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PROSPECTING FOR WATER BY ELECTRICAL RESISTIVITY

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The development of the theory and practical application of earth electrical resistivity measurements for sub-surface prospecting are in large part the result of studies made by the research division of the United States Bureau of Mines.

Early in 1936, the Oklahoma Geological Survey decided to construct an apparatus for making such measurements, hoping that it would be of assistance in locating new sources of water supply for the people of the state during the drougth period. The apparatus constructed by the Survey embodies all of the features recommended by the United States Bureau of Mines, but was modified in some respects to obtain a practical field unit that is portable, rugged and flexible enough to make the required measurements under nearly all field conditions.

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The principal parts of the apparatus constructed by the Survey are as follows:

One double-range potentiometer especially constructed by Leeds & Northrup Instrument Company; the first range reading from zero to 110 millivolts and the second from zero to 1.11 volts. This instrument is so constructed that final reading on either range has the same accuracy.

A four range Weston milliammeter is used, having ranges of one-half, 5, 50 and 500 milliamperes, with 100 scale divisions. This is an extremely sensitive meter.

Eight 45-volt Radio "B" batteries are used for power. These are carried in two boxes which can be used independently or connected together in series and give a maximum power of some 360 volts. The amount of power used is regulated by a rotary switch which cuts in one battery at a time. The amount of power used has no bearing on the problem, as it is only necessary to use the amount necessary to activate the instruments.

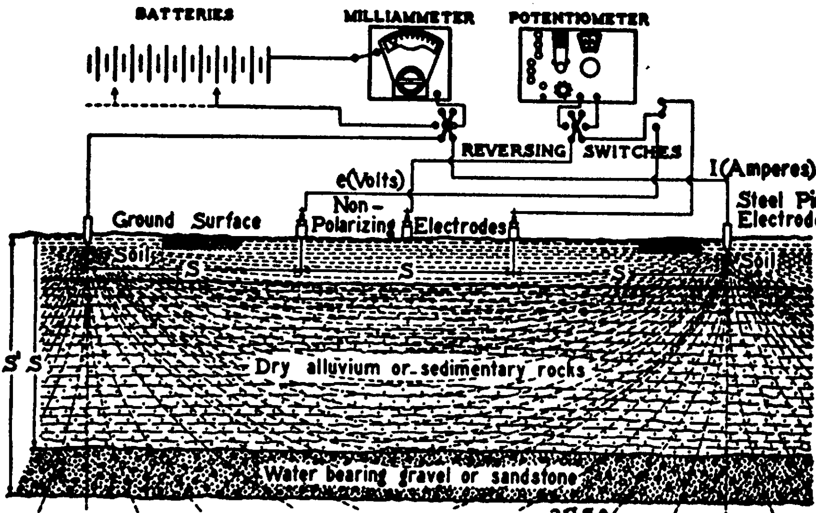
Two steel pins, about 4 feet long and 1 inch in diameter, are used as power electrodes. The pick-up electrodes must be non-polarizing to eliminate error in readings so these are made of small porous porcelain battery cups, which contain a spiral copper wire inserted in a rubber stopper, and are filled with a saturated solution of copper sulphate. While transporting these pick-up electrodes, they are carried in a sealed jar containing this saturated copper sulphate solution. The porous cups permit enough leakage of the solution to make adequate contact with any type of soil or rock.

Direction changing switches are arranged so that all readings can be taken in both directions, with the current also flowing in either direction. In practice, all directional combinations of readings are made and a mean resistivity computed, thereby eliminating error caused by stray ground currents.

The theory of the operation is very simple. The basic equation is, of course, the direct current equation of resistance, namely, that resistance in Ohm units is equal to EMF, or voltage, divided by the current flow measured in ampheres. The accompanying plate illustrates the apparatus and method of use in locating underground water supplies at somewhat shallow depths.

