

Feb. 13, 1940.

G. PETERSON

2,190,324

METHOD OF GEOPHYSICAL PROSPECTING

Filed Feb. 2, 1938

4 Sheets-Sheet 1

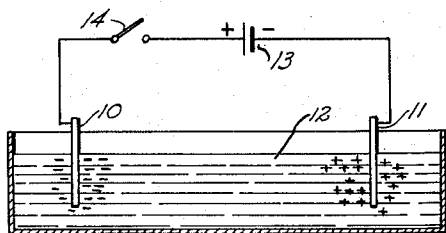


Fig. 1.

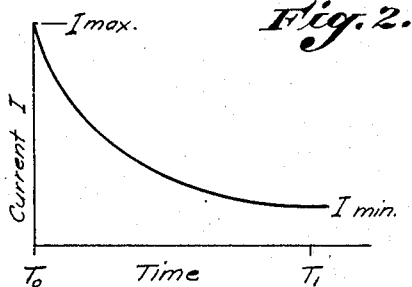


Fig. 2.

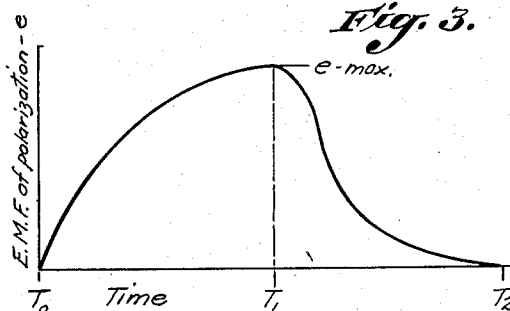


Fig. 3.

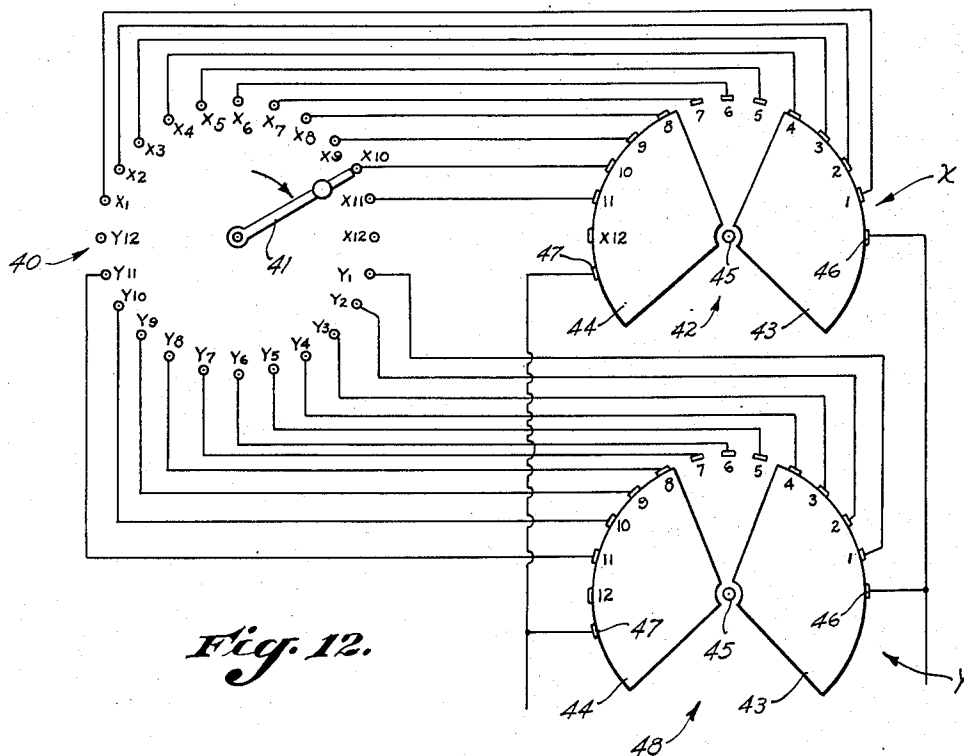


Fig. 12.

