COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF SUPPLY AND SHIPPING.

MINERAL RESOURCES SURVEY.

REPORT No. 1944/19.

Plan Nos. 1054-1060.

REPORT ON THE DETECTION BY RESISTIVITY METHODS, OF ELECTRICALLY RESISTIVE BODIES, BURIED IN WET SOIL AT SHALLOW DEPTHS.

By

R. F. THYER
GEOPHYSICIST.

CANBERRA. 10th May, 1944.

1229. By Authority: L. F. JOHNSTON, Commonwealth Government Printer, Canberra.

DEPARTMENT OF SUPPLY AND SHIPPING

. MINERAL RESOURCES SURVEY

REPORT ON THE DETECTION BY RESISTIVITY METHODS, OF ELECTRICALLY RESISTIVE BODIES, BURIED IN WET SOIL AT SHALLOW DEPTHS.

.Report No.1944/19, Plan Nos.1054-1060.

By

R. F. THYER
GEOPHYSICIST.

CANBERRA. 10th May, 1944.

REPORT ON THE DETECTION BY RESISTIVITY METHODS, OF ELECTRICALLY RESISTIVE BODIES, BURIED IN WET SOIL AT SHALLOW DEPTHS.

Report No.1944/19, Plan Nos.1054-1060.

INTRODUCTION.

This report deals with the problem of detecting electrically resistive bodies of small size buried at shallow depths in wet soils. Detection was attempted by means of measurements made on the surface of the soil using the electrical resistivity method.

The present report can be regarded as an extension of an earlier one (No.1943/64B) in which the results of tests conducted in a water tank have been described. These tests were carried out with a block of paraffin wax of size approximately 3" x 3" x 1" immersed in water. Various electrode arrangements were used and it was shown that the size of the anomaly due to the wax block depended upon the electrode arrangement used to measure it. The effect of varying the depth of the block below the surface was also studied in brief. The results of these tests have been shown in the form of curves and tabulations.

The previous report also dealt briefly with the variation in surface resistivity to be expected from normal causes in soil covered areas of limited size. It was concluded that if any attempt were made to locate resistive bodies buried at shallow depths in soils, the resistivity anomalies due to such bodies would be obscured by variations in surface resistivity due to normal causes.

However, after the results of the previous tests had been discussed with interested parties, it was pointed out that they were concerned primarily with detection in areas where the soils were permanently saturated with water, and it was suggested that under such conditions variations in surface resistivity might be small and hence detection might be possible and reliable. It was agreed, therefore, that this suggestion be tested out under field conditions and the present report deals with the results of such tests.

The purpose of the new set of tests was twofold. Firstly it was proposed to make tests of 'normal' resistivity effects using a constant electrode arrangement and measuring the resistivity at closely spaced points on water saturated soils. Mr.C.H.Zelman carried out this part of the test and his results are set out in another report.

The second part of the testing programme was contingent on the first part proving that under saturated conditions soil resistivities were sufficiently constant to warrant an attempt being made at detection. If this condition of constancy existed, it was proposed to extend the work of the tests, reviewed in the previous report, to actual field conditions. This has been done and the present report deals with the results obtained.

Some difficulty was experienced in finding a suitable place for testing. This was due to the dry weather which Canberra experiences at this time of year. However, a site was finally selected in the bed of Woolshed Creek, about 8 miles northeast of Canberra. The bed of the creek at the site chosen was covered by coarse sand containing an appreciable quantity of clay and saturated with water. The surface was flat, free from stones and vegetation. A small stream was running over one part of the bed and it was possible, by damming up the water, to carry out tests of detectability when the resistive body was buried in the sand which in turn was covered by water.

As a preliminary to the tests of detectability, tests were made of surface resistivity and these indicated that variations in surface resistivity were reasonably small.

The tests of detectability were primarily directed to determining the size of resistivity anomalies under various conditions. The following conditions were studied.

1. The electrode arrangement was varied, the resistive body being at a constant depth.

2. The depth of the resistive body was varied, the electrode arrangement being constant.

3. The resistive body was buried in soils of differing surface resistivities.

4. A water layer was superimposed on the soil covering the resistive body.

The results of the tests under these varied conditions will be dealt with in the following sections of this report, but in the first instance it is necessary to define the terms used and to outline briefly the method and instruments used.

DEFINITION OF TERMS USED.

1. Detectability. For the purposes of this report a term will be defined which will be a measure of the reliability with which the presence of a buried resistive body may be detected.

It will be appreciated that for reliable detection the effect of the buried object must be distinguishable from the effects of such factors as changes in the porosity of the soil. In the case of the resistivity method, with which this report deals, the resistivity change from normal which the buried object causes must be greater than the changes in resistivity due to variations in surface resistivity if reliable detection is to be achieved. Detectability will be defined as the ratio of the change from normal resistivity which the buried object produces to the maximum change from normal produced by variations in surface resistivity. Fig.4a and b illustrate this definition. The curve Fig.4a represents resistivities measured along a traverse over the centre of a buried object. The horizontal line A—A represents the average value of all the surface resistivities measured in the vicinity of the test site. This is called the mean normal resistivity. Fig.4b represents resistivities measured at random about the test site. The mean of these random measurements is the mean normal resistivity represented by the line A—A. The line B—B represents the upper limit of measurements made at random.

If the peak on the resistance curve Fig.4a is x units above the line A—A, and if the line B—B is y units above A—A then the detectability is defined as the ratio x/y.

Although resistivities measured in ohm cm. units have been used as ordinates in Fig.4a and b and the detectability has been defined in terms of resistivity differences, the definition holds equally well if ground resistances, defined below, had been used instead of resistivities.

When the detectability is less than 1.0, the buried object may still cause an appreciable anomaly but this might be indistinguishable from anomalies caused through variations in surface resistivity. For reliable detection the detectability should not be less than 1.0 and preferably greater than 1.5.

2. Ground Resistance. The ground resistance is the resistance reading in ohms on the Megger instrument for any particular set of conditions.

In the discussion of the results that follows, the term ground resistance is used in preference to resistivity. The two terms are related to one another because, for any fixed electrode ar arrangement, the ground resistance, R, is proportional to the resistivity P. The proportionality factor corresponding to the various electrode arrangements is shown on Fig.2. For example, in arrangement A, P = 191 R, where R is in ohms and P is in ohm cm. units

3. <u>The Model.</u> The resistive body used in the tests was a disk of pitch 8 inches in diameter and 4 inches thick. Its resistivity was probably in excess of 10^{11} ohm cms. In the discussion of the results that follows, the resistive body will be referred to as the 'model'.

METHOD AND INSTRUMENTS USED.

The resistivity measurements were made with a Megger earth tester. A simplified circuit of the instrument is shown in Fig.1.

The instrument comprises a small hand-driven DC generator, capable of providing 80 volts to the current circuit, a two-coil galvanometer, a double reversing commutator, and various resistances, switches and terminals.

The circuit is so arranged that the current (I) provided by the generator passes through one of the galvanometer coils while the potential difference (V) between the potential electrodes causes a current to flow through the second galvanometer coil. The galvanometer measures the ratio of these two currents and hence $\frac{V}{I}$ or the ground resistance R. The double commutator reverses the ground current I and potential difference V and thus eliminates the effect of potentials, such as natural earth potentials, not associated with the ground current.

Because current is drawn from the potential electrodes, it will be appreciated that the measured ground resistances depend on the potential electrode contact resistance. This is measured and a correction applied to the Megger readings.

The electrode system used in the tests was a rake-like construction. A sketch of the system is shown in Fig.3. It is provided with a cross-arm to which the electrodes are clamped and a handle for ease in operation. The electrodes, generally four in number, were steel surveyors' arrows. They were clamped at intervals along the cross-arm and each electrode was provided with an insulated collar to limit the depth of electrode penetration. Under test conditions the electrodes and their collars were adjusted so that the collars would lie flat on the ground and the electrodes would have equal penetration.

PROCEDURE.

The procedure consisted of selecting a site at which the surface material was saturated and where there was a reasonable expectation of the surface resistivity being relatively constant over the area to be covered by the test. The resistive model was then buried at a pre-determined depth and its centre accurately marked. A straight line was marked on the surface passing through the centre of the model and distances marked off at 6-inch intervals to a distance of 2 feet each side of the centre.

The electrode system was arranged so that all the electrodes lay on this line, the electrodes were pushed into contact with the ground, and the earth resistances were determined with the Megger.

To simplify the plotting of results, it has been assumed that the line was in an east-west direction and that the centre of the electrode system was moved at intervals from 24 inches west to 24 inches east.

After the ground resistances have been determined with the model in place, it is removed and the readings repeated. The differences in the resistances measured with and without the model were then assumed to be the effect of the model.

RESULTS OF THE TESTS.

1. Effect of Varying the Electrode Spacing. The various electrode arrangement used in the tests are shown in Fig.2. Eight different arrangements are shown, but of these those marked D, F and H were the most satisfactory. The most favourable arrangement, however, probably depends on the dimension of the model and its depth below the surface. In the tests under review, the model was a pitch disk 8 inches in diameter and 4 inches thick. If the model had been smaller, the most favourable electrode arrangements would have had correspondingly smaller electrode separations.

It is obvious that the number of possible electrode arrangements is unlimited, but the selection of arrangements to try in the field tests was guided by the results obtained in the water tank tests previously described. In the previous tests, it was shown that an arrangement of four electrodes in which current and potential electrodes alternated gave the biggest anomalies. In Fig.2, this arrangement is represented by D, E, F, G and H. A special case of this arrangement arises when the separation between the outer electrodes and their nearest inner electrodes is twice the separation between the inner electrodes as in arrangements D, E and F. The results of tests made with these three arrangements over the model buried at a depth of 2¾ inches are shown in Fig.5a. It will be observed that the resistance curves for the inner electrode separation of 5 inches and 6 inches are almost identical while that for 7 inches shows a decided reduction in size of the maximum anomaly. It will be noticed, however, that the width of the anomaly is approximately the same for each case. The arrangement shown as G Fig.2 is a modification of the above. The tests carried out with this arrangement consisted of measuring the ground resistance with the centre of the electrode system over the centre of the model and measuring a corresponding ground resistance over normal ground. The results are shown in the form of ground resistance curves in Fig.9.

