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SEARCH ROOM (2)

Oct. 13, 1931. L. B. SLICHTER 1,826,961

APPARATUS FOR EXPLORING FOR ORE

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Fig. 1.

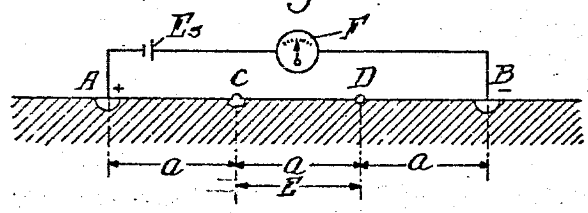


Fig. 2.

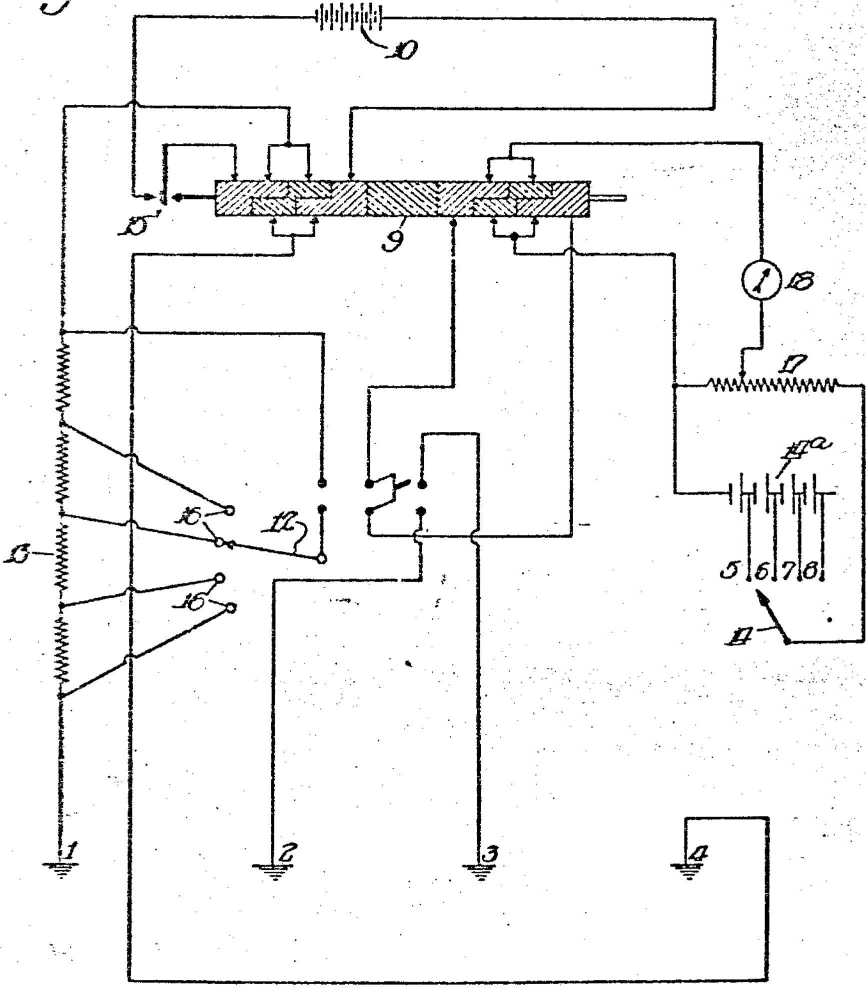
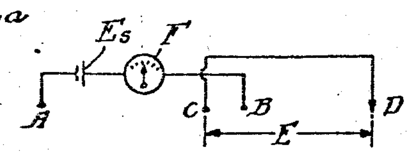


Fig. 1a



Inventor:
Louis B Slichter,

By Wilkinson, Huxley, Byrne & Knight
Attys

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Fig. 3.

