SMALL SCALE RESISTIVITY MODEL EXPERIMENTS IN A TANK

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CERTIFICATE

Certified that the dissertation entitled "Small scale resistivity model Experiments in a Tank", being submitted by Shri HARISH CHANDRA MITAL in partial fulfillment for the award of the Degree of M.Sc. Tech in Applied Geology of the University of Roorkee is a record of student's own work carried out by him under my supervision and guidance. The matter embodied in this dissertation has not been submitted for the award of any other degree or diploma.

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CONTENT

CHAPTER I

INTRODUCTION

Electrical methods of prospecting consist in measuring the electric fields and potentials on the earth's surface and interpreting them in terms of subsurface structures and ore-deposits. They depend for their operation upon the effects produced at the surface of the earth by the distribution of electric currents through subsurface formations. Owing to a large variety of current sources and techniques available for making those measurements, electrical methods have become far more diversified than other geophysical methods.

Often, the electrical properties of adjacent rock formation vary by a much greater amount than their other physical properties. In such cases the electrical methods offer a distinct advantage over other methods. Conversely, electrical methods fail to yield useful data when the electrical properties of adjoining formations are not sufficiently different to create detectable or measurable differences in the electric field.

Electrical Properties of rocks

In electrical prospecting, as in other geophysical methods, the anomaly depends on the contrast in the electrical properties of geological bodies and those of their surrounding formations. These properties are the resistivity, the dielectric constant, and the electrochemical activity.

The resistivity of the formation is determined by its ability to transmit electric-currents when a specified potential difference is applied to it, and may be defined as the resistance offered by a conductor of unit length and unit cross-section.

Apart from conducting ore bodies most of the rock forming minerals are insulators. Notwithstanding this, the conductivities observed insitu are high, because of the presence of electrically conducting fluids in the pore spaces of the rocks. Various attempts have been made to establish a relationship between the resistivity, the porosity and the fractional saturation of sedimentary rocks, which show that the resistivity ρ of a formation can be expressed as follows : (1·1),

$$\rho = I F P_w$$

where F is called the formation factor,

I is called the resistivity index,

and P_w is the resistivity of the water in the formation.

In terms of porosity and saturation, the formation factor and the resistivity index are found to have the following forms :

$$F = aP^{-m} \quad \text{and} \quad I = S^{-n}$$

where P is the porosity of the rock formation,

S the fractional amount of saturation of pore spaces, and a, m, n are emperical constants.

Thus, it is clear that the resistivity of a rock formation is not a characteristic of the formation itself and a given rock type under different conditions of climate and compaction will have different resistivities. However, a correlation of resistivities and rock types with a geological significance can still be attempted. Thus, younger unconsolidated sediments have a resistivity range of 50 to 1000 ohm-cm., whilest older and consolidated sedimentaries have a range between 1000 ohm-cm and 50,000 ohm-cm. and the compact rocks between 20,000 ohm-cm and 1,000,000 ohm-cm. (2·i).

The Dielectric constant, on the other hand, represents the capacity of a formation to store electric charge and is largely dormant when the electric fields are stationary. Under varying fields the dielectric behaviour of rocks leads to displacement currents. The contribution of this property in electrical prospecting as compared to the resistivity, therefore, rises with increasing frequency of the fields. At low frequencies normally employed in the field, the dielectric constant plays little part in determining field conditions and is invariably ignored.

The electrochemical properties of rocks are responsible for the electrical field surrounding chemically polarized ore-bodies, they give rise to interference potentials when metallic electrodes are placed in contact with moist ground. Electrical potentials are also produced when solutions of different concentrations come in contact with one another, or when a conducting fluid flows through a porous formation under pressure. More specifically, these spontaneous potentials are termed as

(i) electrode potentials,
(ii) diffusion potentials, and
(iii) electrofiltration potentials.

On the other hand, potentials caused by the application of extraneous electric field are called polarization potentials.

Applications

Electrical methods have been applied to varied types of problems relating to engineering and mining for highly conducting materials, but its use in exploration for petroleum has been rather limited. This is because ,

a) Oil sands have ordinarily a lower resistivity contrast with their surroundings, and
b) because electrical methods possess a comparatively shallower penetrability owing to the difficulty of energizing a very depp section of the earth by an external source.

However, the telluric currents which are driven by a geomagnetic source penetrate to fairly great depth, where oil and gas are normally found, and this method is beginning to find application in oil prospecting. Electrical methods on the other hand are extensively used in wells for stratigraphic and lithological correlation and play an important role in the development of oil fields.

Electrical prospecting methods are becoming increasingly important in the water supply problems and in engineering geology where resistivity techniques are used to measure depths to bed rocks at prospective dam sites as well as to explore foundation conditions for the location of other engineering works.

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C H A P T E R II

REVIEW OF ELECTRICAL METHODS

The electrical methods are more diversified than any of the other geophysical methods, hence a clear cut classification is not possible. A classification adopted here is based on two criteria i.e.

A. Nature of the electric source, and
B Time variation of the electric fields.

A. The source of an electric current in the earth may be either, natural or artificial. The natural sources consist of (i) Self - Potential, and (ii) Telluric currents.

The artificial source methods are further classified according to the nature of measurement made. These are (i) the Equi-Potential line method, (ii) the Potential-Drop-Ratio method, and (iii) the Resistivity method.

B. On the basis of time variations, two major groups can be distinguished :

a. Methods using direct currents (D.C.), and
b. Methods using alternating or varying currents (A.C.).

In A.C. methods measurements may be made at Audio frequencies or Radio frequencies, depending upon the problem involved.

Self Potential method

The Self-potential method is based on natural phenomena in which the electrical field is furnished by the electrochemical polarization of ore bodies and other geological formations, producing natural flow of currents in the earth. The general subsurface distribution of natural earth currents can be elucidated by observing the pattern of equipotential lines at the surface of the ground. Sulfide ore-bodies in contact with ground water, as well as metals in placer deposits, and migration of subsurface waters give rise to such electrochemical potentials.

At the surface of the earth, the current flow is usually directed towards or away from a point, usually above the ore body which is respectively called the negative centre or the positive centre. Negative centres are usually produced by sulphides, whereas anthracite are known to be associated with positive centres. These centres can be delineated by any of the following three measurements over the surface of the ground;

(a) by locating points at the same potential,

(b) by measuring the earth potentials at regularly spaced intervals and drawing the equipotential contours, and

(c) by obtaining potential profiles across the ore-body.

Telluric Current

Telluric currents are the natural periodic earth currents of global extent flowing through the earth's crust. These cause potential drops across suitably separated points. The form of the potential drops remain substantially similar over long distances.

Although the mechanism by which these currents are generated has not been precisely established, it is generally believed that they are induced in the earth by innospheric currents, and appear to follow the sun. The earth currents can not be measured as such, but the horizontal potential gradients they produce at the surface and in bore holes can be measured. (3·i).

Applications of Telluric Currents

Although the telluric current flows along the earth's surface in large sheets which extend well into the earth's crust. The distribution of current density within the sheet will depend on the resistivity of the formations through which the currents flow.

Thus if poorly conducting bodies penetrate more highly conducting formations, the lines of current flow will tend to by-pass the poorly conducting body and cause distortion in the potential gradients at the surface which are associated with the current. The proper investigation of these distortions make it possible to locate the ore-body.

Methods depending on external energisation

All geoelectric methods employing external energisation, consist of an energizing system i.e. a source of power coupled to the ground either conductively or inductively. For the measurements of the surface potentials the receiver consists of a single electrode or more than one electrodes. These methods fall into three main groups, depending upon the nature of measurements namely, the Equipotential method (E.P.), the Potential-Drop-Ratio method (P.D.R.) and the Earth Resistivity method (E.R.).

Equipotential method

The E.P. method as the name suggests involves the mapping of equipotential lines on the surface in the presence of a pair of grounded electrodes. If an external voltage is applied through two electrodes inserted in the ground, there will be a flow of current through the earth from one electrode to the other. If the medium in which the current flows is homogeneous in its electrical properties, the flow-lines will be regular. Departure of the subsurface region from homogeneity will cause distortions in the lines of current flow, indicating the existance of a heterogeneous material which will thus lend itself to detection.

Potential-Drop-Ratio method

In this method, the ratio of potential differences between successive intervals of the ground is measured. This method is also applied to a determination of depth of horizontal and vertical formation boundaries. It is best adopted to an investigation of vertical formation boundaries. As the P.D.R's resemble potential gradients they have a higher resolving power. when used for direct interpretation they are called the P.D.R. method and involve measurements of P.D.R's at varying distances from one of the power electrodes and usually at right angles to the line joining the two current electrodes. By this means the effect of the second electrode is virtually eleminated.

Resistivity Method

The resistivity methods allow useful geological information to be deduced from the field measurements. In the resistivity methods, a source of potential is applied to the ground between two points and the potential is measured between two additional points whose spacing or distance from the primary electrodes is varied. This ratio of voltage and current, multiplied by a spacing factor, gives what is known as the apparent resistivity as a function of spacing and, hence, as a function of depth penetration. Measurement of the apparent resistivity with electrode spacing thus makes possible the determination of depths to bed rocks, to ore-bodies, to water tables and to beds of stratigraphic significance. If on the other hand the spacing is kept constant and the arrangement as a whole is moved, lateral variations in the character of a given formation upto a certain depth may be determined.

Resistivity methods like other artificial source methods can be applied either using D.C. or A.C. A comparison of these methods thus appears appropriate at this stage.

Direct current method

In D.C. measurements, the energising electrodes are positioned to include the area under investigation. Sufficient amount of current is allowed to flow through electrodes in order to create measurable changes. The current is supplied by a battery or a generator. Wheatstone bridge methods are generally employed for determination of resistance which in tern is used to calculate the apparent resistivity. The methods have attained considerable importance because of the ease that they offer in measurements of rock resistivity either in the laboratory or in situ.

Wenner-Gish-Rooney method, consists of a battery, a double commutator, four electrodes, a milliammeter and a potentiometer. A current is supplied by a battery through a milliammeter to the two external current electrodes. The potential difference between the internal pair of potential electrodes are read on the potentiometer. The ratio of voltage and current, multiplied by a spacing factor, gives the apparent resistivity. (4·i),

$$\rho = 2\pi a \frac{V}{I}$$

Alternating Current

An alternating current can also be used for the measurement of apparent resistivity, using the same relation as given above. Both low and high frequencies have been employed in geophysical prospecting, depending upon the nature of the problem involved.

Frequency effects

A.C. methods have limitations of reduced depth penetration, as compared to the direct current methods. The flow of alternating current is governed by the impedance of the equivalent electrical circuit. For conductors of large thicknesses the inductance of the current path in the interior is greater than that at the surface. Thus alternating currents tend to flow nearer to the surface. This effect is called the 'skin effect'. At very high frequencies the current is almost confined to the outermost surface.

A mathematical relation governing the depth penetration of A.C. (300 to 1000 cycles) may be derived from the laws of electromagnetic wave propagation by introducing certain simplifications. For the above frequencies, the current density at a depth 'd' from the surface of a conductor may be written

(4·ii),

$$i_d = i_o e^{\frac{-2\pi d}{c}\sqrt{\mu f \sigma}} \quad \sin(2 f t - \frac{2\pi d}{c}\sqrt{\mu f \sigma}).$$

where
i_o is the current density at surface,
f is the frequency,
μ is the permeability,
σ is the conductivity,
c is the light velocity
and t is the time.

The equation states that reduction of amplitude and a phase shift between surface and depth current occurs. The attenuation for the peak values of the current is therefore,

$$I_d = I_o e^{\frac{-2\pi d}{c}} \sqrt{f\sigma}$$

where permeability has been assumed to be equal to 1. The depth at which the surface current density has dropped to $\frac{1}{e}$ of its value,

with ρ as resistivity, i.e. $\frac{2\pi d}{c}\sqrt{f\sigma} = 1$.

or $d = \frac{c}{2\pi}\sqrt{\frac{\rho}{f}}$.

