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REPORT ON THE
INDUCED POLARIZATION
AND RESISTIVITY SURVEY
IN THE
ORANGE HILL AREA, ALASKA
FOR
DUVAL CORPORATION

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(Duval)

McPHAR GEOPHYSICS LIMITED

NOTES ON THE THEORY OF INDUCED POLARIZATION AND THE METHOD OF FIELD OPERATION

Induced Polarization as a geophysical measurement refers to the blocking action or polarization of metallic or electronic conductors in a medium of ionic solution conduction.

This electro-chemical phenomenon occurs wherever electrical current is passed through an area which contains metallic minerals such as base metal sulphides. Normally, when current is passed through the ground, as in resistivity measurements, all of the conduction takes place through ions present in the water content of the rock, or soil, i.e. by ionic conduction. This is because almost all minerals have a much higher specific resistivity than ground water. The group of minerals commonly described as "metallic", however, have specific resistivities much lower than ground waters. The induced polarization effect takes place at those interfaces where the mode of conduction changes from ionic in the solutions filling the interstices of the rock to electronic in the metallic minerals present in the rock.

The blocking action or induced polarization mentioned above, which depends upon the chemical energies necessary to allow the ions to give up or receive electrons from the metallic surface, increases with the time that a d.c. current is allowed to flow through the rock; i. e. as ions pile up against the metallic interface the resistance to current flow increases. Eventually, there is enough polarization in the form of excess ions at the interfaces to effectively stop all current flow through the metallic particle. This polarization takes place at each of the infinite number of solution-metal interfaces in a mineralized rock.

When the d. c. voltage used to create this d. c. current flow is cut off, the Coulomb forces between the charged ions forming the polarization cause them to return to their normal position. This movement of charge creates a small current flow which can be measured on the surface of the ground as a decaying potential difference.

From an alternate viewpoint it can be seen that if the direction of the current through the system is reversed repeatedly before the polarization occurs, the effective resistivity of the system as a whole will change as the frequency of the switching is changed. This is a consequence of the fact that the amount of current flowing through each metallic interface depends upon the length of time that current has been passing through it in one direction.

The values of the "metal factor" or "M. F." are a measure of the amount of polarization present in the rock mass being surveyed. This parameter has been found to be very successful in mapping areas of sulphide mineralization, even those in which all other geophysical methods have been unsuccessful. The induced polarization measurement is more sensitive to sulphide content than other electrical measurements because it is much more dependent upon the sulphide content. As the sulphide content of a rock is increased, the "metal factor" of the rock increases much more rapidly than the resistivity decreases.

Because of this increased sensitivity, it is possible to locate and outline zones of less than 10% sulphides that can't be located by E. M. Methods. The method has been successful in locating the disseminated "porphyry copper" type mineralization in the South-western United States.

Measurements and experiments also indicate that it should be possible to locate most massive sulphide bodies at a greater depth with induced polarization than with E. M.

Since there is no I. P. effect from any conductor unless it is metallic, the method is useful in checking E. M. anomalies that are suspected of being due to water filled shear zones or other ionic conductors. There is also no effect from conductive overburden, which frequently confuses E. M. results. It would appear from scale model experiments and calculations that the apparent metal factors measured over a mineralized zone are larger if the material overlying the zone is of low resistivity.

Apropos of this, it should be stated that the induced polarization measurements indicate the total amount of metallic constituents in the rock. Thus all of the metallic minerals in the rock, such as pyrite, as well as the ore minerals chalcopyrite, chalcocite, galena, etc. are responsible for the induced polarization effect. Some oxides such as magnetite, pyrolusite, chromite, and some forms of hematite also conduct by electrons and are metallic. All of the metallic minerals in the rock will contribute to the induced polarization effect measured on the surface.

In the field procedure, measurements on the surface are made in a way that allows the effects of lateral changes in the properties of the ground to be separated from the effects of vertical changes in the properties. Current is applied to the ground at two points a distance (X) apart. The potentials are measured at two other points (X) feet apart, in line with the current electrodes. The distance between the nearest current and potential electrodes is an integer number (N) times the basic distance (X).

