Geology

**Geology** (from the Greek γῆ, gê, "earth" and λόγος, logos, "study") is the science and study of the solid Earth and the processes by which it is shaped and changed. Geology provides primary evidence for plate tectonics, the history of life and evolution, and past climates. In modern times, geology is commercially important for mineral and hydrocarbon exploration, is publically important for predicting and understanding natural hazards, plays an essential role in geotechnical engineering, and is a major academic discipline.

History

The study of the physical material of the Earth dates back at least to ancient Greece when Theophrastus (372-287 BC) wrote the work *Peri Lithon (On Stones)*. In the Roman period, Pliny the Elder wrote in detail of the many minerals and metals then in practical use, and correctly noted the origin of amber.

Some modern scholars, such as Fielding H. Garrison, are of the opinion that modern geology began in the medieval Islamic world.[2] Abu al-Rayhan al-Biruni (973–1048 AD) was one of the earliest Muslim geologists, whose works included the earliest writings on the geology of India, hypothesizing that the Indian subcontinent was once a sea.[3] Islamic Scholar Ibn Sina (Avicenna, 981–1037) proposed detailed explanations for the formation of mountains, the origin of earthquakes, and other topics central to modern Geology, which provided an essential foundation for the later development of the science.[4] In China, the polymath Shen Kua (1031–1095) formulated a hypothesis for the process of land formation: based on his observation of fossil animal shells in a geological stratum in a mountain hundreds of miles from the ocean, he inferred that the land was formed by erosion of the mountains and by deposition of silt.

Nicolas Steno (1638–1686) is credited with the law of superposition, the principle of original horizontality, and the principle of lateral continuity: three defining principles of stratigraphy. The word *geology* was first used by Jean-André Deluc in 1778 and introduced as a fixed term by Horace-Bénédict de Saussure in 1779. The word is derived from the Greek γῆ, gê, meaning "earth" and λόγος, logos, meaning "speech".[5]

William Smith (1769–1839) drew some of the first geological maps and began the process of ordering rock strata (layers) by examining the fossils contained in them.[1]

James Hutton is often viewed as the first modern geologist.[6] In 1785 he presented a paper entitled *Theory of the Earth* to the Royal Society of Edinburgh. In his paper, he explained his theory that the Earth must be much older.
than had previously been supposed in order to allow enough time for mountains to be eroded and for sediments to form new rocks at the bottom of the sea, which in turn were raised up to become dry land. Hutton published a two-volume version of his ideas in 1795 (Vol. 1 [7], Vol. 2 [8]).

Followers of Hutton were known as Plutonists because they believed that some rocks were formed by vulcanism which is the deposition of lava from volcanoes, as opposed to the Neptunists, who believed that all rocks had settled out of a large ocean whose level gradually dropped over time.

Sir Charles Lyell first published his famous book, Principles of Geology, [9] in 1830. The book, which influenced the thought of Charles Darwin, successfully promoted the doctrine of uniformitarianism. This theory states that slow geological processes have occurred throughout the Earth's history and are still occurring today. In contrast, catastrophism is the theory that Earth's features formed in single, catastrophic events and remained unchanged thereafter. Though Hutton believed in uniformitarianism, the idea was not widely accepted at the time.

Much of 19th-century geology revolved around the question of the Earth's exact age. Estimates varied from a few 100,000 to billions of years. [10] By the early 20th century, radiometric dating allowed the Earth's age to be estimated at two billion years. The awareness of this vast amount of time opened the door to new theories about the processes that shaped the planet.

The most significant advances in 20th century geology have been the development of the theory of plate tectonics in the 1960s, and the refinement of estimates of the planet's age. Plate tectonic theory arose out of two separate geological observations: seafloor spreading and continental drift. The theory revolutionized the Earth sciences. Today the Earth is known to be approximately 4.5 billion years old. [11]

**Geologic time**

The geologic time scale encompasses the history of the Earth. [12] It is bracketed at the old end by the dates of the earliest solar system material at 4.567 Ga, [13] (gigaannum: billion years ago) and the age of the Earth at 4.54 Ga [14] [15] at the beginning of the informally recognized Hadean eon. At the young end of the scale, it is bracketed by the present day in the Holocene epoch.

