained with measurements in the frequency domain against those obtained in the time domain.

Three traverses were surveyed in areas where Carpentaria Exploration Co. Pty Ltd obtained interesting results, and a fourth traverse was surveyed in an area where, owing to excessive telluric noise and fluctuating self-potential field, no reliable results could be obtained with measurements in the time domain.

Measurements in the frequency domain supplied information similar to that produced by measurements in the time domain. This was expected since the same effect (induced polarisation) was measured in both domains. However, measurements in the frequency domain gave reliable results in all areas, whereas there was one area where such results could not be obtained by measurements in the time domain.

1. INTRODUCTION

From 14th to 27th September 1966, an induced polarisation (IP) test survey was conducted by the Bureau of Mineral Resources (BMR) in the McArthur River area of the Northern Territory, about 370 miles north-north-west of Mount Isa. The area is held under a prospecting authority by Carpentaria Exploration Company Pty Ltd, which has been conducting IP surveys over it since 1961.

Several silver-lead-zinc occurrences are known in the area, the most important of these being the H.Y.C. deposit situated two miles north of McArthur River Station. Technical problems related to ore treatment preclude the successful exploitation of this deposit for the present.

The BMR conducted electromagnetic surveys in the McArthur River area in 1958 (Horvath, 1959) and contracted out similar work to ABEM in 1963 (BMR, 1964). The areas covered are shown in Plate 2.

The object of the present test was to compare IP measurements obtained with the BMR McPhar equipment operating in the frequency domain with those of the ASARCO equipment of Carpentaria Exploration Co. Pty Ltd operating in the time domain.

The geophysical party consisted of E. C. E. Sedmik and B. B. Farrow (geophysicists), N. A. Ashmore (geophysical assistant), and one field hand. The test was conducted over traverses previously surveyed by Carpentaria Exploration Co. Pty Ltd.

2. GEOLOGY

The geology of the McArthur River district has been described by Cotton (1962), who has also described in detail the H.Y.C. deposit (Cotton, 1965).

The silver-lead-zinc mineralisation in the McArthur River area occurs in a sedimentary horizon within the Barney Member, a subdivision of the Amelia Dolomite, which is one of the older units of the McArthur Group of dolomite sediments. The Lower Proterozoic McArthur Group is about 13,000 ft thick and conformably overlies the arenaceous Tawallah Group. Unconformably overlying the McArthur Group is the Roper Group, another arenaceous succession, of Upper Proterozoic Age, of about 22,000 ft thickness.

In the McArthur River area, the Amelia Dolomite consists of nodular algal dolomite biostromes, massive dolomite, dolomite breccias, dolomitic siltstones, shales, acid tuffs, sandstones, and some volcanic rocks having a total thickness of about 6000 ft. Towards the top of this succession there is a marked change in sediment type from the nodular and massive dolomite to laminated dolomite, acid tuffs, and pyritic shales. These later formations have been grouped together and are known as the Barney Member. All significant known mineralisation occurs at the base of the pyritic shales, just above the tuff beds, and is apparently confined to a relatively small area about the H.Y.C. deposit.

The structure of the H.Y.C. deposit is relatively simple. It represents the western limb of a shallow synclinal fold which dips beneath the bed of McArthur River and flattens easterly to a maximum known depth of 1980 ft. A typical geological section through the H.Y.C. shaft is shown in Plate 3. The eastern margin of the H.Y.C. deposit, as far as it is known, terminates very abruptly against a partly biostromal algal reef structure.

Mineralisation occurs within several closely spaced beds of pyritic shale separated by beds of low-grade shale and breccia. The minerals present in the ore are extremely fine-grained and include sphalerite, galena, and a little chalcopyrite with pyrite, marcasite, and calcite as gangue.

The mineralised horizon is overlain by up to 1200 ft of barren pyritic shales and carbonaceous shales. The pyritic shales contain an average of 10 to 15% pyrite but may contain up to 40% locally. The carbonaceous shales are graphite free and contain an average of 3% free carbon. Induced polarisation measurements made in ASARCO's laboratory, Salt Lake City, Utah, USA on rock specimens taken from the McArthur River area, indicate that the H.Y.C. mineralisation is much more polarisable than the pyritic and carbonaceous shales.

3. DESCRIPTION OF METHOD

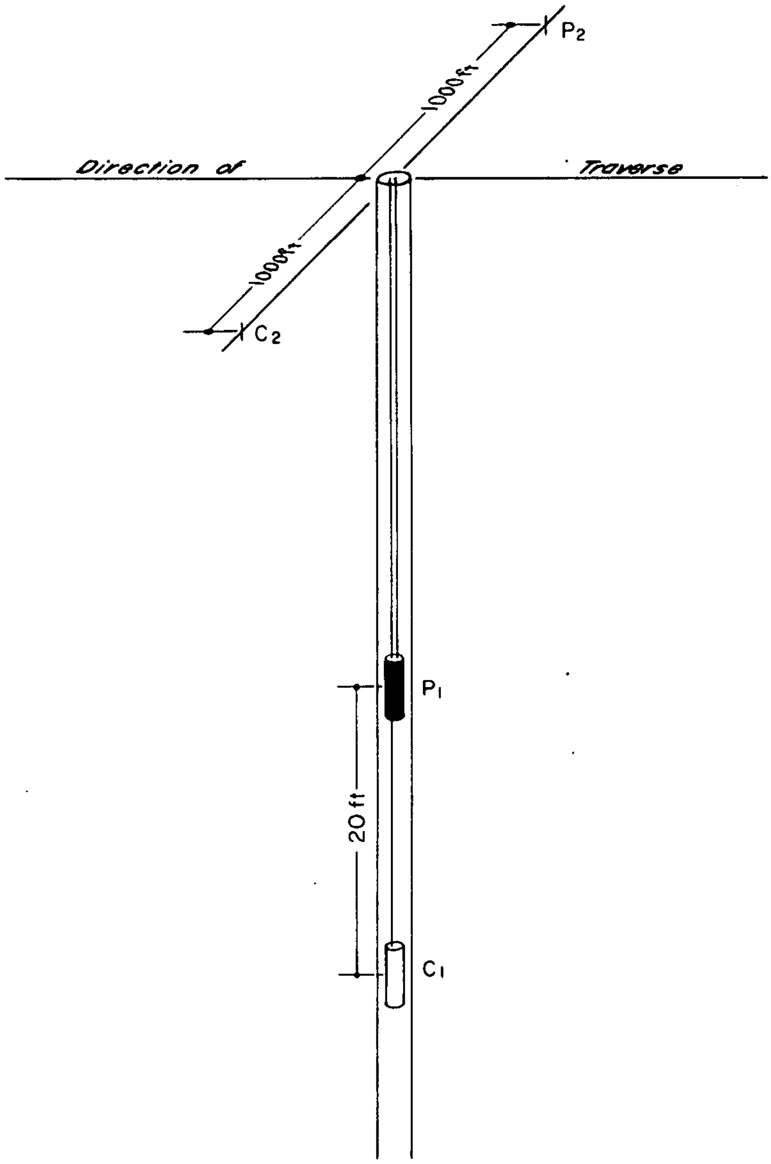
The induced polarisation method of prospecting is based on the overvoltage effect, which has been known for over forty years. However, it is only in the last ten years or so that it has been developed into a geophysical prospecting method.

