1.1. GEOPHYSICS: RELATIONSHIP WITH GEOLOGY

By definition, geophysics is the scientific study of the earth using methods of physics. Along with geology and geography it occupies an important position in earth sciences.

Strictly speaking, the subject covers the physics of the whole earth, from its deepest interior to the extreme fringe of its atmosphere, and so involves many disciplines. However, in current practice it is often used in a more restricted sense to denote the physics applied to the study of the "solid earth" (excluding the hydrosphere and atmosphere), and it is in this sense that the word geophysics will be used in this book.

The domain of geophysics, even in its restricted meaning, involves many fields of study. These fields are as follows:

* **Geodesy and gravimetry**—dealing with the earth's shape and gravitational field.
* **Seismology**—dealing with earthquakes and other ground vibrations (e.g., that caused by chemical or nuclear explosions).
* **Geomagnetism and geoelectricity**—dealing with the earth's magnetic and electric phenomena.
* **Geothermometry**—dealing with the heat flow and temperature distribution in the earth.
* **Tectonophysics**—dealing with the physical aspects of regional and global tectonics.
* **Geocosmogony**—dealing with the origin of the earth.
* **Geochronology**—the dating of events in the earth's history.

In addition there are some fields of study that, although generally recognized as belonging to geophysics, are more closely linked with geology. These are specialized disciplines such as **volcanology**, **hydrology**, and **glaciology** whose fields of interest are evident from their names.
Geophysics developed from the disciplines of physics and geology and has no sharp boundaries that distinguish it from either. Geology involves the study of the earth by direct observations on rocks either from surface exposures or from boreholes and the deduction of its structure, composition, and historical evolution by analysis of such observations. Geophysics, on the other hand, involves the study of "the inaccessible earth" by means of physical measurements, usually on or above the ground surface; it also includes interpretation of the measurements in terms of subsurface structures and phenomena. In its methods, geophysics is a branch of physics, but in studying the various complexities of the earth it shares with geology the common objective of understanding the planet we inhabit.

Geophysical studies are considered to be *quantitative* and *tangible*, in comparison with geological studies, which are traditionally characterized as *qualitative* and *descriptive*. However, this line of distinction between the two disciplines is fading as their discrete endeavors are becoming better coordinated. This trend is quite apparent in exploration geophysics, where the majority of petroleum geologists spend most of their time extracting quantitative information from geophysical data, such as seismic record sections, electrical data, and a family of other well logs. Likewise, geophysicists, who have been largely concerned with measurements of physical phenomena, are nowadays incorporating more geology in order to increase the reliability of the conclusions.

Clearly, the recent revolution in earth sciences, relating to the new developments in the global tectonic theory (such as "sea-floor spreading" and "plate tectonics"), is due mostly to the skill of integrating pieces of information obtained by a variety of geophysical and geological methods. At the university level, however, the distinction between geology and geophysics persists, and radical changes cannot be anticipated very soon. Universities will continue to produce graduate geologists and/or geophysicists instead of "earth scientists" or "explorationists" for a considerable time. Nevertheless it is gratifying to learn that at most universtities a growing demand for introducing geophysics into the geological curricula is being felt. In a way this book attempts to meet this demand.

Every earth scientist, especially the geologist, should be familiar with the methods of geophysics. This familiarity should enable one to know which of the geophysical methods can (or cannot) be of help in a given geological situation. One must also be aware of the limitations of the geophysical methods. It must be emphasized that in studying the earth's hidden features and phenomena, most problems are of an "inverse" type, i.e., of deducing the "source" from the observed "effect." The measured physical effect (e.g., surface variations in gravity, magnetic, or electrical field) in general cannot be interpreted in terms of a unique source (or phenomenon) occurring at a particular depth inside the earth, because a variety of sources with
1.2. Scope of Geophysical Methods

Varying parameters at different depths can theoretically produce the same effect. A combination of several geophysical methods often yields more information that can help reduce the ambiguity by narrowing down the range of possible solutions. The importance of incorporation of the available geological information in interpretation of geophysical measurements can hardly be exaggerated.

1.2. SCOPe OF GEOPHYSICAL METHODS

The physical properties of rocks that are most commonly utilized in geophysical investigations are the elasticity, density, magnetic susceptibility, remanent magnetization, electric resistivity or conductivity, radioactivity, and the thermal conductivity. These properties have been used to devise geophysical methods that essentially detect a discontinuity, that is, where one region differs sufficiently from another in some physical property. In this book these methods are classified and described under eight major headings:

- seismic methods
- gravity methods
- magnetic methods
- paleomagnetic methods
- electrical methods
- electromagnetic methods
- radiometric methods
- geothermal methods

Geophysical methods have been applied to a great variety of problems ranging in diversity from the earth's internal structure, composition, and dynamics to the detection of mineral deposits at shallow depths. Studies of large-scale problems relating to the earth's structure and dynamic behavior are considered to be main areas of general (global) geophysics. On the other hand, special applications of geophysical techniques to exploration for oil and minerals belong to the area of applied (exploration) geophysics. Exploration geophysics developed from the methods used in general geophysics and this relationship has now evolved into a fruitful interdependence between the two. For instance, many of the techniques of explosion seismology, originally developed for use in oil exploration, have been advantageously used in academic studies relating to the structure of the earth's crust and upper mantle. On the other hand, results of many large-scale studies made in the area of global geophysics (e.g., seismotectonics, heat
flow, deep resistivity soundings, paleomagnetism, and plate tectonics) have
been of great utility in demarcating zones with specific tectonic settings
that are favorable for accumulation of oil, minerals, and other energy
resources.

In dealing with the various geophysical methods, this book is biased
toward "surficial geophysics," which is the prime area of interaction with
geology. Most problems in surficial geophysics are related to the study of
crust, its structure, evolution, dynamics, and energy resources. This area of
application has several points of contact with both global and exploration
geophysics, as demonstrated by several field examples given in Chapters 2
through 11.