The spacing between the two power electrodes is divided into three three equal parts. which I have designated as 'S.' Theoretically, only two pick-up electrodes are required and the resistivity of the central one of the three divisions is measured. The amount of current flow between the power electrodes is measured in milliampheres. The drop in potential between the two pick-up electrdes is measured in millivolts. The distance between those pick-up electrodes, or spacing 'S', is measured in feet and then converted to centimeters. All calculations are recorded in ohm-centimeter units. It has been proven that when this spacing arrangement is used, the lines of current flow penetrating the ground to a depth greater than spacing 'S' are negligible and have very little effect on the instruments, therefore any abrupt variation in recorded resistivity accurately indicates some kind of change in conditions in the earth at the depth 'S'. This fact was determined empirically several years ago, but has now been proven mathematically. The mathematical discussion is rather lengthy, so I will not go into it at this time.

The search for underground water with this apparatus is carried on in in two ways. Where the depth to be explored does not exceed about 750 feet, which is the present limit of our apparatus, definite resistance determinations are made progressively at stated depth intervals. Depending on the problem, the intervals generally used are 3, 5 or 10 feet. Resistances so obtained are plotted on a graph and a resistance curve thereby formed. The shape of that curve at different depths indicates the character of the earth or rock at those depths. Usually, the surface of the ground has a



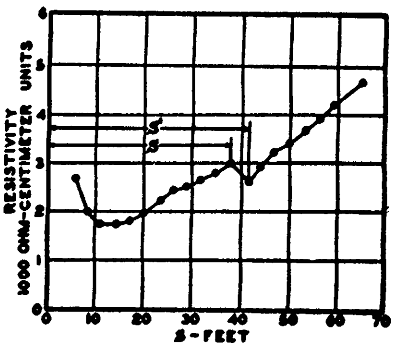
BASIC RESISTIVITY FORMULA $R = \frac{2\pi S e}{I}$

IN WHICH:-

R - SOIL RESISTIVITY S - DISTANCE BETWEEN ELECTRODES IN CENTIMETERS.
e - DIFFERENCE IN POTENTIAL BETWEEN INTERMEDIATE ELECTRODES IN VOLTS
I - CURRENT FLOWING BETWEEN END ELECTRODES IN AMPERES

TYPICAL CURVE INDICATING WATER

As the electrode spacing (S) is progressively increased the depth of current penetration into the ground is proportionately increased. Resistance drops from dry surface as surface moisture increases with depth and then commences to rise at base of surface moisture zone. Water is indicated by sharp drop in resistance as shown by graph.



ARRANGEMENT OF APPARATUS FOR MEASURING ELECTRICAL RESISTIVITY high resistance in dry weather and as the spacing of the electrodes is increased, thereby obtaining greater depth readings, the resistivity will decrease as surface moisture increases. The curve thus will take a downward course through the zone of surface moisture until impervious or dry material is encountered, at which point the curve starts climbing upward. Variations in quality and kind of rock are plainly indicated. Upon encountering water, the curve takes a very sharp drop, as illustrated, and the amount of this drop seems to indicate the proportional amount of water that may be expected in that sand. This is probably a function of the porosity of the water-bearing bed. Estimates of quantity, however, can only be made when a reading has been made adjacent to a well known capacity producing from the same horizon.

Another method, principally useful in determining possible artesian water supply, has been developed during the past year by the Oklahoma Geological Survey. It was found that artesian water sets up a ground current which probably is caused both by movement of the water through sand thereby generating a minute current of electricity and also by the electro-chemical reactions taking place in that water sand. The instruments used are sensitive enough to pick up these currents, measuring their intensity and direction of flow. Their operation is performed without use of batteries.

Readings are taken at various depths and vectors are drawn on a map at the points of reading. It has been determined that the best supplies of artesian water are found at the points designated by the greatest current. Vectors of equal value and direction can be joined together and approximate directions of underground flow and areas of water channel can be determined. We are now carrying on research to further develop the possibilities of this operation.

It should be understood that the electrical resistivity method of prospecting is used only as a tool in the hands of a competent geologist. Each problem must be solved, individually, and the geologist must know how to interpret the results obtained and should have a definite idea of what he is looking for before putting the apparatus into service.

During the past year we have rendered service to many municipalities and institutions throughout the state and have been successful in every instance in discovering the best source of possible water supply.