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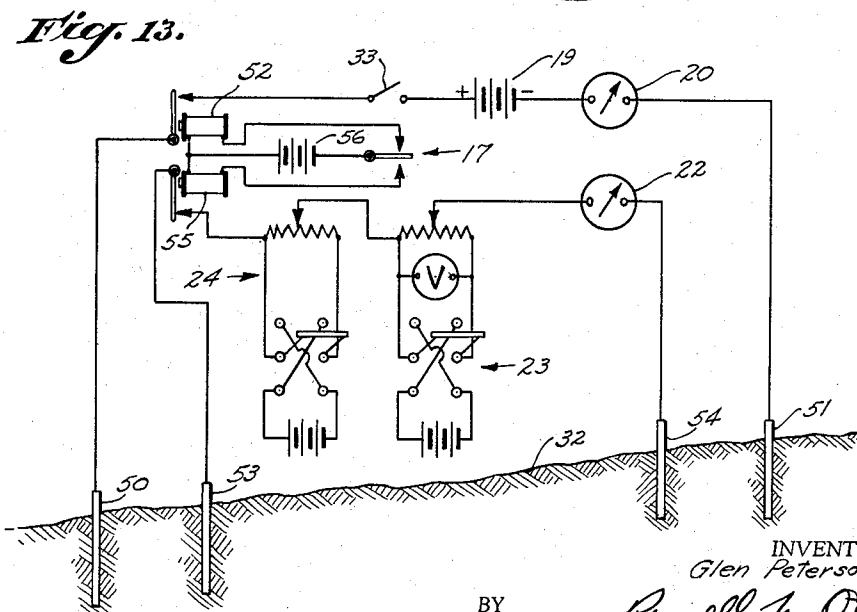
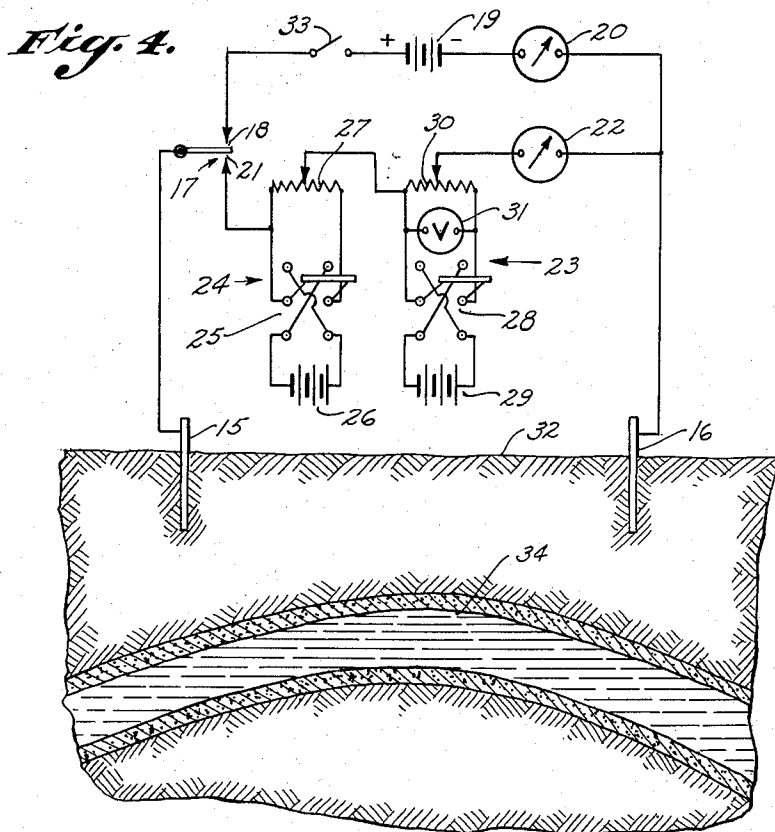
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4 Sheets-Sheet 2



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4 Sheets-Sheet 3

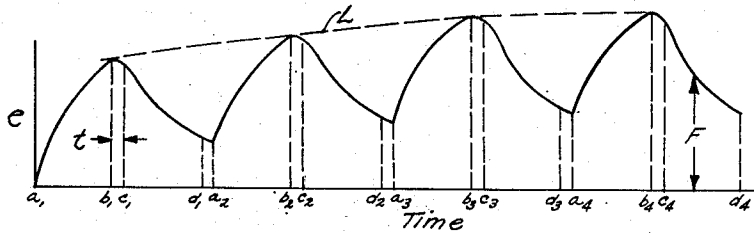


Fig. 5.

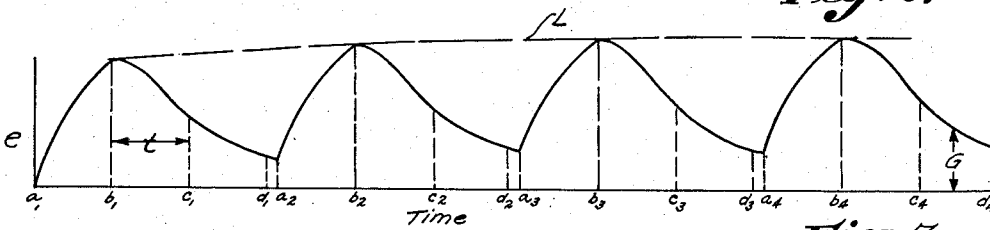


Fig. 6.

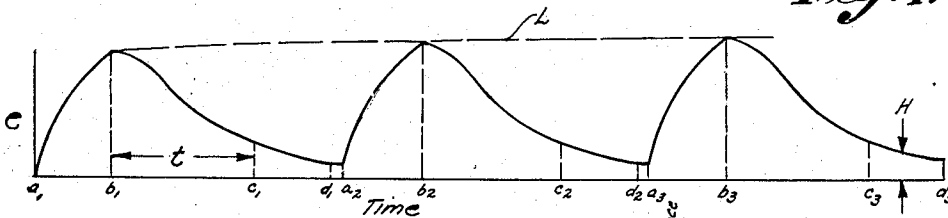


Fig. 7.

Fig. 9.

Fig. 8.

