

ELECTRICAL RESISTIVITY TECHNIQUES FOR SUBSURFACE INVESTIGATION

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ABSTRACT

Geophysical resistivity techniques are based on the response of the earth to the flow of electrical current. With an electrical current passed through the ground and two potential electrodes to record the resultant potential difference between them, we can obtain a direct measure of the electrical impedance of the subsurface material. The resistivity of the subsurface, a material constant, is then a function of the magnitude of the current, the recorded potential difference, and the geometry of the electrode array. Depending upon the survey geometry, the data are plotted as 1-D sounding or profiling curves, or in 2-D cross-section in order to look for anomalous regions. In the shallow subsurface, the presence of water controls much of the conductivity variation. Measurement of resistivity is, in general, a measure of water saturation and connectivity of pore space. Resistivity measurements are associated with varying depths relative to the distance between the current and potential electrodes in the survey, and can be interpreted qualitatively and quantitatively in terms of a lithologic and/or geohydrologic model of the subsurface.

INTRODUCTION

Geophysical resistivity techniques are based on the response of the earth to the flow of electrical current. In these methods, an electrical current is passed through the ground and two potential electrodes allow us to record the resultant potential difference between them, giving us a way to measure the electrical impedance of the subsurface material. The apparent resistivity is then a function of the measured impedance (ratio of potential to current) and the geometry of the electrode array. Depending upon the survey geometry, the apparent resistivity data are plotted as 1-D soundings, 1-D profiles, or in 2-D cross-sections in order to look for anomalous regions.

In the shallow subsurface, the presence of water controls much of the conductivity variation. Measurement of resistivity (inverse of conductivity) is, in general, a measure of water saturation and connectivity of pore space. This is because water has a low resistivity and electric current will follow the path of least resistance. Increasing saturation, increasing salinity of the underground water, increasing porosity of rock (water-filled voids) and increasing number of fractures (water-filled) all tend to decrease measured resistivity. Increasing compaction of soils or rock units will expel water and effectively increase resistivity. Air, with naturally high resistivity, results in the opposite response compared to water when filling voids. Whereas the presence of water will reduce resistivity, the presence of air in voids should increase subsurface resistivity.

Resistivity measurements are associated with varying depths depending on the separation of the current and potential electrodes in the survey, and can be interpreted in terms of a lithologic and/or geohydrologic model of the subsurface. Data are termed apparent resistivity because the resistivity values measured are actually averages over the total current path length but are plotted at one depth point for each potential electrode pair. Two dimensional images of the subsurface apparent resistivity variation are called pseudo-sections. Data plotted in cross-section is a simplistic representation of actual, complex current flow paths. Computer modeling can help interpret geoelectric data in terms of more accurate earth models.

This paper reviews the working ideas behind basic geoelectric methods. In the following sections we present some of the basic resistivity theory, followed by discussions on resistivity field methods and survey geometry associated with the three main surveying techniques: vertical electric sounding (VES), constant separation traversing (CST), and combined sounding and traversing methods. Comprehensive overviews of resistivity methods are presented in Telford (1976), Ward (1990), Kearny and Brooks (1991), and Burger (1992).

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