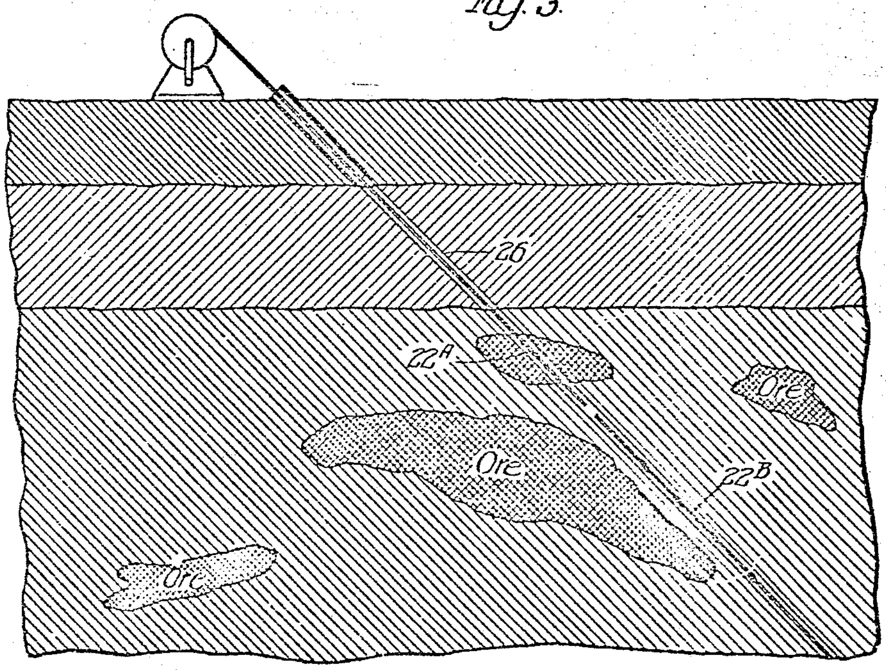
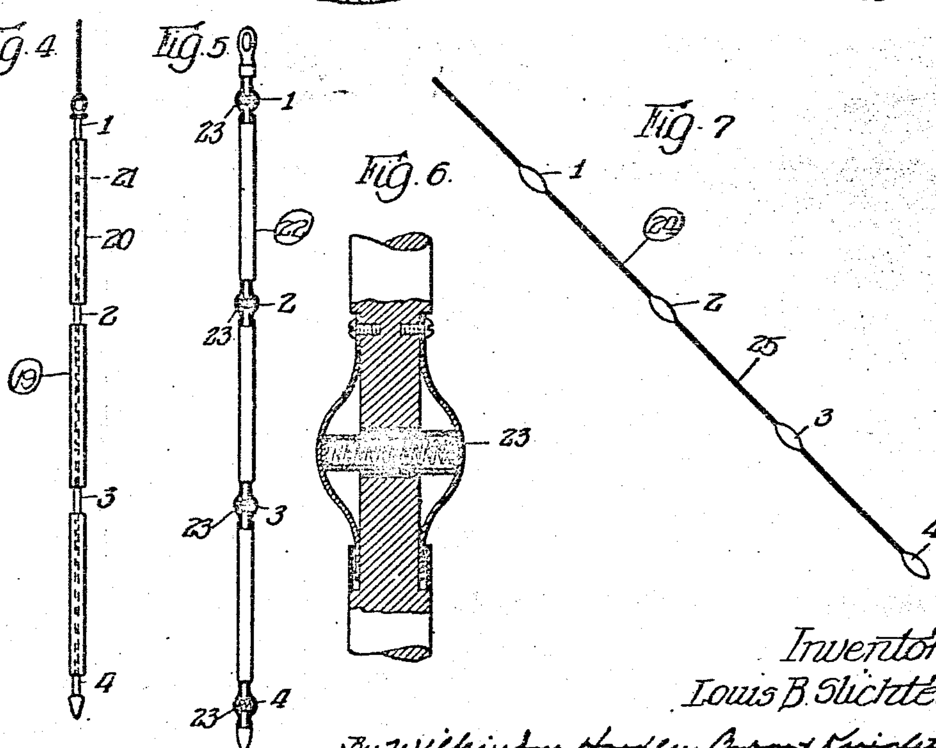


Fig. 4. Fig. 5. Fig. 6. Fig. 7



Inventor:
Louis B. Slichter,
By Wilkinson, Huxley, Byron & Knight Attys.