The measurements are made along a surveyed line, with a constant distance (NX) between the nearest current and potential electrodes. In most surveys, several traverses are made with various values of (N); i. e. (N) = 1, 2, 3, 4, etc. The kind of survey required (detailed or reconnaissance) decides the number of values of (N) used.

In plotting the results, the values of the apparent resistivity and the apparent metal factor measured for each set of electrode positions are plotted at the intersection of grid lines, one from the center point of the current electrodes and the other from the center point of the potential electrodes. The resistivity values are plotted above the line and the metal factor values below. The lateral displacement of a given value is determined by the location along the survey line of the center point between the current and potential electrodes. The distance of the value from the line is determined by the distance (NX) between the current and potential electrodes when the measurement was made.

The separation between sender and receiver electrodes is only one factor which determines the depth to which the ground is being sampled in any particular measurement. These plots then, when contoured, are not section maps of the electrical properties of the ground under the survey line. The interpretation of the results from any given survey must be carried out using the combined experience gained from field, model and theoretical investigations. The position of the electrodes when anomalous values are measured must be used in the interpretation.

In the field procedure, the interval over which the potential differences are measured is the same as the interval over which the electrodes are moved after a series of potential readings has been made. One of the advantages of the induced polarization method is that the same equipment can be used for both detailed and reconnaissance surveys merely by changing the distance (X) over which the electrodes are moved each time. In the past, intervals have been used ranging from 100 feet to 1000 feet for (X). In each case, the decision as to the distance (X) and the values of (N) is largely determined by the expected size of the mineral deposit being sought, the size of the expected anomaly and the speed with which it is desired to progress.

The diagram in Figure 1 below demonstrates the method used in plotting the results. Each value of the apparent resistivity and the apparent "Metal factor" is plotted and identified by the position of the four electrodes when the measurement was made. It can be seen that the values measured for the larger values of (n) are plotted farther from the line indicating that the thickness of the layer of the earth that is being tested is greater than for the smaller values of (n); i. e. the depth of the measurement is increased.