In Fig.9, C_1P_2 was kept constant at 6 inches while $P_1C_1 = P_2C_2$ was varied from 6 to 18 inches. The change in the ground resistance represented by the difference between curves 1 and 2 varies from 0 for $P_1C_1 = 6$ inches to a maximum for $P_1C_1 = 18$ inches. The maximum anomaly expressed as a percentage of the normal value occurs when $P_1C_1 = 10$ inches because the normal value is zero for this separation. Theoretical considerations show that when $P_1C_1 = 9.75$ inches (approximately) the potential drop between P_1 and P_2, and hence the megger reading, is zero for any value of the surface resistivity. The figure of 10 inches obtained from the field test is therefore a close approximation to the theoretical.

A traverse was made over the buried model with the electrode arrangement, $P_1C_1 = P_2C_2 = 10$ inches, $P_1C_2 = 6$ inches as shown in arrangement H Fig.2. The results of this test are shown in Fig. 12. It will be observed that the resistance values shown have p positive and negative values. The sign ascribed to the resistances is in accordance with the direction of the potential drop between P_1 and P_2 relative to the ground current. The potential drop reverses its sign about the zero resistance line.

A point of interest in the resistance curve over the model is that the resistance values are positive only over the model. This fact suggested that this electrode arrangement would be a favourable one for detecting buried resistive bodies. Positive anomalies would correspond to such bodies. This, however, proved not to be the case. In Fig.12b are shown a number of resistances measured at random about the test site with this electrode arrangement. It will be seen that four of these resistances are positive of which two are of magnitude comparable with the maximum resistance measured over the model. The site of the reading marked x was examined in detail to determine what form this resistance maximum had, i.e. whether it was a broad effect or limited in extent. Resistances were measured at closely spaced points about the site and it was apparent that the maximum was of limited extent and similar in shape to that obtained over the buried model. The soil was subsequently dug over to determine if possible the cause of this anomaly. Apart from the disclosure of a few dead gum leaves, nothing was revealed that could explain the anomaly. It seems unlikely that the leaves themselves were responsible but it is possible that oil from the leaves may have prevented the sand from becoming saturated over a limited volume and thus produced a small volume of resistivity greater than normal.

The resistance curves obtained when using electrode arrangements B and C, Fig.2, are shown in Fig.10 and 11 respectively.

After reviewing the results of all tests using different electrode arrangements, it was decided that the arrangement D, Fig.2 was the most suitable one and this was used in subsequent tests in which the depth of the model was varied or the surface was covered with water.

2. <u>The Effect of Varying the Depth of the Model.</u> The effect of varying the thickness of the soil covering the model is shown in Fig.13 and 14a, b and c. Each of these tests was carried out with the electrode arrangement D, Fig.2.

Fig.14a shows the change in earth resistance when the model was varied in depth from 1¼" to 4¼" in steps of one inch. The model was first buried at a depth of 1¼" and the earth resistances determined with the Megger. The soil surface was then built up by addition of soil similar to that in which the model was buried until the surface was raised 1 inch. Earth resistances were again measured and the process repeated until 3 inches had been added and the model was at a depth of 4¼ inches. The model was then removed and the space it had occupied filled with soil and the surface returned to as near its normal condition as possible. An earth resistance test without the mine in place completed the series.

The 'no model' or normal ground curve, Fig.14a, shows a pronounced resistance anomaly near its centre. This is unfortunate because its presence introduced an uncertainty as to the actual size of the maximum anomaly caused by the buried model. It is possible that the soil used to fill in the hole left by the removal of the model may have been more resistive than normal, thus producing the resistance maximum near the centre of the curve.

In an endeavour to obtain more satisfactory results, the test was repeated at a new site. In this case, however, the model was originally buried at a depth of 4¼ inches and the depth of the soil cover decreased as required by scraping away the immediate surface material. When 1½ inches had been removed, the water table was reached and it was obvious that further removal of soil would result in the surface being covered by water. The model was, therefore, removed and the 'no model' or normal ground resistance curve determined.

Neither of these tests was entirely satisfactory and it was obvious that the act of building up the surface or lowering the surface by scraping away, had a pronounced effect on the surface resistivity. For instance, in Fig.13 at 18 inches west, the original surface had a resistance of approximately 6.0 ohms. As the soil was scraped away for the successive tests, the surface resistivity at 18 inches west increased until at the final depth reached (1¼ inches scraped away), the surface resistance at this point had gone up to 10.0 ohms.

In Fig.14 (c), curve 1, the values of the ground resistance anomaly at zero, i.e. over the centre of the model, have been plotted against the depth of the model in inches. The ordinates shown as G, F, E and D, Fig.14a are the maximum resistance measured over the centre of the model for depths of 1¼, 2¼, 3¾ and 4¾ inches respectively. The ordinate C is the resistance measured at the same point after the model had been removed. The ordinates plotted in Fig.14c are the differences (G-C), (F-C), (E-C), and (D-C).

It will be observed that a straight line can be drawn through the points on curve 1. This line intersects the horizontal or zero anomaly axis at a point corresponding to a model depth of 4.3/4 inches. Tests conducted previously in the water tank, however, showed that the line through these points should not intersect the zero anomaly axis but approach it gradually as the model depth is increased. Curve 2, Fig.14c, shows the relationship between resistivity anomaly and model depth obtained in the water tank test, and it is shown for the purposes of comparison with the field test results. It is obvious from the results of both water tank and field tests that the resistance anomaly decreases very rapidly as the model becomes deeper. The ability to detect the model depends on the relative magnitudes of the anomaly due to the model and the maximum variations from normal of the surface resistivity.

Fig.14b, shows the relationship between detectability and model depth. If the line B—B, Fig.14a, represents the upper limit of surface resistances measured in the vicinity of the test site and the line A—A the average value of the surface resistance, then the detectability is the ratio of the resistance differences (G-C), (F-C), etc. to the difference (B-A). In Fig.14b detectabilities vary between 2.6 for a model depth of 1¼ inches and 0.4 for a model depth of 4¾ inches. A horizontal line has been drawn at a detectability of 1.0 to mark the limit of reliable detection. This line intersects curve 1 at a point corresponding to a model depth of 3½ inches. For depths greater than this the detectability is less than 1.0 and detection is unreliable.

It should be borne in mind that the above discussion refers to a model 8" diameter by 4" thick. If the model had been smaller it is probable that depth corresponding to the limit of reliable detection would have been less.

3. <u>The Effect of Surface Resistivity on Detectability.</u> The results of resistivity tests carried out by Mr.Zelman on undisturbed soils suggested that the clayey or more conductive soils were more uniform in character than the sandy and more resistive soils. This suggests that detection might be more readily achieved in clayey soils than in sandy soils. However, detectability depends not only on the magnitude of the random variations in resistivity of the surface soils but also on the magnitude of the anomaly of the buried model. The reduction in the former noticed in the clayey soils could result in a substantial increase in detectability only if the resistivity changes due to the buried model remained substantially unaltered by a change in surface resistivity. A number of tests were carried out with the model buried in different soil types to test whether changing the surface resistivity would greatly affect the magnitude of the anomaly due to the buried model.

The resistance curves shown in Fig.6, 7 and 8 were obtained at sites where the soil was much more clayey than in the creek bed where the tests previously described had been made. In the creek bed site the normal resistivity of the soil (mostly sand with a little clay) varied between 3000 and 4000 ohm cms. At the more clayey sites, however, the normal resistivity varied between 1300 and 2000 ohm. cms.

At the site where the curves shown in Fig.6 were obtained, the average surface resistivity was approximately 1350 ohm. cms. The model was buried at a depth of 2¼ inches. The change in ground resistance measured by the Megger at the centre point with and without the model in place was 4.2 ohms. Normal ground resistance was approximately 2.8 ohms.

Comparing this result with that shown in Fig.14(a).for a similar model depth and electrode arrangement but with a different average surface resistivity, we see that the maximum anomaly and the normal ground resistance, expressed in ohms, are considerably greater in the latter case, being approximately 16.3 ohms and 10 ohms respectively. The maximum anomaly expressed as a percentage of the mean normal value, however, is approximately the same in each case, namely, 150 per cent. and 160 per cent. for Fig.6 and 14a respectively. The same condition holds approximately for the anomaly curves in Fig.7 and 8.

It would appear from these tests, therefore, that if the change in resistance due to the buried model is expressed as a percentage of normal resistance it is substantially independent of the resistivity of the soil. The tests of surface resistivity made by Mr.Zelman showed that the maximum departure in resistivity from the mean value was much smaller in the case of conductive clay soils than in sandy soils. However, if these departures are expressed as a percentage of the mean value it is seen that the maximum percentage departure from mean is substantially independent of the surface resistivity. It follows that the detectability, which can be expressed as the ratio of the two percentage effects, is, for a given electrode arrangement and model depth, substantially independe[nt] of the surface resistivity.

THE AREAL EXTENT OF THE ANOMALY.

Tests to determine the areal extent of the anomaly due to the buried mine are illustrated in Fig.16a and 16c. Fig.16a shows two resistance curves. The east-west curve was obtained with the electrode system arranged along an east-west line and the centre of the system moved from west to east along the line. The north-south curve was obtained with the electrodes still arranged in an east-west direction, but the system was moved with its centre along a north-south line passing through the centre of the model. A plan of these electrode arrangements is shown in Fig.16b. Fig.16c is a ground resistance contour plan showing lines of equal ground resistance. The position of the model is shown superimposed on the contours.