The overvoltage effect is exhibited by rocks in which the ionic conduction paths are blocked by electronic conductors. When current is passed through such rocks, an electrochemical force must be overcome to permit the passage of current. If the applied current is switched off the voltage decays in a finite time. Since this effect occurs primarily in rocks containing electronic conductors (e.g. metallic sulphides, magnetite, graphite, etc.) it can be used as a geophysical method to detect these conductors.

The IP effect can be measured in the 'time domain' (pulse-transient method) in which a current pulse is sent into the ground; the decay voltage obtained after the pulse is switched off is a measure of the 'chargeability' or 'IP effect' parameter, expressed in millivolts per volt. The ASARCO equipment uses this technique. The equipment is powered by dry batteries (2000 volts). The operator turns on the current pulse manually and while the current is flowing through the ground the potential (Δv) between two potential electrodes is measured. After four seconds a time switch turns off the current and simultaneously a synchronising signal triggers a timing circuit, which switches the elements of the potential-measuring circuit to integrate and store the IP potential (P). The measurements enable calculation of apparent resistivity (R apparent), and apparent chargeability (IP apparent). For a three-array electrode configuration (Plate 3) the following formulae apply:

FIG. 1

(To face page 3)



ELECTRODE ARRANGEMENT FOR IP MEASUREMENTS IN DRILL HOLES

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

G29-9

TO ACCOMPANY RECORD No. 1967/79

$$R \text{ apparent} = 4\pi a \frac{\Delta v}{I} \text{ ohm-metres}$$

$$\text{and IP apparent} = \frac{P}{\Delta v} \text{ millivolts/volt}$$

where a = spacing between moving electrodes (measured in metres)
Δv = potential between P1 and P2 (measured in volts)
I = current flowing between C1 and C2 (measured in amperes)
P = integrated IP decay potential (measured in millivolts)

The three-electorde array was used by Carpentaria Exploration Co. Pty Ltd. With this configuration (Plate 3) one current electrode C2 is kept fixed at a great distance (1 to 2 miles) from the surveyed area while three equidistant electrodes P2, P1, and C1 are moved along traverses. The depth of penetration is controlled by the separation of electrodes P2, P1, and C1. Thus by surveying a line at consecutively larger electrode separation an increasingly thick layer of the Earth's crust is sampled. The results can be plotted as single profiles for any given electrode separation or as vertical pseudo-sections (resistivity and chargeability) when several electrode spacings are used. In the course of a normal survey, the data are correlated from line to line and a contour map is produced indicating the horizontal extent of the feature being investigated.

The ASARCO equipment is supplied with attachments to enable IP measurements to be made in drill holes. For this a specially designed porous pot P1 followed by a current electrode C1 at 20-ft spacing is lowered in the drill hole while C2 and P2 are kept at the surface about 1000 ft away from the drill hole collar (Figure 1). Measurements are made at short depth intervals and the results are plotted against values of depth half way between P1 and C1.

The IP effect can also be measured in the 'frequency domain' (variable frequency method) in which the apparent resistivity of the ground (R apparent) is measured at two frequencies. A decrease of the apparent resistivity with increase in frequency signifies the presence of polarisation. The percentage change in resistivity is called the 'frequency effect' (F.E.).

The 'metal factor' (M.F.) term used in the variable frequency method is the ratio of the frequency effect to the apparent resistivity multiplied by a constant. This parameter is considered by many as being more indicative of the amount of metallic mineralisation present in the ground (Hallof, 1964).

The BMR McPhar equipment operates in the frequency domain. With this equipment, frequencies of 0.3 c/s and 5 c/s were used. The electrode configuration used was dipole-dipole (Plate 3) for which the following formulae apply:

$$R \text{ apparent} = \pi(n - 1)\, n\, (n + 1)\, a \frac{V_p}{I} \text{ ohm-metres}$$

where V_p = potential between P1 and P2 (measured in volts)
I = current applied between C1 and C2 (measured in amperes)
a = dipole length (measured in metres)
n = number of dipole separations between centres of the transmitting and receiving dipoles

$$\text{F.E. apparent} = \frac{Rdc - Rac}{Rac} \times 100\% \quad \text{and}$$

$$\text{M.F. apparent} = \frac{2000\pi \times \text{F.E.}}{Rac} \quad \text{mhos/ft}$$

where Rdc = apparent resistivity at low frequency or direct current
Rac = apparent resistivity at high frequency.

Results are plotted in two-dimensional pseudo-sections as shown in Plate 3. The usual practice of expressing metal factors in units of mhos/ft has been followed in Plate 3, to facilitate comparison with results in other areas. The pseudo-sections must not be considered as true cross-sections of the earth's electrical properties.

The frequency effect can be related to the chargeability parameter of the pulse-transient method. Hallof (1964) has shown theoretically that in a polarisable medium the maximum of the frequency effect is equal to the maximum value of chargeability, but, in practice, field equipment does not permit the measurement of the maximum effect in either case. He concludes that both the variable frequency method and the pulse-transient method measure the same property and provide the same basic information, and any advantage of one method over the other depends on equipment design and on the use of more economic field techniques.

4. DISCUSSION OF RESULTS

Four traverses were selected by Carpentaria Exploration Co. Pty Ltd for the test survey. The first crossed the H.Y.C. deposit about 100 ft south of the H.Y.C. shaft; the second was about one mile to the east in an area where difficulty had been experienced in obtaining reliable results with the ASARCO equipment; the remaining two were in the Wickens Hill area, where the Company had completed detailed geophysicsl work and test drilling (Plate 2).

Traverse CDU

This traverse was surveyed with the McPhar equipment, firstly with 200-ft dipoles (Plate 3) and then with 400-ft dipoles (Plate 4). The ASARCO equipment was used on traverse 12,200N of an earlier grid, which crossed the H.Y.C. shaft at 430E. This traverse was parallel to and about 100 ft north of traverse CDU. A geological section through the H.Y.C. deposit is included in Plate 3 for comparison. The projected position of the H.Y.C. shaft on traverse CDU is at 2900W.

The area is occupied by alluvial flats covered by black soil, which allowed currents up to 4 amp to be transmitted into the ground with the McPhar equipment, and measurements with 400-ft dipoles could be made easily.

Although different electrode configurations and different methods of plotting results were used with the two sets of equipment, the results, presented in Plate 3, are very similar. Both detected the outcropping portion of the H.Y.C. mineralisation but failed to give a distinct indication over the deeper flat-lying portion further east.