METHOD USED IN PLOTTING DIPOLE-DIPOLE
INDUCED POLARIZATION AND RESISTIVITY RESULTS

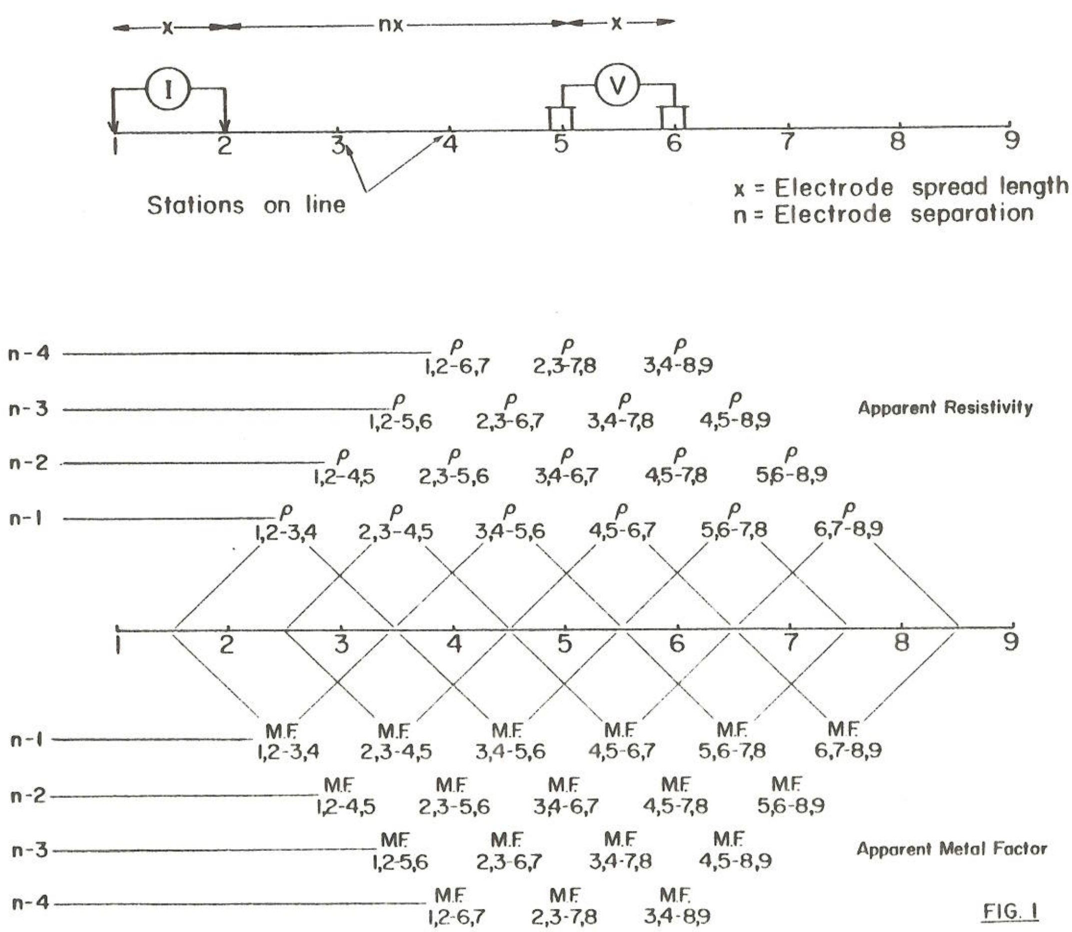

FIG. I

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REPORT ON THE INDUCED POLARIZATION AND RESISTIVITY SURVEY IN THE ORANGE HILL AREA, ALASKA FOR DUVAL CORPORATION

1. INTRODUCTION

At the request of Mr. R. E. Gale, District Geologist for the Company, a brief induced polarization and resistivity survey has been carried out near Orange Hill, Alaska on behalf of Duval Corporation. The area is of interest as the possible location of a "porphyry copper" type deposit.

The limited geologic information in the area shows a wide area of quartz diorite and quartz feldspar intrusives. There is a broad zone of fracturing and quartz-veining. A previous geochemical survey, and two later drill holes, have indicated the presence of weakly disseminated sulphide mineralization with some copper and molybdenum.

The induced polarization and resistivity survey was planned in an attempt to locate, and outline, any unknown zones of metallic mineralization. In the geologic environment at the Orange

Hill Area, any zone of disseminated metallic mineralization could be of potential economic importance.

2. PRESENTATION OF RESULTS

The induced polarization and resistivity results are shown on the following enclosed data plots. The results are plotted in the manner described in the notes preceding this report.

Line 482N	300' electrode intervals	Dwg. IP 2741-1
Line 470N	300' electrode intervals	Dwg. IP 2741-2
Line 452N	300' electrode intervals	Dwg. IP 2741-3
Line 443N	300' electrode intervals	Dwg. IP 2741-4
	200' electrode intervals	Dwg. IP 2741-5
Line 518E	300' electrode intervals	Dwg. IP 2741-6
Line 506E	300' electrode intervals	Dwg. IP 2741-7
Line 503E	200' electrode intervals	Dwg. IP 2741-8
Line 500E	300' electrode intervals	Dwg. IP 2741-9
	200' electrode intervals	Dwg. IP 2741-10
Line 494E	300' electrode intervals	Dwg. IP 2741-11

Also enclosed with this report is Dwg. Misc. 2740, a plan map of the Orange Hill Area at a scale of 1" = 800'. The definite and possible induced polarization anomalies are indicated by solid and broken bars respectively on this plan map as well as the data plots. These bars represent the surface projection of the anomalous zones as interpreted from the location of the transmitter and receiver electrodes when the anomalous values were measured.

Since the induced polarization measurement is essentially an averaging process, as are all potential methods, it is frequently difficult to exactly pinpoint the source of an anomaly. Certainly, no anomaly can be located with more accuracy than the spread length; i.e. when using 300 foot spreads the position of a narrow sulphide body can only be determined to lie between two stations 300 feet apart. In order to locate sources at some depth, larger spreads must be used, with a corresponding increase in the uncertainties of location. Therefore, while the center of the indicated anomaly probably corresponds fairly well with source, the length of the indicated anomaly along the line should not be taken to represent the exact edges of the anomalous material.