In Fig.16a, it will be observed that the average normal ground resistance is approximately 6.0 ohms, while the maximum ground resistance, measured over the centre of the mine, is 14.0 ohms. If it is assumed that normal ground resistance may vary by ± 50 per cent., then the ground resistance anomaly due to the buried model must exceed 9.0 ohms. if the detectability is to exceed 1.0 and the anomaly is to be distinguished from normal ground variations. On this basis, we can assume that the 10.0 ohm. contour in Fig.16c delimits the area in which high ground resistance is indicative of the buried model. This contour line is roughly circular in shape and encloses an area approximately equal to the surface area of the model, i.e. its diameter is approximately 8 inches. For the purposes of detection, therefore, the centre of the electrode system must be placed within the area occupied by the 10.0 ohm contour if the model is to be detected. To be certain of detection under the conditions represented by these tests, the area in which the buried model is thought to lie must be covered by resistance readings made with the centre of the electrode system at all points on a rectangular grid of spacing equal to half the diameter of the 10.0 ohm contour circle, namely 4 inches. In other words, if an area 2' x 2' square is to be covered, approximately 50 separate resistance determinations would be required.

DETECTION UNDER WATER

Fig.15a shows the results of a test carried out with the electrode arrangement D, Fig.2. The model was covered by 2¾ inches of soil which in turn was covered by water layers ¾ of an inch and 2 inches, deep. The effect of the added water is to reduce considerably the change in ground resistance caused by the buried model. Fig.15b shows the relationship between the depth of water cover and maximum change in ground resistance caused by the model. The reciprocals of the resistance changes are plotted against the water depth in inches. It will be observed that the three points lie on a straight line or, in other words, the maximum change in ground resistance due to the buried model is inversely proportional to the depth of water. It does not follow, however, that detectability falls off inversely with water depth because tests of normal resistance variations in water covered soils indicates that soils so covered are much more uniform in resistance than saturated or damp soils without water covering. In the latter case, normal variations in resistance may be of the order of ± 50 per cent. while for corresponding soils covered by water, the variation may be as low as ± 20 per cent. The tests carried out were not extensive enough to to determine whether detectability was seriously altered by the presence of a water cover.

CONCLUSIONS.

The tests show that, under field conditions, the method of locating buried resistive bodies by resistivity methods has serious limitations, which render it unsuitable for the problem in hand.

These limitations may be summarized as follows:-

1. Detectability decreases rapidly as the thickness of soil covering the model increases. For a model 8 inches diameter by 4 inches thick under test condition, the detectability was 1.0 at a depth of approximately 3¼ inches. At greater depth than this detection is unreliable if not impossible.

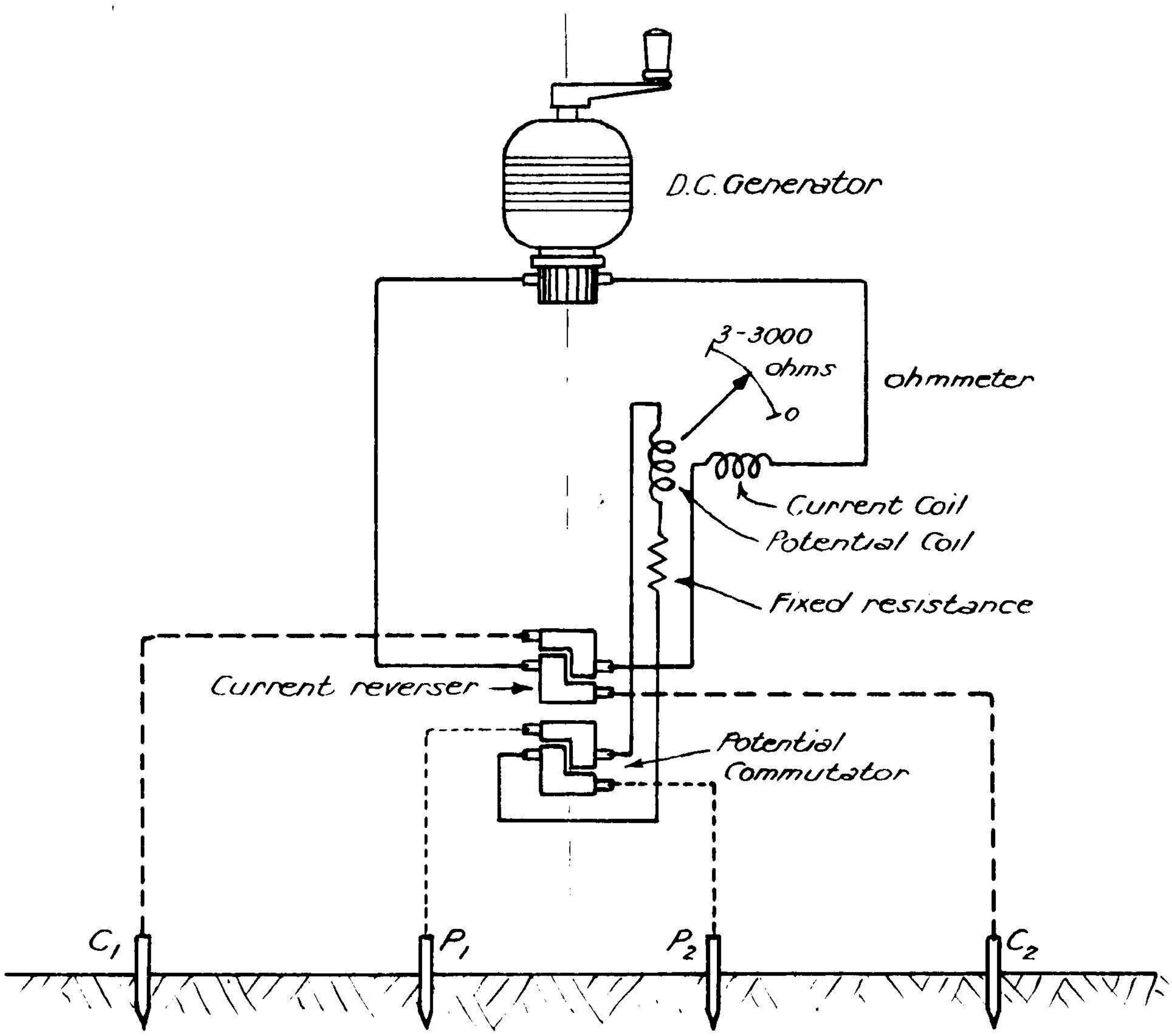
2. The areal extent of the effect due to the buried model is very limited. For a model 8 inches diameter by 4 inches thick at a depth of 2¾ inches, the detectability exceeded 1.0 over an area approximately equal to the area of the model. To be certain of detection, an area under examination would need to be covered by observations on a grid, the spacing of which should not exceed half the diameter of the object being sought. For a model 8 inches diameter, the grid spacing should not exceed 4 inches.

(R. F. Thyer)
GEOPHYSICIST.

10th May, 1944.

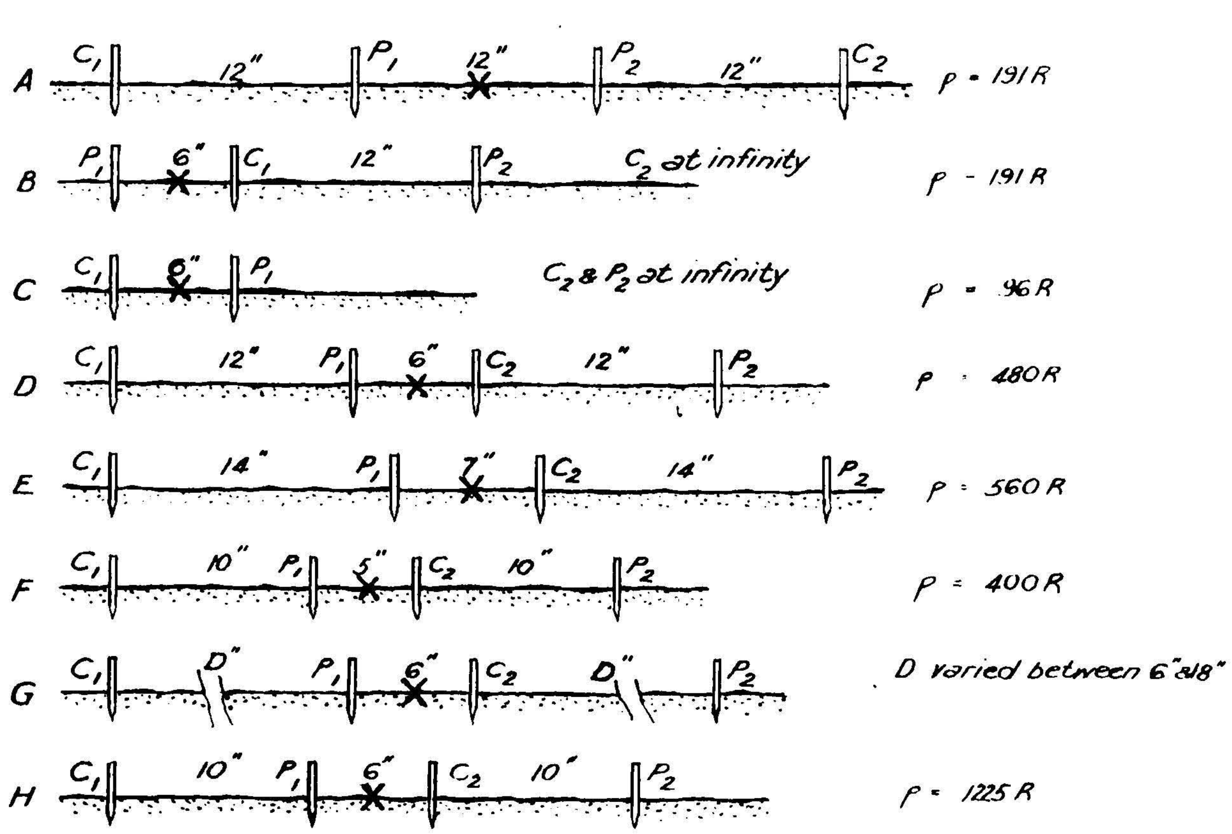
MEGGER EARTH TESTER

FIG. 1



PRINCIPLE ELECTRODE ARRANGEMENTS USED IN THE RESISTIVITY TESTS

FIG. 2



In the resistivity curves Figs. 4 - 16, the resistivities plotted on vertical scale, are the values obtained when the centre of the system, marked X, was at the distances shown on the horizontal scale from the centre of the buried object.