The sectional plots for traverse 12,200N indicate low resistivities between 60E and 600E and between 1800E and 2600E with corresponding high IP effect values between 300E and 600E and between 1800E and 2600E. A third area of low resistivities between 2800E and 4200E is not accompanied by high IP effects. Traverse CDU similarly shows a low resistivity, high frequency effect, and high metal factor anomaly between 2600W and 3200W, and a weaker anomaly between 1800W and 4000W. The latter is interpreted as caused by the presence of strongly mineralised pyritic shales. The IP effect (ASARCO) and the metal factor values (Mc Phar) for the pyritic shales are distinctly lower than those obtained over the outcropping H.Y.C. mineralisation. The low apparent resistivities in Plate 3 can be correlated with areas where strongly mineralised pyritic shales crop out, except east of 2800E (on traverse 12,200N), where the low resistivity is attributed to the presence of breccia.

The results of the IP work with the McPhar equipment using 400-ft dipoles (Plate 4) show an increase in the depth of penetration. There was some loss of resolution as larger portions of ground were averaged by using the greater electrode spacing. The results indicate high frequency effects and metal factor values near 2800W, which persist at depth and suggest an easterly dip. The values are approximately of the same order as those obtained with 200-ft dipoles. The depth of penetration of the IP measurements is actually less than might be suggested by Plate 4 as no IP anomalies were obtained over the deeper flat-lying portion of the H.Y.C. mineralisation. A weak IP anomaly is recorded between 1500W and 400W over outcropping pyritic shales.

Traverse BCU

This traverse was included in the test survey because no reliable results could be obtained with the ASARCO equipment in this area owing to excessive telluric noise and fluctuating self-potential field. The traverse cuts across the Emu Fault, along which sporadic lead-zinc mineralisation occurs.

As the reliability of measurements with the ASARCO equipment depended on the accuracy of bucking out the influence of the self-potential effect, it was generally felt that the use of a field technique not necessitating direct current measurements, and consequently no self-potential bucking, was more appropriate.

Measurements in the frequency domain using 200-ft dipoles could be made without difficulty with the McPhar equipment. The results shown in Plate 5 indicate two areas of low resistivity, one located between 800W and 1200W accompanied by well defined frequency effect and metal factor anomalies of weak to medium strength, and the other located between 1600W and 2000W not accompanied by frequency effect or metal factor anomalies. The former appears to correspond in position to the Emu Fault. The IP results suggest possible mineralisation of limited depth extent (200 to 400 ft) in association with the fault. The low metal factor values suggest sparse disseminated mineralisation.

Traverses CHU-4S and traverse GHU-40W

The traverses are located in the Wickens Hill area and intersect at right angles (Plate 2). A test drill hole WH No. 1 intersected 17 ft of lead-zinc mineralisation in pyritic shales. The IP results with the ASARCO equipment indicated much higher chargeability values along GHU-40W than along GHU-4S. Because of this unexpected feature it was considered that tests with the McPhar equipment along the same traverses would be of interest.

The sectional plots presented in Plate 6 indicate similar trends in the results obtained with the McPhar equipment and those obtained with the ASARCO equipment. Traverse GHU-40W indicates an area of low resistivity, high frequency effect, and high metal factor values near peg 0 exhibiting a well defined boundary towards the north. Traverse GHU-4S shows high resistivity values in its eastern portion followed by a resistivity 'low' between 3600W and 4000W. The apparent resistivity values obtained with the ASARCO equipment appear to be higher than those obtained with the McPhar equipment. The magnitude of the metal factor anomaly on traverse GHU-40W is higher than on traverse GHU-4S, as with ASARCO's chargeability values, but slightly higher frequency effects were observed on traverse GHU-4S than on traverse GHU-40W.

The IP response on the two traverses at the point of intersection need not be the same, the response on each traverse being dependent on the position of the electrodes in relation to mineralisation. Hallof (1965) has shown with model tests that the IP response is higher when an electrode is near the mineralisation than when the mineralisation is in between electrodes.

The detailed induced polarisation survey in the Wickens Hill area by Carpentaria Exploration Co. Pty Ltd enabled compilation of interpretation maps showing the horizontal extent of IP response at different electrode spacings. These maps were correlated with the known geology and were used as an aid in geological mapping.

The field work in this area did not encounter difficulties with the ASARCO equipment, but with the McPhar equipment only small currents could be sent into the ground even after careful preparation of electrodes and using several spikes and alufoils at each electrode.

5. CONCLUSIONS

The induced polarisation tests made by the BMR in the McArthur River area gave results similar to those previously obtained by Carpentaria Exploration Co. Pty Ltd. Such results were expected as the same effect (IP) was measured in both surveys and only the measuring techniques were different. Although the exponents of different techniques claim advantages for the respective methods, very few comparisons between the two methods have been published.

Measurements in the frequency domain (McPhar equipment) using dipole-dipole electrode configuration were obtained in all areas tested. Reliable results were also obtained in the time domain (ASARCO equipment) along all traverses except traverse BCU, where reliable results could not be obtained because of a fluctuating self-potential field and telluric noise.

The McPhar equipment was simpler to use than the ASARCO equipment and necessitated three men to operate it as against four for the latter. The time spent on electrode preparation using the McPhar equipment was about the same as with the ASARCO equipment in all areas tested except on traverses GHU-4S and GHU-40W in the Wickens Hill area, where several spikes and alufoils had to be used at each electrode to decrease contact resistances.

The ASARCO equipment appeared ideally suited for the McArthur River area. The flat open country enabled speedy movement of electrodes along traverses, and no electrode preparation other than watering was needed as the equipment could be operated with low transmitted current. The field technique used necessitated surveying the same line with several electrode separations in order to produce a vertical pseudo-section comparable with that obtained in the frequency domain. This does not necessarily mean that the method using the ASARCO equipment is more cumbersome as most of the field work is carried out using one electrode separation and only when interesting anomalies are discovered is surveying with several electrode separations necessary.

The pulse method appears to have an advantage over the variable-frequency method since, under favourable geological conditions (near-horizontal layers), readily established techniques enable IP depth probing measurements to be made. Theoretically, similar measurements ought to be possible also in the frequency domain but, to the author's knowledge, no such techniques have been developed yet. The expanding Wenner electrode arrangement is used with the measurements in the time domain and resistivity values are determined in conventional manner using Mooney and Wetzel (1956) curves. Theoretical IP-type curves supplied by ASARCO for various resistivity contrasts enable the depth to the polarisable layer to be determined.

The ASARCO equipment can be adapted for IP borehole logging, but similar measurements cannot be done in the frequency domain when only one hole is available in the area because of difficulties with capacitive coupling. These difficulties can be partly overcome in areas where more than one hole is available by lowering one current electrode in one hole while keeping the other on the surface at a great distance from the hole. The potential electrodes are lowered in a different hole and the potential is measured at two frequencies in the conventional manner.

6. ACKNOWLEDGEMENTS

The author wishes to thank the management and staff of Carpentaria Exploration Company Pty Ltd for the co-operation given during the test survey, and for permission to use the Company's survey data presented in this report. In particular, it is desired to acknowledge the help and information provided by the Company's Chief Geophysicist Mr. P. Woyzburn and the party leader of the McArthur River party, Senior Geophysicist Mr. R. Rawlins.