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UNITED STATES PATENT OFFICE

LOUIS B. SLICHTER, OF MADISON, WISCONSIN

APPARATUS FOR EXPLORING FOR ORE

Application filed September 7, 1928. Serial No. 304,449.

The present invention relates to apparatus for exploring for ore.

More particularly, the present invention relates to the detection of conducting ore bodies through the use of exploring means disposed within a drill hole or the like. The method comprising the present invention is in essence one of determining the effective or mean electrical conductivity of the material pierced by or located in the vicinity of a drill hole.

An object of the present invention is to provide an effective apparatus whereby sections of the earth may be explored for buried ore.

A further object is to provide an apparatus for effectively exploring the neighborhood of a drill hole or the like for conducting ore.

Further objects will appear as the description proceeds.

Referring to the drawings—

Figure 1 is a schematic diagram submitted for the purpose of describing the present invention;

Figure 1*a* is a modified schematic diagram submitted for the purpose of indicating another arrangement of electrodes;

Figure 2 is a schematic diagram showing a preferred electric circuit which may be used in the practice of the present invention;

Figure 3 is a view illustrating the method comprising the present invention;

Figure 4 is a view illustrating an exploring unit which may be used in the practice of the present invention;

Figure 5 is a modified form of exploring unit;

Figure 6 shows, on an enlarged scale, a detail of the construction shown in Figure 5; and

Figure 7 shows another modification of the exploring unit.

Figure 1 illustrates a well known method of measuring earth resistivity at the surface. The letters A, C, D and B indicate electrodes having electrical connection with the earth at the surface thereof. Said electrodes are spaced apart at equal distances indicated by the letter *a*. Electrodes A and B are connected together through a circuit including a source of E. M. F. indicated by the letter E, and the current measuring instrument F. Let it be assumed that current flows into the ground at electrode A and out at B, and let the measured total current be *i*. Let the potential difference, E, between electrodes C and D be measured. Knowledge of the current *i*, the drop E and the geometrical relationship of the four electrodes A, B, C and D is sufficient to determine the electrical conductivity of the earth at the points being tested. In the example shown, having equi-spacing of the four electrodes, the computation of the resistivity is simple, as follows:

Where r_0 is the radius of the electrodes A and B considered as small hemispheres; a the spacing between electrodes; ϕ_0 and $-\phi_0$ the potentials of the surfaces of said hemispheres; k the conductivity of the surrounding medium; ϕ_c the potential at point C; ϕ_d the potential at point D; and

$$\frac{\sigma\phi}{\sigma r}$$

the potential gradient:

$$(1)\qquad E=\phi_c-\phi_d=\left\{\left(\phi_0\frac{r_0}{a}-\phi_0\frac{r_0}{2a}\right)-\left(\phi_0\frac{r_0}{2a}-\phi_0\frac{r_0}{a}\right)\right\}=\phi_0\frac{r_0}{a}$$

Also, the current leaving the electrode B is

$$i=2\pi r_0^2 k\frac{\sigma\phi}{\sigma r}.$$

At the surface of the electrode

$$\frac{\sigma\phi}{\sigma r}\text{ is }-\frac{\phi_0 r_0}{r_0^2}.$$

$$(2)\qquad \text{Thus } i=2\pi k\,\phi_0 r_0.$$

Hence, from 1 and 2,

$$k=\frac{i}{2\pi a E}.$$

The above example is given for the purpose of illustrating the so-called four-electrode method. Full explanation of such methods is given in the following references:

(1) Wenner, Bulletin U. S. Bureau of Standards, Vol. 12, pp. 469–78, 1916; and

(2) McCollum, "Measurement of Earth Currents", Electric R. R. Journal, November 5, 1921, Vol. 58, page 809.

Applications of the so-called four-electrode method to the measurement of resistivity of geological structures have been described in the following references:

(1) Results of Earth Resistivity Survey near Watheroo, Australia, Terrestrial Magnetism, Vol. 32, #2, p. 49;

(2) Earth Resistivity Measurements in the Copper Country, Michigan, W. J. Rooney, Terrestrial Magnetism, Vol. 32, #3, page 97; and

(3) Certain applications of the Surface Potential Method. Warren Weaver. Technical Publication #121. Am. Inst. of Mining and Metallurgical Engineers.

