



GEOLOGY

Geology is the study of the origin, structure, composition, and history of Earth

Earth is a dynamic planet whose energy is often expressed in catastrophic phenomena, from earthquakes to volcanic eruptions and changes to the climate. The science that seeks to understand and link all such processes is known as geology, earth science, or geoscience.

CONNECTIONS

- The understanding of geologic processes and the evolution of [EARTH](#) were changed with the development of the theory of [PLATE TECTONICS](#).
- Geology is dependent on theories of [PHYSICS](#) and [CHEMISTRY](#).

Geology is fundamental to human life today in ways that people do not realize. Most of the materials people use are essentially geological and, either directly or indirectly, derived from Earth. Nuclear energy is made from radioactive elements, which are found in some natural ore minerals. Most plastics are manufactured from oil (see [OIL](#)), a fossil fuel made from previously living organisms. Glass is derived from natural deposits of silica sand (see [SEDIMENTARY ROCKS](#)). Metal comes from ore deposits (see [ORES](#)). Finally, the food chain ultimately depends on soils with minerals that are essential ingredients for plant growth. In short, geology is the study of Earth, its structure, materials, processes, and history—including its past life.

History of the study of geology

Like other scientific studies, the history of the study of Earth has developed in fits and starts from early observations by the ancient Greeks, including Aristotle (384–322 B.C.E.). The modern phase has its academic origins in the 17th century, with the development of the early universities and learned societies in Europe, for example, the foundation of the Royal Society in London in 1662. The practical experience of geology is rooted in the practice of mining, which extends back into prehistoric times when neolithic people quarried rock such as flint, obsidian, and jadeite to make hand axes.

CORE FACTS

- Humans have had a fundamental need for geological or Earth materials since prehistoric times, when stone tools were first used.
- The study of geology dates back to the time of the ancient Greeks.
- The practical exploitation of Earth's geological resources, such as

- minerals, building stone, and fossil fuels, predates the theoretical understanding of how they were formed.
- Modern study of geology dates from around the time of the Renaissance, when scientists began to make a connection between fossil remains and organisms that were once alive.
 - National geological surveys date from the 19th century, along with the foundation of geological societies and the scientific study of geology in universities.

Only in the Industrial Revolution of the late 18th and early 19th centuries did theory and practice really begin to come together. However, there was still no consensus of opinion about how the rocks were formed. Nevertheless, through close fieldwork and mapping, it became clearer when fossils were compared with modern animals that fossils represented the remains of once-living organisms and that most of the sediments that contained them were originally deposited in the sea. Descriptions, illustrations, and classifications of rocks, minerals, and fossils, collected and preserved in the first private museums were widely published for the first time.

From the end of the 18th century, the study of natural sciences grew enormously. The scientific and philosophical basis for this investigation was laid by naturalists such as James Hutton (1726–1797) in Scotland, Georges Cuvier (1769–1832) in France, and William Smith (1769–1839) and Charles Lyell (1797–1875), both in England. Hutton developed the first rational theory of Earth based on careful field observation and ushered in the beginning of modern geology. Cuvier founded the science of comparative anatomy, without which the scientific interpretation of the fossil record of extinct organisms would not have been possible (see [PALEONTOLOGY](#)). At the same time, there was a growing realization by thinkers that the sequence of strata (layers) of rocks and the fossils in each one represented a history of successive events in the past and could be read like the pages of a book. Scientists began to explore Earth's prehistory through its layers of strata. Smith published the first large-scale geologic map of England based on stratigraphic principles and fossil evolution. Lyell's *Principles of Geology*, first published in 1830, was an essential work for the development of geology as a science. British naturalist Charles Darwin (1809–1882) learned much of his geology from a copy of Lyell's book that he had with him on the travels of the HMS *Beagle* around South America and the Pacific Ocean. This voyage helped Darwin establish his theory of evolution.

The disruption of belief

Geology became increasingly popular during the 19th century, but it also created huge problems because its discoveries contradicted accepted religious views and beliefs. The discovery of very early geological time and the history of past life, with its suggestions of evolution and extinctions of organisms, conflicted with the ideas of those who believed in a literal interpretation of the Bible. Matters came to a head with the publication of the first edition of Darwin's *On the Origin of Species by Means of Natural Selection* in 1859.