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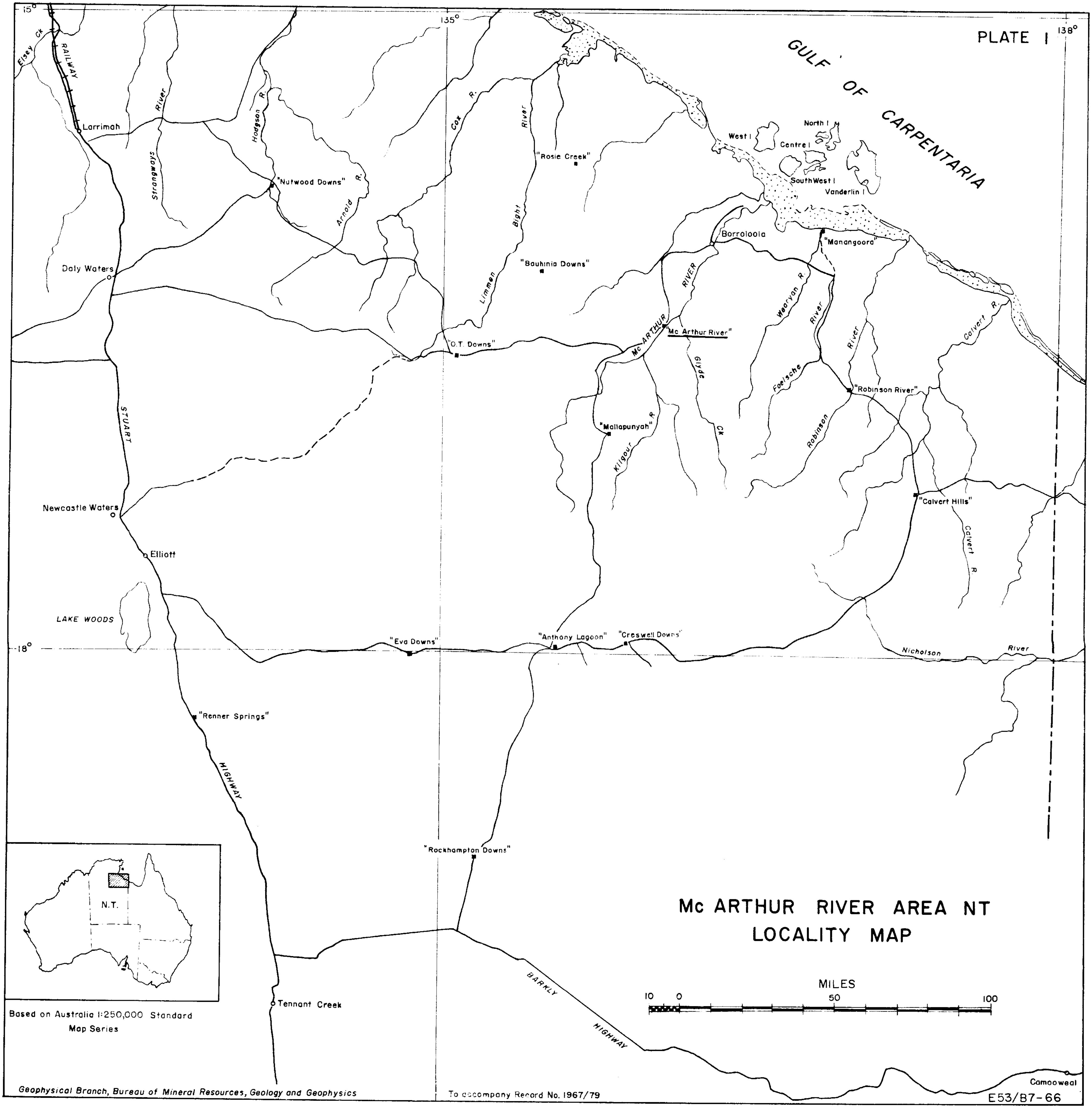
PLATE I
Mc ARTHUR RIVER AREA NT
LOCALITY MAP
GULF OF CARPENTARIA
15°
135°
138°
-18°
Elsey Ck
RAILWAY
Larrimah
Strongways
River
Hodgson R.
"Nutwood Downs"
Arnold R.
Cox R.
Limmen
Bight
River
"Rosie Creek"
"Bauhinia Downs"
West I
North I
Centre I
SouthWest I
Vanderlin I
Borroloola
"Manangoora"
Daly Waters
"O.T. Downs"
Mc ARTHUR
RIVER
"Mc Arthur River"
Glyde
Ck
Wearyan R.
River
Foelsche
River
"Robinson River"
Robinson
Calvert R.
"Mallapunyah"
Kilgour R.
STUART
Newcastle Waters
Elliott
"Calvert Hills"
Calvert
R.
LAKE WOODS
"Eva Downs"
"Anthony Lagoon"
"Creswell Downs"
Nicholson
River
"Renner Springs"
HIGHWAY
"Rockhampton Downs"
N.T.
MILES
10
0
50
100
BARKLY
HIGHWAY
Tennant Creek
Based on Australia 1:250,000 Standard
Map Series
Camooweal
Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics
To accompany Record No. 1967/79
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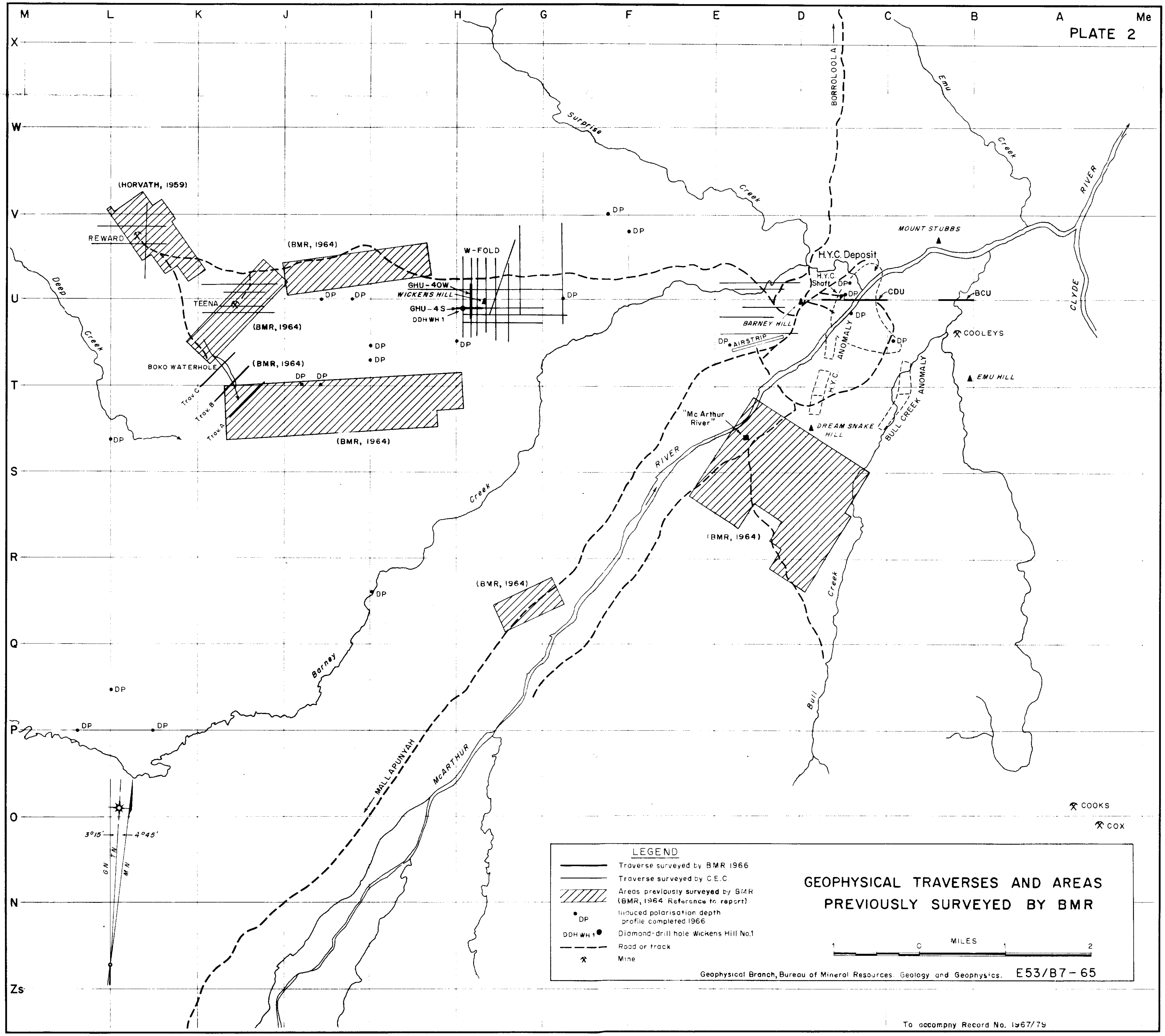