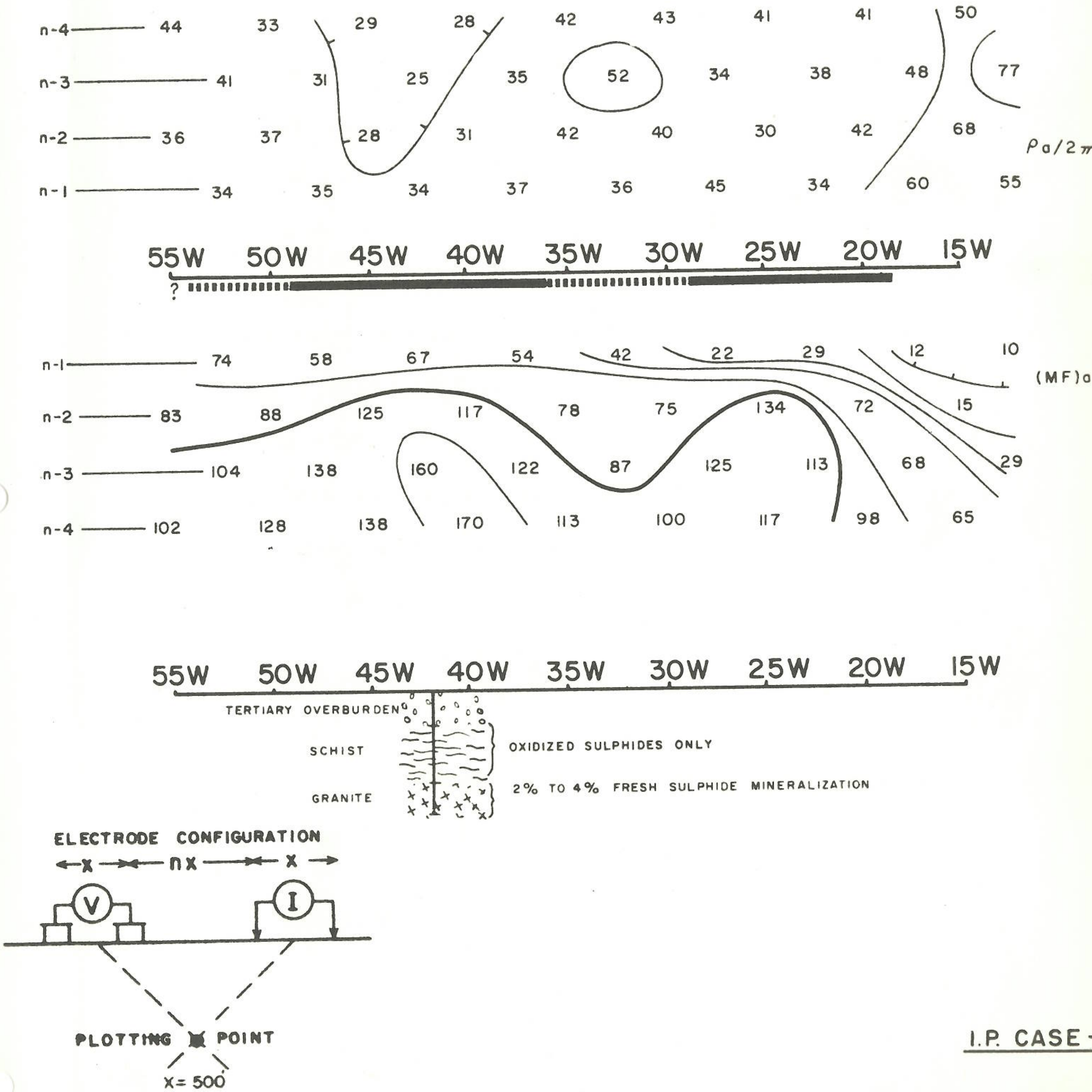
The drill hole locations and the geological information shown on Dwg. Misc. 2740 was supplied by the staff of Duval Corporation.

3. DISCUSSION OF RESULTS

Our experience in other areas has shown that the induced polarization method can be used with great success in locating, and outlining, zones of disseminated sulphide mineralization of the "porphyry copper" type. The results shown in Case History 23 and Case History 24 are typical.