FIG. 3

ELECTRODE SYSTEM USED IN RESISTIVITY TESTS

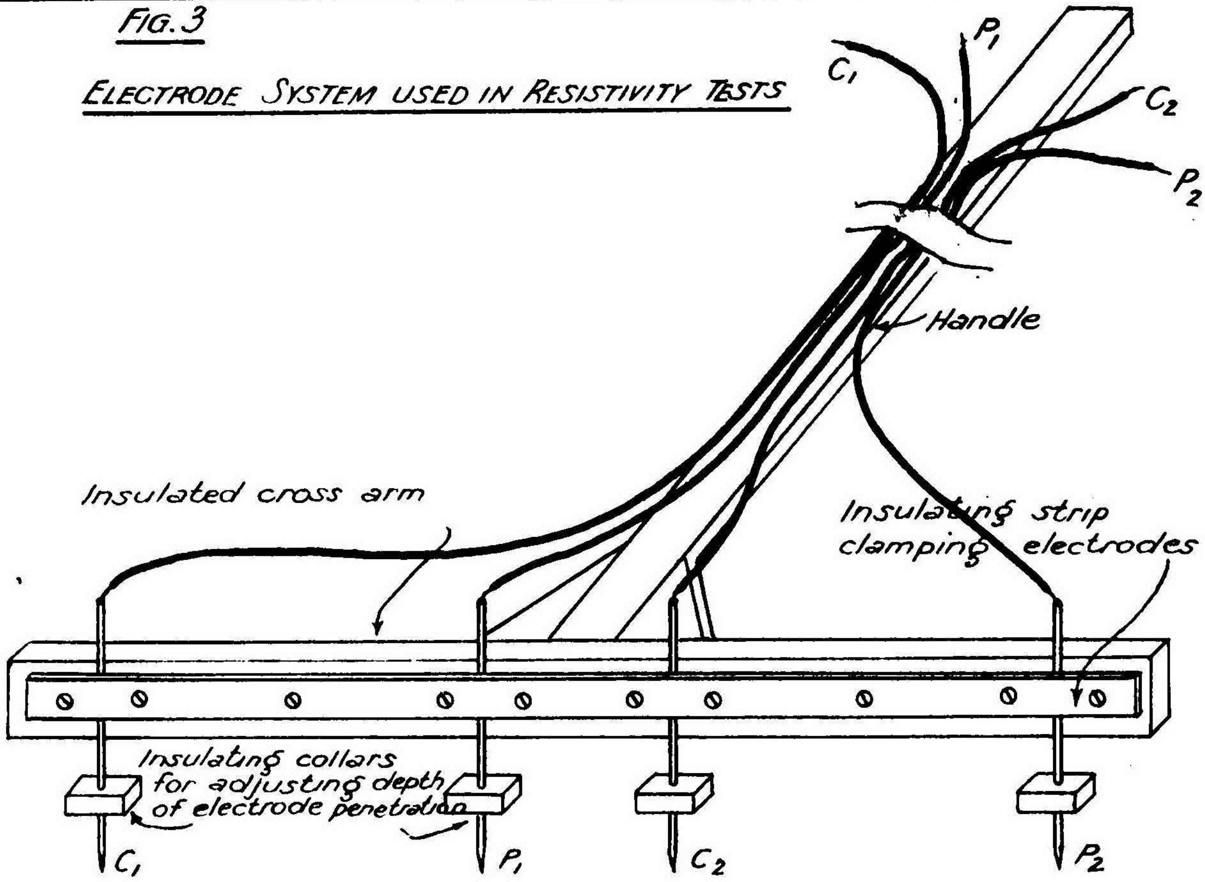
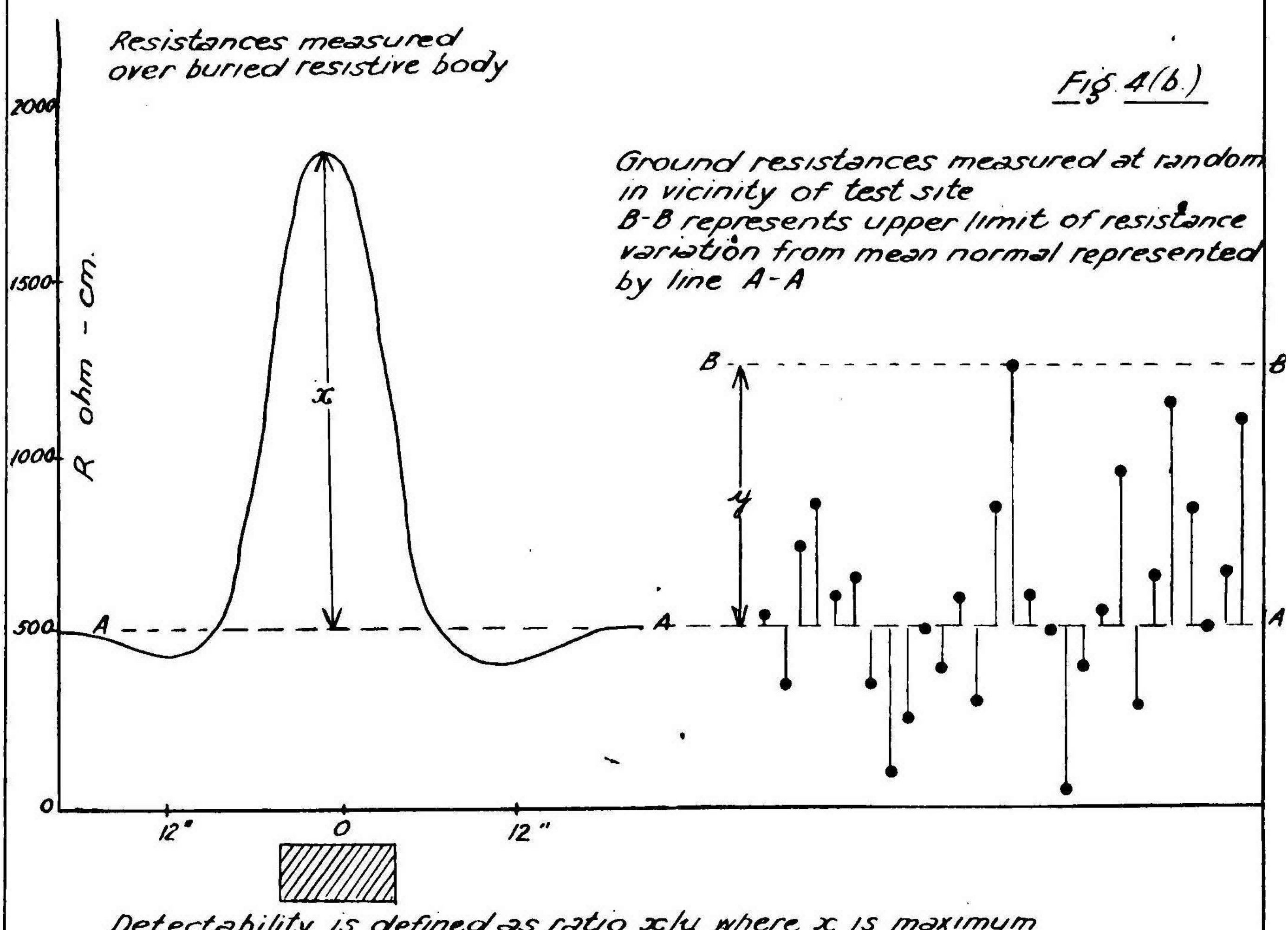
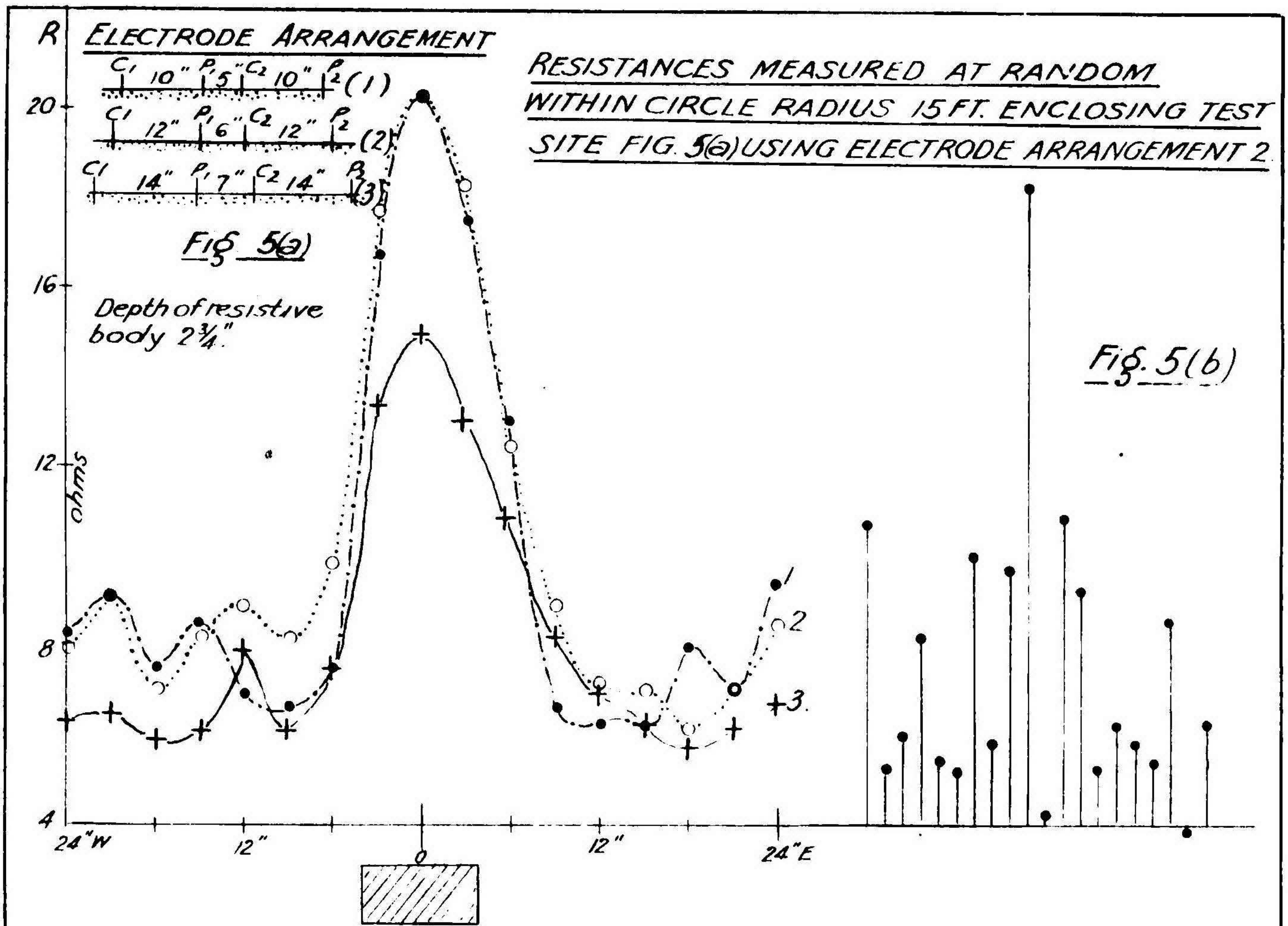