Since the presence of good conductors at the surface or near the surface reduces the depth of penetration, provision is made in some A.C. method to lower the frequency when greater penetration is desired. The low frequency methods are well suited for laboratory measurements because low-frequency A.C. is readily available. Usually audio-frequency from 50 to 1000 cycle are employed for resistivity measurements in the field. In this range the head-phone can be conveniently employed as an indicating instrument.

Penetrability of electrical methods

The penetration of electric currents is governed both by the spacing of electrodes and frequency of the alternating current. In homogeneous ground and at low frequencies the penetration of current is proportional to the electrode - separation 'a' and can be controlled as desired depending upon the depth to which apparent resistivity is measured. If, therefore, the electrical character of the ground changes, the resistivity obtained for a given electrode separation does not correspond to that at any depth, but is the apparent resistivity.

In the case of A.C., the depth of penetration depends on the frequency of the current also, as unlike the direct current, the passage of alternating current is controlled by the capacitive and inductive reactances as well as by the resistance of the circuit.

Since the presence of good conductors at the surface or near the surface reduces the depth of penetration.

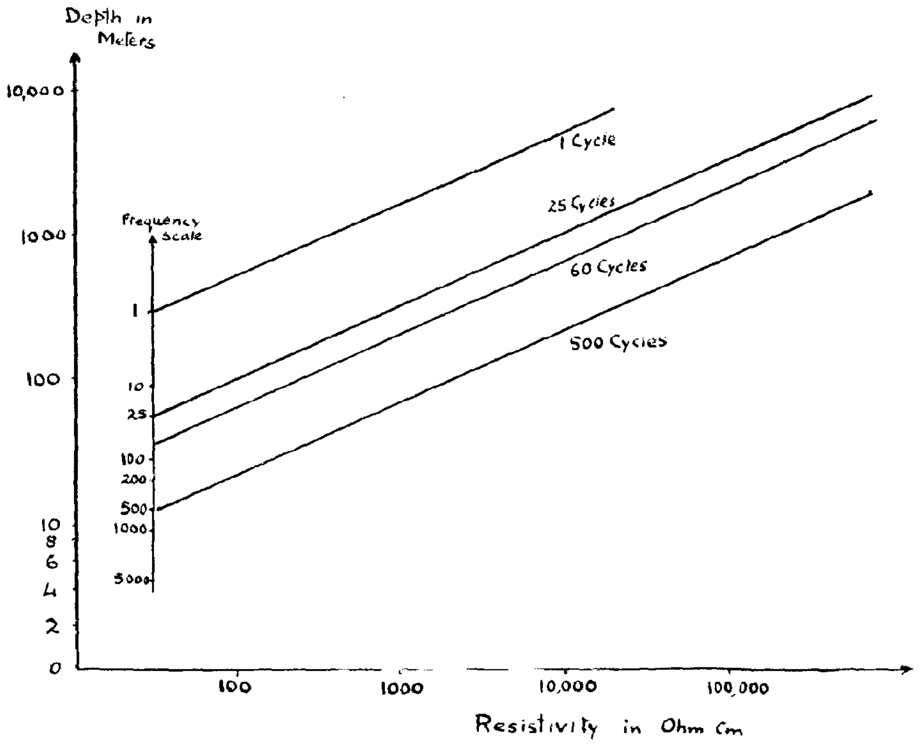


FIG 2·1 DEPTH PENETRATION FOR A.C. OF VARIOUS FREQUENCIES.

Lower frequencies are used in A.C. methods when greater penetration is desired. Figure 2·1 shows on a double logarithmic scale, the depth of penetration of alternatic currents at frequencies of 1,25,60 and 500 cycles, as a function of resistivity. (4·ii).

On the basis of certain differences in applicability and technique, a comparative study between the D.C. and A.C. methods has been attempted which is given below :

	D.C. Methods	A.C. Methods
1.	In the D.C. Methods, contact resistances also have their effects due to electrode polarisation.	The ground resistances are eliminated as the current changes its direction rapidly.
2.	There is no elliptical polarization.	Elliptical polarization takes place.
3.	Depth of penetration is governed by electrode spacing, i.e. greater spacing more is the penetration.	Depth control is governed both by spacing and frequancy, i.e. the larger the frequency the less is penetration.
4.	Detectors used are of electromagnetic type.	Head-phones can be used as detectors.
5.	No quadrature component.	Quadrature component generally present.
6.	Null methods can be used with the aid of ordinary potentiometers, i.e. by balancing amplitudes.	Null methods can be used only with A.C. potentiometers offering controls of both amplitud and phase.

Direct current has the advantage that the equipotential points can be located with greater precision and that the galvanometer gives a clear indication of the direction in which to move the electrode. A disadvantage is the necessity for porous pots and the interference from polarization and other D.C. effects.

Alternating currents on the other hand offer the advantage of portability of the movable circuit, possibility of amplification of signals, use of head-phones and freedom from current interference. Disadvantages may arise from its use in regions where equipotentials have to be drawn separately for the inphase and the quadrature components.

CHAPTER III

THEORY OF RESISTIVITY METHODS

The resistivity method is based essentially on the same principle as the equipotential line method but it is much more powerful in that it provides a quantitative measure of the conducting properties of the subsurface.

The effect of a vertical change in conductivity on surface potential is illustrated in the Fig. No. 3·1 , which shows a two layer ground. The lower layer having more conducting. The current lines are naturally attracted towards the lower medium and the current density in the upper-medium is consequently less than in the lower. (4·iii) Since the equipotential lines are at right angles to the current lines, their spacing and hence the potential gradient, is likewise affected by the presence of layers of different conductivities.

Measurements of potential differences in the vicinity of one power electrode, or between two power electrodes, can, therefore, give information regarding the presence of subsurface formations of different conductivities. When these measurements are supplemented by measurements of the current, it is possible to determine the resistance of the circuit. By applying a factor depending on the spacing of the electrodes, the apparent ground resistivity can be obtained. This will represent the true resistivity only if the medium is homogenous. The depth to which resistivity is measured can

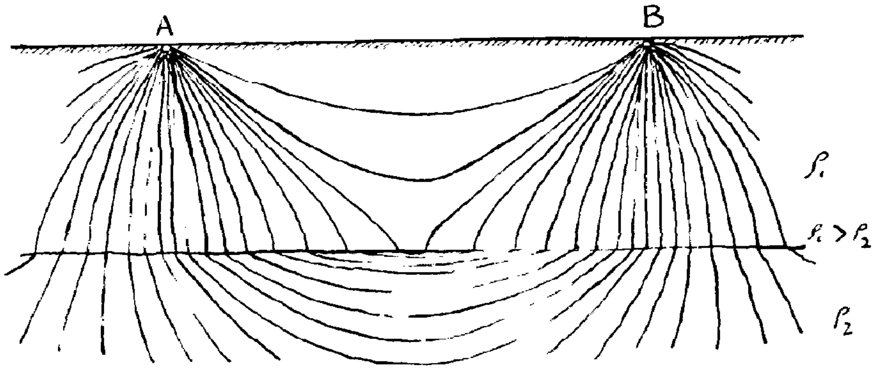


FIG 3·1, LINES OF CURRENT FLOW IN LAYERED SECTION

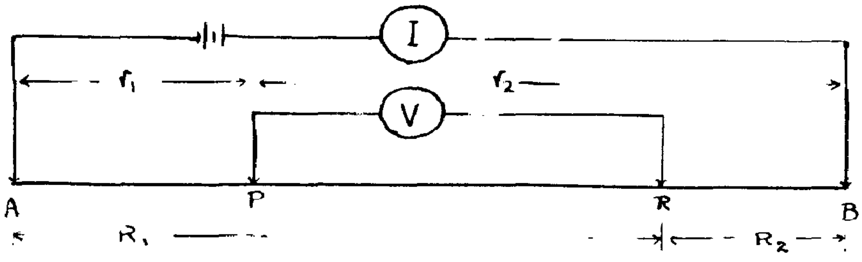


FIG. 3·2, ARRANGEMENT OF ELECTRODES.

be controlled by varying the spacing between the electrodes. This makes possible two applications of the method. In the first place the spacing is kept constant and the arrangement as a whole is moved over the ground. In the second, measurements are made at one location which is the centre of the measuring arrangement, whilst the separation between the electrodes is continually increased as if the electrode system were expanding about this point. Thus, by expanding the electrode system, the depth penetration is increased and the apparent resistivity is obtained as a function of depth.

For the apparent resistivity measurements, four equally spaced electrode system is the most generally used arrangement; other arrangements can also be used according to the nature of the problem.

Principle

If, at the surface of the homogenous and isotropic ground of conductivity σ , an electric current I is introduced by means of two point electrodes, A and B, and if the current flows from A to B, the potential at any point P on the surface is given by, (4·iv),

$$V_P = \frac{I}{2\pi\sigma}\left(\frac{1}{r_1} - \frac{1}{r_2}\right),$$

where r_1 and r_2 are the distances of point P from electrodes

A and B, respectively. The potential difference between two points P and R, which have the distances r_1 ; r_2 and R_1 ; R_2 respectively, from the electrodes(fig. 3·2) is

$$V_P - V_R = V = \frac{I}{2\pi\sigma} \left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{R_1} + \frac{1}{R_2} \right) \qquad (1)$$

Hence, the resistivity

$$\rho = \frac{1}{\sigma} = 2\pi \frac{V}{I} \left(\frac{1}{\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{R_1} + \frac{1}{R_2}} \right) \qquad (2)$$

This equation holds for any postion of the current electrodes A and B and the potential electrodes P and R and does not change when current and potential electrodes are interchanged.

Differences in the position of the potential electrodes with respect to the current electrodes give rise to various resistivity methods. By selecting definite positions, it is possible to simplify the field prosedure or to give the expression for resistivity a form that will simplify the interpretation of the results.

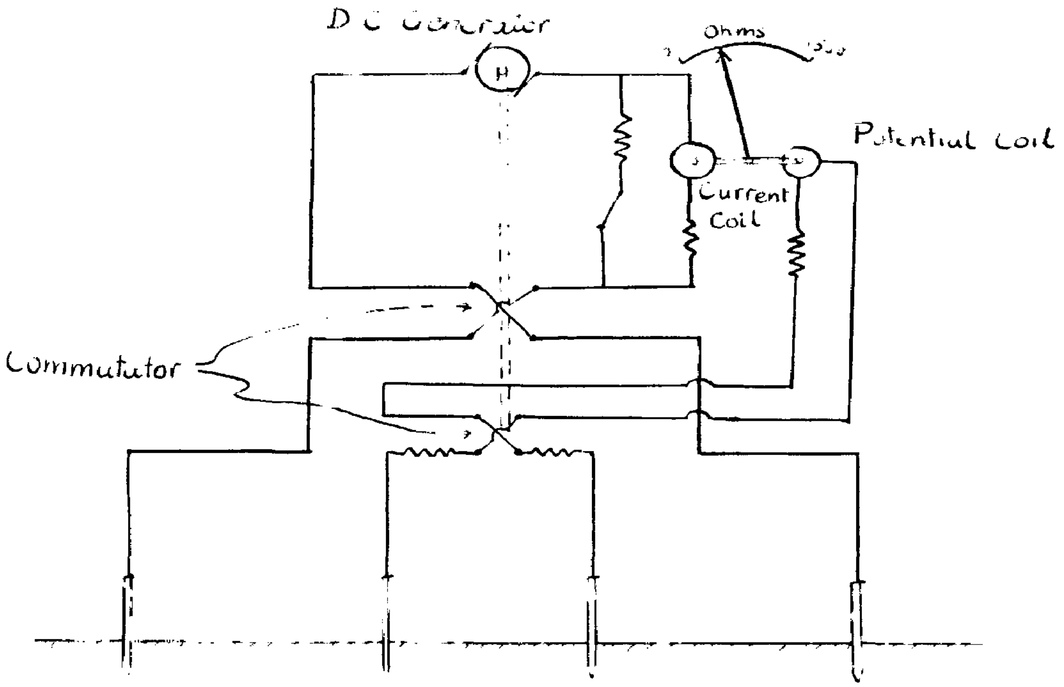
If the electrodes are laid out along a line and the separations are increased in a systematic manner, the change in ρ with electrode spacing makes it possible in many simple cases to determine the variation of resistivity with depth.