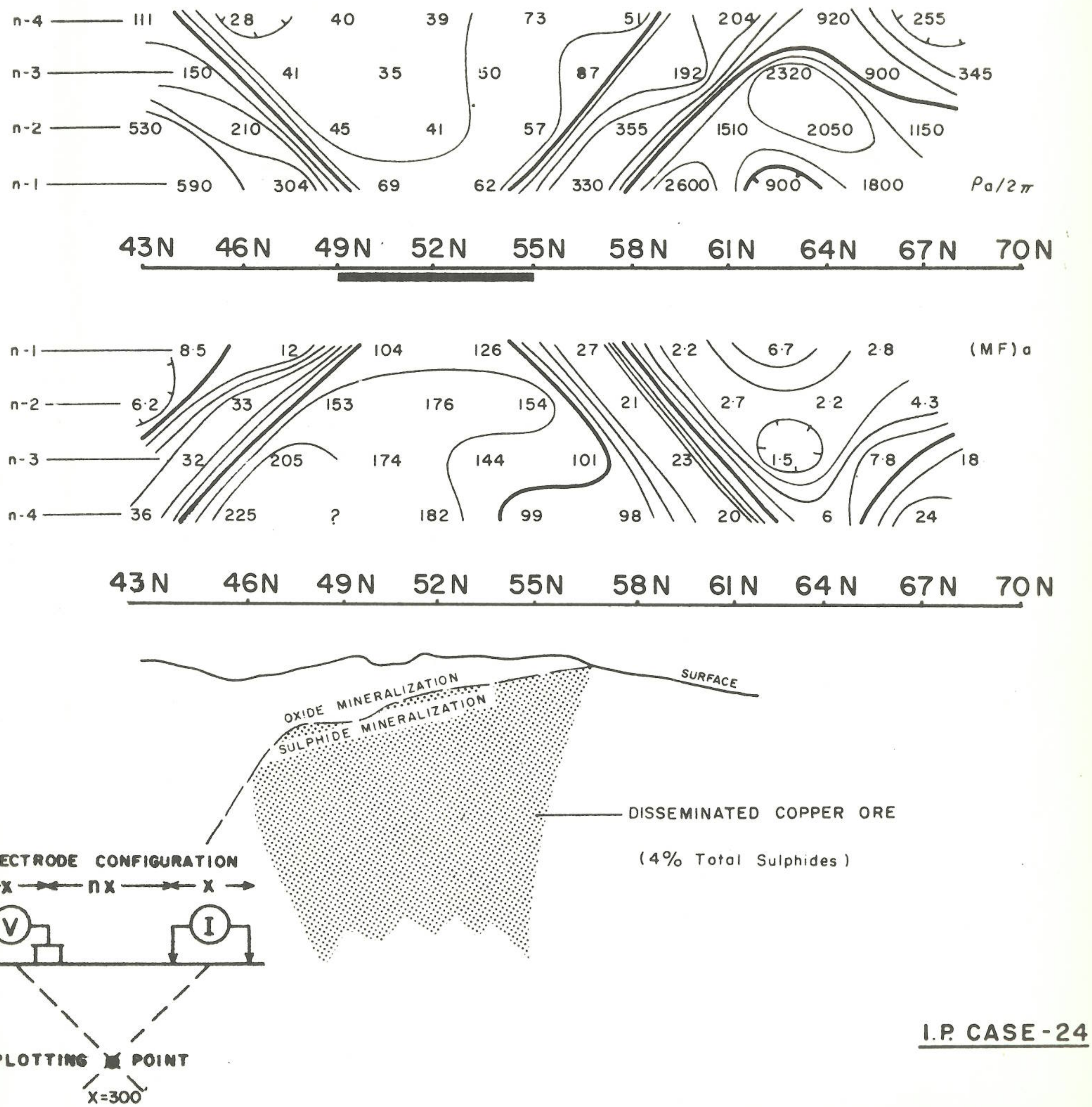
The sources of these anomalous IP effects contain approximately 4% metallic mineralization. The IP anomalies in the two areas are very similar; it should be noted that IP effects in the "ore-grade"

INDUCED POLARIZATION AND DRILLING RESULTS FROM ZONE OF DISSEMINATED MINERALIZATION QUARTZITE, ARIZONA



I.P. CASE-23

INDUCED POLARIZATION AND DRILLING RESULTS FROM COPPER MOUNTAIN OREBODY GASPE AREA, QUEBEC



I.P. CASE-24

copper-bearing zone in Quebec are the same as those from the almost barren pyrite zone in Arizona.

