FOUNDATIONS OF GEOPHYSICS AND GEOCHEMISTRY

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Summary

Contemporary geophysics and geochemistry are two closely collaborating branches of the earth sciences with roots in ancient times.

Geophysics is concerned with physical phenomena. The different disciplines into which present-day geophysics is subdivided are described here. Modern geophysics does not deal exclusively with the solid earth, it also includes upper atmosphere investigations (aeronomy and magnetospheric physics), solar wind, and planetology. The separation of geophysics into different disciplines is based partly on the different methods used to study the same physical body, and partly on the investigations of different media and processes. However, within the natural environment, various disciplines of geophysics are interrelated and interact with each other.

Geochemistry deals with the distribution and cycling of the chemical elements and their isotopes throughout nature. It is of high importance in understanding the earth and the planets, and their origin and nature. Geochemistry is an interdisciplinary subject that touches geophysics, geology, astronomy, planetary sciences, atmospheric science, physics, chemistry, biology, material sciences, and others. The subject has evolved from a substantially descriptive to a highly quantitative and predictive discipline.

1. Introduction

In ancient Greece, the word *physis* denoted nature, the natural order, the world. Therefore, the word "physics" can be understood as the designation of the scientific discipline dealing with these objects. However, during the long historical development of physics, its orientation and objects of interest gradually changed. Contemporary physics is a wide scientific discipline, studying many other processes and properties of matter, while the study of general earth-related natural phenomena has become the subject of geophysics and the other earth sciences. Since chemical processes are also important, one of the key earth sciences is geochemistry.

The names of the scientific disciplines dealing with the earth generally start with the prefix "geo," since the ancient Greek name for the earth was *Ge*. The main earth sciences are: geodesy, geology, geophysics, geochemistry, and geography.

Geophysics—the physics of the earth—is a branch of physics that studies the phenomena and processes occurring in the earth and in its vicinity by means of physical methods. It also studies the effects that other celestial bodies, in particular the sun and the moon, have on the earth.

From the point of view of this definition, geophysics includes physics of the solid part of the earth and of its liquid and gaseous envelopes. In this case we speak of geophysics in a broader sense. However, meteorology, oceanography, and hydrology are usually separated from geophysics as independent scientific disciplines with specific problems and methods of investigation. We speak then of geophysics in a narrower sense—of solid-earth and upper-atmosphere physics. Attention should be paid to a certain terminological inconsistency here, for solid-earth physics is understood to be the physics of the whole interior of the earth, including its liquid parts, especially the liquid outer core.

The solid body of the earth has mechanical, elastic, and thermal properties, which are studied by seismology (see *Seismology and Volcanology*), gravimetry (see *Gravimetry*), and geothermics (see *Terrestrial Heat Flow*), respectively. These disciplines deal with near-surface phenomena as well as with the processes, composition, and structure of the earth deep below the surface, including the earth's mantle and core. Tectonic processes and the motion of continents (see *Tectonic Processes*) are joint interests of geophysics and geology. The earth also has magnetic and electric properties. Investigations of magnetic and electric properties of the earth, and their application in studies of the earth's crust, as well as deep structure, and the search for the earth's past form the subject of two geophysical disciplines—geomagnetism and geoelectricity (see *Geomagnetism and Geoelectricity*).

The solid body of the earth is not the only part of the earth's system where magnetic and electric processes play a role. They also play a decisive role in the ionized part of the upper atmosphere of the earth: in the ionosphere and magnetosphere, the latter being the most remote part of the earth's system. They are studied by scientific disciplines called aeronomy, space plasma physics, and solar–terrestrial relationships (see *Aeronomy and Magnetosphere*). While there are relatively clear boundaries between geomagnetism and geoelectricity, this is not the case with aeronomy, space-plasma physics and solar–terrestrial science. Moreover, the latter two also include extraterrestrial space. Extraterrestrial processes, particularly variations of solar wind and of its magnetic field, control the behavior of the magnetosphere, affect substantially the ionosphere, and also influence electric and magnetic processes in the earth—at least near its surface. Therefore, modern geophysics includes interplanetary space and/or solar wind studies (see *Solar Wind and Interplanetary Magnetic Field*).

