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Geophysical Prospecting

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Geophysics is defined as the physics of the earth. Geophysical prospecting is geophysics applied to the location of mineral deposits or geological structures concealed beneath the surface of the earth.[1] Geophysical prospecting as related to the discovery of gas or oil is only used to find favorable geological structure and contrary to general opinion none of the methods are able to determine the presence of gas or oil.

Some of the better known geophysical methods of prospecting are the magnetic, the gravitational, the seismic, the electrical resistivity and the electromagnetic method. From the various methods mentioned above, I have chosen to discuss briefly the seismic and electrical resistivity methods.

If you are looking for brief and condensed material which could be readily read and understood by the average person, you will find that all the geophysical methods of prospecting are highly technical. You will also discover that there are no pure and simple rules on which they operate but in general their procedures and interpretations are based on the fundamental laws of physics.

The seismic method of geophysical prospecting is the best known method, and it has probably exerted a greater influence on geophysical prospecting than any other method. The word *seismograph* comes from the Greek word meaning *earthquake,* and is was for the purpose of recording the vibrations of the earth that the instrument was developed. We speak of it as an instrument, but it really is a well-coordinated series of instruments which require a number of men to operate. The seismograph as used in geophysical prospecting is for the recording of shock of small, artificial earthquakes produced by a charge of dynamite discharged in the ground.

The seismic method was first employed in Europe and introduced into the United States in the spring of 1924. Its value was first proven by the Gulf Company in the Texas Gulf Coast area when the Orchard Salt Dome, in Fort Bend County, was discovered. This was the first seismograph dome discovery in the United States and was followed immediately by others.[2] (In explanation, a salt dome is a peculiar cylindrical plug-like mass of salt that penetrates the earth's crust from below the surface.)[3]

Today a modern seismograph party is fully equipped with mobile units which can take to the sea and marshes as well as the open fields or roads. The unit will probably consist of ten to twelve cars and trucks to transport the men and equipment. The larger trucks will be the shot-hole drillers and water trucks, for it is often necessary for the party to furnish its own water. You will have two shooters and for every shooter you must have a truck to carry the dynamite, loading poles, radio and probably water. It is found that by filling the hole with a column of water more of the energy of the explosion is directed downward and less surface damage results. The instrument truck is a complete laboratory on wheels equipped with all the instruments making up the seismograph.

Sixteen to twenty men make up the crew of an ordinary party. The men range from semi-skilled laborers to technicians with degrees in engineering, physics and geology.

Before the party goes into operation for a day's work, the land has been well surveyed and the geological structure has been checked for all available information. The drill holes are drilled to a specific depth and charged with a predetermined amount of dynamite. The detectors are placed either on the ground or at a specific depth in the ground depending on the surface conditions, and at a definite distance from the charge to be fired. There will probably be any number of detectors used but all will be connected to the laboratory. The shooters will be notified by radio from the laboratory when to fire the charge. The time of firing is transmitted back to the laboratory by radio and the vibrations set up by the explosion are picked up by the detectors. Both the time the shot was fired and the vibrations are recorded in the laboratory on a sound track from which the oscillograph field record is produced.

It is now recognized that there are three general types of waves that pass through solid rock. These have been defined as the longitudinal wave, in which all particles vibrate in the direction of propogation, the transverse waves, in which the particles vibrate at right angles to the path of propagation and the surface, or rolling ground

[1] Lewis, Robert S., *Elements of Mining,* p. 39, John Wiley and Sons, Inc., New York, 1941.

[2] Eby, J. Brian, "Geophysics—Its Application To Petroleum Prospecting, *The Petroleum Engineer,* 8:129, February, 1937.

[3] Moore, Raymond C., *Historical Geology,* p. 528, McGraw-Hill Book Company, Inc., New York, 1938.

wave known as the Love or Raleigh wave.[4] Of these different waves the ones of chief interest in applied seismology at the present time are the longtitudinal waves, but it has been suggested and facts do indicate that any of the waves which pass through the earth may be of equal value in geophysical prospecting when they are properly recorded and correctly interpreted. Even at the present time there is considerable progress being made. One group uses the refracted wave and another the reflected. The reflected is considered to be the best at the present time, probably because it is the newer method.

The general theory on which the accuracy of the seismograph is based is the fact that the speed of the vibrating waves is dependent on the density and pressure of the material which it passes through. It is also known that the earth's crust is made of material of different density, therefore waves will pass through this crust at varying speeds.

In making a seismograph survey a charge of dynamite is set off in the ground to produce the waves. One wave of interest that is produced is the ground wave which passes just beneath the ground. Often this wave is of no importance but it is the strongest wave produced. Then there are the reflected and refracted waves. When a wave meets a contact plane between material of definitely different physical characteristics the wave is both reflected and refracted. The refracted part penetrates the next layer and on meeting a contact plane is reflected and refracted once more. This process continues until the amplitude of the wave diminishes to infinity.