To illustrate the method, let us assume that the subsurface consists of two layers, the upper layer having a resistivity ρ_1 and the lower one having a resistivity ρ_2 which is less than ρ_1. The current between electrodes A and B will not flow along circular arcs as it would in the case of a homogeneous earth. The lines of flow are distorted downwards as shown in figure 31 because the higher conductivity below the interface results in an easier path for the current within the deeper zone. For the same reason, the total current is greater than it would be if the upper material were to extend downward to infinity.

Moreover, the deeper the interface, the smaller the increase in the current flow, while the greater the electrode separation in proportion to the depth of the interface, the greater the effect of the low-resistivity-substratum on the current that flows between the electrodes.

Electrode Arrangements

In actual practice a number of different surface configurations are used for the current and potential electrodes. Here, for the model experiments the spacing of the electrodes is kept constant and the arrangement as a whole is moved for resistivity mapping.



Schematic Megger Circuit

FIG 3·4

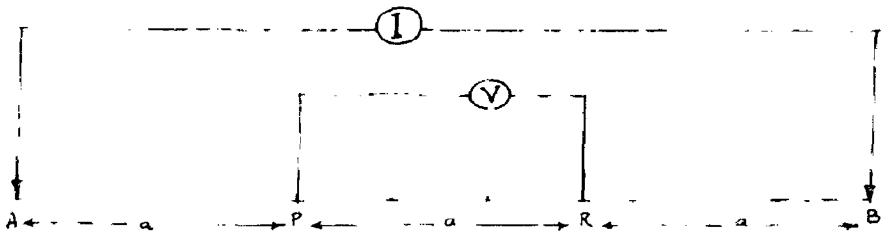


FIG. 3·3

Wenner-Gish-Rooney method

This is the most common electrode setup. In this method two potential electrodes are placed in line with the two current electrodes, so that all four electrodes are situated at equal distances from one another (fig. 3.3) ,with 'a' as the distance between the electrodes $r_1 = R_2 = a$ and $r_2 = R_1 = 2a$. Then equation gives the expression for the resistivity as

$$\rho = 2\pi a \frac{V}{I} \qquad (3)$$

Prodedure and Equipment

For measurement of the apparent resistitity, widely different procedures, electrode arrangements and equipment are used. However, only the ratio $\frac{E}{I}$ is needed for calculating the apparent resistivity, and it is advantageous to use instruments which measure this ratio directly. The Megger earth tester is the best known at present and may be used in resistivity measurements to delineate shallow subsurface bodies.

The schematic Megger circuit is as shown in figure 3.4 . The current coil is in series with the current or external leads, while the potential coil is across the internal or potential pair of electrodes. (4.V) .

The current coil and the potential coil of the ohmmeter are mounted on a common spindle (not shown in diagram), so that the resultant effect of the potential and the current is obtained at the Megger scale directly in ohms. The instrument therefore indicated the effective resistance between terminals P and R.

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CHAPTER IV

INTERPRETATION AND MODEL EXPERIMENTS

INTERPRETATION

The data obtained from a resistivity survey (either resistivity mapping or resistivity soun-ding) is subjected to various techniques for interpretation of the geology of the area. These interpretations can be made either :

(i) Qualitatively (using appearance of the curve),

(ii) Quantitatively, by analytical interpretation methods,

(iii) Quantitatively, using 'type' curves calculated for given conditions, or

(iv) With the help of model Experiments.

(i) Qualitative methods

This is a purely non-mathematical treatment which seeks to interpret resistivity data directly in terms of the geology based and therefore possesses a definite place in resistivity methods. Rise in the values of apparent resistivity generally corresponds to poor conductors within the depth range of penetration, and vice-versa. In some cases these may also refer to lateral variation of apparent resistivity of the formation due to change in lithology or due to change in depth of the formation.

Though these methods are frequently employed for preliminary interpretation, a complete reliance on this method may sometime lead to serious error in interpretation.

(ii) Quantitative interpretation (analytical)

These methods of interpretation are particularly applicable for simple cases of two or three layer problems. The most frequently employed is Tagg's methods. This method involves the solution of a number of simultaneous equations, giving depth 'h' as a function of dimming factor K, which depends upon the resistivity of the formations involved. A family of curves giving the ratio of apparent resistivities divided by surface resistivity as a function of h/a are prepared for different values of K from -0.1 to + 1 at steps of 0.1 K values. Theoretically two observations of resistivities for two different electrode separations can yield the values of both (depth) 'h' and K, using the Tagg's curves.

The value of K when obtained can be further used to give the resistivity of the lower horizon being mapped, by the equation. (4·vi),

$$\rho = \rho_s \left(\frac{1+K}{1-K} \right)$$

where ρ_s is the surface resistivity,

ρ is the resistivity of the formation being mapped,

and K is the dimming factor of the area.

When the data is available for a number of electrode separations a family of curves is drawn showing variations of h/a with different values of K and the point of common intersection of these curves give fairly accurate values of h and K for further interpretation.

Three layer problem

The Tagg's method of interpretation can be extended to tackle a three layer case provided it is justified to assume that the third layer does not influence the first part of the curve. This requirement is satisfied when the thickness of the second layer is two to three times the thickness of the top layer.

Thus, the problem is redused to two-layer case by considering first the upper two layers behaving as a single unit as far as the electrical behaviour is concerned and then this single unit and the third layer behave as a double layer. The average resistivity of two infinite layers of resistivity ρ_1 and ρ_2 and respectively thickness h_1 and h_2, can be written as follows, using Kirchoff's relation : (4·vii),

$$\frac{h_1 + h_2}{\rho_{av}} = \frac{h_1}{\rho_1} + \frac{h_2}{\rho_2}$$

where ρ_{av} is the average resistivity of the combined two layers.

Having obtained the average resistivities of the top two layers, the upper two layers may be considered as one unit and considering a two layer problem the resistivity and depth of the third layer can be calculated.

MODEL EXPERIMENTS

Small-Scale Experiments

Model experiments are of grèat value in interpreting and checking the anomalies produced by ore-bodies, as theoretical calculation would be two time consuming and tedious. They, thus serve a two fold purpose in the interpretation of resistivity measurements i.e.

(i) they offer a check on theoretical calculations,

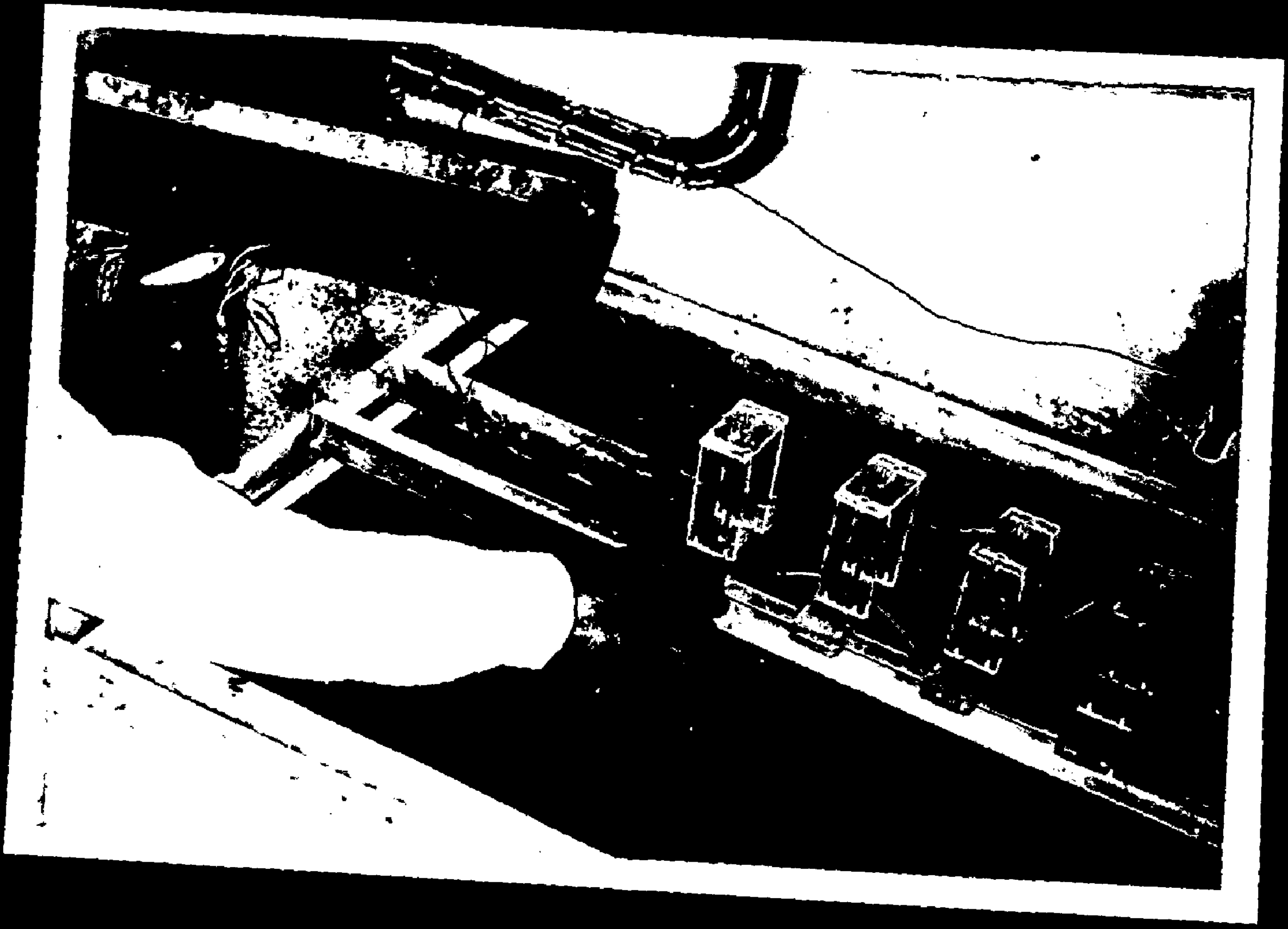
(ii) they permit simulation of geologic bodies whose effects can not be calculated, theoretically.

Model experiments in the laboratory are usually performed in tanks filled with a solution of appropriate resistivity to simulate the country rock.

The ore-body or the geological structure whose anomaly is to be studied is then simulated by a metallic or carbon material of suitably scaled resistivity and immersed in the solution.

Experimental Details

The experimental model in which the laboratory work



was carried out is made of concrete. The tank being 119.0cm long, 58.0 cm wide and 38 cm deep. The tank was filled with a solution of copper sulphate to simulate a homogeneous and isotropic ground.

The ore models used here were conducting plates of Graphite, Aluminium, copper and Brass. The dimensions of the plates were all identical but the thicknesses varied. The plates were 50.7 cms in length and 8.8 cms in width. Their thicknesses were as follows :

Plates	Thickness
Graphite	1.9 cms.
Aluminium	.2 cm.
Copper	.08 cm.
Brass	.1 cm.