The subdivision of geological time

This phase of investigation in the early 19th century led to the establishment of a formal subdivision of geological time (see [GEOLOGIC TIMESCALE](#)), with individual periods being given regional names from those areas where the particular period was well developed. British academic professor of geology Adam Sedgwick (1785–1873), for example, named the first period of relatively abundant fossil life the Cambrian period (see [CAMBRIAN PERIOD](#)), after the Cambrian area of northern Wales. His contemporary Scottish geologist Roderick Murchison (1792–1871) named the Silurian (see [SILURIAN PERIOD](#)) after another area in Wales. By the late 19th century, the broad outline of the fossiliferous phase, called the Phanerozoic eon—the part of Earth's history that occurred within the last 545 million years—had been established.

HISTORY OF SCIENCE

THE ICE AGE AND CLIMATE CHANGE

A major phenomenon of Earth history that is particularly pertinent today is the discovery of climate change. The last ice age (see [ICE AGES](#)) has radically affected human prehistory and landscapes in the Northern Hemisphere.

The discovery of climate change has its roots in the 19th century. In the mid-19th century, attempts were being made to understand the surface processes of weathering, erosion, and transport of their sediment products. It was all part of the study of the geological cycle (rock cycle) and of the different surface processes by Scottish geologist Charles Lyell (1797–1875) and his contemporaries. Questions had arisen from this research about the processes of formation of valleys and whether the rivers of the day were powerful enough to excavate valleys. Some British valleys, especially those in mountainous regions such as northern Wales, the Lake District, and Scotland had features that could not easily be explained by river erosion. It was not until Louis Agassiz (1807–1873), an eminent Swiss-American scientist, visited Scotland in 1840 with English geologist William Buckland (1784–1856) that the scientific community was convinced that the British Isles had been glaciated in the past, just as alpine regions such as Switzerland, are still being glaciated today. Agassiz pointed out the typical glaciated U-shaped profile of the valleys, the depositional features of glacial moraines (an accumulation of material previously transported and deposited by ice), and erratic boulders (whose composition differs from the bedrock beneath).

The impact of this discovery and its implications for the rates of change of past climate and sea levels are only being fully realized today. Even so, the mechanism of global climate change is still not completely understood.

Geological surveys

Geological surveying and mapping played an important part in helping geologists chart Earth's history. Initially, these tasks were done by individuals such as Sedgwick and Murchison, but it

soon became professionalized with the establishment of national geological surveys (the United States Geological Survey [USGS] was established in 1879) once the economic importance of the new science of geology had been recognized by governments. The professionalization of geology was reinforced by its establishment as a subject for study in new universities in the late 19th century. National museums were already being developed as repositories for the new geologic discoveries of the natural world from diamonds to dinosaur fossils; the Smithsonian Institution, the national museum and repository of the United States, was founded in 1846.

The age of Earth

Geology is a secondary science in that it relies on the principles of physics, chemistry, and mathematics. It was the application of theory and practice in the late 19th century that gradually took geology beyond mere description. One of the most important developments was the attempt to measure time. Lyell and other geologists tried to measure the age of Earth using very indirect methods, such as measuring the rates of sedimentation, and came up with figures of more than 100 million years. In 1897 British physicist William Thomson (later Lord Kelvin; 1824–1907) calculated the age of Earth on the assumption that it had cooled from an initial molten state. His result—between 20 and 40 million years—contradicted the rough estimates of the geologists. They were unhappy about this age because, if it were correct, it would greatly compress their complex history of Earth. It was not until the beginning of the 20th century that Ernest Rutherford (1871–1937) realized the role played by the decay of radioactive minerals within Earth. Their continuing release of energy had led to Kelvin’s gross underestimate. The age of Earth is now calculated at around 4.6 billion years. This figure is based on the age-dating of meteorites.

The plate tectonic revolution

There has been a fundamental renaissance in geology since the 1960s, largely as a result of the development of the theory of plate tectonics (see [PLATE TECTONICS](#)). This theory has helped resolve many of the outstanding problems in the understanding of Earth processes and structures. This theory spans many aspects of geology, for example, the study of Earth history (stratigraphy), fossils and their distribution in space and time (paleontology), the formation of folds and faults (structural geology), the processes of sedimentation (sedimentology), and the processes changing the shape and appearance of Earth’s surface (geomorphology).

