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GEOPHYSICAL METHODS IN MINERAL, GROUNDWATER, AND HYDROCARBON EXPLORATION.

From the point of view of geophysicists, geophysical methods are playing an important role in mineral, groundwater investigation and hydrocarbon exploration. Various geophysical techniques rely upon different physical properties present in the subsurface or deeper. For a geophysical technique to be useful in mineral exploration, there must be contrasts in the physical properties of the rocks concerned that are related, directly or indirectly, to the presence of economically significant minerals. Geophysical anomalies, defined as differences from a constant or slowly varying background, may then be recorded. Anomalies may take many different forms and need not necessarily be centered over their sources (Figure 1.8). Ideally, they will be produced by the actual economic minerals, but even the existence of a strong physical contrast between ore minerals and the surrounding rocks does not guarantee a significant anomaly.

The effect of gold, which is both dense and electrically conductive, is negligible in deposits suitable for large-scale mining because of the very low concentrations. Diamonds (the other present day "high profile" targets) are also present in deposits in very low concentration and have, moreover, no outstanding physical properties. In these and similar cases, geophysicists must rely on detecting associated minerals or, as in the use of seismic reflection to locate offshore placers, and magnetic and electromagnetics to locate kimberlites on defining favourable environments.

In terms of the amount of money expended annually, seismic methods are the most important techniques because of their routine and widespread use in the exploration for hydrocarbons. Seismic methods are particularly well suited to the investigation of the layered sequences in sedimentary basins that are the primary targets for oil or gas. On the other hand, seismic methods are quite unsuited to the exploration of igneous and metamorphic terrains for the near-surface, irregular ore bodies that represent the main source of metalliferous minerals

The selection of a particular method relies on various parameters including cost, efficiency, accessibility, and type of application. In addition, a single choice of a geophysical method in any application occasionally provides poorly constrained results. So, a combination of two or more approaches certifies much more consistent results. This methodology is called integrated geophysical approach that ensures more prominent precision and higher consistency of results. Typically, more than one method is used in one survey, to decrease the ambiguity in deciphering the nature of unknown resources below the surface.

Some important geophysical methods (Table 1) are shown to demonstrate how we use these methods in mineral, groundwater, and hydrocarbon exploration.

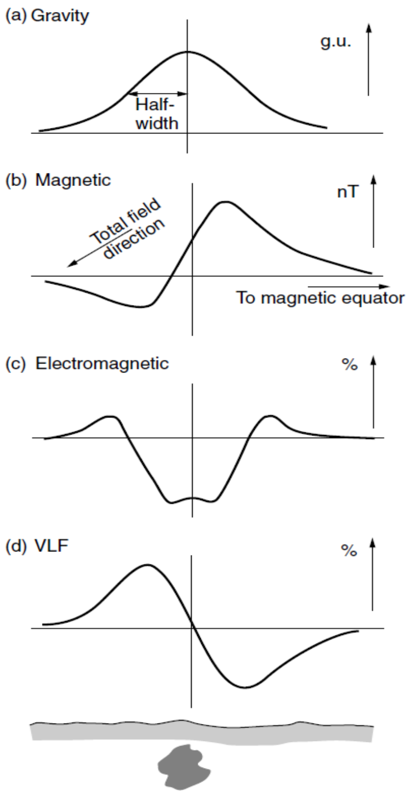

Figure 1.8 Geophysical profiles across a pyrrhotite-bearing sulphide mass. The amplitude of the gravity anomaly (a) might be a few g.u. and of the magnetic anomaly (b) a few hundred nT. The electromagnetic anomalies are for (c) a two-coil co-planar system and (d) a VLF dip-angle system. Neither of these is likely to have an amplitude of more than about 20%.

Table 1-Main geophysical methods and their essential parameters used in mineral, groundwater, and hydrocarbon exploration.

Geophysical Surveying Methods with Parameters and Properties Suitable for Type Deposits

Method	Measured parameters	Operative physical property	Suitable deposit type
Seismic	Travel time of reflected and refracted seismic waves.	Density and elastic mode velocity	Oil and gas, layered sedimentary basin.
Gravity	Spatial variation in the strength of Earth's gravitational field.	Density contrast between the surrounding host rocks	Massive sulfides, chromite, salt dome, barite, kimberlite, concealed basin.
Magnetic	Spatial variation in the strength of geomagnetic field.	Magnetic susceptibility	Magnetite, ilmenite, pyrrhotite-rich sulfides.
Electrical			
1. Resistivity	Earth's resistance	Electrical conductivity	Groundwater, sulfide ore.
2. Induced Potential (IP)	Polarization voltage/frequency development of ground resistance	Electrical capacitance	Large sulfide dissemination, graphite.
3. Self-Potential (SP)	Electrical potential	Electrical conductivity	Sulfide veins, graphite, groundwater.
EM	Response to EM radiation	Electrical conductivity and inductance	Sulfide ore, graphite deposits.
Radiometric	Gamma radiation	Gamma ray	Thorium, uranium, radium.
Borehole geophysics and Mise-á-la-Masse	Down-hole probe	All types	Continuity of mineralization in strike and dip.