Figure 1*a* illustrates an arrangement having the electrode C disposed between the electrodes A and B and with the electrode D outside of said electrodes A and B, spacings between the electrodes being unequal. The arrangement shown in Figure 1*a* is illustrated to show that the invention is not limited to the arrangement shown in Figure 1, though the arrangement shown in Figure 1 will in general be preferred.

The present invention carries forward the teachings of the references above referred to and contemplates the exploration of earth resistivity in the neighborhood of a drill hole or similar hole extending down into the earth. The present invention contemplates the use of an exploring member or means carrying four electrodes adapted to have electrical contact with the wall of the hole referred to. Such contact with the wall of the hole may usually be made through the water in the hole, or may be made through mechanical contact means, such as illustrated in the accompanying drawings. The test member is lowered down the hole a short distance at a time, and the current and voltage drops measured at each station. In order to avoid polarization potentials, it is preferred to use a commutator and reverse the current at intervals, which may be about ten per second. If preferred, special non-polarizing electrodes may be used, as for example, those using a copper sulphate solution in a porous cup.

At present, in diamond drilling, the core sample obtained is from an inch to several inches in diameter, and in churn drilling, the sludge obtained represents a hole about six inches in diameter. A drill hole, however, may pass within a few feet of an ore deposit and give no indication of its presence. Because the small samples referred to may easily fail to represent adequately the true condition of the zone surrounding said drill holes, many attempts have been been made to explore the walls of the drill holes radially for some distance. In this connection, reference may be had to the United States Patent No. 1,092,065 to Loewy and the United States Patent No. 1,652,227 to Zuschlag.

The present invention has decided practical advantages over any of the methods above referred to and affords an economical and reliable means of ascertaining the electrical conductivity of a zone located at any desired and known depth down a hole. Moreover, the size of the zone whose resistivity is being measured can be readily altered to suit the needs of the particular exploration.

Referring to Figure 2, four electrodes are indicated by the numerals 1, 2, 3 and 4, electrodes 1 and 4 being current electrodes and electrodes 2 and 3 being potential electrodes. The numeral 10 indicates a source of direct current E. M. F., such as a battery. The numeral 9 indicates a double rotary commutator and the numeral 15 indicates an automatic switch adapted to carry current from the battery 10 to said commutator 9. Said current passes through the known resistance 13 having the taps 16, which taps communicate, by means of a selector switch 12, with one pole of a double pole double throw switch 11. From the known resistance 13, a circuit extends to the electrode 1. The return circuit passes from the electrode 4 to the commutator 9 and thence to the battery 10. The current passing between electrodes 1 and 4 is measured after commutation by means of the known resistance 13 in the following way. The double throw switch 11 when thrown to the left communicates with a circuit across the adjustable known resistance 13. The potential across this resistance is measured by means of the potentiometer 17. This potentiometer is adjustable in range by means of the selector switch 14, which communicates with the terminals 5, 6, 7 and 8 of a series battery 14*a* in the potentiometer circuit. By changing the voltage impressed upon the potentiometer, its scale value is correspondingly changed. The current flow through the known resistance 13 is then given by Ohm's law. In this way the true current flow between electrodes 1 and 4 is measured. It is to be noted that any errors due to leakage of current in the commutator 9 are avoided by making the measurement on the rectified current, whereby accuracy is increased. In order to measure the potential differences between electrodes 2 and 3, the double throw double pole switch 11 is thrown to the right and the potentiometer 17 and the galvanometer 18 balanced as before.

By means of the apparatus schematically indicated in Figure 2, it is a simple matter to measure the potential drops across two different points, to wit—across the known resistance selected by the switch 12, and across an unknown resistance between the electrodes 2 and 3.