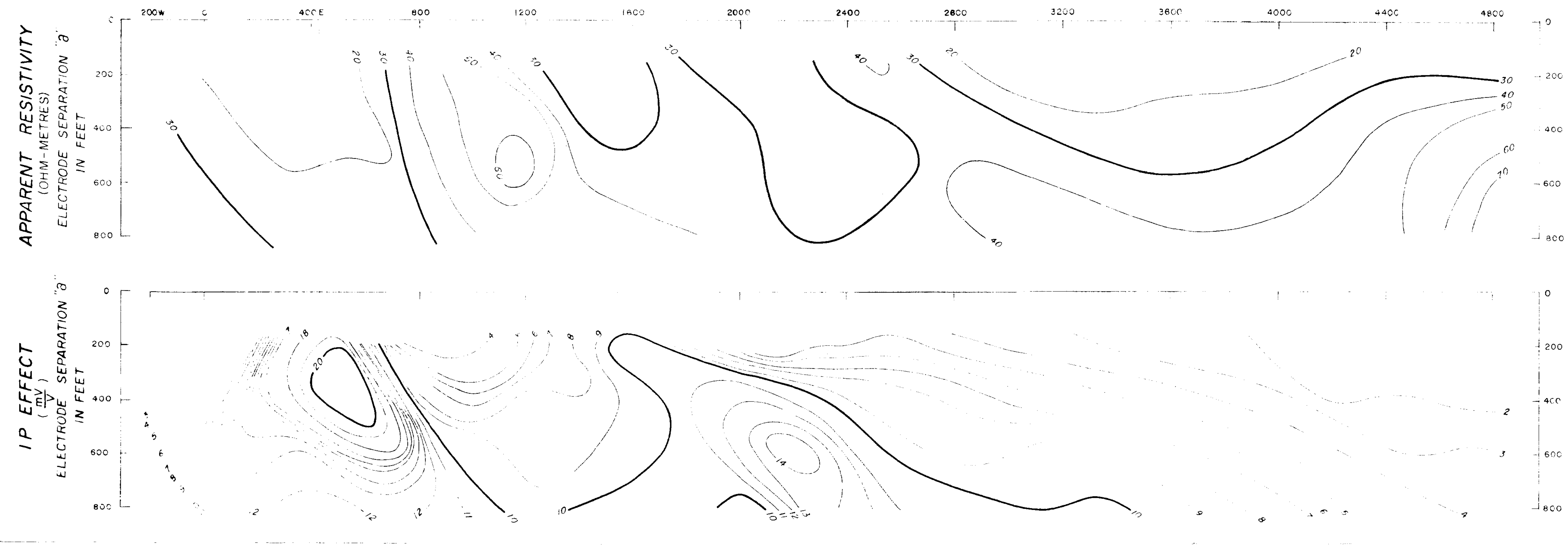
PLATE 2

GEOPHYSICAL TRAVERSES AND AREAS PREVIOUSLY SURVEYED BY BMR

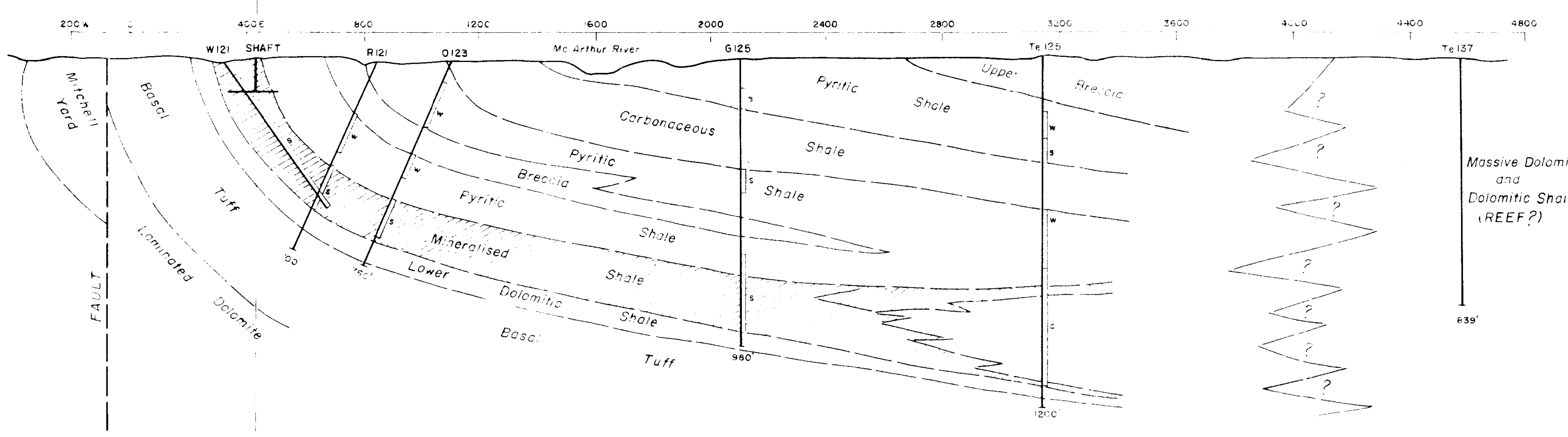
McARTHUR RIVER, N.T. 1966

PLATE 3

TRAVERSE 12,200 N – SURVEYED WITH ASARCO EQUIPMENT



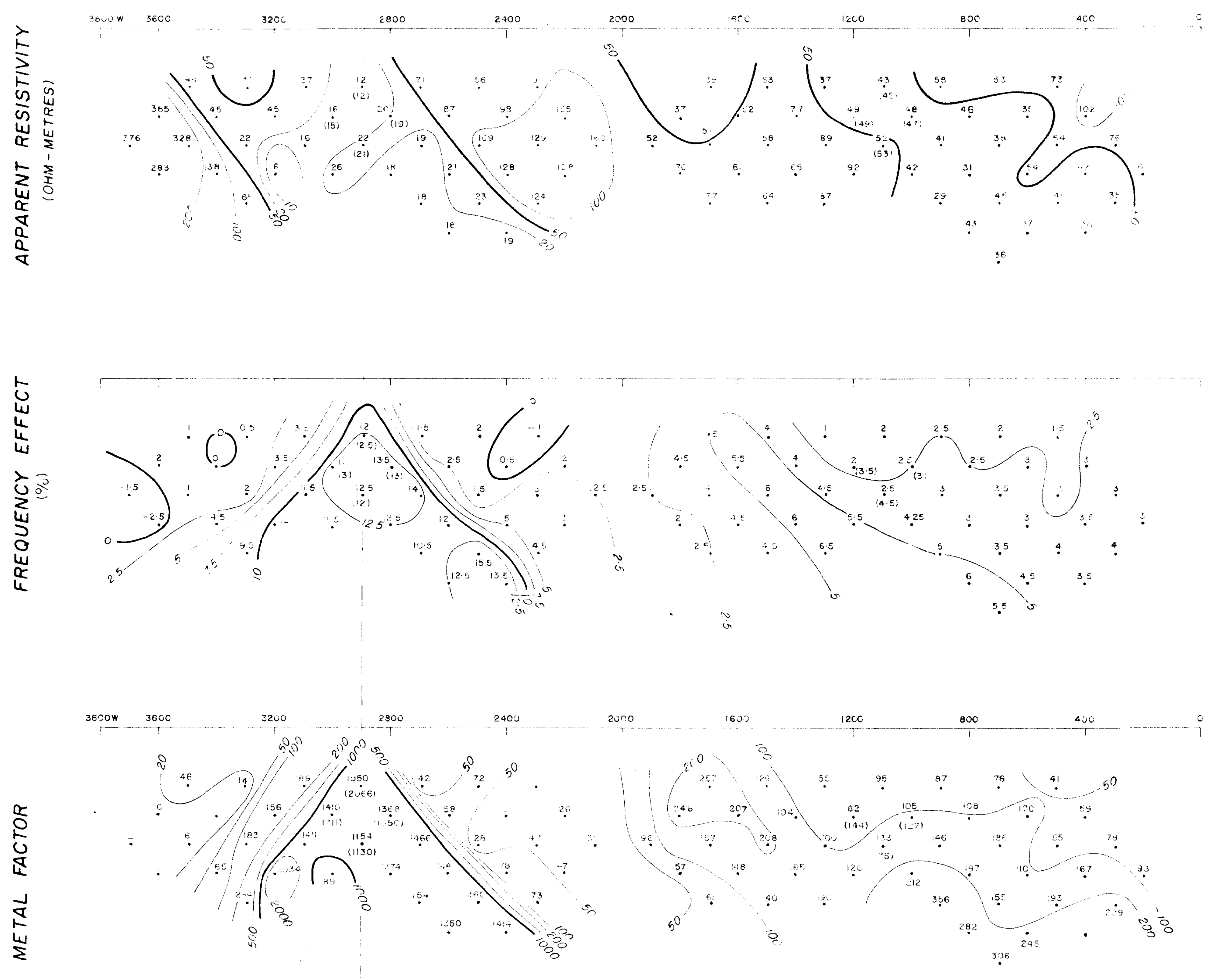
GEOLOGICAL SECTION THROUGH H.Y.C. SHAFT – BEARING N 83° E – LOOKING NORTH