Extraterrestrial planets of the solar system have many features, properties, and processes similar to those of the earth and its atmosphere (see *Planetology*). Their observation and understanding sometimes help to understand better processes observed in the earth's system. On the other hand, many methods of studying extraterrestrial planets are identical with or similar to those used in geophysical investigations. Therefore, planetology is considered to be a part of modern geophysics, even though it is at the interface between astronomy and geophysics. This may be another example that shows that a strict disciplinary division does not apply in modern science.

In addition to these disciplines, some others that have a rather interdisciplinary character also partly belong to geophysics. On the boundary between geodesy and geophysics are physical geodesy and the study of recent motions. Between geology and geophysics are tectonophysics, volcanology, and geochronology (the determination of the age of rocks and geological processes). Of common interest to astronomy and geophysics are the motions of the earth, satellite gravimetry, planetary physics, solar wind, and cosmogony (the study of the origin of the solar system).

The above disciplines basically deal with physical phenomena, properties, and processes. However, chemical processes and phenomena are important as well. These processes are treated by geochemistry. Modern geochemistry includes investigations of the geochemical origin of the earth, and cosmochemistry related to planetology (see *Geochemistry and Cosmochemistry*). Many of the above "physical" sciences also contain important chemical "ingredients," for instance, aeronomy or volcanology. The structure of the earth cannot be understood without understanding basic geochemical processes.

The understanding of the chemistry of the earth and its components (minerals, rocks, natural water, gasses, lithosphere, hydrosphere, atmosphere, and biosphere) in space and time is the main task of geochemistry. Historically, geochemistry has been the science intimately connected with inorganic chemistry, and studied the relations between chemistry and minerals used by humans as raw materials. The development of geochemistry was greatly advanced by the progress of analytical chemistry during the last century.

Geochemistry affects on an increasing scale all branches of geoscience. It has mutual links with many neighboring disciplines—several fields of chemistry, oceanography, meteorology, biology, agriculture, the environment, medicine, and so on. It owes its importance to the collection of information about the composition of the earth and the cosmos, as well as the study of the dynamics of distribution, and the migration of chemical elements, isotopes, and compounds during geological processes and events that have shaped the earth over the past 4.5 billion years.

The classical task of geochemistry, in the words of Victor M. Goldschmidt (1888–1947) is "to discover the laws which control the distribution of the individual elements."

W.S. Fyfe defined five main questions that geochemistry solves:

1. What is the bulk chemistry of the earth?
2. What is the chemistry of the major geospheres?
3. In which processes and to what extent are chemical elements of the geospheres exchanged?
4. Has the chemical composition evolved over time?
5. What are the relationships between all of the above and life?

After brief historical notes, each of disciplines and/or branches of geophysics and geochemistry will be briefly described, particularly from the point of view of their foundations and basic applications in studies of the earth as a life-supporting system. (More details about branches of geophysics and geochemistry, and about geophysical and geochemical processes and phenomena, may be found in *Branches of Geophysics*, *Geophysical Phenomena and Processes*, and *Geochemistry: Branches, Processes, Phenomena*.)

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Biographical Sketches

Dr Jan Lastovička,,is currently Director of the Institute of Atmospheric Physics of the Academy of Sciences of the Czech Republic and Vice President of the International Association of Geomagnetism and Aeronomy. He graduated in Geophysics at Charles University in Prague in 1966. He received his CSc degree (equal to PhD) in 1974 and DrSc (equivalent to Professorship) in 1987, both from the Czechoslovak Academy of Sciences. From 1967 to 1994 he was with the Geophysical Institute of the Czechoslovak Academy of Sciences, from doctoral student to head of the Ionospheric Department. Since 1994 he has been working in the Institute of Atmospheric Physics of the Academy of Sciences of the Czech Republic. His main research interests are: the ionosphere, solar-terrestrial relations, the middle atmosphere (including the ozone and the effects of atmospheric waves on the ionosphere), and long-term trends (potentially of greenhouse origin). He is the author/coauthor of more than 220 published papers in scientific journals and various proceedings, and more than 210 presentations at scientific meetings. He has also organized a number of international scientific meetings.

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