**Important milestones**

- 4.54 Ga: Accretion of Earth [14] [15]
- c. 4 Ga: End of Late Heavy Bombardment, first life
- c. 3.5 Ga: Start of photosynthesis
- c. 2.3 Ga: Oxygenated atmosphere, first snowball Earth
- 730–635 Ma (megaannum: million years ago): two snowball Earths
- 542± 0.3 Ma: Cambrian explosion – vast multiplication of hard-bodied life; first abundant fossils; start of the Paleozoic
- c. 380 Ma: First vertebrate land animals
- 250 Ma: Permian-Triassic extinction – 90% of all land animals die. End of Paleozoic and beginning of Mesozoic
- 65 Ma: Cretaceous-Tertiary extinction – Dinosaurs die; end of Mesozoic and beginning of Cenozoic
- c. 7 Ma – Present: Hominins
  - c. 7 Ma: First hominins appear
  - 3.9 Ma: First Australopithecus, direct ancestor to modern Homo sapiens, appear
  - 200 ka (kiloannum: thousand years ago): First modern Homo sapiens appear in East Africa

**Brief time scale**

The second and third timelines are each subsections of their preceding timeline as indicated by asterisks. The Holocene (the latest epoch) is too small to be shown clearly on this timeline.

**Relative and absolute dating**

Geological events can be given a precise date at a point in time, or they can be related to other events that came before and after them. Geologists use a variety of methods to give both relative and absolute dates to geological events. They then use these dates to find the rates at which processes occur.

**Relative dating**

Methods for relative dating were developed when geology first emerged as a formal science. Geologists still use the following principles today as a means to provide information about geologic history and the timing of geologic events.

- **The principle of intrusive relationships** concerns crosscutting intrusions. In geology, when an igneous intrusion cuts across a formation of sedimentary rock, it can be determined that the igneous intrusion is younger than the sedimentary rock. There are a number of different types of intrusions, including stocks, laccoliths, batholiths, sills and dikes.

**The principle of cross-cutting relationships** pertains to the formation of faults and the age of the sequences through which they cut. Faults are younger than the rocks they cut; accordingly, if a fault is found that penetrates...
some formations but not those on top of it, then the formations that were cut are older than the fault, and the ones that are not cut must be younger than the fault. Finding the key bed in these situations may help determine whether the fault is a normal fault or a thrust fault.\[16\]

**The principle of inclusions and components** states that, with sedimentary rocks, if inclusions (or clasts) are found in a formation, then the inclusions must be older than the formation that contains them. For example, in sedimentary rocks, it is common for gravel from an older formation to be ripped up and included in a newer layer. A similar situation with igneous rocks occurs when xenoliths are found. These foreign bodies are picked up as magma or lava flows, and are incorporated, later to cool in the matrix. As a result, xenoliths are older than the rock which contains them.

**The principle of uniformitarianism** states that the geologic processes observed in operation that modify the Earth's crust at present have worked in much the same way over geologic time.\[17\] A fundamental principle of geology advanced by the 18th century Scottish physician and geologist James Hutton, is that "the present is the key to the past." In Hutton's words: "the past history of our globe must be explained by what can be seen to be happening now."

**The principle of original horizontality** states that the deposition of sediments occurs as essentially horizontal beds. Observation of modern marine and non-marine sediments in a wide variety of environments supports this generalization (although cross-bedding is inclined, the overall orientation of cross-bedded units is horizontal).\[16\]

**The principle of superposition** states that a sedimentary rock layer in a tectonically undisturbed sequence is younger than the one beneath it and older than the one above it. Logically a younger layer cannot slip beneath a layer previously deposited. This principle allows sedimentary layers to be viewed as a form of vertical time line, a partial or complete record of the time elapsed from deposition of the lowest layer to deposition of the highest bed.\[16\]

**The principle of faunal succession** is based on the appearance of fossils in sedimentary rocks. As organisms exist at the same time period throughout the world, their presence or (sometimes) absence may be used to provide a relative age of the formations in which they are found. Based on principles laid out by William Smith almost a hundred years before the publication of Charles Darwin's theory of evolution, the principles of succession were developed independently of evolutionary thought. The principle becomes quite complex, however, given the uncertainties of fossilization, the localization of fossil types due to lateral changes in habitat (facies change in sedimentary strata), and that not all fossils may be found globally at the same time.\[18\]

