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Methods of ELECTRICAL PROSPECTING*

Electrical methods of prospecting are becoming increasingly important as the search for hidden deposits of ore extends deeper and deeper below the surface of the earth. Electrical prospecting is not limited to this use, however; it has found many valuable applications in engineering and in geology. The 4 general methods of electrical prospecting are described briefly in this paper.

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EVER since man has known that mineral wealth lies hidden in the earth, he has been devising schemes for unearthing that wealth with the least possible effort. The search for a divining rod is, in fact, older than the equally dubious arts of alchemy. Only in comparatively recent years, however, have successful, and therefore accredited, schemes for divining the earth been developed. The success of these newer methods would not account for the high interest shown in them were it not for the real need that exists for some reliable method of subsurface exploration. This need is made only too clear by the fact that rocks that can be seen from the surface constitute only 1 percent of the total area of mining districts. Since by now this easily available 1 percent has been thoroughly exploited, the attention of prospectors has been turned to the remaining 99 percent which lies hidden beneath the surface—a portion none the less valuable but vastly harder to explore. In the search for these hidden deposits, electrical methods are beginning to play an important part, and the importance of electricity in this field may be expected to increase. It is the purpose of this paper to review briefly the more important methods of electrical prospecting and to emphasize their possibilities and limitations.

All Methods Fundamentally Similar

All methods of geophysical prospecting, which is the general name for prospecting by gravitational, seismic, and electrical methods, are carried out in the same fundamental way, that is, by measurement of the response of rocks and ore bodies to various types of physical fields, such as the field of gravity, electric and magnetic fields, and seismic shocks. The study of electrical prospecting is, therefore, the study of the appropriate electric fields, the appropriate methods of response measurement, and, finally, the interpretation of the response. A field fitted to the particular problem at hand should be used, so that the response will be not only a maximum intensity, but also of a unique character. If this be done, the reactions of the ore may be distinguished from those of the other geological elements, and, in addition, reliable indications as to its size, shape, and depth may be obtained.

The various types of electric fields used are four in number; these give rise to four different types of electrical prospecting. It is convenient to discuss them in two groups, the "natural field" methods and the "artificial field" methods. The natural fields are provided by the earth itself; the artificial fields are produced by the prospector.

Magnetic Surveying

Magnetic surveying, the method to be described first, makes use of a natural field, that of the earth's magnetism. It is well known that the magnetic field of the earth is greatly intensified in the presence of certain magnetic ores. Hence, this type of ore may be located simply by measuring the field intensity at various points over the area to be explored. A pocket magnetic dip needle, which is nothing more than a compass needle mounted on a horizontal shaft, is the simplest and commonest method of doing this; but refined magnetic balances have been developed which are much more sensitive. The usual field magnetometer, for example, will detect changes in the earth's magnetic field intensity of as small an order as three parts in 10,000.

Important iron ores, such as magnetite, and some nickel ores, may be detected in this way. Iron pyrites, however, better known as "fool's gold," are magnetically inert. Magnetically inert ores cannot be explored by this method, of course, but this fact is at once a disadvantage and an advantage. Magnetite, a strongly magnetic ore, is distributed so widely that it may be used as an index for the discovery of other types of deposit. Quarry rock has been discovered in New England by this method, simply because it contained ½ percent of magnetite. The magnetic method has had many such commercial successes.

Self-Potential Method

The second natural earth field that is used is less obvious than the magnetic one. This field is known as the "self-potential" field. It arises from the fact that many ores, particularly the sulphides, are chemically active. Differences in the degree of oxidation give rise to a difference of electric potential between various parts of the ore. A current flow thus is established which creates a potential distribution throughout the ground. The intensity of this potential field on the surface may be measured by placing two electrodes, in the form of porous cups filled with copper sulphate, on the ground and measuring whatever potential appears between them with an ordinary potentiometer. The electrodes are moved from one location to another, and the process of measuring the potential difference between them is repeated at each location. By covering the terrain in this manner, a map of the existing surface potential may be made. The singularities or distortions in the map indicate the sources of the current. The interpretation of the map is difficult, since it is complicated by numerous chemical reactions occurring in the ground independent of the ore body. This method is used extensively, however, because the field is localized about the ore, and because the method is cheap and rapid and may be carried out easily in conjunction with other methods

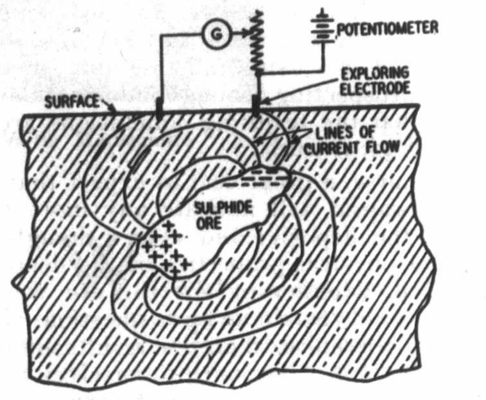

Fig. 1—An idealized view of the self-potential method. Current flow between parts of the sulphide ore sets up a potential gradient at the surface which can be measured with a potentiometer.