In the proper geologic environment, the method will detect even very low concentrations of metallic mineralization. The IP results shown in Figure 1 located the ore zone at the Brenda Property near Peachland, B. C. The zone contains 1.3 to 1.5 per cent metallic mineralization; however, the mineralization is "ore-grade" because only molybdenite, bornite and chalcopyrite are present.

In a particular geological situation, the IP results can be used to indicate the relative concentrations of metallic mineralization within a large area. The most concentrated sulphide mineralization will be associated with the largest magnitude IP effects. The very weak IP anomalies will be due to smaller (1% or less) concentrations.

However, the IP results can not be used to interpret the location of the highest grade concentrations of copper and/or molybdenum. In some areas they are with the most concentrated pyrite; in other areas there is zoning and the most concentrated pyrite zones will be barren.

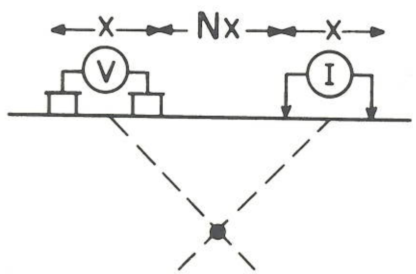
The induced polarization results from the Orange Hill Area are similar to those described above. They indicate the widespread presence of disseminated sulphide mineralization.

One fairly definite, weak zone extends along the western side of Orange Hill. The IP results on Line 500E suggest that the line extends more-or-less parallel to the source. The results on the line to the east and west are lower in magnitude. This anomalous IP zone

INDUCED POLARIZATION
AND
DRILLING RESULTS
FROM
BRENDA AREA
PEACHLAND, B.C.

LINE - 8 S

FREQUENCIES - 0·31 & 5·0 CPS.