Fig. 4(a) SKETCH ILLUSTRATING DEFINITION OF DETECTABILITY

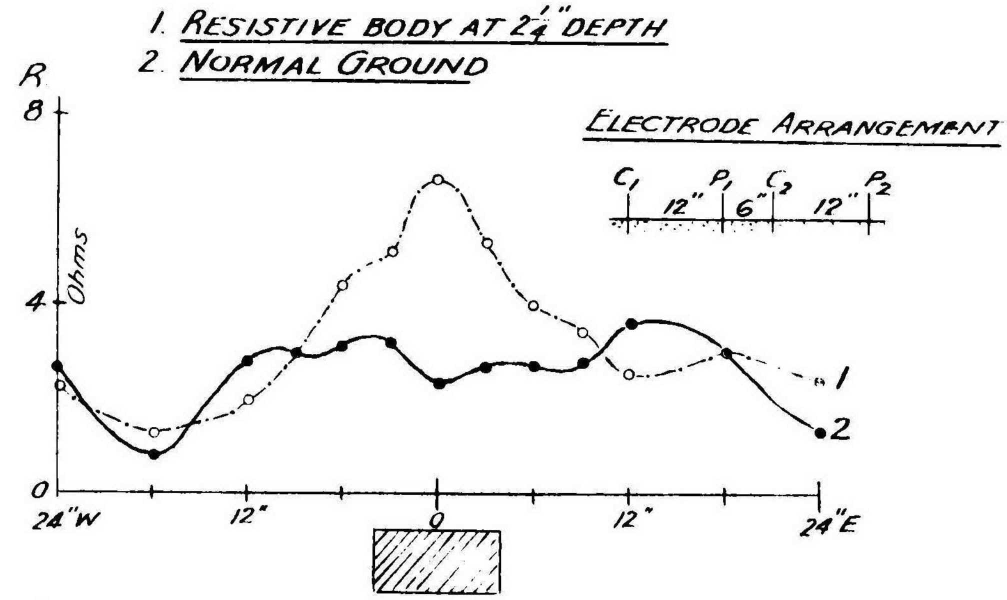


Detectability is defined as ratio x/y where x is maximum change in R from mean normal due to the buried body & y is the maximum positive departure of ground resistance from mean normal.



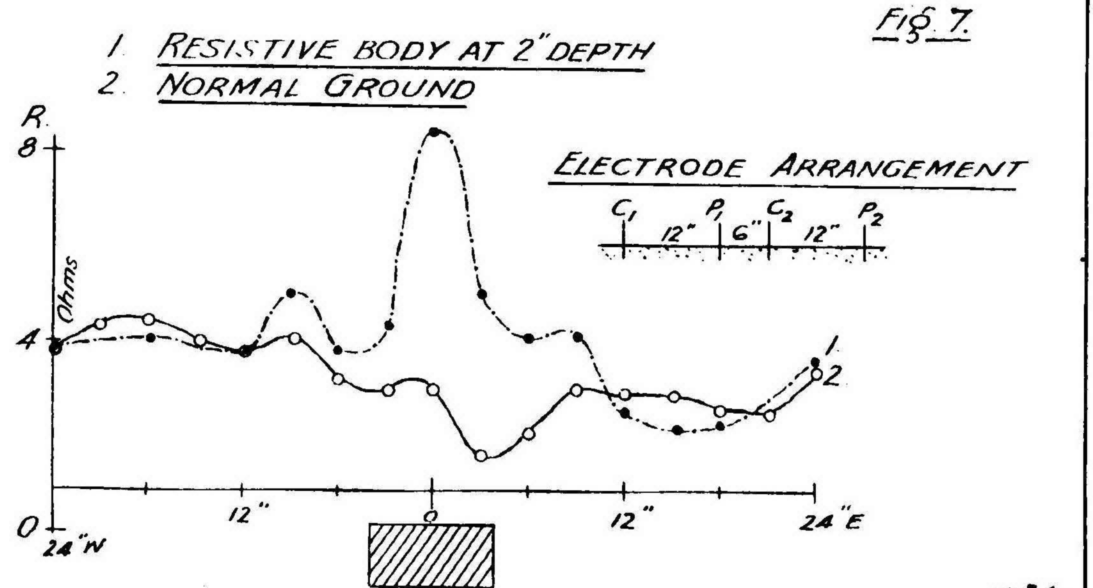
R
ELECTRODE ARRANGEMENT
C1 10" P1 5" C2 10" P2 (1)
C1 12" P1 6" C2 12" P2 (2)
C1 14" P1 7" C2 14" P2 (3)
Fig 5(a)
Depth of resistive body 2¾"
Ohms
RESISTANCES MEASURED AT RANDOM WITHIN CIRCLE RADIUS 15 FT. ENCLOSING TEST SITE FIG. 5(a) USING ELECTRODE ARRANGEMENT 2.
Fig. 5(b)
24"W
12"
0
12"
24"E

Fig 6.



1. RESISTIVE BODY AT 2¼" DEPTH
2. NORMAL GROUND
R
Ohms
ELECTRODE ARRANGEMENT
C1 12" P1 6" C2 12" P2
24"W
12"
0
12"
24"E

Fig 7.



1. RESISTIVE BODY AT 2" DEPTH
2. NORMAL GROUND
R
Ohms
ELECTRODE ARRANGEMENT
C1 12" P1 6" C2 12" P2
24"W
12"
0
12"
24"E

Fig. 8

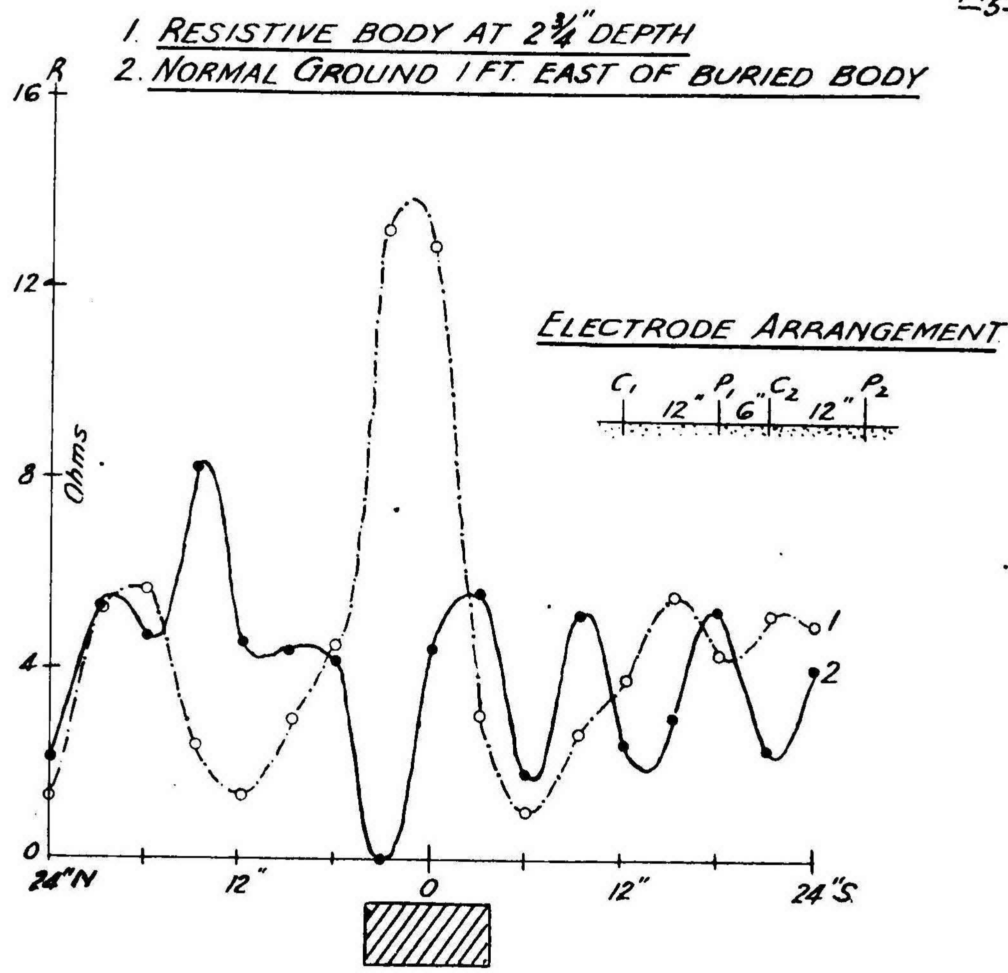

1. RESISTIVE BODY AT 2¾" DEPTH
2. NORMAL GROUND 1 FT. EAST OF BURIED BODY
R
Ohms
16
12
8
4
0
ELECTRODE ARRANGEMENT
C1 12" P1 6" C2 12" P2
1
2
24" N
12"
0
12"
24" S