The experiment was carried out with the Wenner configueration, in which the electrodes are equally spaced, with a constant electrode separation of 10 cms. For the resistivity mapping, the whole arrangement was moved in a line over the surface of the tank. The observations were made by moving the whole arrangement of electrodes at steps of 5 cms. each.

The observations with the conducting sheets were made for different configurations. In the first cast, the mapping was done along a line at right angles to the strike of the sheet with various dips of 0°, 30°, 60° and 90°. Next a profile was drawn along a line askew to the strike by 30° and 60°, the sheet being first kept horizontal and then vertical. The sheets were immersed in the copper-sulphate solution, with their tops kept at 8 cms. below the surface in all cases and at the same position in the tank, so as to allow a comparative study of the anomalies produces by different sheets.

Precautions

Chemically active electrodes, such as iron or copper have to be avoided. Finally, it was ensured that the electrodes did not extend into the conducting material of the tank to a depth greater than one percent of the minimum electrode separation employed in the investigations.

A considerable care must be taken in using tank results as an aid in interpretation of field data.

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C H A P T E R V

RESULTS AND CONCLUSIONS

Results of model experiments are presented in the form of curves showing variations in apparent resistivities with position over burried sheet like bodies.

The abscissae denote the positions of the centre of the electrode system from the left side of the tank, which has four equally spaced electrodes and the ordinate denotes the apparent resistivities. The general shape of the curves is dependent upon the relative thicknesses, conductivities and dispositions of the sheets.

Experimental results are recorded in figures 5·1 to 5·12 and the two sets of observations were taken for different conductivities (1507 and 1808 ohm-cm.) of the homogeneous surrounding media, i.e. the copper sulphate solution. The resistivity curves for different sheets are drawn separately, and a comparative study is made for varying dips of individual sheets and for different directions of the line of profile with respect to the strike of the sheet.

A relative idea of variation of the apparent resistivities for graphite and aluminium sheets, identical in length and width but of different thicknesses can be had from figure 5·1 and 5·2 , for different dips and a traverse perpendicular to the strike of the sheet. In figure the nature of variation of the resistivity curves is shown for graphite and aluminium sheets dipping at 0° and 90° and the traverse made askew at 30° and 60° to the strike of the sheets.

The variation in resistivity curves for Copper and Brass sheets are also studied for horizontal and vertical sheets immersed at the same depth. These curves are shown in figures 5·5 - 5·6 and 5·11 - 5·12.

Conclusions

The instrument employed for small scale investigations may be those used for the large field studies provided they have sufficiently large scale range to read very low current and relatively high potentials.

The results obtained from the model experiments, performed with the conducting sheets of different conductivities of identical length and width but of different thicknesses, can be of use in interpretation of their nature and behaviour. The dotted curve in the graphs indicate the reading when the tank is only full of the copper sulphate solution, without the ore-body from which region of the wall effect can be noted to extend upto 35 cms. from both ends of the tank. Considering only the middle region in which the wall effects are negligible, (i.e. between 35 cm to

65 cm.), the following comments can be made on the nature of variation of the apparent resistivities for the variable dips and conductivities of the sheets.

In the case of graphite, as the dip angle varies from 0° to 90°, the resistivity over the body increases and attains a peak value flanked by two minima as the dip approaches 90°. But in the case of Aluminium, upto 60° dip there is only a slight change in resistivity, which is greater than the horizontal case. On further increase in dip to 90°, there is an abrupt and marked change in the resistivity and the curve attains a maximum flanked with two minima. The comparative study of the variation in apparent resistivities with dips for graphite and Aluminium sheets can be made from Figure 5.13.

The effect of orientation of the traverse line was also studied on horizontal and vertical sheets. As the orientation of the ore model with respect to line of traverse departs from 90°, the peak value of the apparent resistivity decreases and even becomes negative. In case of the askew traverse at 60° over a vertical sheet the curve shows a negative anomaly with a smaller maximum in the centre. This latter feature is however absent for the case of the horizontal sheet. When the traverse is made askew at 30° to the strike, similar negative anomalies are obtained for both the vertical and horizontal sheet.

The resistivity variation due to changes in orientation of the profile are shown in figure 5.14 for a vertical sheet and a horizontal sheet. From this it can be inferred that for vertical sheets the resistivity increases gradually as the orientation of the profile changes from 30° to 90°.

Small scale experiments may supply considerable information which will be indicative of the results to be expected in the field work. However, the tank experiments usually do not yield the same curve characteristics obtained in the field work. This may be due to the absence of polarization and related phenomena in the small scale tests. It is evident, therefore, that considerable care must be taken in using tank results as an aid in interpretation.

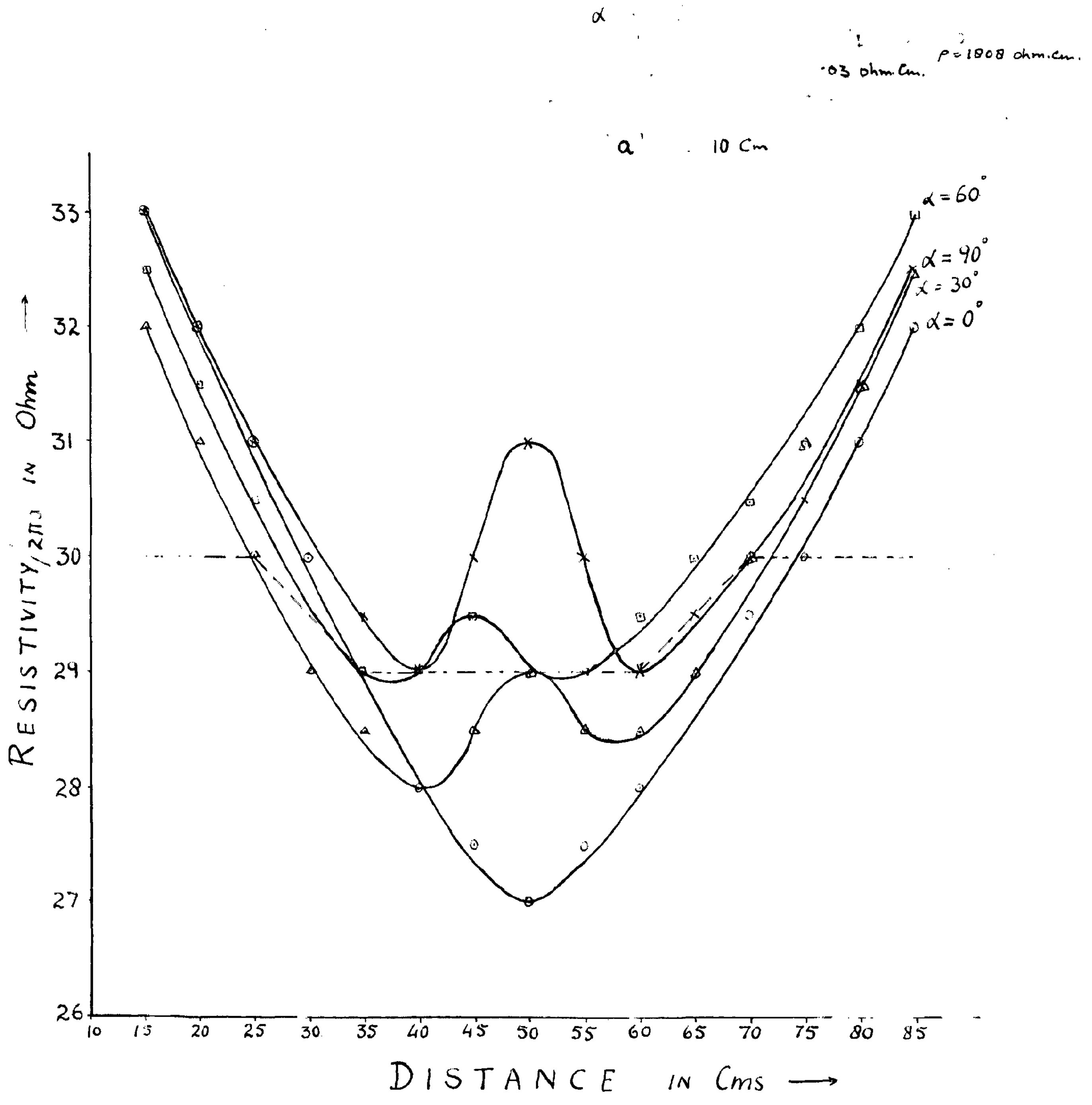
α
ρ = 1808 ohm.cm.
·03 ohm.Cm.
a' 10 Cm
α = 60°
α = 90°
α = 30°
α = 0°
RESISTIVITY/2π in Ohm →
33
32
31
30
29
28
27
26
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
DISTANCE in Cms →

FIG. 5·1

α

[illegible] $3{\cdot}21\times10^{-6}$ ohm-Cm.

Electrode Separation 'a' = 10 Cm

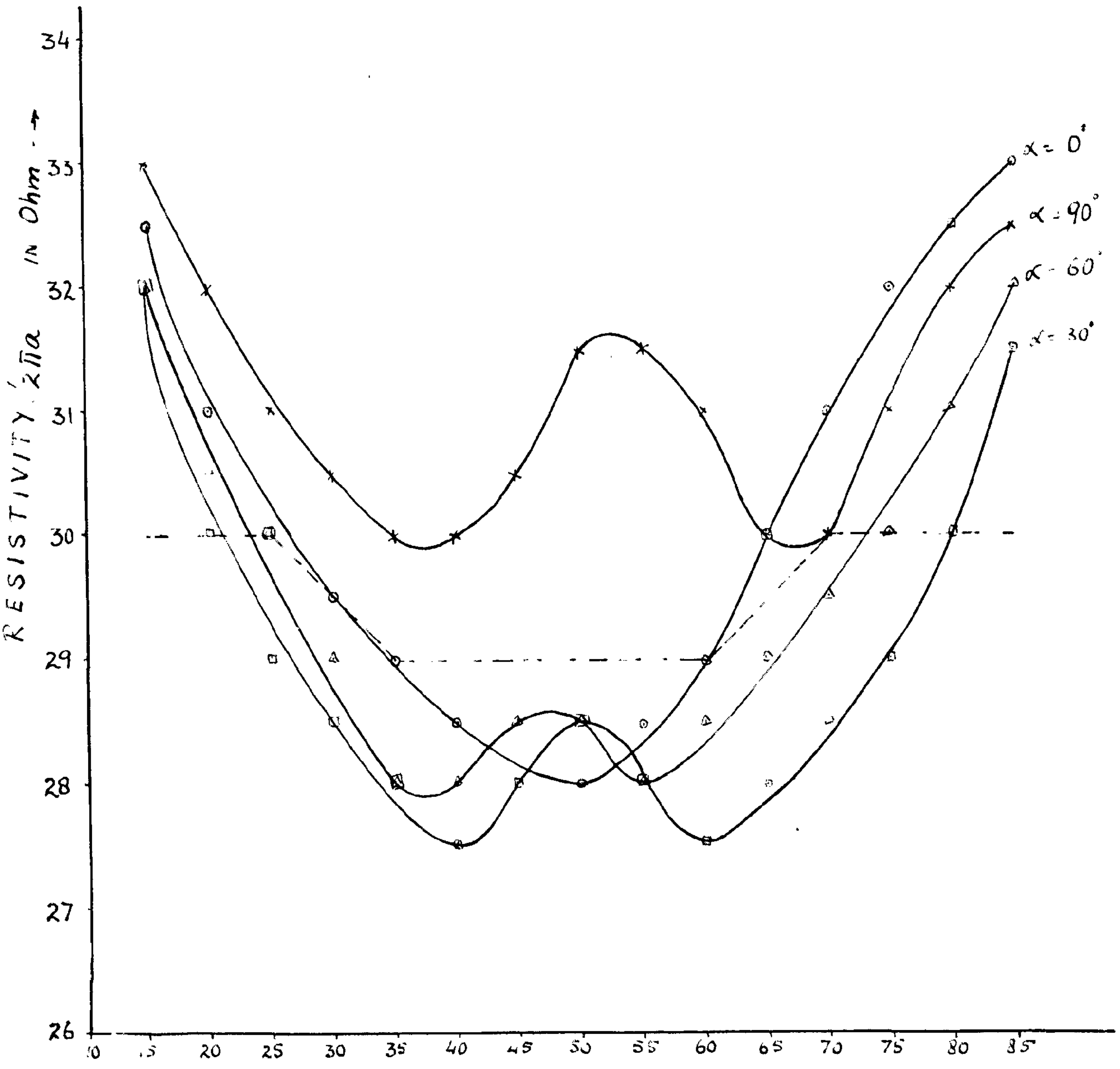

FIG. 5·2.