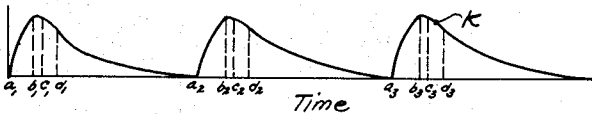
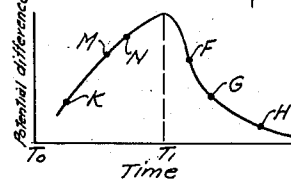


Fig. 10.

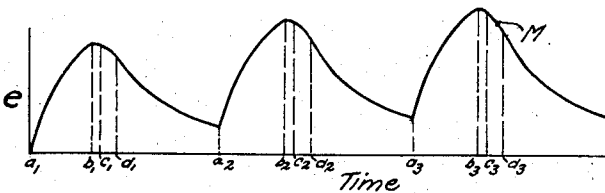
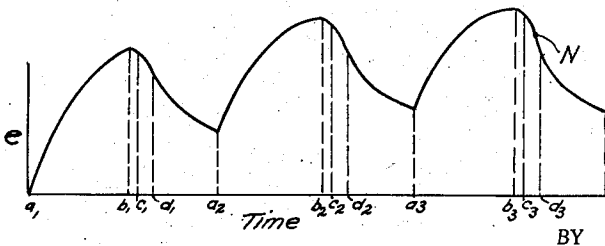


Fig. 11.



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4 Sheets-Sheet 4

Fig. 14.

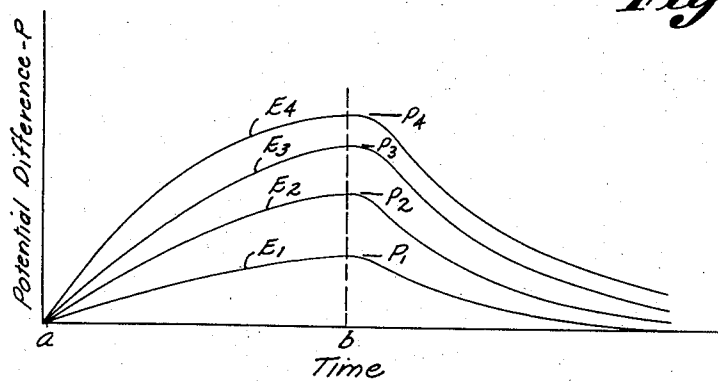
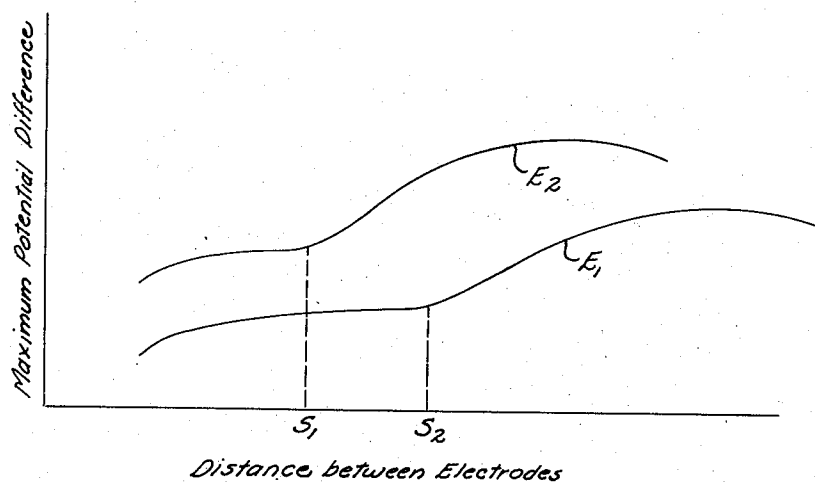


Fig. 15.



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UNITED STATES PATENT OFFICE

2,190,324

METHOD OF GEOPHYSICAL PROSPECTING

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Application February 2, 1938, Serial No. 188,299

8 Claims. (Cl. 175—182)

This invention relates to geophysical prospecting and particularly to a method of, and apparatus for, geophysical prospecting involving measurements which depends upon the electrolytic polarization characteristics of underground formations.

An object of my invention is to provide a method of geophysical prospecting by which underground formations and structures may be indicated by measurements which reflect the degree of electrolytic polarization of the earth and the manner in which the polarization builds up and discharges.

Another object is to provide apparatus by which the afore-mentioned measurements may conveniently be made.

These and other apparent objects I attain in a manner which will be clear from a consideration of the following description taken in connection with the accompanying drawings, of which:

Fig. 1 is a diagrammatic illustration of a simple arrangement to demonstrate the underlying principles of my invention.

Fig. 2 is a diagram showing the manner in which the polarizing current in the circuit of Fig. 1 changes with time.

Fig. 3 is a diagram showing the manner in which the E. M. F. of polarization of the earth varies with time.

Fig. 4 is a diagrammatic illustration of a circuit arrangement employed in the practice of my invention.

Figs. 5, 6, and 7 are diagrams illustrating the variation of E. M. F. of polarization with time under three different conditions employed in the practice of my method, and illustrating the relation between the periods of polarization and of measurement.

Fig. 8 is a diagram illustrating the curve of potential difference vs. time obtainable from practice of my method.

Figs. 9, 10, and 11 are diagrams illustrating the variation of E. M. F. of polarization with time under three conditions employed in determining the first part of the curve of Fig. 8.