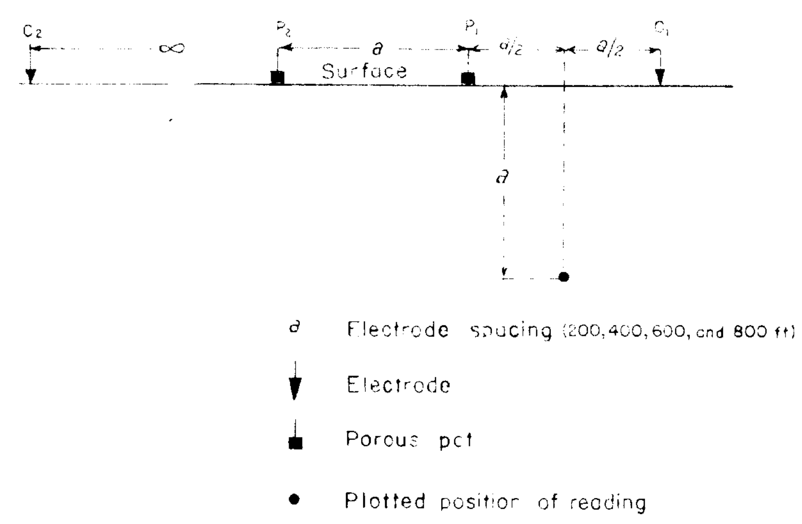
w – Weakly pyritic < 10% Fe } The iron content of the Pyritic Shales varies considerably over the drill hole sections,
s – Strongly pyritic > 10% Fe } and these figures are therefore only an indication of the iron in the strata.

NOTE: Projected position of H.Y.C. shaft on traverse CDU at 2900 E. Traverse 12,200 N is about 100 feet north of traverse CDU.