These natural fields, the magnetic and the self-potential, have the advantage that they are provided free of charge; there is an attendant disadvantage in the fact that the excitation of the ore is not under the control of the prospector. The artificial fields offer a much more fertile field for the exercise of engineering ingenuity. By their use the prospector may choose the particular type of field, or combination of fields, best suited to his problem, and he may use it under control. Moreover, the use of artificial fields is suited particularly to exploration for deposits having high electrical conductivity, and it is a significant fact that many commercially valuable ores do possess this property. Hence the methods about to be described are of considerable commercial importance, but the results are often misleading and they must be used with skill and judgment.

Inductive Method

The first of the artificial field methods, the so-called inductive method, makes use of a sinusoidally varying magnetic field. The frequency of oscillations used depends upon the type of ore it is desired to locate, and, equally, upon the surrounding rocks. Usually a frequency of from 500 to 1,000 cycles per second is used. The field is produced by a large loop antenna, energized by a gasoline-engine-driven alternator of the correct frequency. One type of loop is triangular in shape, about 25 ft. on a side, and set up in a vertical plane. Other systems use a horizontal loop of greater extent.

The theory of the measurement is this: The lines of force in the magnetic field at a distance from the loop lie, in general, in a plane perpendicular to the plane of the loop; but if an ore body interferes with this field, eddy currents are set up in the ore body, and these eddy currents in turn set up a secondary field. The original field and the secondary field combine in a resultant field the direction of which at the point in question is changed from the direction of the original field. The situation is closely analogous to that of armature reaction in d-c machines. By means of locating the changes in field direction caused by such reactions, the ore body may be located. It becomes necessary, then, to measure the direction of field intensity at many different points.

To measure the field direction, a receiving coil, to which an amplifier and a pair of headphones are attached, is mounted on a tripod in gimbals, so that the plane of the coil can assume any position relative to the ground plane. The plane of the receiving coil then is rotated about its vertical axis until the sound in the headphones is minimum; the plane of the coil then coincides with the horizontal component of the field intensity; knowing this direction, the direction of the resultant field may be determined by rotating the coil about its horizontal axis until the sound is minimum. By making a systematic series of such observations over the area, the magnetic field may be mapped, and the distortions caused by ore bodies discovered. However, it remains for a skillful interpreter to locate the ore bodies accurately.

Surface Potential Method

The method to be described last is called the surface potential method. In this method, an electric field is set up by sending a commutated direct current through the ground. To establish this field two power electrodes are driven into the ground above the suspected ore body, separated by as large a distance as is practicable, often several thousand feet or more. These power electrodes then are connected to a source of direct current, such as a battery or a gasoline-engine-driven generator, but they are connected through a commutating mechanism. Usually ordinary ring commutators are used. As the commutator turns, a rever-

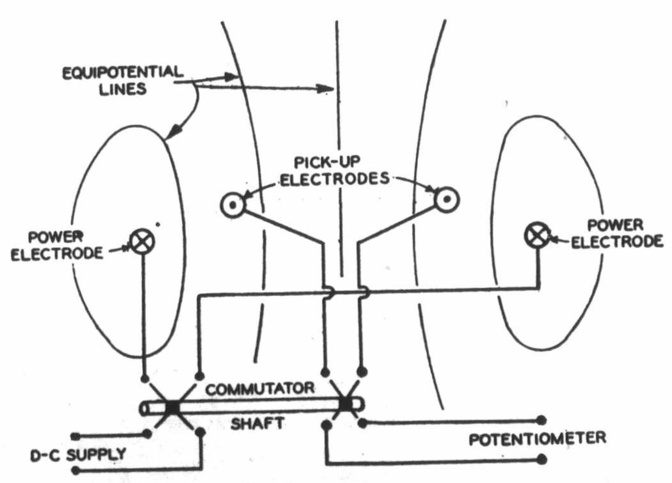

Fig. 2—The commutated d-c method, shown in plan view. The equipotential lines set up by the current flow are explored by the pick-up electrodes. Ore or other conducting material is indicated by distortions of the equipotential lines. Simultaneous commutation of power and pick-up circuits eliminates extraneous potentials.

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