Fig. 9

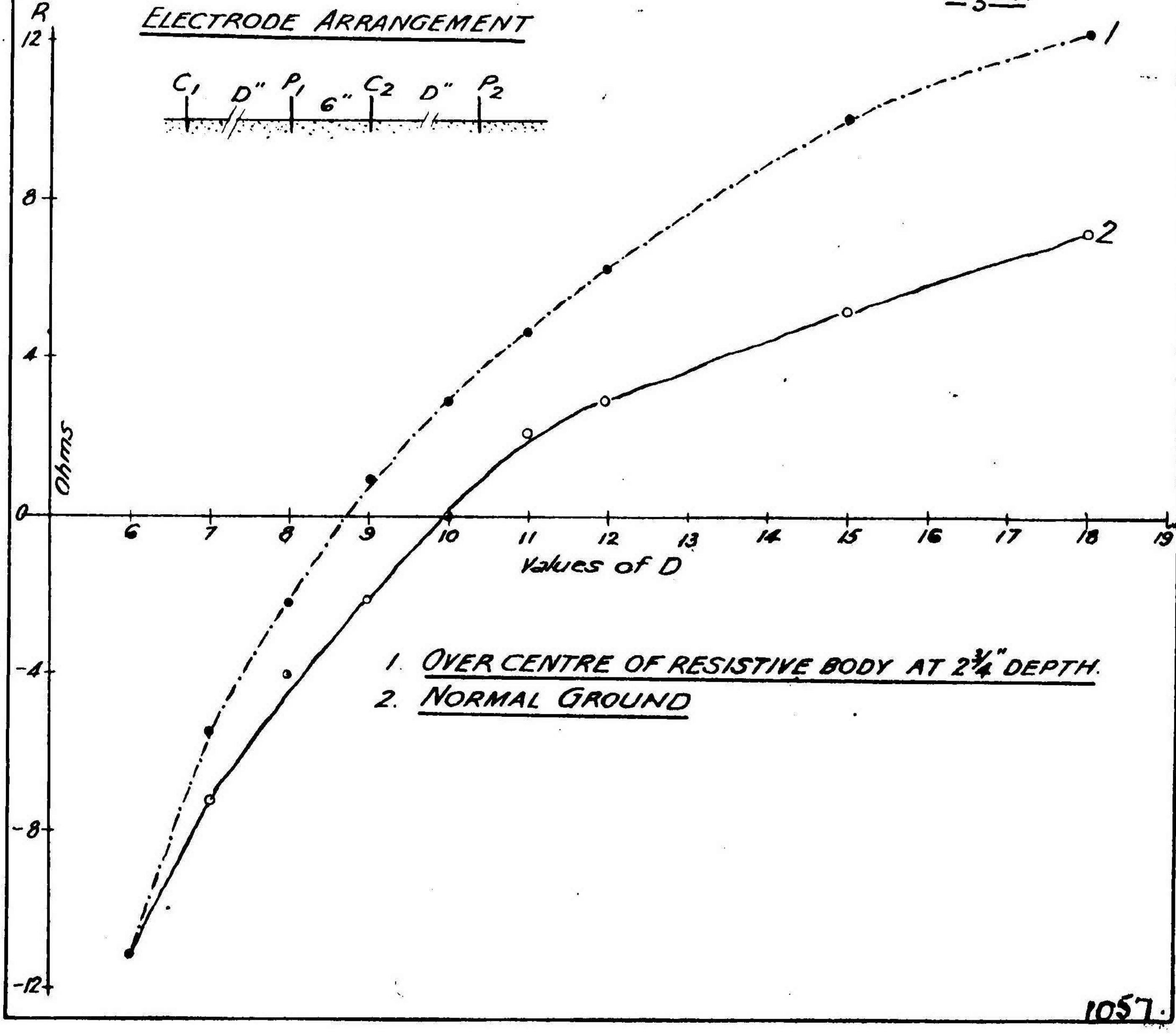

ELECTRODE ARRANGEMENT
C1 D" P1 6" C2 D" P2
R
Ohms
12
8
4
0
-4
-8
-12
6 7 8 9 10 11 12 13 14 15 16 17 18 19
Values of D
1. OVER CENTRE OF RESISTIVE BODY AT 2¾" DEPTH.
2. NORMAL GROUND
1
2

Fig. 10

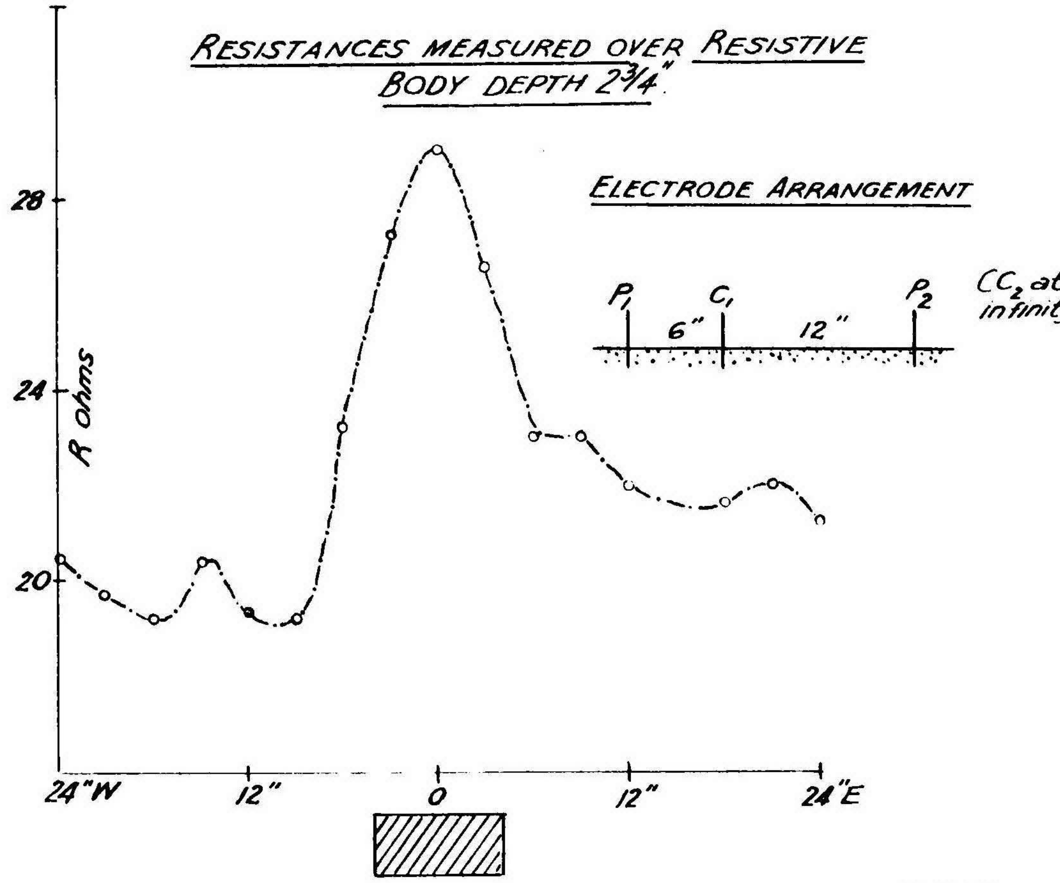


Fig. 11.

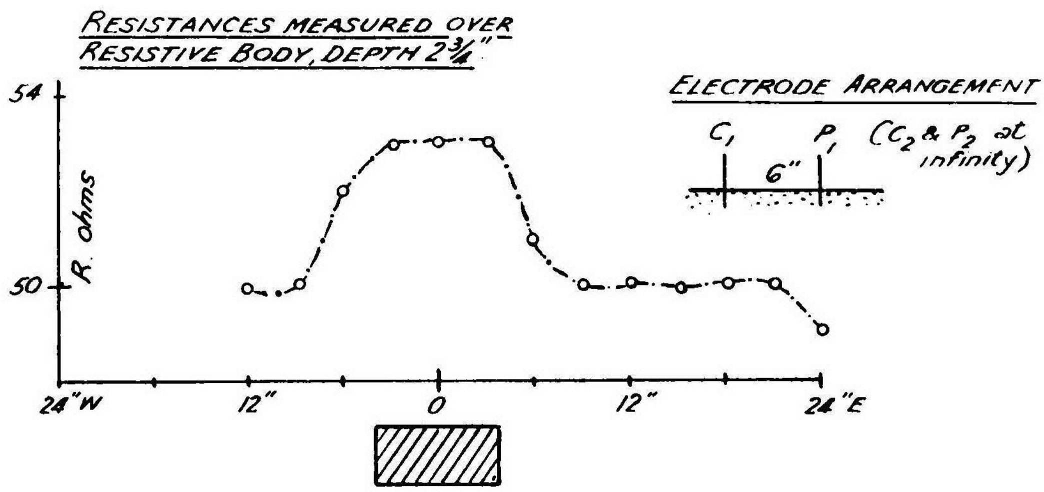


Fig 12(a)