**Absolute dating**

Geologists can also give precise absolute dates to geologic events. These dates are useful on their own, and can also be used in conjunction with relative dating methods or to calibrate relative dating methods.\[19\]
A large advance in geology in the advent of the 20th century was the ability to give precise absolute dates to geologic events through radioactive isotopes and other methods. The advent of radiometric dating changed the understanding of geologic time. Before, geologists could only use fossils to date sections of rock relative to one another. With isotopic dates, absolute dating became possible, and these absolute dates could be applied fossil sequences in which there was datable material, converting the old relative ages into new absolute ages.

For many geologic applications, isotope ratios are measured in minerals that give the amount of time that has passed since a rock passed through its particular closure temperature, the point at which different radiometric isotopes stop diffusing into and out of the crystal lattice.[20] [21] These are used in geochronologic and thermochronologic studies. Common methods include uranium-lead dating, potassium-argon dating and argon-argon dating, and uranium-thorium dating. These methods are used for a variety of applications. Dating of lavas and ash layers can help to date stratigraphy and calibrate relative dating techniques. These methods can also be used to determine ages of pluton emplacement. Thermochemical techniques can be used to determine temperature profiles within the crust, the uplift of mountain ranges, and paleotopography.

Fractionation of the lanthanide series elements is used to compute ages since rocks were removed from the mantle. Other methods are used for more recent events. Optically stimulated luminescence and cosmogenic radionucleide dating are used to date surfaces and/or erosion rates. Dendrochronology can also be used for the dating of landscapes. Radiocarbon dating is used for young organic material.

**Geologic materials**

The majority of geological data come from research on solid Earth materials. These typically fall into one of two categories: rock and unconsolidated material.

**Rock**

There are three major types of rock: igneous, sedimentary, and metamorphic. The rock cycle is an important concept in geology which illustrates the relationships between these three types of rock, and magma. When a rock crystallizes from melt (magma and/or lava), it is an igneous rock. This rock can be weathered and eroded, and then redeposited and lithified into a sedimentary rock, or be turned into a metamorphic rock due to heat and pressure that change the mineral content of the rock and give it a characteristic fabric. The sedimentary rock can then be subsequently turned into a metamorphic rock due to heat and pressure, and the metamorphic rock can be weathered, eroded, deposited, and lithified, becoming a sedimentary rock. Sedimentary rock may also be re-eroded and redeposited, and metamorphic rock may also undergo additional metamorphism. All three
types of rocks may be re-melted; when this happens, a new magma is formed, from which an igneous rock may once again crystallize.

The majority of research in geology is associated with the study of rock, as rock provides the primary record of the majority of the geologic history of the Earth.

Unconsolidated material

Geologists also study un lithified material, which typically comes from more recent deposits. Because of this, the study of such material is often known as Quaternary geology, after the recent Quaternary Period. This includes the study of sediment and soils, and is important to some (or many) studies in geomorphology, sedimentology, and paleoclimatology.

Whole-Earth structure

Plate tectonics

In the 1960s, a series of discoveries, the most important of which was seafloor spreading,\cite{22} \cite{23} showed that the Earth's lithosphere, which includes the crust and rigid uppermost portion of the upper mantle, is separated into a number of tectonic plates that move across the plastically deforming, solid, upper mantle, which is called the asthenosphere. There is an intimate coupling between the movement of the plates on the surface and the convection of the mantle: oceanic plate motions and mantle convection currents always move in the same direction, because the oceanic lithosphere is the rigid upper thermal boundary layer of the convecting mantle. This coupling between rigid plates moving on the surface of the Earth and the convecting mantle is called plate tectonics.