α

$\cdot 03$ and $3{\cdot}21 \times 10^{-6}$ ohm-Cm.

'a' - 10 Cm

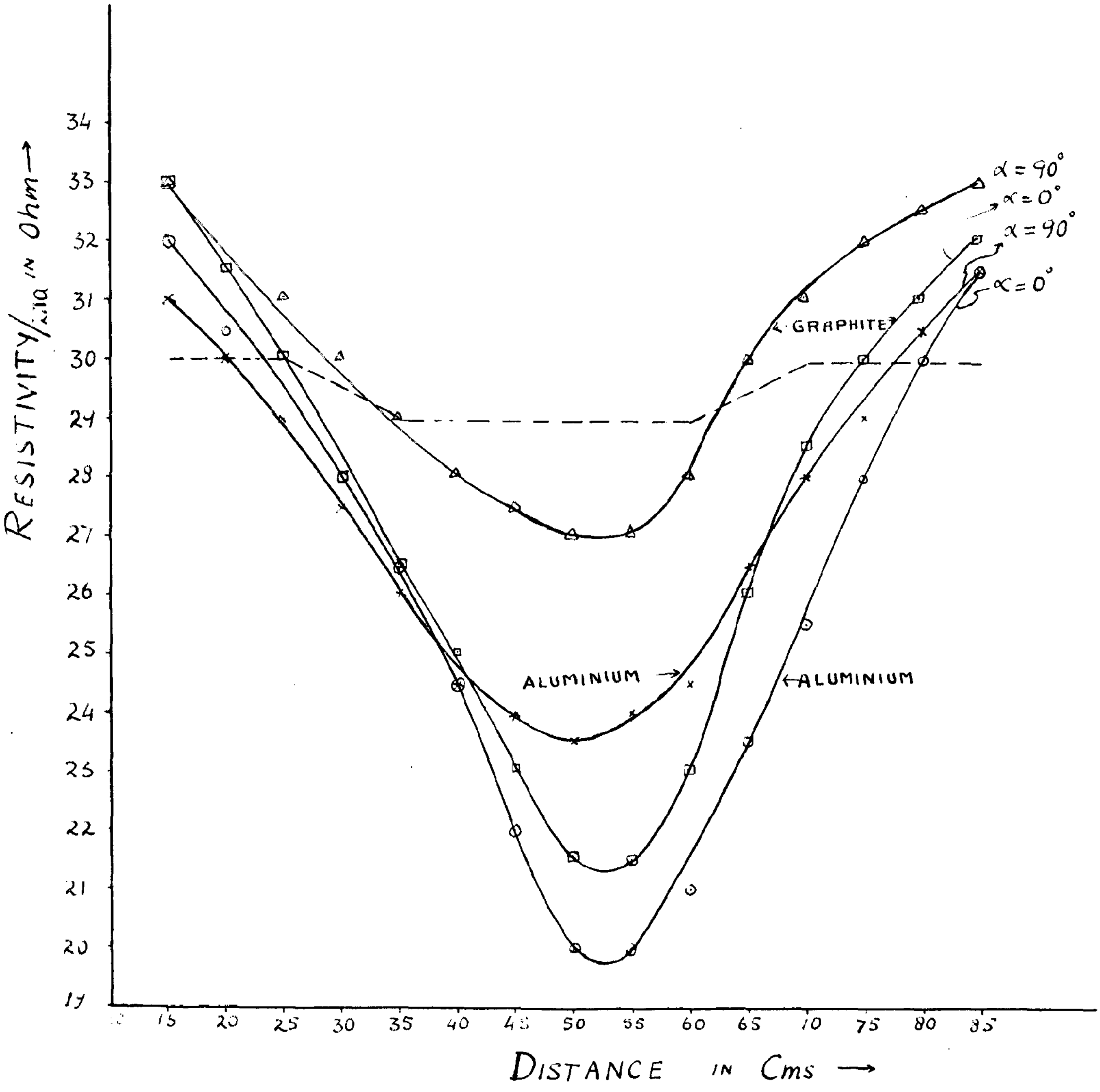

FIG. 5·3

Model

α 90°

·03 and 3·21 × 10⁻⁶ ohm-Cm.

'a' = 10 Cm

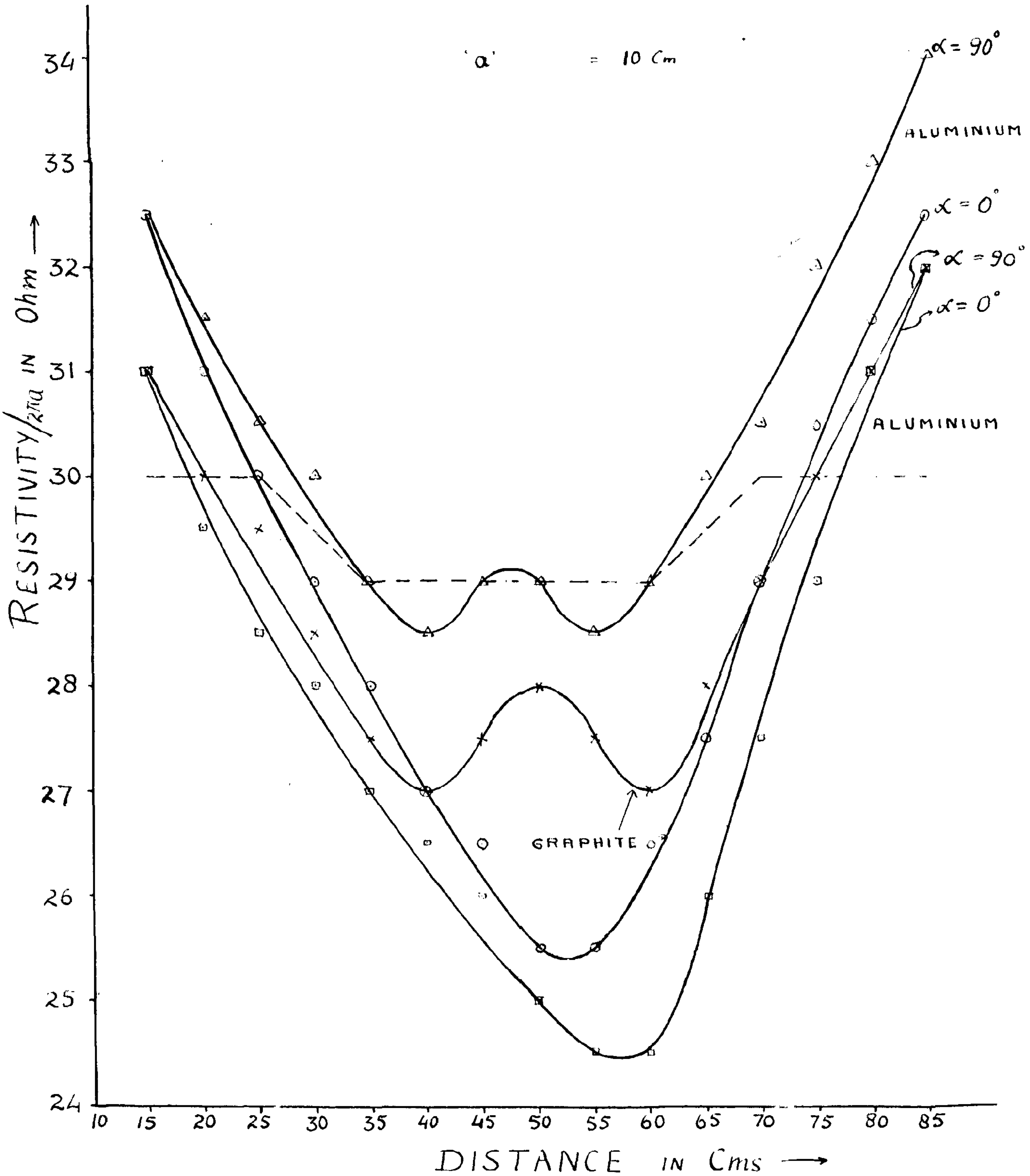

FIG 5·4

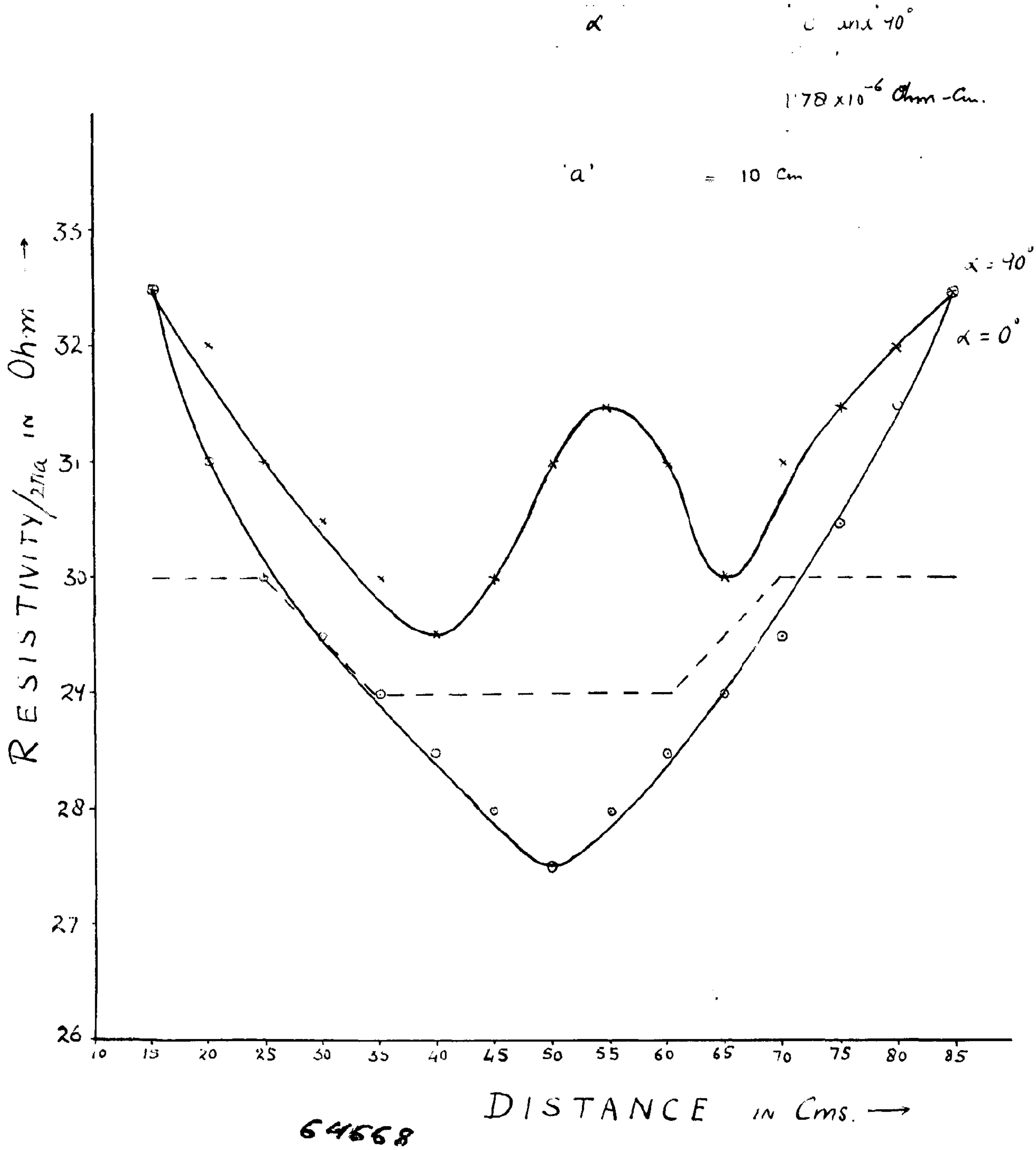
α
0 and 40°
1.78 x 10⁻⁶ Ohm-Cm.
'a' = 10 Cm
α = 40°
α = 0°
RESISTIVITY/2πa IN Ohm
33
32
31
30
29
28
27
26
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
DISTANCE IN Cms. →

FIG. 5·5

α 0° and 90°

$6{\cdot}76 \times 10^{-6}$ Ohm-Cm.