A CLOSER LOOK

RADIOACTIVE DATING OF ROCKS

The age of formation of minerals can be calculated from the known decay rates of daughter isotopes of radioactive elements (see [RADIOACTIVITY](#)). This technique has transformed many aspects of geology, as it has provided an independent method for dating rocks and calculating a so-called absolute age of their formation. This method can mostly be used in crystalline igneous and metamorphic rocks containing some radioactive elements, and it has been successfully related to the stratigraphic record. With the use of radioactive dating, it has become possible to add ages in years to phases in Earth history, such as the Silurian period (from 408 to about 438 million years ago), which

otherwise would have only a relative age (that is, post-Ordovician and pre-Devonian). In addition, the timing of major events in the evolution of life, such as the appearance of the first algal mats (3.5 billion years ago), can now be estimated.

Geology subsciences

Today, the vast subject area of geology is linked to many other science subjects, from astronomy to biology and geography, and includes many subsciences. Astrogeology places the early evolution of Earth in the context of the evolution of the solar system. The growing observation of the geological structure and surface processes of the planets that have been reached by space probes increases understanding more about the formation of Earth.

Geophysicists measure the behavior of Earth materials under particular conditions, such as earthquakes (see [GEOPHYSICS](#)). Interpretation of the data has produced enormous breakthroughs in the understanding of the fundamental features of Earth, including its internal structure. This data also gives useful clues about the structure of rocks in Earth's crust, information that is especially important for the subsurface mapping of structures that may contain oil and gas (see [OIL](#)).

Measurement of Earth's magnetic field and the magnetism (see [MAGNETIC POLES](#)) sealed in the rock record has provided critical evidence for the displacement of crustal plates and growth of the ocean floor. Geochemistry looks at the distribution of chemical elements in all their forms within Earth and how it relates to the origin and formation of Earth (see [GEOCHEMISTRY](#)). Geochemistry is used in mineral exploration and the dating of rocks. Chemical analysis of soils and groundwater can indicate the otherwise hidden presence of ore deposits. For example, one of the largest lead-zinc and silver deposits in Europe was found in Navan, Ireland, from a geochemical survey.

Petrology and mineralogy allow the identification of minerals and rocks from observation of their components and properties: cleavage, hardness, color, and luster, for example. Relatively simple methods of field observation, such as studying rocks and soils in rock outcrops or road cuts, can lead to the identification of most of the important individual minerals and rocks in Earth's crust. More sophisticated laboratory techniques, especially X-ray diffraction (see [X RAYS](#)), have been developed and used since the the 20th century to identify the atomic structure of minerals and analyze the physical and chemical relationships between different minerals and examine the way they combine to form rocks. From this data scientists have obtained a much better understanding of the internal workings of Earth and of the production of different kinds of igneous rocks, such as granite and ultrabasic olivenite (see [IGNEOUS ROCKS](#)), and metamorphic rocks, such as marble and schist (see [METAMORPHIC ROCKS](#)).

Sedimentology is the part of geology that involves the study of all aspects of sediments and the rocks made from them. It includes the study of all processes that occur, from erosion to transportation, deposition, and diagenesis (changes to sediments after deposition and before they are converted to metamorphic rocks). From this data geologists can understand more about the complexities and importance of lacustrine (lake), fluvial (river), windblown, and

oceanic processes and their interaction with the atmosphere, the biosphere, and the lithosphere (see [EARTH, STRUCTURE OF](#)).

One of the great recent oceanographic discoveries has been the role of midocean ridges in the formation of new ocean-floor crust. These ridges form a narrow belt of mountains below the ocean water, and scientists now know that lavas erupt from volcanoes and fissures along the crests of the ridges and form new ocean crust. The study of such eruptions, whether on land or under the sea, falls within that branch of science known as volcanology (see [VOLCANOES](#)). Volcanoes represent a major natural hazard for life on Earth, and an understanding of their eruption mechanisms is vital. Volcanologists aim to predict the timing and nature of eruptions. The study of volcanoes is itself an extremely hazardous occupation, and a number of volcanologists have been killed in the course of their research.

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See also: [CAMBRIAN PERIOD](#); [FOSSIL RECORD](#); [GEOCHEMISTRY](#); [GEOLOGIC TIMESCALE](#); [GEOPHYSICS](#); [ICE AGES](#); [IGNEOUS ROCKS](#); [MAGNETIC POLES](#); [MAPS AND MAPPING](#); [METAMORPHIC ROCKS](#); [MINERALS AND MINERALOGY](#); [OIL](#); [ORES](#); [PALEONTOLOGY](#); [RADIOACTIVITY](#); [ROCKS](#); [SEDIMENTARY ROCKS](#); [SILURIAN PERIOD](#); [SURVEYING](#); [U.S. GEOLOGICAL SURVEY](#); [VOLCANOES](#); [X RAYS](#).

Further reading:

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