RESOURCE NOTES

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Applications of Electrical Resistivity: A Surface Geophysical Method

By Brent R. Lewis, Geologist
BLM, National Science and Technology Center

Background

Bureau of Land Management (BLM) geologists, hydrogeologists, and hazardous materials specialists must frequently obtain subsurface geologic information while working under time and budget constraints. It is possible to image the subsurface quickly and inexpensively through the application of various nonintrusive surface geophysical methods. I discuss here one method known as direct current electrical resistivity, which is used on a variety of BLM projects such as:

- Performing geologic and stratigraphic mapping
- Mapping leachate leaking from evaporation ponds
- Estimating volumes of tailing piles and tar pits
- Optimizing the placements of water supply wells and groundwater monitoring wells
- Conducting validity exams of sand and gravel deposits

Electrical resistivity technology has recently evolved with the increased sophistication of electrical hardware and software. Formerly, two methods of subsurface imaging using electrical resistivity were available: electrical sounding for investigating depth and electrical trenching for assessing lateral variations. Electrical soundings presented a one-dimensional vertical profile of limited lateral control, whereas electrical trenching generated a lateral profile but was limited to a constant depth and the bulk resistivity of only that depth interval. It is easier using today's instruments to acquire the data as a set of soundings comprising a two-dimensional cross-section or profile of the subsurface. On the basis of the distribution of resistivity within a profile, an accurate interpretation of the subsurface geologic setting can be made. This information can be used in the field to optimize the location of a well or excavation.

Discussion

Electrical resistivity surveys measure the electrical resistive properties of earthen materials. Resistance is the ability of the material to inhibit an electrical current; it is the opposite or reciprocal of electrical conductivity. This method considers the subsurface geologic setting as a series of electrical resistors that naturally inhibit an electrical current. The success of electrical resistivity surveys lies in their ability to detect changes in the electrical field caused by these resistors and, subsequently, to determine their locations, depths, and thicknesses. The two-dimensional electrical resistivity surveys are employed by using a linear array of metal electrodes connected by a cable. An electrical current is applied to the ground through two source electrodes along this array, and the potential difference (voltage drop) created at the surface is measured between two receiving electrodes located at a known location and distance. The potential difference produced as the current encounters earthen material (a resistor) is measured and used to determine the resistivity of the material between the electrode pairs. To produce a cross-section composed of many resistivity measurements, the position along the array and the distances separating the electrode pairs must be varied for each measurement.

The effective depth of a measurement is sequentially increased by increasing the distance between the source electrodes and the receiving electrodes. The farther this distance, the greater the vertical interval in which the bulk of the current flows. To acquire data from a new, lateral position, the lateral location of these electrode pairs is sequentially moved down the array after each measurement, and a new measurement is collected at a new lateral location. As the electrode separation is incrementally changed or moved and a new resistor or different geoelectric property is encountered, differences or contrasts of resistivity are noted. The electrical current tends to flow in areas of low resistivity such as clay, resulting in a relatively lower resistivity value than sand. The apparent resistivity value is recorded by the instrument and is typically measured in ohm-meters or ohm-feet.

Although the magnitude of resistivity and cause is important, the information obtained from the lateral and vertical changes, (i.e., spatial distributions of the data) is often more diagnostic. These spatial variations are boundaries from which inference can be made regarding the distribution of the stratigraphy or sediment facies. These changes are inferred as geologic boundaries that may actually be caused by one or more of the following: a change in lithology, sediment grain size, or chemical boundaries resulting from changes in water chemistry or moisture content. In all instances, the user must determine if the results are possible given the existing knowledge of site conditions. It is important, therefore, to have conceptual ideas of the geologic setting and the effects it may have on the geophysical signature for a more accurate interpretation.

The sequential changes in electrode arrangements can be performed manually—or automatically if specialized equipment is used. The BLM uses an automated, multielectrode system consisting of a Sting R1 resistivity meter and a Swift automatic switching box and multielectrode cable (Advanced Geosciences Inc., Austin, Texas; Figure 1).

Interpretations made from the raw, unprocessed resistivity field data (pseudosections) can be difficult. Potentially more accurate methods rely on a computer processing method known as data inversion. The inversion process accounts for many of the variables, such as the array, current, voltage potential, and the matrix of readings, and suggests the true resistivity rather than the apparent resistivity presented in the pseudosection. Inversion can be further controlled with known information such as a drill log. If such control is not available, the inversion process can still be used. In either situation, a best-fit model is generated from which interpretations are made.

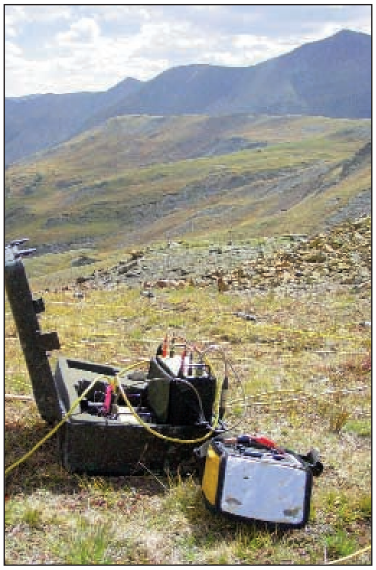

Figure 1. A Sting R1 resistivity meter and a Swift automatic switching box and multielectrode cable are used to perform sequential changes in electrode arrangements.

The BLM now uses inversion processing software (IP2DI version 4.12 from Interpex, Golden, Colorado). The National Science and Technology Center (NSTC) is developing the integration of two-dimensional profiles into three-dimensional models by intersecting survey lines and using earthVision software (Dynamic Graphics, Inc., Alameda, California; Figure 2).

The in-house resistivity equipment now being used has 60 electrodes and is capable of acquiring data from depths as great as 200 feet. The vertical accuracy in the upper 50 feet is typically within 2 feet; for depths between 50 and 100 feet, vertical accuracy is about 4 feet. A single line typically takes 1.5 hours to set up, acquire, process, and plot in the field.

National Science and Technology Center staff have collected and interpreted data from a variety of applications of electrical resistivity on BLM projects.

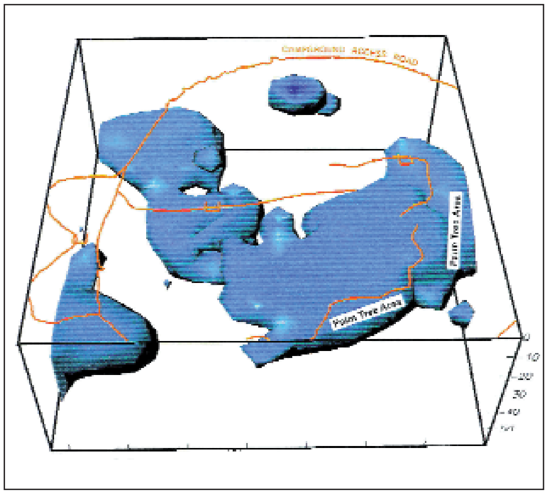

Figure 2. EarthVision software aids in the integration of two-dimensional profiles into three-dimensional models.

Contact

Brent Lewis
National Science and Technology Center
Denver Federal Center
Building 50
P.O. Box 25047
Denver, CO, 80225-0047
Phone: 303-236-0550
Fax: 303-236-3508
Email: *Brent_Lewis@blm.gov*

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