The development of plate tectonics provided a physical basis for many observations of the solid Earth. Long linear regions of geologic features could be explained as plate boundaries.\cite{24} Mid-ocean ridges, high regions on the seafloor where hydrothermal vents and volcanoes exist, were explained as divergent boundaries, where two plates move apart. Arcs of volcanoes and earthquakes were explained as convergent boundaries, where one plate subducts under another. Transform boundaries, such as the San Andreas fault system, resulted in widespread powerful earthquakes. Plate tectonics also provided a mechanism for Alfred Wegener's theory of continental drift,\cite{25} in which the continents move across the surface of the Earth over geologic time. They also provided a driving force for crustal deformation, and a new setting for the observations of
structural geology. The power of the theory of plate tectonics lies in its ability to combine all of these observations into a single theory of how the lithosphere moves over the convecting mantle.

**Earth structure**

Advances in seismology, computer modeling, and mineralogy and crystallography at high temperatures and pressures give insights into the internal composition and structure of the Earth.

Seismologists can use the arrival times of seismic waves in reverse to image the interior of the Earth. Early advances in this field showed the existence of a liquid outer core (where shear waves were not able to propagate) and a dense solid inner core. These advances led to the development of a layered model of the Earth, with a crust and lithosphere on top, the mantle below (separated within itself by seismic discontinuities at 410 and 660 kilometers), and the outer core and inner core below that. More recently, seismologists have been able to create detailed images of wave speeds inside the earth in the same way a doctor images a body in a CT scan. These images have led to a much more detailed view of the interior of the Earth, and have replaced the simplified layered model with a much more dynamic model.

Mineralogists have been able to use the pressure and temperature data from the seismic and modelling studies alongside knowledge of the elemental composition of the Earth at depth to reproduce these conditions in experimental settings and measure changes in crystal structure. These studies explain the chemical changes associated with the major seismic discontinuities in the mantle, and show the crystallographic structures expected in the inner core of the Earth.
**Geological evolution of an area**

The geology of an area evolves through time as rock units are deposited and inserted and deformational processes change their shapes and locations.

Rock units are first emplaced either by deposition onto the surface or intrusion into the overlying rock. Deposition can occur when sediments settle onto the surface of the Earth and later lithify into sedimentary rock, or when as volcanic material such as volcanic ash or lava flows blanket the surface. Igneous intrusions such as batholiths, laccoliths, dikes, and sills, push upwards into the overlying rock, and crystallize as they intrude.

After the initial sequence of rocks has been deposited, the rock units can be deformed and/or metamorphosed. Deformation typically occurs as a result of horizontal shortening, horizontal extension, or side-to-side (strike-slip) motion. These structural regimes broadly relate to convergent boundaries, divergent boundaries, and transform boundaries, respectively, between tectonic plates.

When rock units are placed under horizontal compression, they shorten and become thicker. Because rock units, other than muds, do not significantly change in volume, this is accomplished in two primary ways: through faulting and folding. In the shallow crust, where brittle deformation can occur, thrust faults form, which cause deeper rock to move on top of shallower rock. Because deeper rock is often older, as noted by the principle of superposition, this can result in older rocks moving on top of younger ones. Movement along faults can result in folding, either because the faults are not planar, or because the rock layers are dragged along, forming drag folds, as slip occurs are along the fault. Deeper in the...
An illustration of the three types of faults. Strike-slip faults occur when rock units slide past one another, normal faults occur when rocks are undergoing horizontal extension, and thrust faults occur when rocks are undergoing horizontal shortening.

Even higher pressures and temperatures during horizontal shortening can cause both folding and metamorphism of the rocks. This metamorphism causes changes in the mineral composition of the rocks; creates a foliation, or planar surface, that is related to mineral growth under stress; and can remove signs of the original textures of the rocks, such as bedding in sedimentary rocks, flow features of lavas, and crystal patterns in crystalline rocks.

Extension causes the rock units as a whole to become longer and thinner. This is primarily accomplished through normal faulting and through the ductile stretching and thinning. Normal faults drop rock units that are higher below those that are lower. This typically results in younger units being placed below older units. Stretching of units can result in their thinning; in fact, there is a location within the Maria Fold and Thrust Belt in which the entire sedimentary sequence of the Grand Canyon can be seen over a length of less than a meter. Rocks at the depth to be ductilely stretched are often also metamorphosed. These stretched rocks can also pinch into lenses, known as boudins, after the French word for "sausage", because of their visual similarity.
Where rock units slide past one another, strike-slip faults develop in shallow regions, and become shear zones at deeper depths where the rocks deform ductilely.