Fig. 12 is a diagrammatic illustration of a relay employed in my apparatus.

Fig. 13 is a diagrammatic illustration of an alternative circuit arrangement that may be employed in the practice of my invention.

Fig. 14 is a diagram illustrating the type of curves derived from data obtainable by use of my method, showing the variation of the potential difference due to earth polarization during

the build-up and the decay of polarization for various polarizing electromotive forces acting over one particular polarizing time period.

Fig. 15 is a diagram illustrating the variation of the maximum potential difference due to earth polarization, obtained during the build-up and decay of polarization, with a change in the distance between electrodes, for two different polarizing electromotive forces.

My invention is based upon the phenomenon of electrolytic polarization which can best be understood by reference to Figs. 1, 2, and 3. Consider the simple circuit consisting of two spaced electrodes 10 and 11 in electric contact with an electrolyte 12, and in circuit with a source 13 of direct current, and a switch 14. When the switch 14 is closed, current starts to flow through the circuit with an initial value I_{max} , determined by Ohm's law, but gradually decreases to a minimum I_{min} , due to polarization which is built up in the electrolyte. In the case of most electrolytes the decrease of current with time is about as represented in Fig. 2. In the case of oil, however, there is a delay of about 1 second before the current is observed to decrease by polarization.

The polarization which is responsible for the decrease of current in an electrolytic circuit may be considered as mainly due to the concentration of electrically-charged ions at inhomogeneities in the electrolyte, amounting in effect to an electromotive force in the electrolyte portion of the circuit in opposition to the applied E. M. F. Thus, in the apparatus of Fig. 1, negatively-charged ions are found in the neighborhood of positive electrode 10 and positively-charged ions are found in the neighborhood of negative electrode 11.

The earth conducts current chiefly as an electrolyte, and since it is composed of many substances which are largely distributed in the earth in strata and lenticular deposits, there are many inhomogeneities and many obstacles to the free passage of ions therethrough. The various boundaries between dissimilar formations existing in the earth, therefore, afford excellent opportunity for the accumulation of ions and the resultant production of polarization effects. Since the polarization effects are dependent upon the underground formations and structures in which they arise, they may be used for the determination of these formations and structures.

Assuming the switch 14 is closed at time T_0 , the E. M. F. of polarization, corresponding to decrease of current in the circuit, will build up according to the curve of e shown from time T_0 to

T₁. It will be observed that as the current decreases asymptotically to I_{min.} the E. M. F. of polarization increases and asymptotically approaches the value e_{max.} The relations existing between the various quantities are as follows:

- (1) $RI_{\max.} = E$
- (2) $RI = E - e$
- (3) $RI_{\min.} = E - e_{\max.}$

in which E is E. M. F. applied to the electrodes; e is E. M. F. of polarization; I is the current in the circuit; R is the ohmic resistance of the electrolyte between the electrodes.

At time T₁ if the switch 14 is opened, the E. M. F. of polarization e will discharge itself through the electrolyte between the concentrations of oppositely-charged ions and will, in consequence, decrease rapidly and asymptotically approach zero, which is substantially reached at time T₂. When the switch 14 is open and polarization is decreasing, a potential difference, proportional to the E. M. F. of polarization exists between the electrodes 10 and 11, and the manner in which the E. M. F. of polarization e decreases to zero is reflected by the manner in which the potential difference at the electrodes decreases. The extent and shape of the curve of Fig. 3 is important and is dependent upon the character of the electrolytically-conducting material traversed by the polarizing current. Thus, when a region of the earth is polarized by application of an electromotive force thereto, the character of underground formations and structures may be determined from analysis of the degree of polarization and the manner in which it builds up and discharges.

The degree of polarization for the same applied E. M. F. is different for different substances, and this effect alone, as indicated by difference in the value of e_{max.} or of I_{min.} may be employed to recognize underground formations. Oil-bearing sand is prominent in exhibiting a different degree of polarization from other substances which may surround it.

The presence of oil in a formation also tends to delay polarization by a time interval which in pure oil is of the order of 1 second. The shape of the curve of E. M. F. of polarization vs. time for earth containing oil, therefore, should be different from that for ordinary electrolytes. The energy absorbed by the electrolytic process is also important because it is characteristic of the particular earth formations through which the current passes, and when the energy or a function of the energy is determined, it may be used to indicate the composition of underground formations. The theoretical value of energy absorbed is

$$(4) \quad W = E \int_{T_0}^{T_1} I dt$$

T being time and having the same subscripts as in Figs. 2 and 3.

According to my invention, I provide a method of and apparatus for examining the polarization effects of the earth and for finding a curve which is related to the curve of E. M. F. of polarization vs. time, shown in Fig. 3, as will hereinafter be described in detail. The curve which I can determine by my method is significant because the curve of Fig. 3 is significant, and it will be obvious, therefore, that the information contained in the curve which my method enables me to determine constitutes a valuable tool in geophysical prospecting to aid in determining both the

structure and composition of underground formations.