'a' : 10 Cm

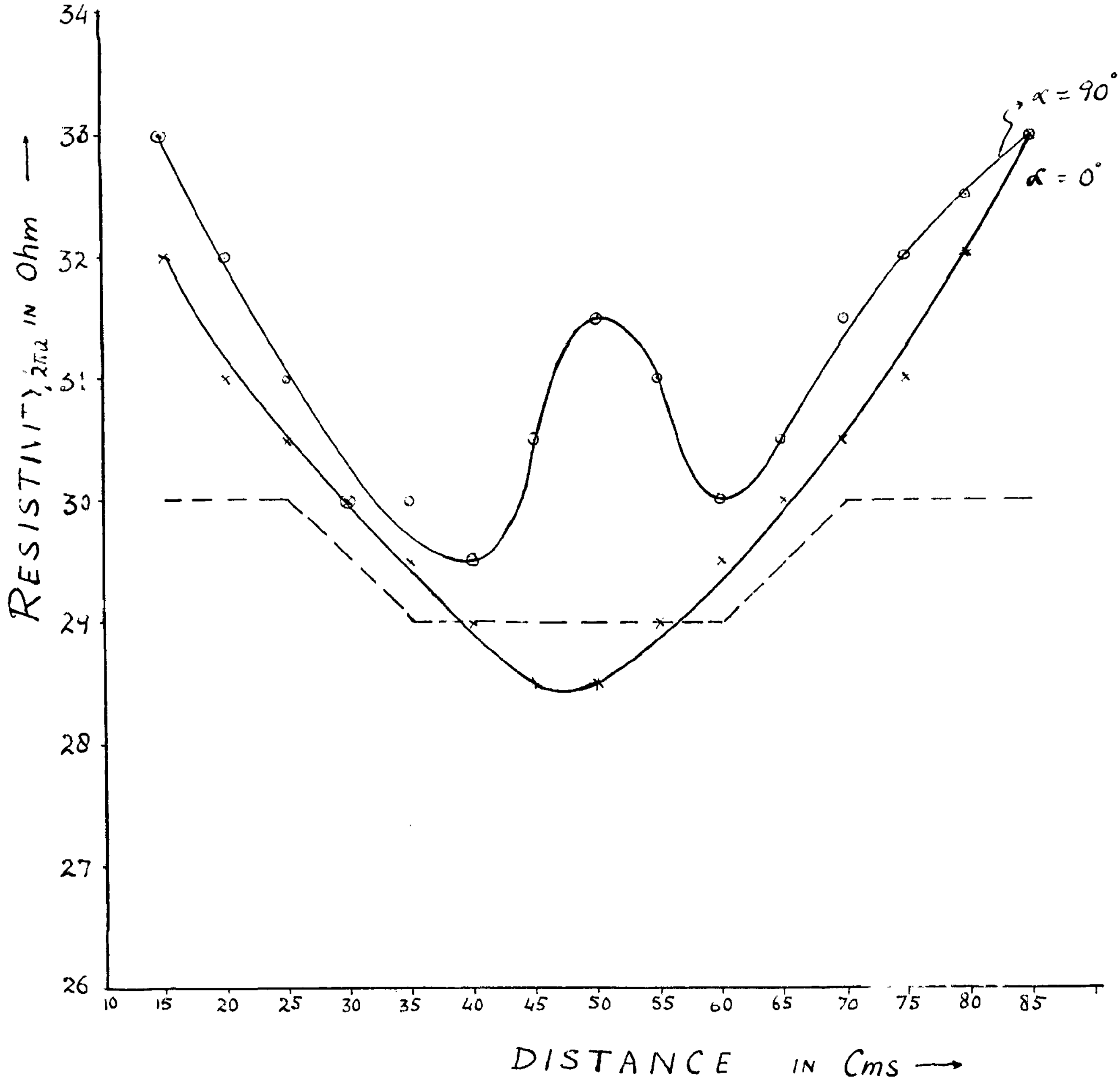

FIG. 5·6.

α

$\rho = 1507$ ohm. Cm.

·03 ohm. Cm.

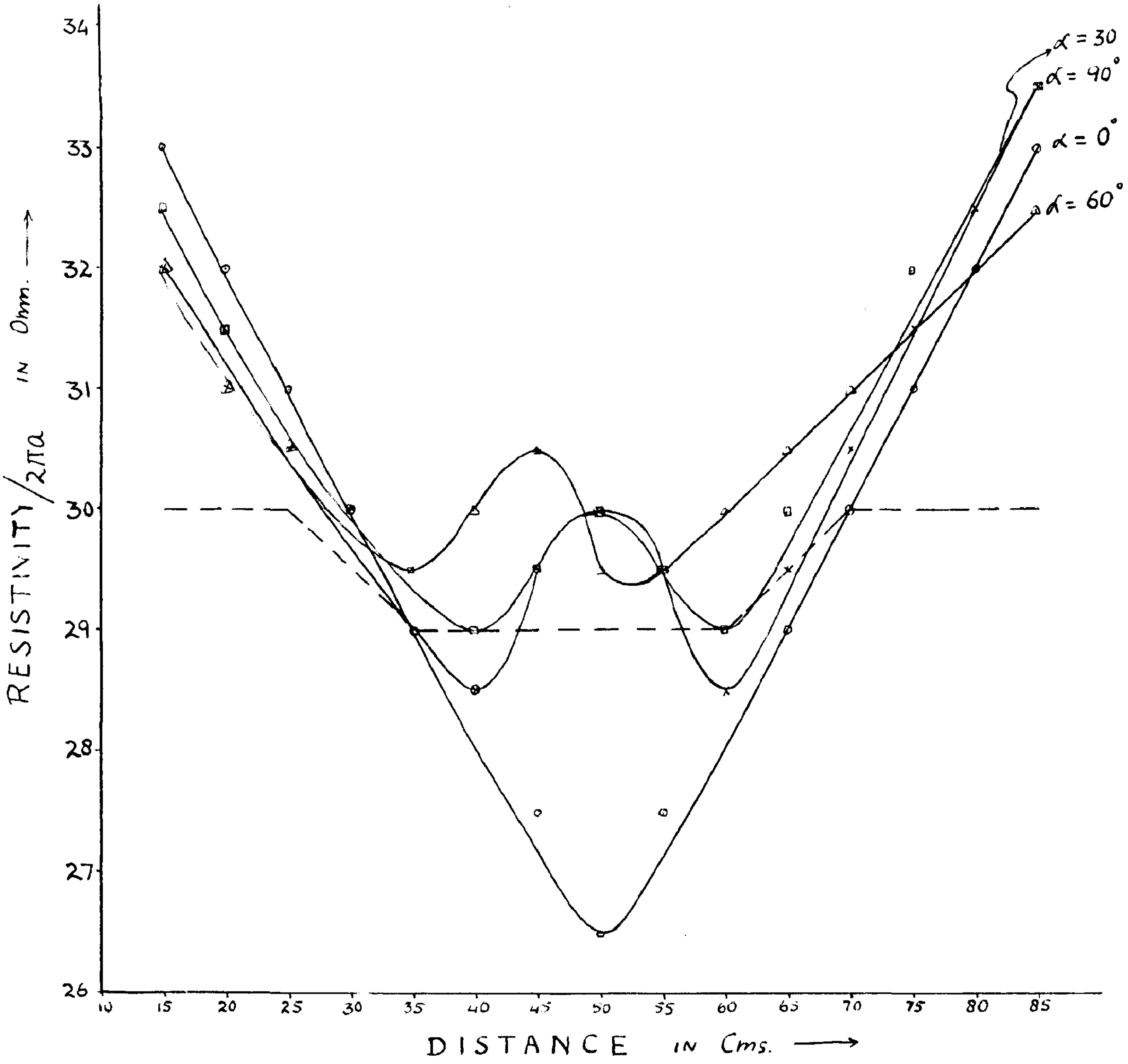

FIG. 5·7

$3{\cdot}21 \times 10^{-6}$ ohm Cm.

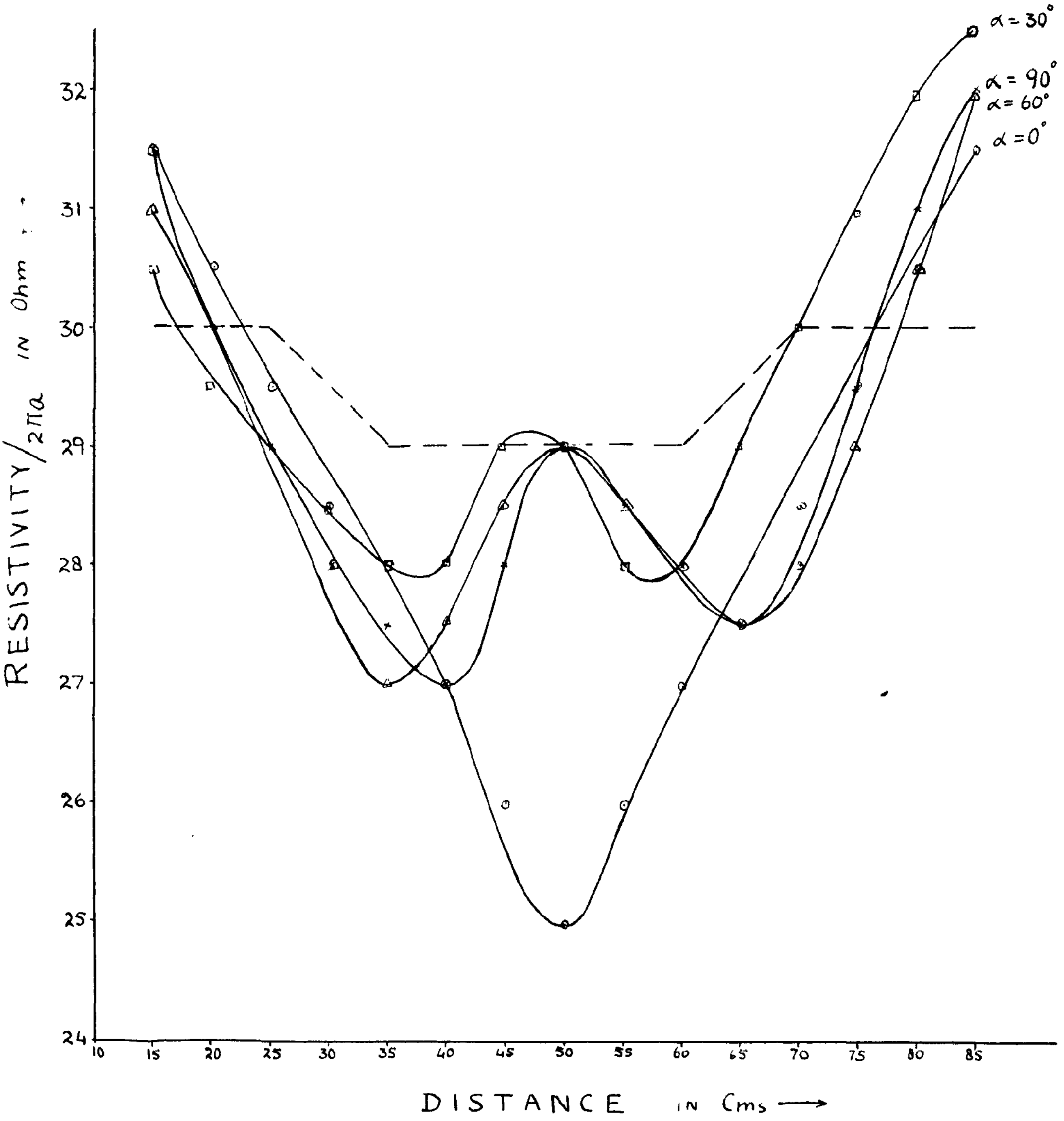

FIG. 5·8

α

·03 and $3{\cdot}21 \times 10^{-6}$ ohm Cm.