The addition of new rock units, both depositionally and intrusively, often occurs during deformation. Faulting and other deformational processes result in the creation of topographic gradients, causing material on the rock unit that is increasing in elevation to be eroded by hillslopes and channels. These sediments are deposited on the rock unit that is going down. Continual motion along the fault maintains the topographic gradient in spite of the movement of sediment, and continues to create accommodation space for the material to deposit. Deformational events are often also associated with volcanism and igneous activity. Volcanic ashes and lavas accumulate on the surface, and igneous intrusions enter from below. Dikes, long, planar igneous intrusions, enter along cracks, and therefore often form in large numbers in areas that are being actively deformed. This can result in the emplacement of dike swarms, such as those that are observable across the Canadian shield, or rings of dikes around the lava tube of a volcano.

All of these processes do not necessarily occur in a single environment, and do not necessarily occur in a single order. The Hawaiian Islands, for example, consist almost entirely of layered basaltic lava flows. The sedimentary sequences of the mid-continental United States and the Grand Canyon in the southwestern United States contain almost-undeformed stacks of sedimentary rocks that have remained in place since Cambrian time. Other areas are much more geologically complex. In the southwestern United States, sedimentary, volcanic, and intrusive rocks have been metamorphosed, faulted, foliated, and folded. Even older rocks, such as the Acasta gneiss of the Slave craton in northwestern Canada, the oldest known rock in the world have been metamorphosed to the point where their origin is undiscernable without laboratory analysis. In addition, these processes can occur in stages. In many places, the Grand Canyon in the southwestern United States being a very visible example, the lower rock units were metamorphosed and deformed, and then deformation ended and the upper, undeformed units were deposited. Although any amount of rock emplacement and rock deformation can occur, and they can occur any number of times, these concepts provide a guide to understanding the geological history of an area.

**Methods of geology**

Geologists use a number of field, laboratory, and numerical modeling methods to decipher Earth history and understand the processes that occur on and in the Earth. In typical geological investigations, geologists use primary information related to petrology (the study of rocks), stratigraphy (the study of sedimentary layers), and structural geology (the study of positions of rock units and their deformation). In many cases, geologists also study modern soils, rivers, landscapes, and glaciers; investigate past and current life and biogeochemical pathways, and use geophysical methods to investigate the subsurface.
Field methods

Geological field work varies depending on the task at hand. Typical fieldwork could consist of:

- **Geological mapping**[^26]
  - Structural mapping: the locations of the major rock units and the faults and folds that led to their placement there.
  - Stratigraphic mapping: the locations of sedimentary facies (lithofacies and biofacies) or the mapping of isopachs of equal thickness of sedimentary rock.
  - Surficial mapping: the locations of soils and surficial deposits.
- **Surveying of topographic features**
  - Creation of topographic maps[^27]
  - Work to understand change across landscapes, including:
    - Patterns of erosion and deposition
    - River channel change through migration and avulsion
    - Hillslope processes
- **Subsurface mapping through geophysical methods**[^28]
  - These methods include:
    - Shallow seismic surveys
    - Ground-penetrating radar
    - Electrical resistivity tomography
  - They are used for:
    - Hydrocarbon exploration
    - Finding groundwater
    - Locating buried archaeological artifacts
- **High-resolution stratigraphy**
  - Measuring and describing stratigraphic sections on the surface
  - Well drilling and logging
- **Biogeochemistry and geomicrobiology**[^29]
  - Collecting samples to:
    - Determine biochemical pathways
    - Identify new species of organisms. These organisms may help to show:
      - Identify new chemical compounds
    - And to use these discoveries to:
      - Understand early life on Earth and how it functioned and metabolized
      - Find important compounds for use in pharmaceuticals.
  - **Paleontology:** excavation of fossil material
    - For research into past life and evolution
    - For museums and education
- **Collection of samples for geochronology and thermochronology**[^30]
- **Glaciology:** measurement of characteristics of glaciers and their motion[^31]
Laboratory methods

Petrology

In addition to the field identification of rocks, petrologists identify rock samples in the laboratory. Two of the primary methods for identifying rocks in the laboratory are through optical microscopy and by using an electron microprobe. In an optical mineralogy analysis, thin sections of rock samples are analyzed through a petrographic microscope, where the minerals can be identified through their different properties in plane-polarized and cross-polarized light, including their birefringence, pleochroism, twinning, and interference properties with a conoscopic lens. In the electron microprobe, individual locations are analyzed for their exact chemical compositions and variation in composition within individual crystals. Stable and radioactive isotope studies provide insight into the geochemical evolution of rock units.