I prefer to determine a curve related to that of Fig. 3 in the following manner. The circuit diagrammatically illustrated in Fig. 4 is preferably employed. Spaced non-polarizing electrodes 15 and 16 are electrically connected to the earth 32. Electrode 15 is connected to an arm of relay 17, which, when relay switch 18 is closed, connects the electrode 15 through switch 23 to the positive terminal of a source 19 of direct current, the negative terminal of which is connected to the electrode 16 through a direct current measuring instrument 20. When the switch 18 is opened and switch 21 is closed, the electrodes 15 and 16 are connected through the measuring circuit comprising direct current indicating instrument 22 and the balancing circuits 23 and 24 in series. The balancing circuit 24 comprises a double-pole, double-throw reversing switch 25 with a battery 26 connected to two of the stationary terminals and a potentiometer 27 connected to the movable terminals, the other stationary terminals being cross connected with the first to cause a potential difference of a certain value to be applied to potentiometer 27 in one position of the switch and an equal but opposite potential difference to be applied thereto in the other position of the switch. The balancing circuit 23 comprises the double-pole, double-throw reversing switch 28, the battery 29, and the potentiometer 30 connected in the same manner as in the circuit 24; and in addition has the voltage measuring instrument 31 connected across the potentiometer 30.

The relay 17, detailed description of one form of which will hereinafter be given, is adapted to close switch 18 and remain closed for a predetermined time interval, then open and remain open for another relatively predetermined time interval, then close switch 21 and remain closed for another predetermined interval, then open and repeat the cycle. During the time when switch 18 is closed, polarization is being built up in the earth and the E. M. F. of polarization is increasing in a manner similar to that part of the curve of Fig. 3 between T₀ and T₁; while during the time when switch 18 is open, the earth polarization is being discharged and the E. M. F. of polarization is decreasing in a manner similar to that part of the curve of Fig. 3 between T₁ and T₂. During the time when switch 21 is closed the potential difference between the electrodes 15 and 16 due to earth polarization previously set up is impressed upon the measuring circuit.

In making observations, I first close the relay switch 21, the switches 25 and 28 being open. Ordinarily a small earth current will be observed to pass through instrument 22. Then with the potentiometer 27 set to insert zero E. M. F. in the measuring circuit, I close the switch 25 in a direction to cause a potential difference across potentiometer 27 which is of proper direction to neutralize the current flowing through instrument 22, and I then gradually adjust the potentiometer 27 until no current passes through the instrument 22. With the normal earth currents balanced out in this manner, I then proceed to repeatedly polarize the earth and measure potential differences between the electrodes during various intervals of time in a manner that can best be understood by reference to Figs. 5, 6, and 7.

With switch 33 closed, I may close the switch 18 at time a₁ and allow it to remain closed until 75

time b_1 when the switch 18 is opened and the earth polarization starts to decrease. At time c_1 after an interval $t=b_1c_1$ has elapsed the switch 21 is closed connecting the voltage measuring circuit to measure the potential difference between the electrodes during the time interval c_1d_1 . At time d_1 the switch 21 is opened and at time a_2 the cycle is repeated, the time intervals for each of the foregoing periods in each cycle being maintained the same as in every other cycle. Referring to Fig. 5, it will be observed that when switch 18 is closed at the start of the second cycle the E. M. F. of polarization has not returned to zero and therefore starts to build up from a value higher than in the first cycle. Hence, at the end b_2 of the polarization period of the second cycle, the E. M. F. of polarization has reached a value higher than in the first cycle. In a similar manner, the polarization reaches a higher value in each succeeding cycle until an equilibrium value is arrived at, the progress of the maximum E. M. F. value being traced by the dotted line L.

The instruments 20 and 22 are preferably of a type that will indicate the average current passing through them over the longest cycle that is to be used. Thus, the instrument 20 measures the average polarizing current throughout the cycle and the instrument 22 will be affected by the average potential difference between the electrodes due to the E. M. F. of polarization during the measuring period c_1d_1 , again averaged over the cycle. By knowing the average throughout the cycle and what portion of the cycle the currents are active it is possible to compute the average value of polarizing current and electrode potential difference during the time periods when they are active.

In measuring the electrode potential difference, I may make the measurement directly on the instrument 22 as described above, but I preferably use the instrument 22 only as an indicating instrument and adjust the potential difference of potentiometer 30 to include in series with instrument 22 a sufficient potential difference to just neutralize the potential difference due to E. M. F. of polarization. The potential difference as determined from the voltage read on instrument 31 and the position of the variable arm of the potentiometer 30 is a measure of the potential difference between the electrodes due to E. M. F. of polarization.

The whole procedure above described is repeated as in Figs. 6 and 7, preferably with the same polarizing interval ab , and the same measuring interval cd , and with the same interval da , but with successively longer intervals t between the termination of the polarizing period and the beginning of the measuring period, and therefore successively longer cycles. It will be observed that in Fig. 6 the period t is longer than in Fig. 5 and hence the potential difference is measured further along the polarization decay curve. One result of this is that the polarizing period of the second cycle in Fig. 6 does not start with so high an E. M. F. as in Fig. 5, and therefore in Fig. 6 there is not such a great difference between the equilibrium value of maximum E. M. F. and that which exists after the polarizing period of the first cycle. In Fig. 7 the time period t and the cycle length are still longer than in Fig. 6, and the potential difference is measured at a point still further down on the polarization decay curve. Also there is very little difference between the equilibrium value of the maximum

polarization E. M. F. and the value after the polarizing period of the first cycle.