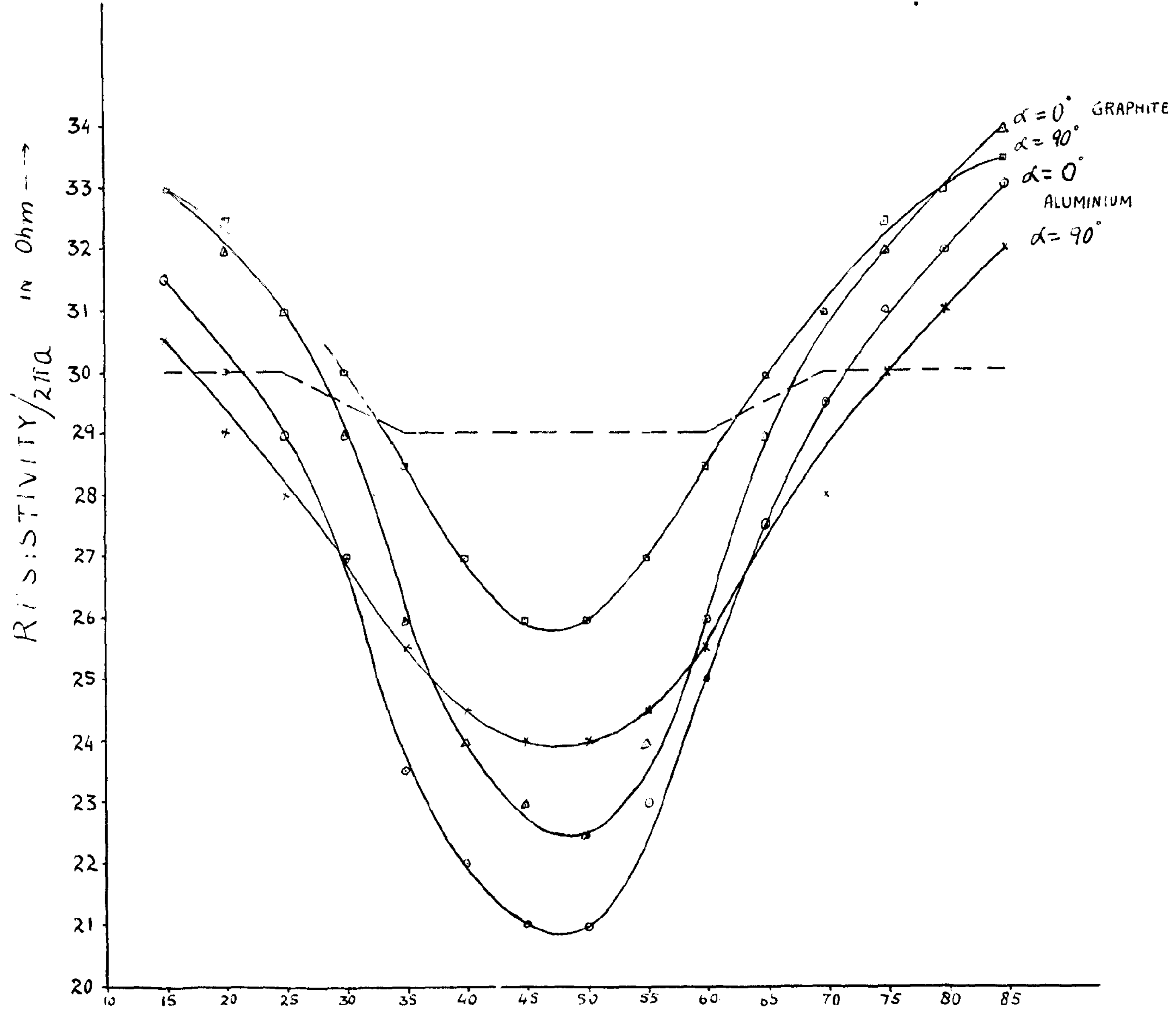

FIG. 5·9

α

$\cdot 03$ and $3{\cdot}21 \times 10^{-6}$ ohm.Cm.

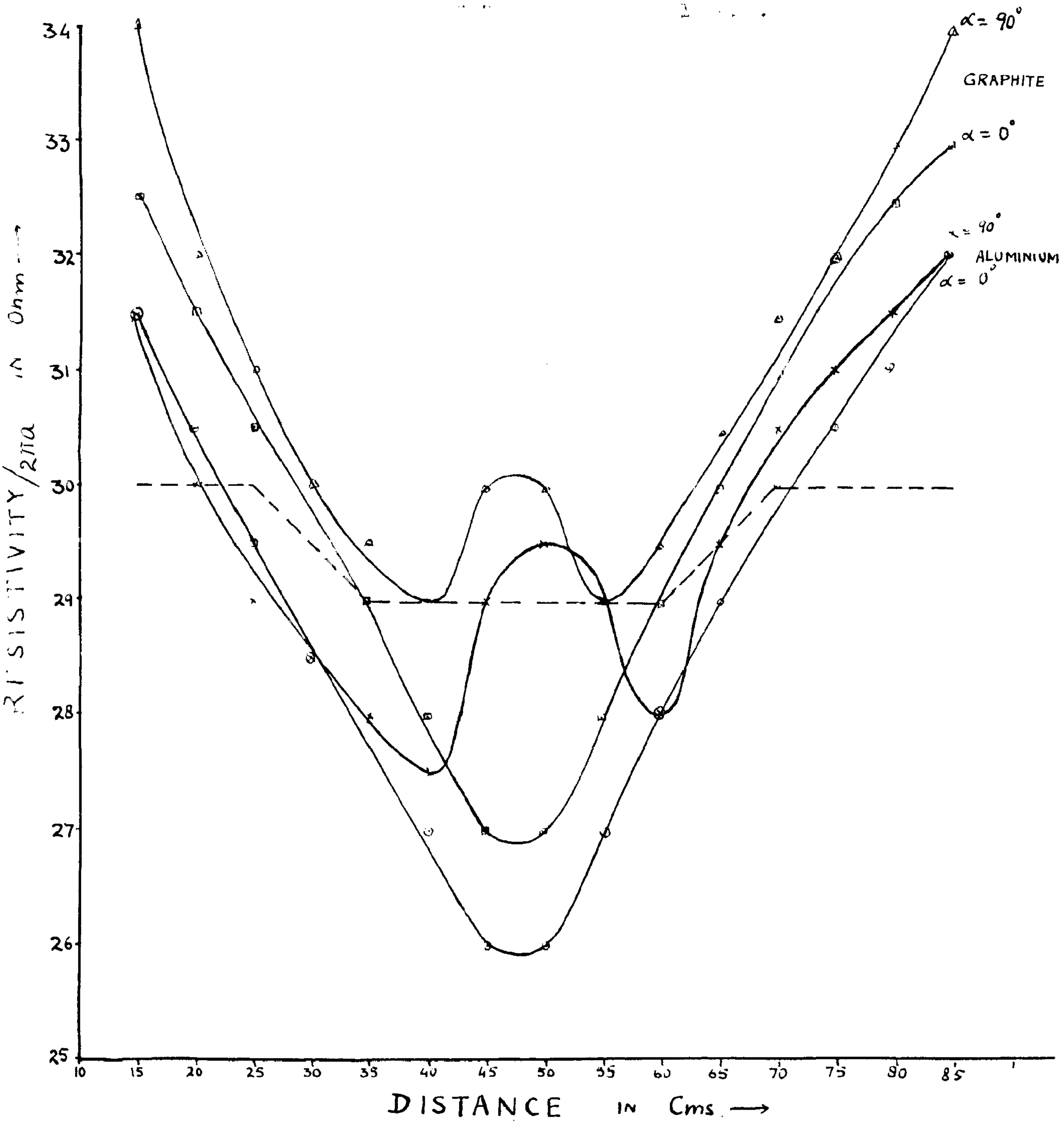

FIG. 5·10

1·78 × 10⁻⁶ ohm. Cm.

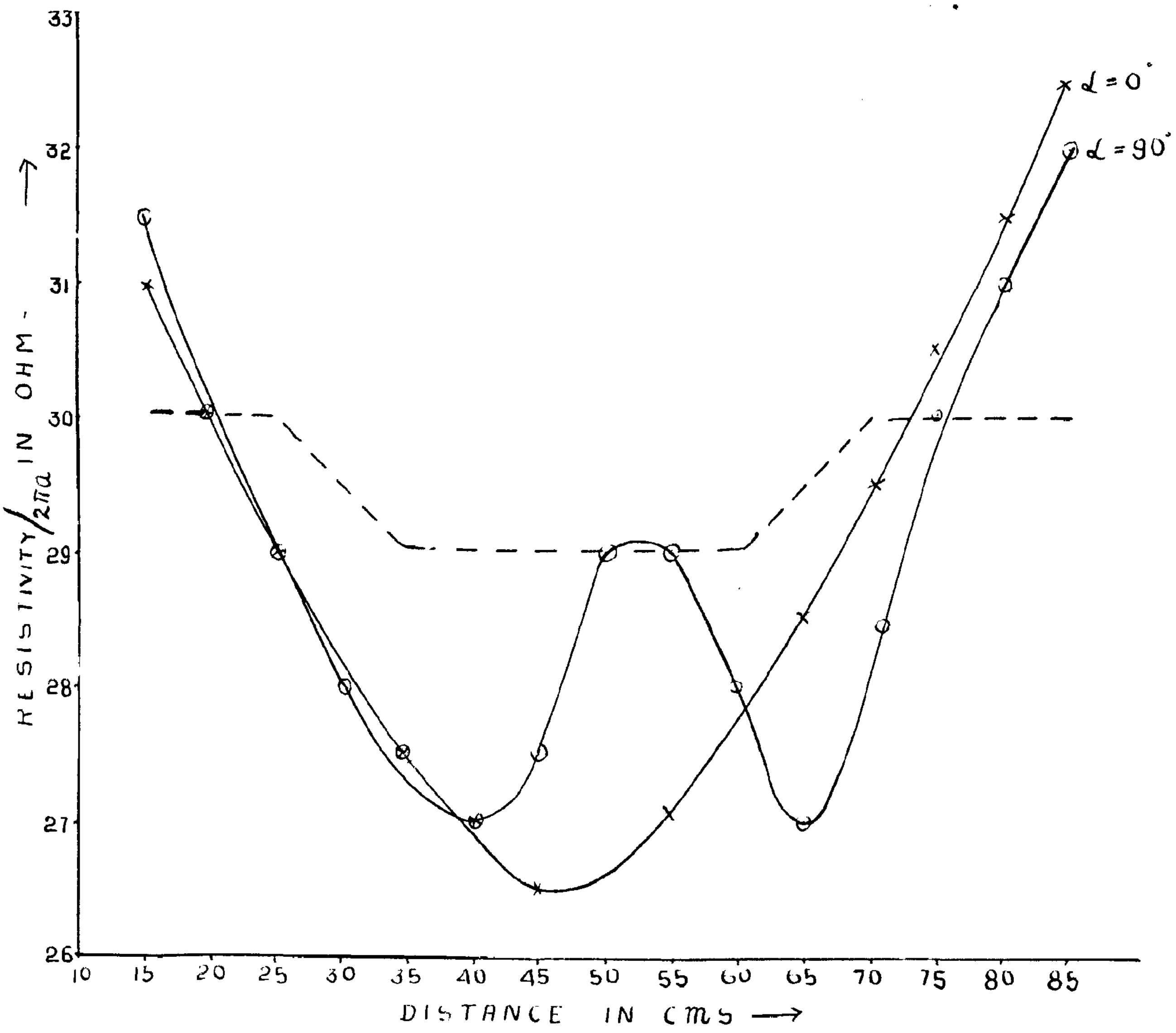

FIG. 5·11

α

6·76 x10⁻⁶ ohm.Cm.