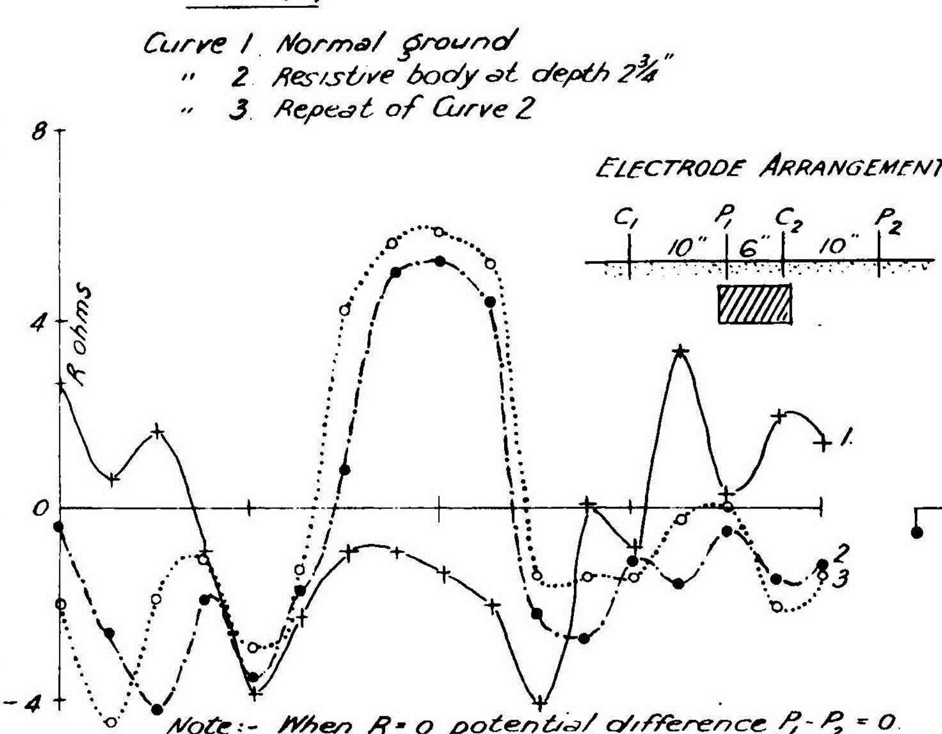


Fig 12(b)

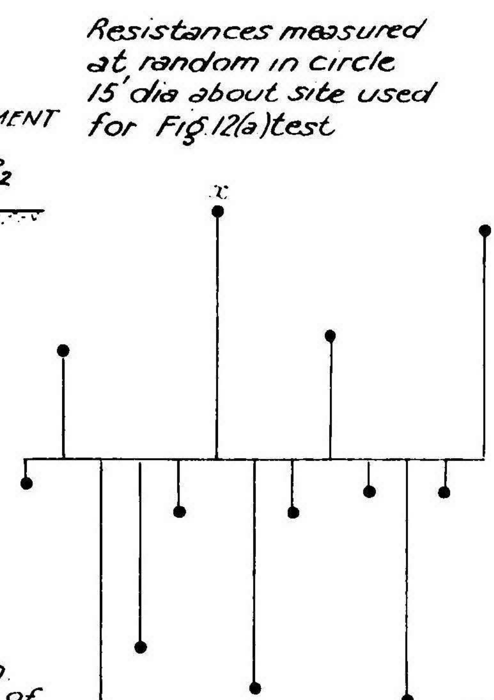


FIG 13

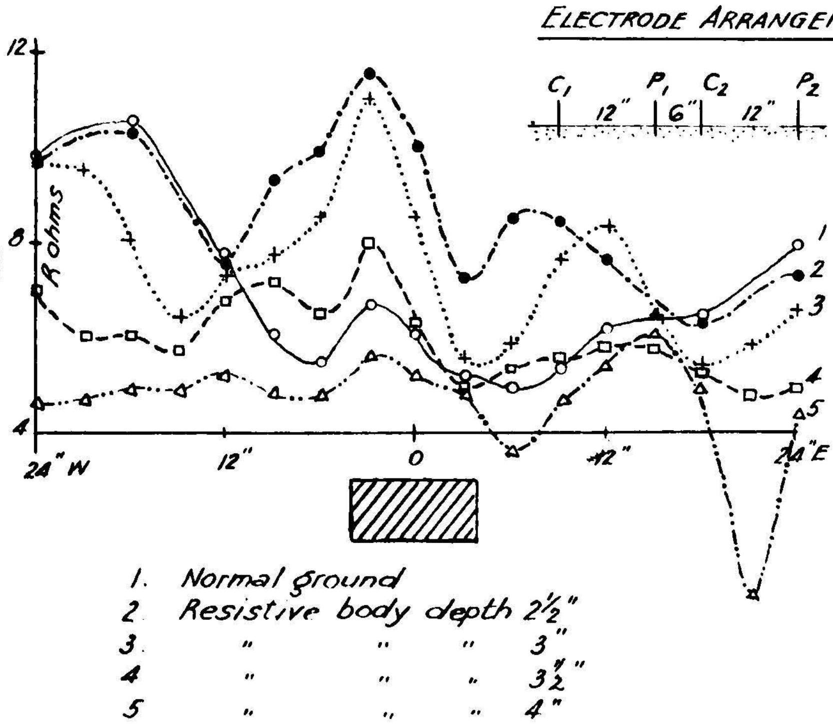


Fig. 14(b)

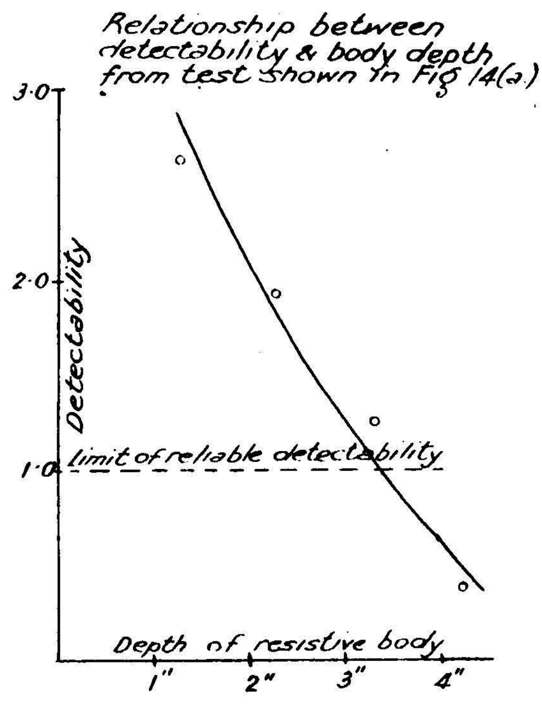
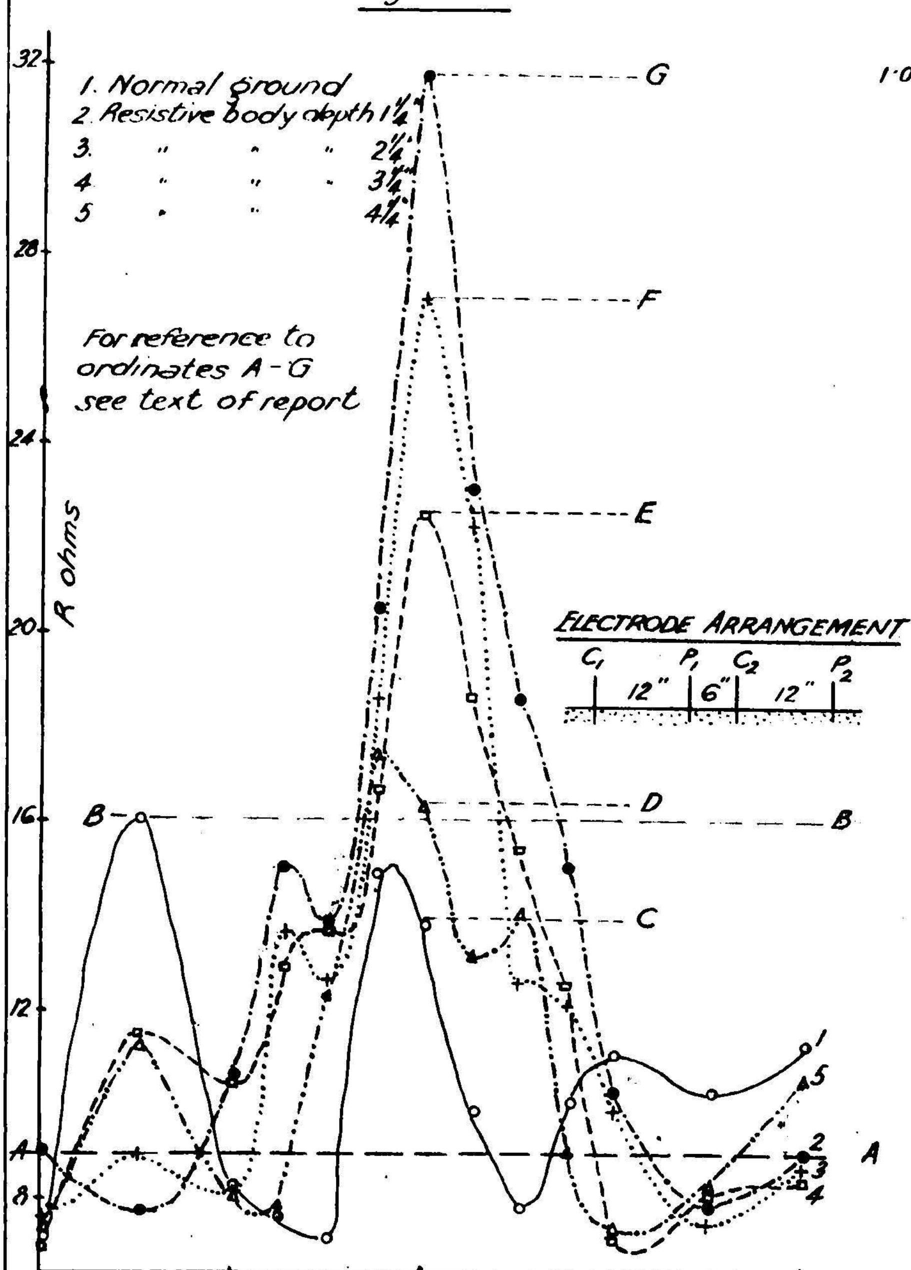
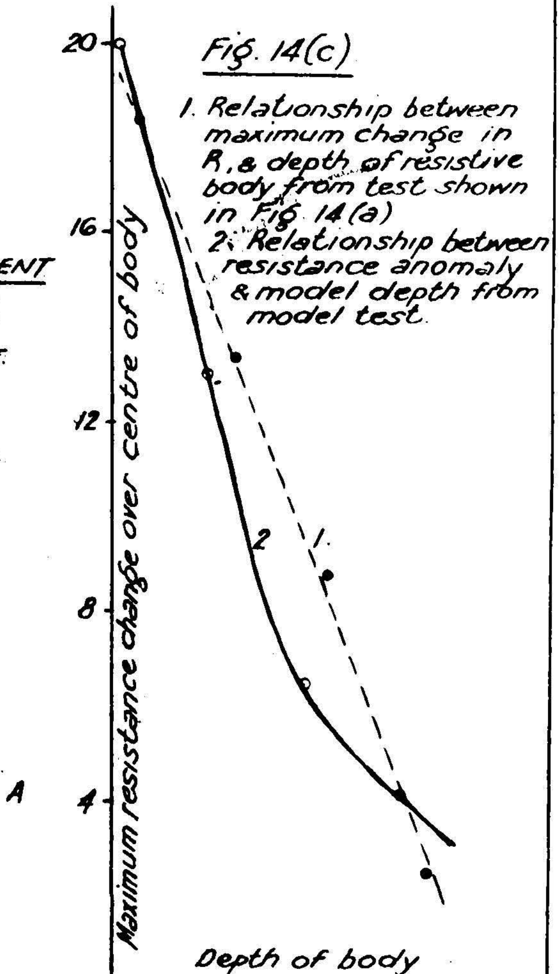


