Geophysics primer

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| ../images/foursurveys.jpg |

Geophysical surveys are performed when information about the earth's subsurface is desired, but direct sampling through expensive and invasive techniques such as drilling or trenching is insufficient, impractical or ill-advised. A survey may be as large as the whole Earth, as small as the top few meters of the subsurface, or anywhere in between.

# Measuring physical properties

During a geophysical survey, energy is put into the earth and responses are recorded at the surface, in the air or in boreholes. Resulting data reveal information about the earth because the behavior of the energy within the ground is controlled by the distribution of the earth's physical properties. For instance, one basic physical property is magnetic susceptibility, which describes a rock's ability to become magnetized. This physical property provides information on rock type and structures because the rock's magnetic susceptibility relates directly to mineral type and the chemical alteration processes. A second important physical property is electrical conductivity, which quantifies a material's ability to carry electrical current. Figure 2 illustrates one way a geophysical survey can be carried out to provide information about the subsurface distribution of electrical conductivity.

Evidently, the application of geophysics to problems involving earth's subsurface is a non-trivial process and should be conducted through the seven-step procedure.

# Traditional interpretation

Traditionally, useful information was extracted from geophysical field results by examining maps or line profiles of raw or filtered survey data. Such images are useful for estimating locations and quantities of buried materials and to help choose locations for more invasive (and expensive) techniques such as drilling. For example, large-scale maps of magnetic or gravity data often show the geologic structure or identify an anomalous region that might be associated with a desired target. As an example, Figure 3 shows the magnetic data acquired at the Bathurst region of New Brunswick. The major features observed are related to geologic structure.

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| ../images/graphic5.gif |

Figure 3. Tetatouche Antiform - Total Magnetic Field, from "Airborne Geophysical Survey of the Bathurst Mining Camp", Geological Survey of Canada website.

Historically, in mineral exploration, the identification of an anomalous region was often the endpoint of the analysis, and the image was used to plan the location of a drill hole. Unfortunately, the success rate was generally poor. At best, data maps provide some information about the lateral extent of a body but little information about what is happening at depth. Quantitative analysis, in particular inversion, is required to obtain 3D information.

# Inversion

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The goal of the inverse problem is to find a mathematical model of the earth that produced the field observations. That is, "What subsurface physical property distribution caused the data observed at the surface?" Earlier inversion solutions involved characterizing the earth by a few prisms or layers and finding geometrical and physical properties of these simplified earth models.

Due to the earth's extreme complexity, useful models often need many parameters, usually more than the number of data. This means that the problem of finding a model (i.e. estimating values for every parameter) is one in which there are more unknowns than data. Such problems do not have unique solutions, and this nonuniqueness is exacerbated when data are noisy or inaccurate. Formal inversion methods address these issues using well-defined mathematical techniques. An appendix explains inversion in a little more detail.

Some benefits of applying rigorous inversion can be seen by comparing traditional map and pseudosection plots of the raw data to the information in 3D and 2D models obtained by inversion.