I may now plot the average value of electrode potential difference, F, G, and H, during the measuring periods of Figs. 5, 6, and 7, as in Fig. 8 against the corresponding times and a curve may be drawn through them as indicated. In practice, of course, I make many more observations corresponding to different intervals t , in order to be able to plot the curve accurately all along its length. While this curve is not exactly that of polarization E. M. F. vs. time because of the fact that the potential differences measured are averages over a substantial time period and because of the differences in equilibrium value of the maximum polarization E. M. F. under the conditions of the various measurements; nevertheless the curve representing decay of polarization in Fig. 8 is dependent upon and related to the true curve as shown in Fig. 3, and is therefore significant and can be employed as a tool in determining underground formation.

In order to determine a curve related to the charging curve of Fig. 3, I may make a series of measurements under the conditions illustrated in Figs. 9, 10, and 11, in which the various periods of the cycle are designated similarly to those of Figs. 5, 6, and 7. Instead of holding the polarizing period ab constant, it is successively increased in this series, and the measuring period cd , the time interval bc , and the total time of one cycle, are held constant. The measuring period is in each case taken as close to the end of the polarizing period as is convenient. When equilibrium is attained, the average potential differences K, M, and N, existing during the measuring period are measured, and may then be plotted against the corresponding time as in Fig. 8 to represent the points on the charging curve, from T_0 to T_1 . While there is an error in assigning these values of potential difference measured on the discharge curve, as points on the charging curve, the error may be reduced by making the measuring period closely follow the termination of the polarizing period. In any case, the charging curve plotted from a series of measurements as K, M, and N is related to the actual charging curve of Fig. 3, and may be employed to provide information useful in determining underground formations.

I may resort to Equation 3 to determine e_{max} . I_{min} may be obtained by keeping the relay switch 18 closed for a very long time and noting the value to which the current through meter 20 falls. R may be determined by impressing upon the electrodes in the earth an electromotive force large compared to the E. M. F.'s of polarization normally set up and measuring the rate of change of the current with the impressed E. M. F. This rate of change is the conductance of which the resistance is the reciprocal. The value of e_{max} found in this way may be assigned to the maximum in the curve of Fig. 8, and corresponding values of e may then be found for various times T from the curve of Fig. 8. By use of Equation 2, values of I may then be found for these values of T and may be employed in Equation 4 to get a value which, while it is not strictly the energy absorbed in the polarization process, is related to the energy and may be employed as indicative of underground formations traversed by the polarizing current.

While, in the foregoing procedures, the polarizing electromotive force has been assumed constant, I may vary it, holding the polarizing time

ab constant and measuring the electrode potential difference immediately following the termination of the polarizing period in the case of each particular value of polarizing E. M. F.; and I may make the entire series of tests previously described with each of a plurality of different polarizing electromotive forces. An important result of conducting the tests with various values of polarizing E. M. F. is that with larger values of polarizing E. M. F. the earth layers near the surface become saturated with respect to polarization and increases in polarization are mainly contributed by the deeper earth layers, the composition of which it is desired to determine.

Thus, as illustrated in Fig. 14, I may obtain the curve of potential difference vs. time during the build-up of polarization over a polarizing period *ab* and for an applied polarizing E. M. F. E_1 as previously described in connection with Figs. 9, 10, and 11, and may then determine the curve of potential difference vs. time during the discharge of polarization as previously described in connection with Figs. 5, 6, and 7, plotting the complete curve E_1 in Fig. 14, as was done in Fig. 8. The charging curve over the period *ab* is then determined in a like manner for a greater polarizing E. M. F. E_2 , the corresponding discharge curve is determined and the complete curve is plotted as curve E_2 in Fig. 14. In a similar manner curves E_3 and E_4 corresponding to progressively greater values of polarizing E. M. F. are determined and plotted in Fig. 14 as curves E_3 and E_4 respectively.

As shown in Fig. 14, the curve E_1 in the time interval *ab* is nearly straight because the applied E. M. F. is so small that not even the earth layers near the surface are saturated in the sense of reaching their highest possible polarization. When the polarizing E. M. F. is increased to E_2 the charging curve is more curved, showing more tendency to approach an upper limit, and the potential difference P_2 due to polarization at time *b* is considerably greater than that of P_1 when the applied E. M. F. was lower. By increasing the applied E. M. F. from E_1 to E_2 the resultant polarization in the various parts of the earth affected is increased, resulting in a higher curve for E_2 and in a higher maximum value P_2 . This will be readily understood when it is remembered that the polarization E. M. F. arising in any part of the earth cannot be higher than the applied potential difference existing in that part of the earth. But the resulting polarization in any part of the earth has a maximum value above which it cannot go regardless of the applied E. M. F., and this results in the upper surface layers of earth, where the greatest potential gradient exists, becoming saturated before the lower layers. This causes equal increments in applied E. M. F. to produce a less increase in polarization as the applied E. M. F. is increased. Thus $P_4 - P_3 < P_3 - P_2 < P_2 - P_1 < P_1$. Another effect of an increased applied E. M. F. is that the movement of ions within the earth is more rapid and the approach toward equilibrium proceeds more rapidly. Thus it will be observed that the curve E_4 , for example, bends over at an earlier time than the curve E_2 corresponding to a lower value of applied E. M. F.