Fig. 14(a)





Test with Resistive Body under Water

1. Normal ground-surface wet
2. Resistive body at 2¾" depth - surface wet
3. " " " " " - ¾" water covering surface
4. " " " " " - 2" " " "

Fig 15(a)

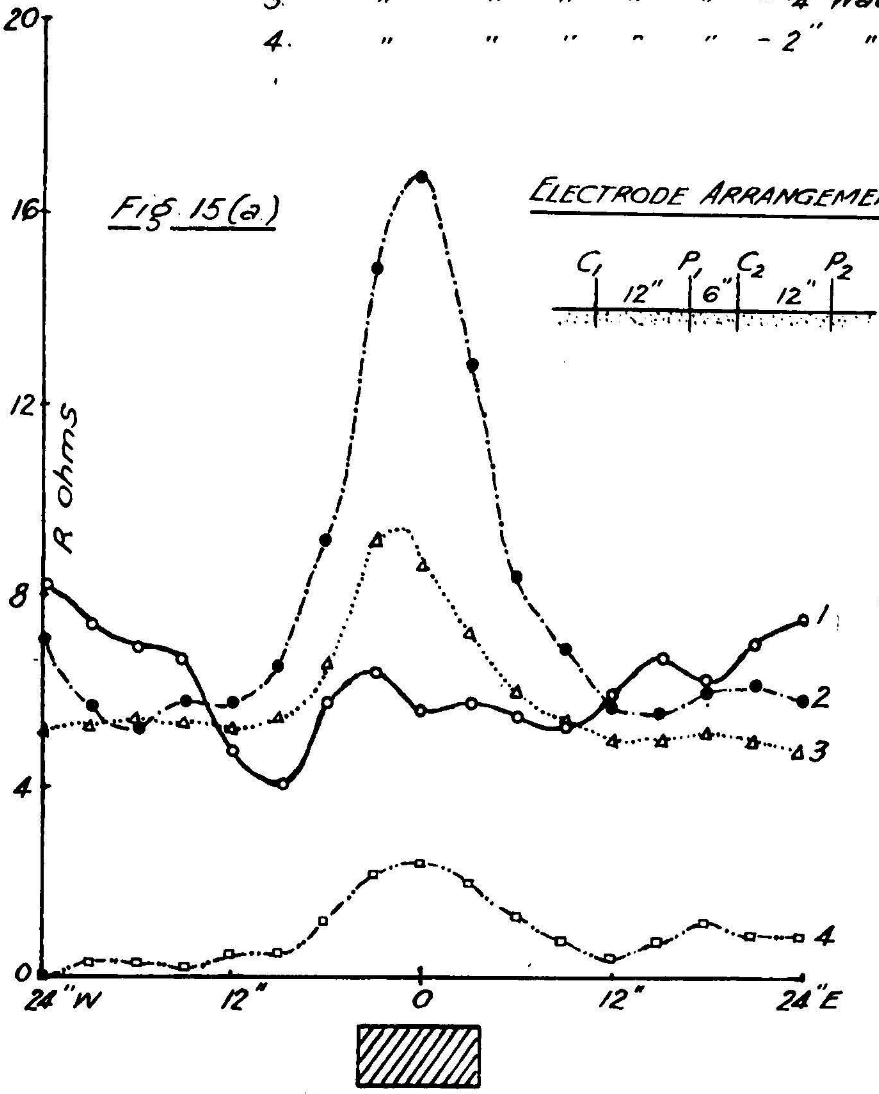


Fig 15(b)

Relationship between depth of water covering the surface & the reciprocal of maximum resistance change due to the buried resistive body

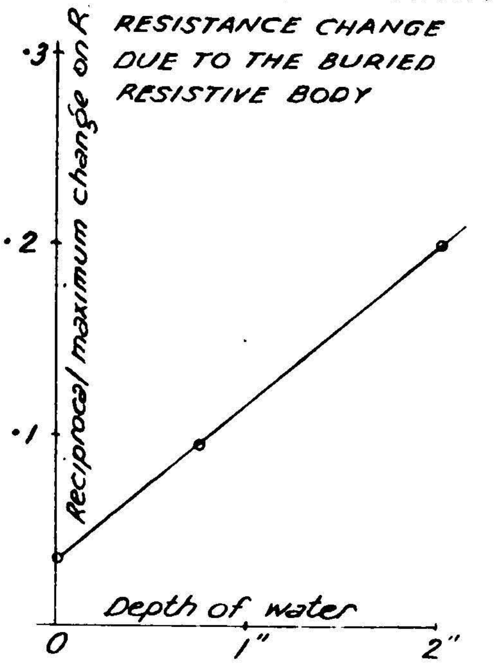


Fig 16(a)

Plan of Electrode Arrangements Used in Tests Shown Below

Fig 16(b)

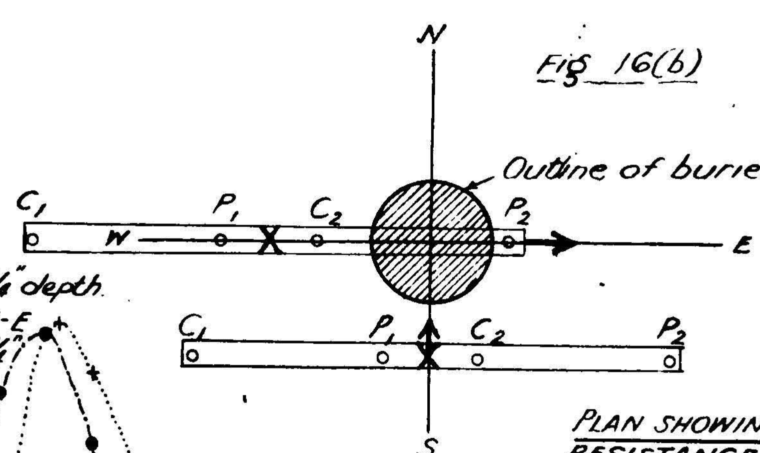


Fig 16(a)

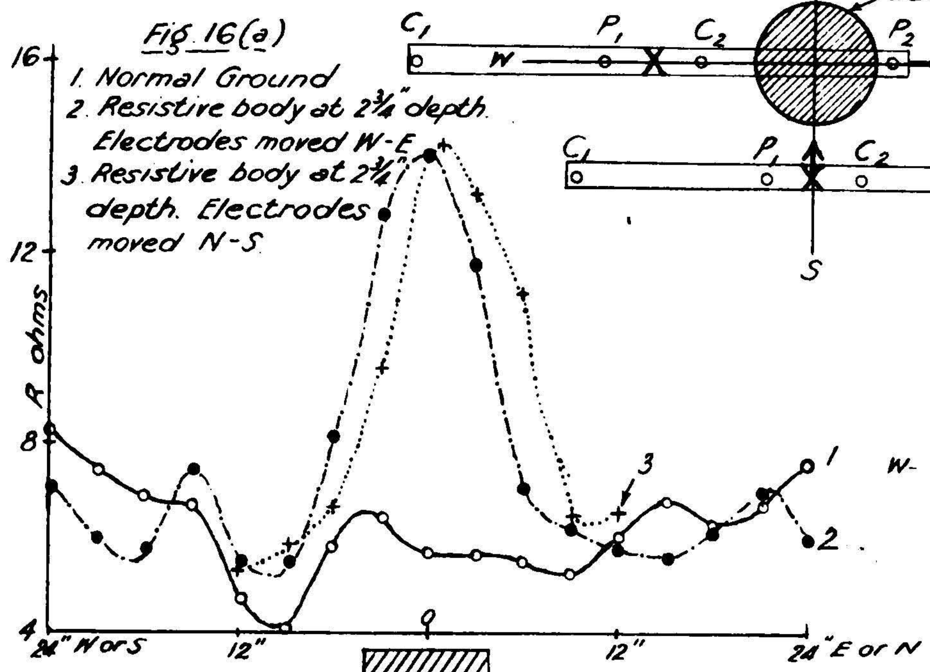


Fig 16(c)

Plan showing lines of equal resistance & outline of buried body