ELECTRICAL RESISTIVITY SURVEYS

Rational

Electrical resistivity is the resistance of a volume of earth material to the flow of electrical current. The electrical resistivity of earth materials is directly affected by moisture content and permeability. Typically, electrical resistivity decreases as permeability and moisture content increases. The resistivity of earth materials is also greatly effected by the concentration of dissolved salts or free ions in the saturating fluid. Generally, fine-grained materials such as clays have a lower electrical resistivity than coarse grained materials such as sands and gravels. The presence of fluids that have a high concentration of dissolved salts or free ions can significantly decrease the electrical resistivity of both fine and coarse-grained materials.

Electrical properties of rock can vary greatly depending upon degree of weathering and fracturing, as well as composition. Rock formations that are deeply buried and not exposed to chemical weathering are generally impermeable, contain little water, and have a relatively high electrical resistivity. Conversely, highly weathered and fractured rock that contains moisture typically has lower resistivity.

Based on the above relationships, geophysical methods that measure the electrical resistivity of the subsurface can be used to determine the depth and/or lateral extent of possible water-bearing formations as well as the depth to bedrock.

Methodology

The electrical resistivity of the subsurface is measured using a galvanic resistivity method. This consists of transmitting electrical current into the earth through a pair of grounded metal electrodes, and measuring the resulting potential drop across the second pair of grounded metal electrodes. There are a variety of electrode arrangements (arrays) that can be used. The dipole-dipole electrode configuration is typically used because it provides information on both the depth and lateral extent of subsurface electrical properties.

The dipole-dipole array consists of four electrodes that are placed in the ground in a collinear arrangement. One pair of adjacent electrodes is used to transmit current into the earth and is referred to as the current dipole. The second pair of electrodes is used to measure the resulting potential drop, and is referred to as the potential dipole. Both dipoles have the same length.

To begin a profile, a reading is taken with the dipoles separated by their common length. Subsequent readings are taken as the potential dipole is moved along the profile while the current dipole remains stationary. As the separation between dipoles increases, so does the depth of investigation. Once the maximum separation is reached, the current dipole is moved along the profile one dipole length and the entire procedure is repeated.

For each reading, a value is calculated that represents the apparent resistivity of the volume of earth that the current flows through. The term, apparent, is used because the value represents the resistivity of a volume rather than an individual layer. The apparent resistivity values are then plotted in cross-section and contoured to form what is referred to as a "pseudo-section". The term "pseudo" is used because the vertical scale is not scalar but is proportional to the dipole separation. In addition, the resistivities are apparent rather than true. However, the pseudo-section can be inverted to generate a 2-D model showing the depth and true resistivity of subsurface layers.

Instrumentation

Apparent resistivity data is typically acquired using a SuperSting R1 Resistivity meter with the Swift automatic multi-electrode system. Both systems are manufactured by Advanced Geosciences Incorporated (AGI). The Sting is a self-contained unit that transmits current at outputs ranging from 1 to 500 milliAmps (mA). The unit also measures the potential drop and converts the data to values of apparent resistivity for a number of electrode arrays. The data are stored in internal memory and can be downloaded to a computer for processing. The Swift consists of an electrode interface console, four cables, and 56 stainless steel electrodes. Each cable has 14 individual take-outs that can be connected to electrodes at intervals up to 10 meters. Depending on the objective of the survey, the Swift can operate using 28 to 56 electrodes.

Data Acquisition

ER surveys using the Sting/Swift resistivity system are initiated by laying out the cables, end-to-end, along each profile. The Swift console is then connected between the two cables and to the Sting ER meter. At each take-out in the cable, stainless steel electrodes are driven into the ground and then fastened to the respective take-out. To begin the survey, the ER meter tests the contact resistance of each electrode. If any of the values are abnormally high, the electrode plant as well as the connection between the electrode and the cable is inspected, and if necessary, improved.

The survey is begun once all of the electrode contacts test satisfactory. To start out, readings are taken with the dipoles separated by their common length and moved along the length of the array. For example, if the length between two electrodes (referred to as a dipole) is 10 meters, then the distance between the current and potential dipoles (two electrodes each) will also be 10 meters. Using the Swift switch box, the measurements are moved along the electrode array. Subsequent readings are then taken by increasing the distance between dipoles, up to eight times the dipole separation, along the array. The system then repeats the entire procedure using dipole lengths typically two to three times the length of the initial dipole. For example, if the initial dipole was 10 meters, then the Sting/Swift system repeats the process using dipole lengths of 20 and 30 meters.

Data Analysis

Upon completion of a dipole-dipole survey, apparent resistivity data are downloaded from the Sting to a laptop computer using the program STINGDMP. The data are inverted to true resistivity versus depth and distance using the program EARTHIMAGER. Both programs are written by AGI. The data generated by the EARTHIMAGER program are then gridded and contoured using the computer program Surfer 8.0 by Golden Software to produce 2-D models.

Limitations

A common feature of all electrical methods is that the models derived from the electric profiling are not unique. That is, depending on the subsurface geo-electric structure, there may be many models that will produce essentially the same apparent resistivities. This is known as the *principal of equivalence*. To overcome this limitation, computer software programs include routines for evaluating the equivalence of a given model relative to the observed resistivity values, resulting in a model that provides the closest fit to the observed data.