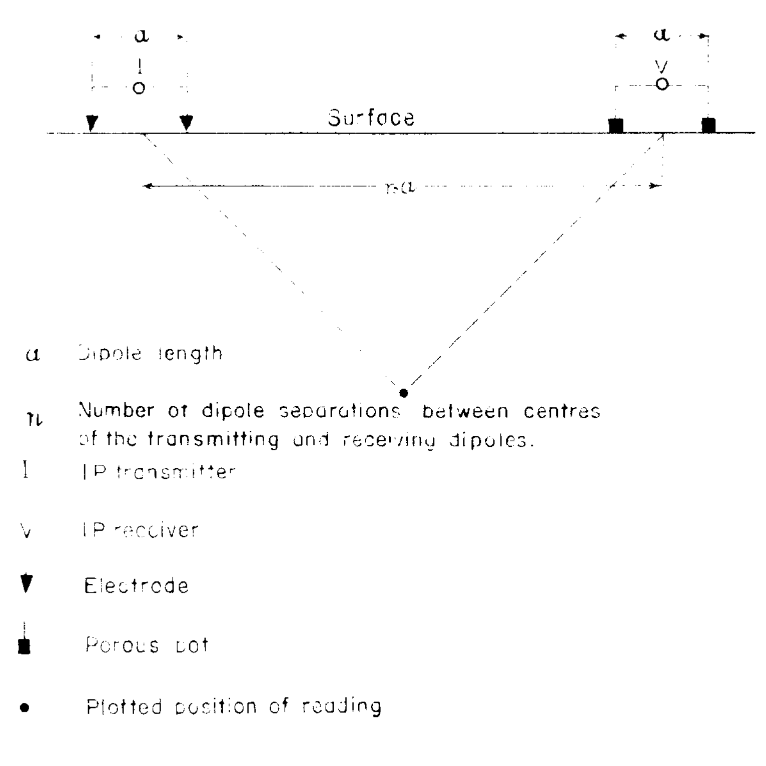
TRAVERSE CDU – 200 FT DIPOLE LENGTH – SURVEYED WITH Mc PHAR EQUIPMENT



THREE-ARRAY ELECTRODE CONFIGURATION USED WITH ASARCO EQUIPMENT



DIPOLE-DIPOLE ELECTRODE ARRAY USED WITH Mc PHAR EQUIPMENT



TRAVERSE CDU, H.Y.C. DEPOSIT
COMPARISON OF IP AND DRILLING RESULTS

(ASARCO RESULTS AND GEOLOGICAL SECTION SUPPLIED BY CARPENTARIA EXPLORATION CO. PTY LTD)

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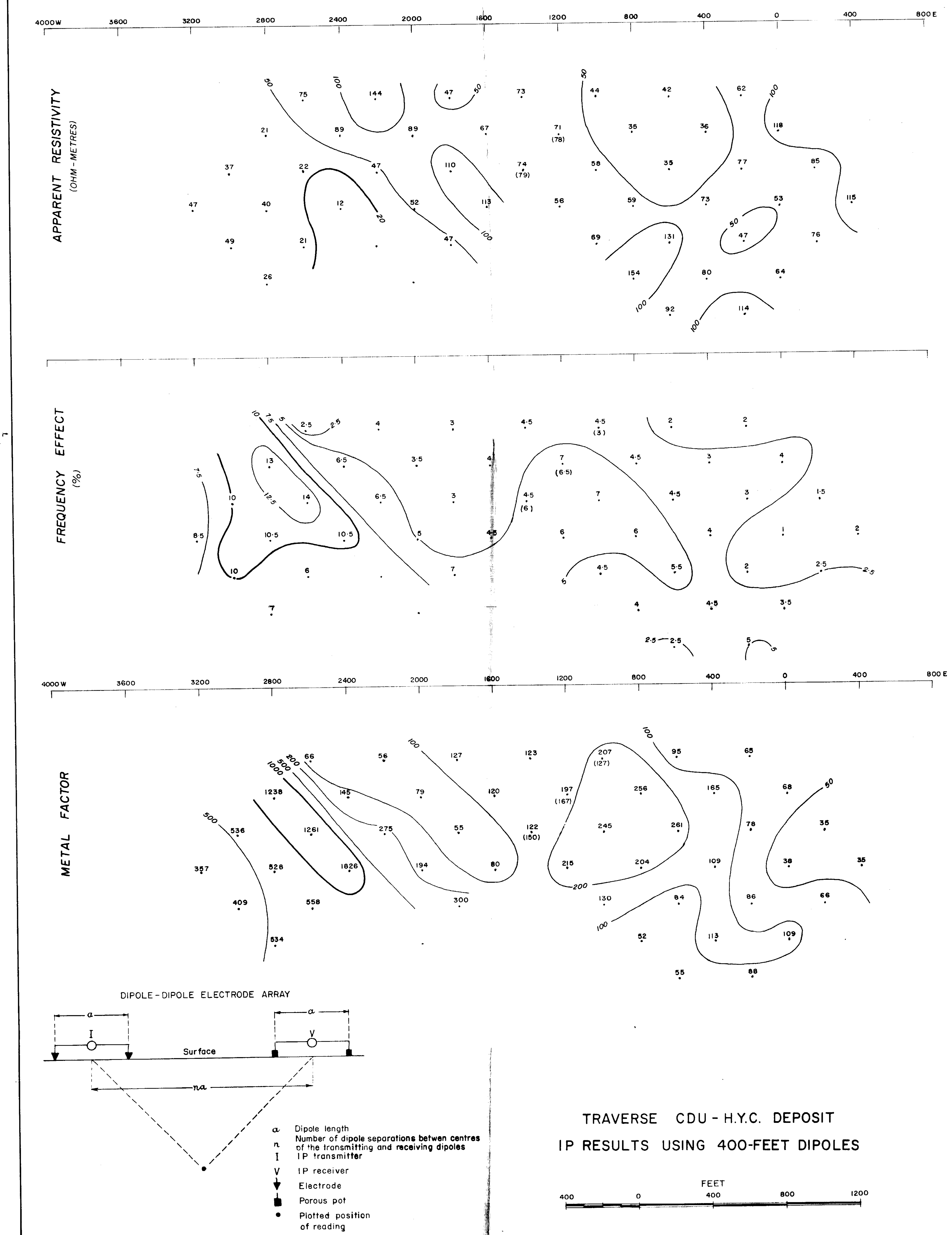
Mc ARTHUR RIVER N.T. 1966

To accompany Record No. 1967/79 Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics E53/B7-67