It will now be clear that as the applied E. M. F. is increased the increment in polarization will, due to the saturation of the upper layers of earth, be contributed mainly by the under layers of earth. As the applied E. M. F. is progres-

sively increased by equal amounts, the curves similar to E_1, E_2, E_3, E_4 may be obtained and the differences between the ordinates of successive curves may be found and plotted to indicate the polarization characteristics of successively deeper earth layers. The method of geophysical prospecting above described, therefore, offers the possibility of determining the characteristics of deep underlying strata of earth exclusively.

In practice, in the field, I preferably make all of the above-described measurements at each of a number of different electrode spacings. The depth of an earth formation which can contribute to the polarization effect is dependent upon the electrode spacing, being greater for a greater electrode spacing. By gradually increasing the electrode spacing and noting at what spacing the curve of Fig. 8 or those of Fig. 14, showing potential differences vs. time, exhibit shapes and values characteristic of certain formations and structures, the depths of these formations and structures may be estimated. In this manner, a zone 34 of oil-bearing sand, for example, may be located.

I may determine the maximum potential difference P of one of the curves of Fig. 14, corresponding to a given applied E. M. F. E_1 and a given polarizing time *ab* and, keeping E_1 and *ab* constant, vary the distance between the earthed electrodes. I may then plot the maximum potential difference obtained for the various electrode spacings and obtain a curve E_1 in Fig. 15. I may then follow the same procedure to obtain a curve E_2 for a higher value of applied E. M. F. As the electrode spacing is increased, deeper lying earth layers become of importance in determining the shapes of the curves of Fig. 15. If there exists in the earth a stratum exhibiting unusually large polarization, the curve E_1 in Fig. 15 may start to rise rapidly at the spacing S_2 , and the distance S_2 together with the E. M. F. E_1 will serve to indicate the depth of this stratum. The rise in curve E_2 , however, will be found to occur at a smaller electrode spacing S_1 , due to the fact that the larger applied E. M. F. E_2 has been able to affect this stratum even at the relatively closer spacing. By this procedure two or more separate but related sets of data are made available from which to more accurately compute the depth of the stratum causing the irregularities in the curves.

While various devices may be employed to act as relays in the performance of the functions required in making the measurements described above, I shall describe in detail one such device, illustrated in Fig. 12. A distributor 40 has a large number of segments, here shown for simplicity as only 24 in number, $X_1, X_2, X_3, \dots, Y_1, Y_2, Y_3$, etc., which are successively contacted by the rotating brush 41 which moves at a uniform speed in the direction of the arrow. In conjunction with this distributor 40, a plurality of connectors such as those generally designated by the numerals 42 and 48 are employed, a group of segments of the distributor 40 being connected to contacts of each connector. I have illustrated the distributor 40 as having one group of 12 segments X_1 to X_{12} connected to corresponding contacts of the X connector 42 and the segments Y_1 to Y_{12} of the distributor connected to corresponding contacts of the Y connector 48, similar to connector 42, the segments Y_1 to Y_{12} preferably being connected to contacts of the Y connector which correspond in position respectively to the contacts of the X con-

nectors 42 to which segments X_1 to X_{12} are connected. In each of the connectors 42 and 48 are two plates 43 and 44 independently adjustable through wide angles about the common axis 45 and insulated from one another, the plates 43 of both connectors being adapted to be rotated together, as are also the plates 44 of both connectors. The plates 43 and 44 are adapted to connect together varying numbers of the contacts of each connector depending upon the angular position of the plates. Contacts 46 and 47 are placed one at each end of the row of contacts to make connection with the plates 43 and 44 respectively, and the contacts 46 of the connectors 42 and 48 are connected together, as are the contacts 47 of both connectors. It will be observed that with the setting of the connectors 42 and 48 shown, the arm 41 will be connected to plate 43 while passing from segment X_1 of the distributor to segment X_4 , and that since segments X_5 to X_7 , inclusive, are connected to contacts of the connector which do not contact any plate, the arm 41 will be unconnected during the time of passing over these segments. During passage over segments X_8 to X_{11} , the arm 41 is connected to plate 44 and, since segment X_{12} is unconnected, the arm 41 is also unconnected during passage by this segment. As the arm 41 passes over the segments Y_1 to Y_{12} , the cycle of connection is repeated. Obviously, the distributor may be constructed with a sufficient number of segments to accommodate any desired number of connectors such as 42 and 48. If, now, the plates 43 are connected through contacts 46 to the polarizing circuit containing the source 19, and the plates 44 are connected through contacts 47 to the measuring circuit of Fig. 4, it will be seen that the device of Fig. 12 can perform the functions required of relay 17. The adjustment and connection of the connectors 42 and 48 as shown in Fig. 12 are such as to result in a condition resembling that of Fig. 6. To get a different distribution between the various periods of the cycle, the plates 43 and 44 may be rotated to connect more or less contacts and the desired number of segments of the distributor may be left unconnected. To vary the time period of a complete cycle, the speed of rotation of the arm 41 is changed, and to this end I preferably rotate the arm 41 by means of a motor of constant but adjustable speed.