Figures 4, 5, 6 and 7 indicate various forms of exploring units which may be used. In Figure 4 an exploring unit 19 is shown comprising a staff 20, which may be of wood, on which are placed, at equal intervals, the electrodes 1, 2, 3 and 4. These electrodes may take the form of metal members exposed to the exterior of the staff 20. To each of said electrodes there is attached one conductor of a four-conductor cable 21. Said electrodes 1, 2, 3 and 4 are adapted to make electrical contact with the water which usually exists in a drill hole.

Figures 5 and 6 illustrate a form of exploring unit, indicated by the numeral 22, for use in a dry hole. The unit 22 is similar in principle to the unit 19, except that the metal electrodes 1, 2, 3 and 4 are expanded, by means of springs 23—23, to make contact with the wall of a drill hole.

Figure 7 illustrates a different type of exploring unit, indicated by the numeral 24. The exploring unit 24 is provided with the equi-spaced electrodes 1, 2, 3 and 4 carried by the flexible connecting cable 25. Said electrodes may take the form of lead weights, each of which is tapered at its two ends to avoid catching in the drill hole. It will be understood that the form of electrode shown in Figure 7 cannot be conveniently utilized in a horizontal hole. For such holes, and for holes drilled upward in a mine, the rigid type of exploring unit, examples of which are shown in Figures 4 and 5, should be used.

The improved method comprising the present invention will be clear from an inspection of Figure 3. In this figure, a slanting drill hole is shown, which drill hole is indicated by the numeral 26. It will be noted that said drill hole is illustrated as extending through several different strata. Figure 3 illustrates the use of two different sizes of exploring unit, one unit being indicated by the numeral 22A and the other being indicated by the numeral 22B. It will be understood that though the two exploring units are shown in the same hole, said two units are not necessarily used simultaneously. In the unit 22A the electrode spacing is very small and said unit is shown located within a small ore bleb. In measuring the resistivity of the exploring unit 22A, the region explored will extend only a small distance from said exploring unit. In exploring unit 22B the spacing of the electrodes 1, 2, 3 and 4 is greater and the region explored will be much greater than with exploring unit 22A. In the use of either exploring unit 22A or 22B, said unit will be located at successive depths along the drill hole and a measurement taken of the current flow and potential drop in the manner already described. The result of such a survey is a systematic mapping of the conductivity of the material at and adjacent to the drill hole. It will be noted that the exploring unit 22B is illustrated in a position adjacent to but out of contact with an ore body. In such an instance, a drill core might show no indication of ore, but an electrical survey of the hole made with an exploring unit 22B having a large spacing of its electrodes relative to the distance between the hole and the ore will establish the existance and location along the hole of the ore body. By increasing the electrode spacing, the zone of exploration is correspondingly increased. For example, if a hole is 1,000 feet deep in uniform material, it will be practicable to explore the neighborhood of the hole for a radius of approximately 100 feet by means of an exploring unit having electrode spacing of approximately 100 feet. Readings would then be taken at longer intervals down the hole, for example at 50 foot intervals.

I claim:

1. Apparatus for exploring the conductivity of the earth down a drill hole comprising an elongated member having four electrodes adapted to connect electrically with the earth surrounding said drill hole, means for applying current to the outermost of said electrodes, means for reversing said current at intervals, and means for measuring the potential between the intermediate electrodes of said four electrodes.

2. Apparatus for measuring the conductivity of the earth along a drill hole comprising an elongated member having four electrodes disposed along its length, each of said electrodes including resilient means adapted to contact with the wall of said drill hole while permitting sliding of said rod along said drill hole, means for applying an electric current to the outermost of said electrodes, and means for measuring the potential difference between the intermediate electrodes of said four electrodes.

3. Apparatus for measuring the conductivity of the earth along a drill hole comprising an elongated member having four electrodes disposed along its length, each of said electrodes including resilient means adapted to contact with the wall of said drill hole while permitting sliding of said elongated member along said drill hole, means for applying an electric current to the outermost of said electrodes, means for measuring the potential difference between the intermediate electrodes of said four electrodes, and means for reversing the polarities of said outermost electrodes.

Signed at Madison, Wisconsin, this 22nd day of August, 1928.

LOUIS B. SLICHTER.