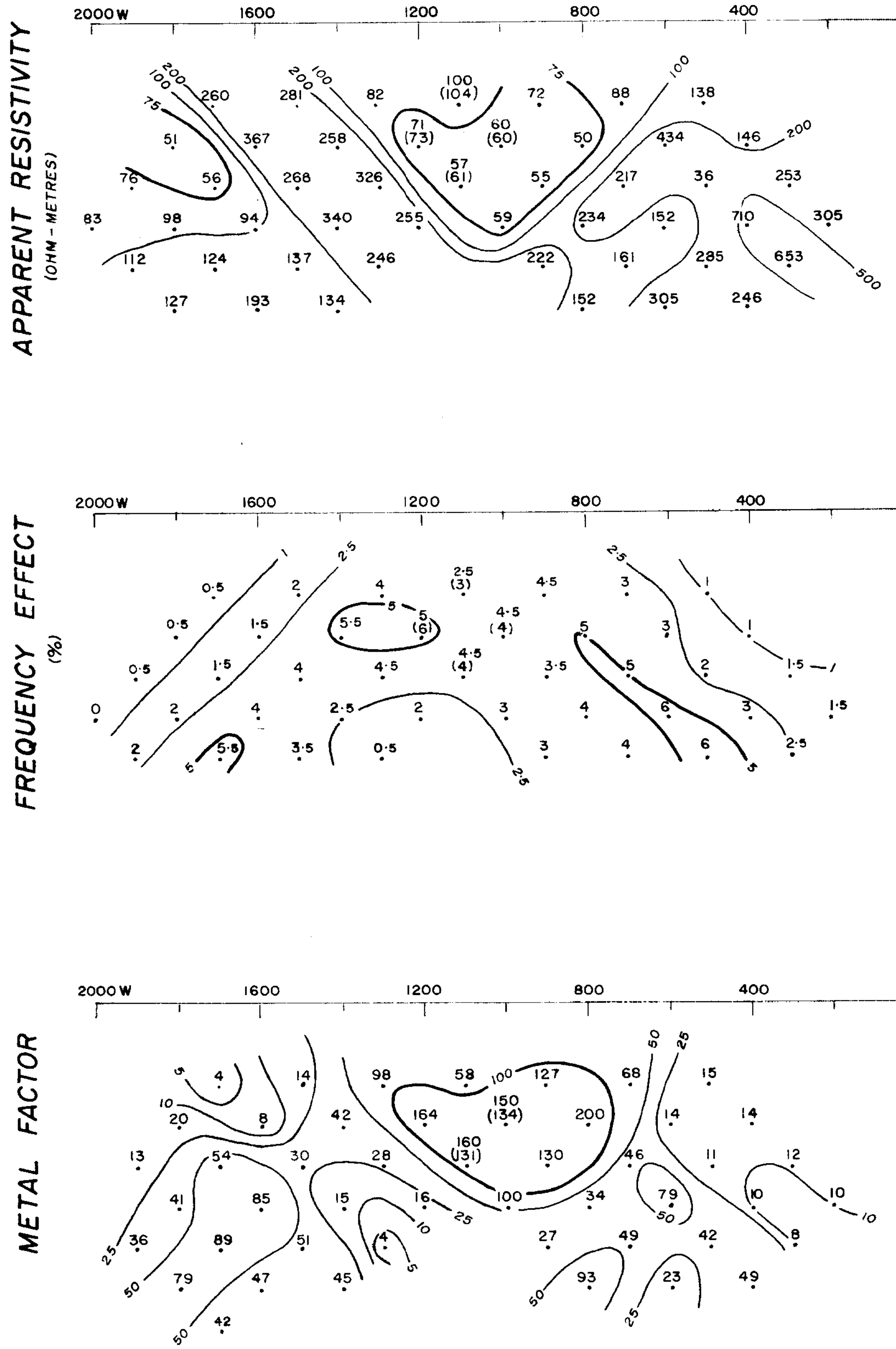


TRAVERSE CDU - H.Y.C. DEPOSIT

IP RESULTS USING 400-FEET DIPOLES

To accompany Record No. 1967/79

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics. E 53/B7-68



TRAVERSE BCU - IP RESULTS USING 200 FEET DIPOLES

For details of the dipole - dipole electrode array, see Plate 3

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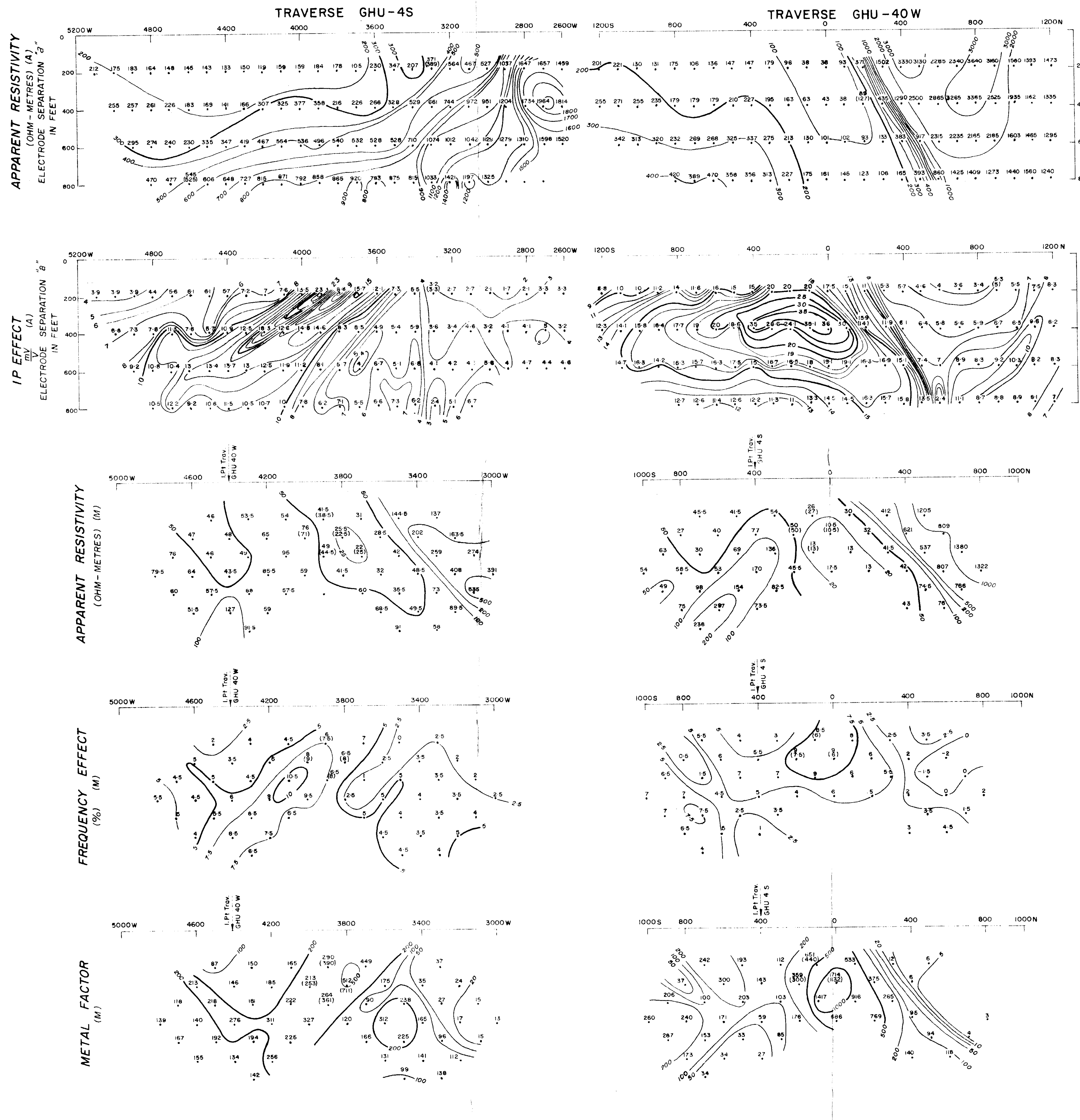
Mc ARTHUR RIVER, NT 1966

PLATE 6



TRAVERSE GHU-4S AND TRAVERSE GHU-40W
COMPARISON OF IP RESULTS

(A) Surveyed with ASARCO equipment
(M) Surveyed with Mc Phar equipment - 200 ft dipole length

} For electrode configuration see Plate 3

FEET
400 0 400 800 1200