I may, if desired, employ the relay of Fig. 12 in the circuit of Fig. 13 to connect the polarizing and measuring circuits to four electrodes, as shown, instead of two. The polarizing circuit including the source of direct current 19 may be connected to the electrodes 50 and 51 through the relay 52, and the measuring circuit comprising instrument 22 and balancing circuits 23 and 24 may be connected to the separate measuring electrodes 53 and 54 by the relay 55. A battery 56 energizes either of the coils of relays 52 and 55 when the appropriate switch of relay 17 is closed. Thus, as relay 17 opens and closes in one or the other direction, the relays 52 and 55 act correspondingly to open and close the polarizing and measuring circuits. In applying the device of Fig. 12 as the relay 17 in this arrangement, the plates 43 and 44 are connected to the coils of relays 52 and 55 and the arm 41 is connected to the battery 56.

It is understood that various changes in the method and apparatus disclosed herein may be made by those skilled in the art without depart-

ing from the spirit of the invention as defined in the appended claims.

I claim as my invention:

1. A method of geophysical prospecting comprising subjecting the earth through spaced electrodes to intermittent polarizing applications of a unidirectional electromotive force of constant duration, intermittently measuring between spaced points in the earth the potential difference due to the resultant earth polarization during measuring periods of constant duration following said polarizing applications by a constant time interval, and repeating said intermittent measurement of potential difference employing measuring periods following said polarizing applications by time intervals having a plurality of values different from said first-mentioned time interval, the repetitions of said measurement being sufficient in number to establish a relation between the measured potential difference and said time interval.

2. A method of geophysical prospecting comprising subjecting the earth through spaced electrodes to intermittent polarizing applications of a unidirectional electromotive force of constant duration, intermittently measuring between spaced points in the earth the potential difference due to the resultant earth polarization during measuring periods of constant duration following said polarizing applications by a constant time interval, and repeating said intermittent measurement of potential difference employing measuring periods of the same duration but following said polarizing applications by time intervals having a plurality of values different from said first-mentioned time interval, the repetitions of said measurement being sufficient in number to establish a relation between the measured potential difference and said time interval.

3. A method of geophysical prospecting comprising subjecting the earth through spaced electrodes to intermittent polarizing applications of a unidirectional electromotive force of constant duration, intermittently measuring between spaced points in the earth the potential difference due to the resultant earth polarization during measuring periods of constant duration following said polarizing applications by a constant time interval, and repeatedly making said intermittent measurement of potential difference employing measuring periods of the same duration but following said polarizing applications by time intervals having a plurality of values different from said first-mentioned time interval, the times elapsing between the terminations of the measuring periods and the beginnings of the polarizing applications remaining the same in all instances.

4. A method of geophysical prospecting comprising subjecting the earth through spaced electrodes to intermittent polarizing applications of a unidirectional electromotive force, intermittently measuring between spaced points in the earth the potential difference due to the resultant earth polarization during measuring periods closely following said polarizing applications, and repeating a plurality of times said intermittent polarization and intermittent measurement, the durations of said polarizing applications being different in each repetition, and the repetitions of said intermittent polarization and intermittent measurement being sufficient in number to establish a relation between the measured potential difference and the duration of the polarizing application.

5. A method of geophysical prospecting comprising subjecting the earth through spaced electrodes to intermittent polarizing applications of a unidirectional electromotive force of constant duration, intermittently measuring between spaced points in the earth the potential difference due to the resultant earth polarization during measuring periods of constant duration following said polarizing applications by a constant relatively short time interval, and repeating said intermittent polarization and intermittent measurement, said measuring periods being the same in each repetition, said time intervals following the polarizing applications being the same in each repetition, but the durations of said polarizing applications being different in each repetition, and the repetitions of said intermittent polarization and intermittent measurement being sufficient in number to establish a relation between the measured potential difference and the duration of the polarizing application.

6. A method of geophysical prospecting comprising polarizing the earth for a plurality of different limited time periods by applying a unidirectional electromotive force thereto through electrodes spaced along the earth's surface in contact therewith, measuring the resultant earth polarization during measuring periods closely fol-

lowing the terminations of said polarizing periods, again polarizing the earth for a plurality of different limited time periods by applying thereto through said electrodes a unidirectional electromotive force different in amount from said first electromotive force, and measuring the resultant earth polarization during measuring periods closely following the terminations of said second mentioned polarizing time periods.

7. A method of geophysical prospecting comprising successively polarizing the earth by application of unidirectional electromotive forces of different value to electrodes spaced along the earth's surface in contact therewith, and measuring between spaced points on the earth's surface the potential difference due to the resultant earth polarization corresponding to each of said electromotive forces.

8. A method of geophysical prospecting comprising polarizing the earth a plurality of times by application of a unidirectional electromotive force to electrodes spaced along the earth's surface in contact therewith, the amount of said electromotive force being different but the time of application being the same in each case, and measuring in each case the potential difference between spaced points on the earth's surface due to the resultant earth polarization.

GLEN PETERSON.