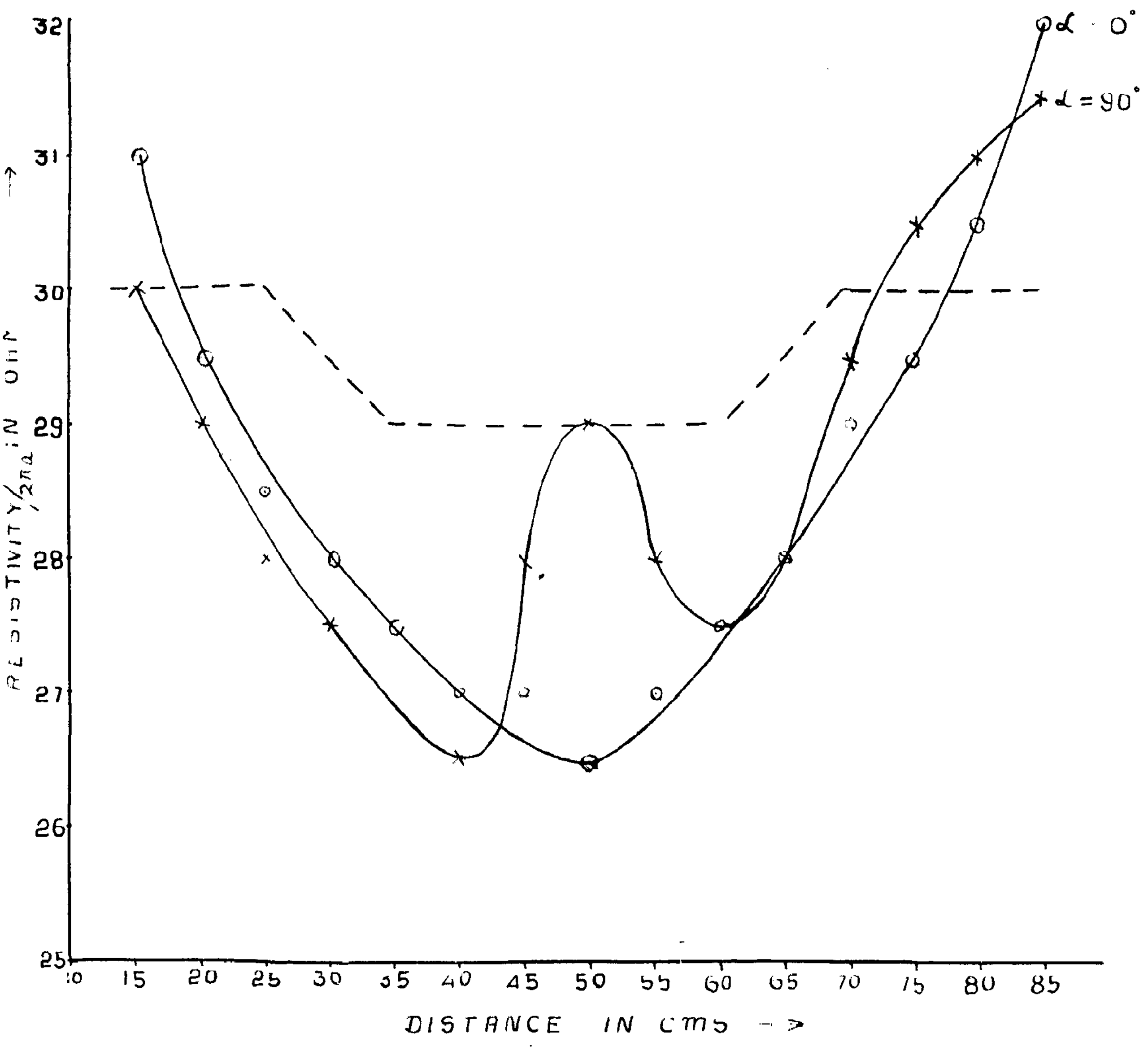

FIG. 5·12.

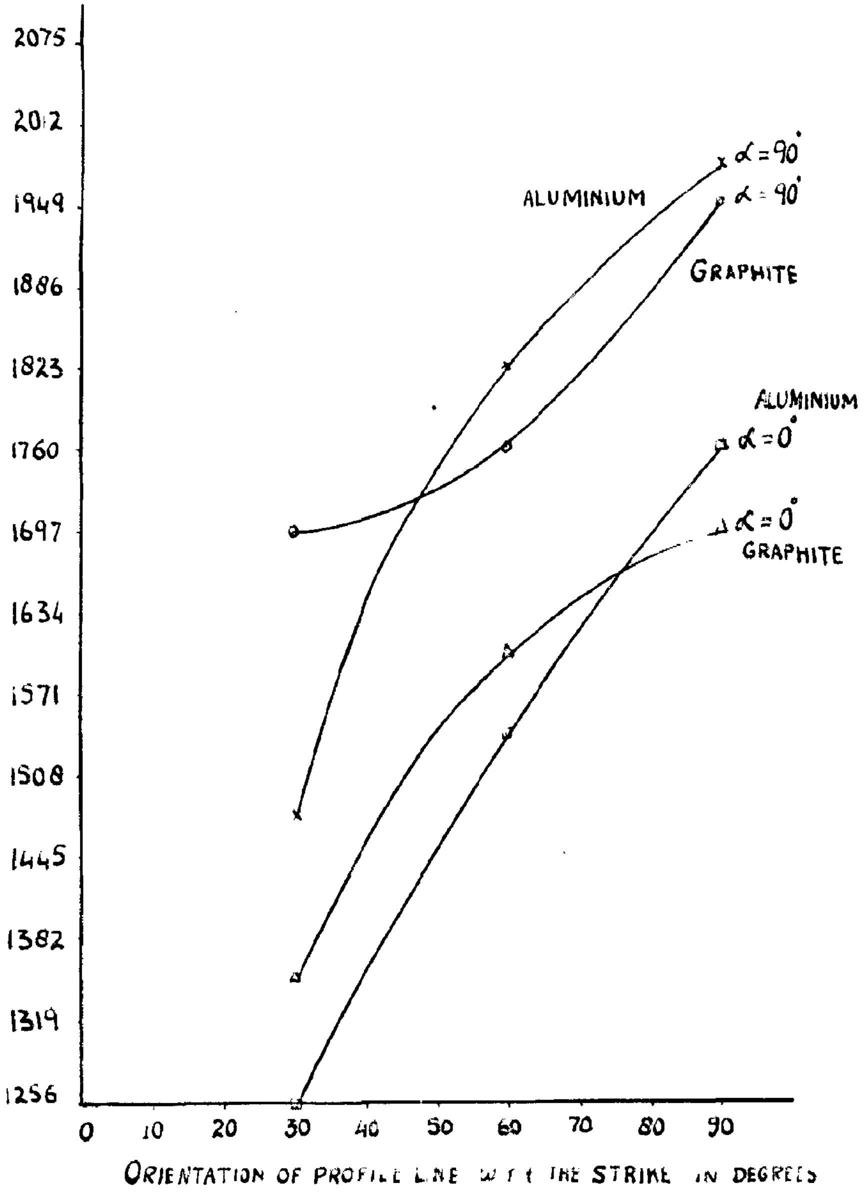

FIG 5·14

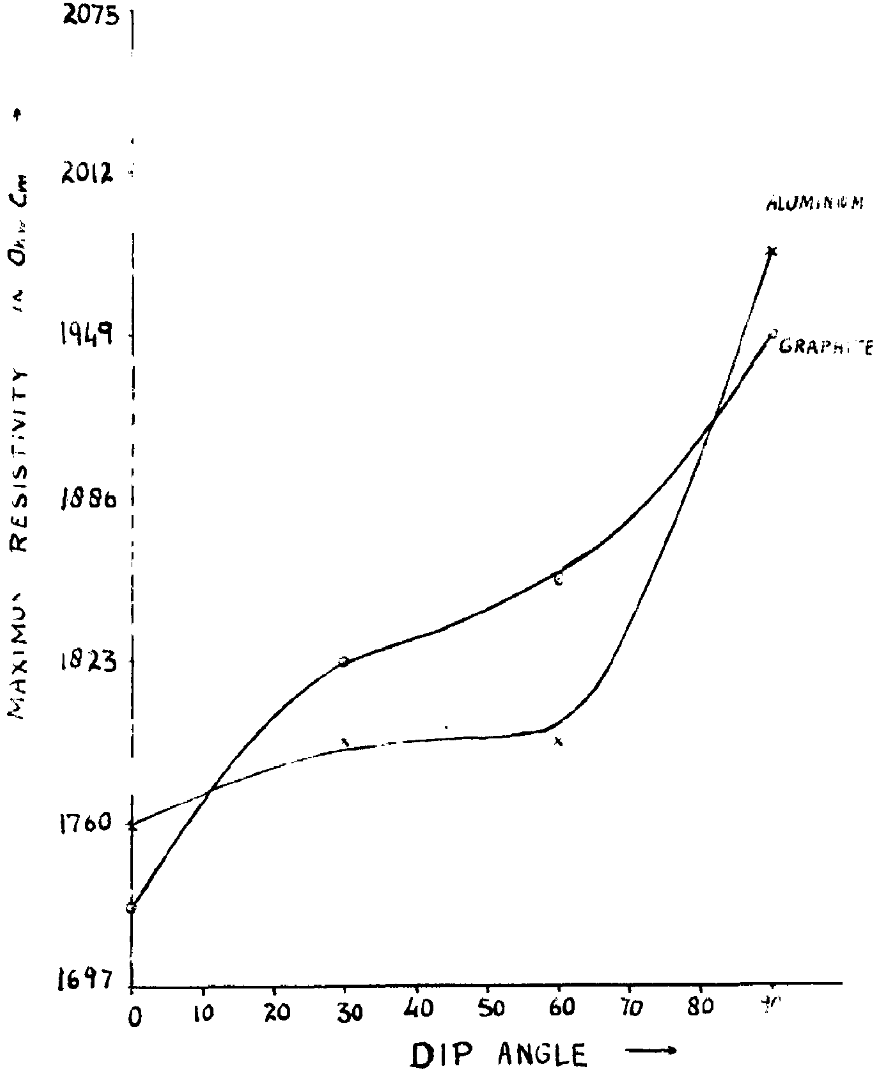

FIG. 5.13

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