X EQUALS 400 FEET

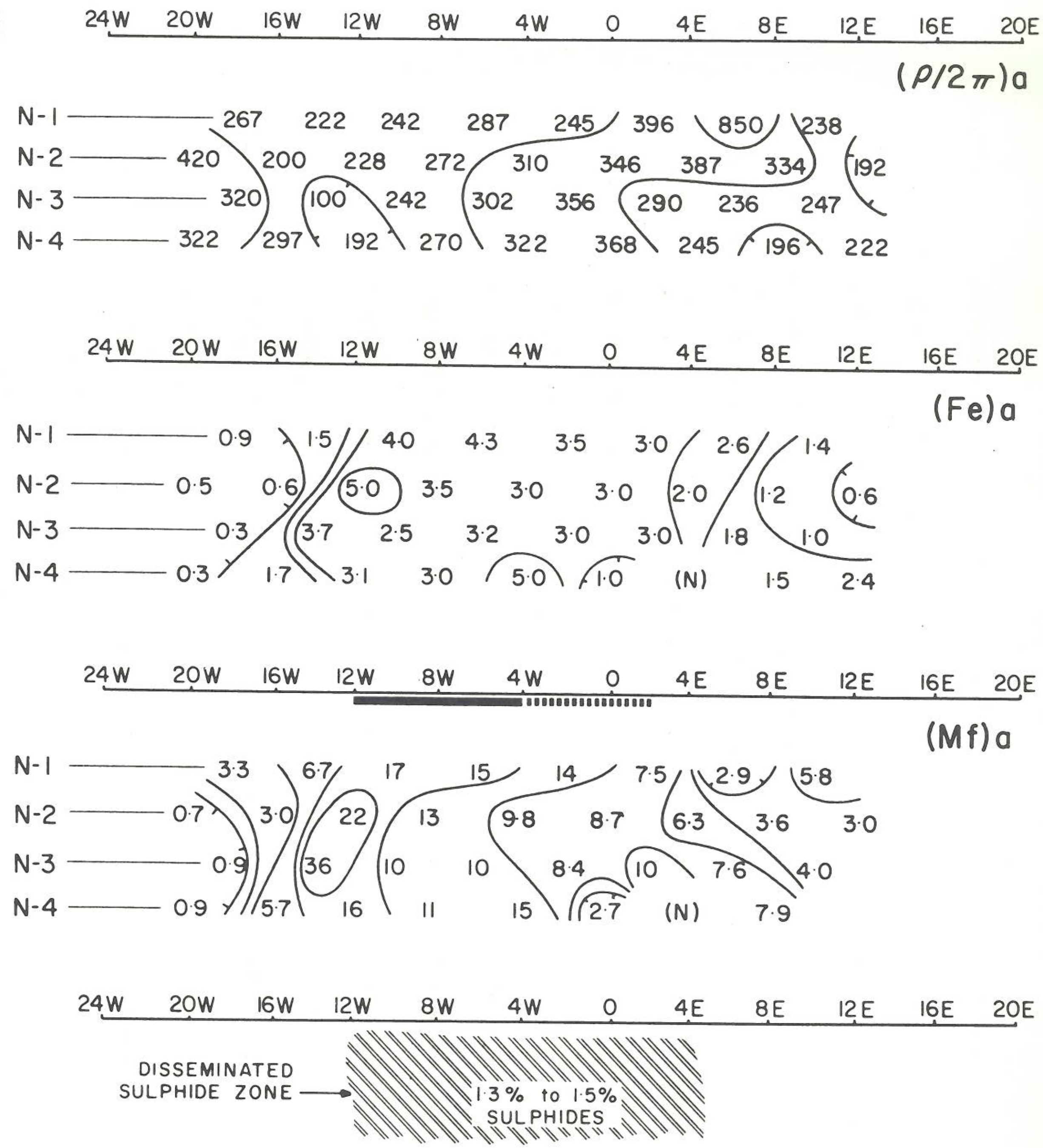


FIG. I

appears to correlate with the mineralization observed in the outcrop at the base of Orange Hill and in the two drill holes. The drill holes may have tested only the eastern portion of the IP anomaly, but there is no indication that the western portion would contain different mineralization. The relatively low magnitude of the anomaly suggests that the total concentration of metallic mineralization is less than four or five per cent, perhaps as low as one or two per cent.

The IP zone centered at Line 452N, 530E to 533E and at Line 443N, 527E to 533E is appreciably larger in magnitude. This anomaly lies east of Orange Hill and correlates with the location of Adit E on Line 452N. Adit E is reported to have encountered more than 50 feet of pyrrhotite, pyrite, chalcopyrite and magnetite that averaged about 0.5% copper, 24% iron and 0.02 ounces of gold. All of the reported mineralization occurs in a skarn zone near the limestone-diorite contact but since the adit and several drill holes stopped in the mineralization, its true width has not been determined.

The detailed measurements with 200 foot electrode intervals on Line 443N clearly outline the source. The source is indicated to be shallow (i.e. less than 200 feet in depth) since the n = 1 measurement is anomalous. The strongest portion of the anomaly has a width of 600 feet or more; however, the anomaly may be as much as 1,400 feet in width. The IP results indicate that the source of this anomaly contains appreciably more metallic mineralization than the zone to the west.

4. CONCLUSIONS AND RECOMMENDATIONS

The induced polarization and resistivity results from the Orange Hill Area have shown the widespread presence of disseminated metallic mineralization.

One low magnitude zone correlates with the known mineralization along the western edge of Orange Hill. This has been tested by two angle holes as shown on the plan. These holes are reported to have encountered mineralization assaying about 0.3% copper with some molybdenum values. Since this drilling has already tested part of the geophysical anomaly further investigations should be based on geological evidence.

There is a more definite anomaly lying 3,000 feet to the east which correlates with the interesting mineralization encountered in Adit E and several short drill holes near Line 452N. This anomaly is most clearly outlined by the 200 foot electrode intervals on Line 443N where the source is stronger, has appreciable width and is quite shallow. An angle hole drilled to pass beneath Line 443N, 532E at a depth of 225 to 250 feet, should intersect the source. The results from this first hole should indicate the possible economic importance of the source and whether further work is warranted.

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