All of these waves are found to have different frequency and different wave lengths which must be determined for the specific locations on which the tests are to be made. Average values are available. The ground wave is assumed to have a wave length of one hundred feet and a frequency of twenty cycles per second. The reflected waves are of forty cycles and are assumed to be traveling at an average velocity of eight thousand feet per second.[5]

After the artificial disturbance has put these waves in motion they are all picked up by the detectors along with many other natural waves, so that it is the job of the seismograph to shield out all waves that are not wanted and allow only the waves of interest to be recorded on the sound track. If you consider all the waves as a whole, the first waves to reach the detectors are the reflected waves, if the detectors are placed at a sufficient distance from the source to out-distance the direct waves. But actually the shortest time wave merges into a series of waves of increasing amplitude for several cycles with a break which may indicate the arrival of the direct wave then there is a gradual decline in the amplitude.[6]

The seismogram is a record of the waves plotted as a series of waving lines. Each line is the record of a different detector but from the same disturbance. The time is plotted on the horizontal and the amplitude on the vertical. The whole graph will be a record of probably five to six seconds so the time intervals dealt with in the final calculations are very small. The calculations necessary for final determinations are based on previous, confirmed seismograms. This is true for a reflection can only be recognized on a seismogram by its distinctive pattern, just as one recognizes an aeroplane. Due to this fact the success or failure of a survey depends on the reader's ability to interpret the graph. Because of this ability to interpret the graph. Because of this personal judgment involved in the interpretation of a large staff which sifts and selects the reflections, draw their own profile and contour maps which are finally compared before the final interpretation is made.

It appears that a good interpreter must possess an excellent pair of eyes, an ability to recognize reflections, a reliable memory, some imagination, (and a curb on that imagination) and a bushel of old-fashioned common sense.

The electrical resistivity method of geophysical prospecting is based fundamentally on the variation of resistivity of the subsurface stratas which can be determined by passing an electric current between two electrodes placed in the ground. The depth of penetration is governed largely by the separation between the two electrodes.[7]

The flow of electricity through the subsurface rock material included between the two electrodes is by means of electrolytic conduction. The current is carried by the natural moisture in the subsurface, which is the electrolyte consisting of water solutions of various soluble salts contained within the rock. The factors affecting conduction are in general the same as those affecting electrolytic conduction.

It has been well established that the conductivity of practically all non-metallic materials making up the earth's crust is very low when these

[4] Steinmann, Kurt W., "Seismic Reflection Shooting," *Oil Weekly*, 88:42, March 7, 1938.

[5] McDermott, Eugene, "Use of Multiple Seismometers," *The Petroleum Engineer*, 8:135, February, 1937.

[6] "Geophysical Prospecting," *Canadian Mining Journal*, p. 260, May, 1938.

[7] Jakosky, J. J. and Wilson, C. H., "Prospecting for Oil Structures by Electrical Methods," *The Petroleum Engineer*, 8:148, February, 1938.

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materials are dry. Their conductivity depends on the following: (1) the percentage of moisture disseminated through the material, (2) chemical properties and ionization factors of the soluable salt in the material and (3) the nature of the rock material. Of these three factors the percentage of moisture usually is the most important in actual field work. In rocks containing a high percentage of soluable salts a critical point has been found to exist in the relationship between resistivity and percentage of moisture. The point is generally about ten to fifteen percent moisture. With greater amounts of moisture present there is little change in resistivity, but below this value the resistivity changes sharply.[8]

Another factor affecting resistivity is the time of current flow, but it has been determined that results taken from short flow of current are more accurate, for the same results may be reproduced under like conditions at a later date.[8]

Theoretically the depth of penetration is governed by the distance that the surface electrodes are separated. Actually, the penetration depends upon the relative conductivities of the various materials making up the subsurface, and this depth of penetration varies from twenty-five to thirty-five percent of the distance between electrodes. The major portion of geophysical prospecting using the resistivity method has been confined to depths of four to five thousand feet.[7]

In general, the procedure in making an observation is to establish station points and work from them in one or more directions until an entire area is covered. The number of station points needed will depend on the area in which you are working. Few will be needed if it is the mid-continental area where electrolytic conditions are uniform over many miles of area. In California, electrolytic conditions change rapidly because of its geological characteristic such as in the oil producing areas where the beds are lens shaped with considerable variation in thickness. In such areas the stations may not be over one thousand feet apart if you care to carry certain markers from one station to the next so that you may have a clear correlation between stations.

As the change in resistivity is measured graphs are plotted with the current variation as in the abscissa and depth of penetration as the ordinate.[7] This graph produced is called the electrolytical log of which one or more may be produced for every station. These logs are correlated with actual geological data probably from previous

[8] Eve, A. S., "Geophysical Methods of Prospecting," *U. S. Bureau of Mines,* Technical Paper, No. 420, 1939.

wells and then local variations are determined by the change in resistivity shown on the logs.

The resistivity method was used to cover about twenty-five square miles near the southern end of San Joaquin Valley adjacent to the southern foothills in Kern County, California. A structural profile found by this method showed a very distinct correlation between it and wells drilled in this area. Wells drilled after the survey was made were found to be very close. This is just one case where the resistivity method has proven of value but there are a number of others most of which are unknown to the public.[9]

It is evident that great strides and discoveries have been made possible by geophysical methods of prospecting but the geophysists are a strange group of selfish people. Each group works independently of another group thereby forcing all to make the mistakes others have previously discovered. Only when the geophysist shares his discoveries and ideas with his fellow workers will they be able to obtain the full benefits of the fundamental ideas with which they are now toying.

[9] Resistivity Measurements of Oil Bearing Beds," *U. S. Bureau of Mines,* Technical Paper, No. 481, 1940.