Petrologists use fluid inclusion data and perform high temperature and pressure physical experiments to understand the temperatures and pressures at which different mineral phases appear, and how they change through igneous and metamorphic processes. This research can be extrapolated to the field to understand metamorphic processes and the conditions of crystallization of igneous rocks. This work can also help to explain processes that occur within the Earth, such as subduction and magma chamber evolution.

Structural geology

Structural geologists use microscopic analysis of oriented thin sections of geologic samples to observe the fabric within the rocks which gives information about strain within the crystal structure of the rocks. They also plot and combine measurements of geological structures in order to better understand the orientations of faults and folds in order to reconstruct the history of rock deformation in the area. In addition, they perform analog and numerical experiments of rock deformation in large and small settings.

The analysis of structures is often accomplished by plotting the orientations various features onto stereonets. A stereonet is a stereographic projection of a sphere onto a plane, in which planes are projected as lines and lines are projected as points. These can be used to find the locations of fold axes, relationships between several faults, and relationships between other geologic structures.

Among the most well-known experiments in structural geology are those involving orogenic wedges, which are zones in which mountains are built along convergent tectonic plate boundaries. In the analog versions of these
experiments, horizontal layers of sand are pulled along a lower surface into a back stop, which results in realistic-looking patterns of faulting and the growth of a critically tapered (all angles remain the same) orogenic wedge.[41] Numerical models work in the same way as these analog models, though they are often more sophisticated and can include patterns of erosion and uplift in the mountain belt. [42] This helps to show the relationship between erosion and the shape of the mountain range. These studies can also give useful information about pathways for metamorphism through pressure, temperature, space, and time.[43]

**Stratigraphy**

In the laboratory, stratigraphers analyze samples of stratigraphic sections that can be returned from the field, such as those from drill cores.[44] Stratigraphers also analyze data from geophysical surveys that show the locations of stratigraphic units in the subsurface.[45] Geophysical data and well logs can be combined to produce a better view of the subsurface, and stratigraphers often use computer programs to do this in three dimensions.[46] Stratigraphers can then use these data to reconstruct ancient processes occurring on the surface of the Earth,[47] interpret past environments, and locate areas for water, coal, and hydrocarbon extraction.

In the laboratory, biostratigraphers analyze rock samples from outcrop and drill cores for the fossils found in them.[44] These fossils help scientists to date the core and to understand the depositional environment in which the rock units formed. Geochronologists precisely date rocks within the stratigraphic section in order to provide better absolute bounds on the timing and rates of deposition.[48] Magnetic stratigraphers look for signs of magnetic reversals in igneous rock units within the drill cores.[44] Other scientists perform stable isotope studies on the rocks to gain information about past climate.[44]

**Planetary geology**

With the advent of space exploration in the twentieth century, geologists have begun to look at other planetary bodies in the same way as the Earth. This led to the establishment of the field of planetary geology, sometimes known as Astrogeology, in which geologic principles are applied to other bodies of the solar system.

Although the Greek-language-origin prefix geo refers to Earth, "geology" is often used in conjunction with the names of other planetary bodies when describing their composition and internal processes: examples are "the geology of Mars" and "Lunar geology". Specialised terms such as selenology (studies of the Moon), areology (of Mars), etc., are also in use.

Although planetary geologists are interested in all aspects of the planets, a significant focus is in the search for past or present life on other worlds. This has led to many missions whose purpose (or one of their purposes) is to examine planetary bodies for evidence of life. One of these is the Phoenix lander, which analyzed Martian polar soil for water and chemical and mineralogical constituents related to biological processes.
Applied geology

Economic geology
Economic geologists help locate and manage the Earth's natural resources, such as petroleum and coal, as well as mineral resources, which include metals such as iron, copper, and uranium.

Mining geology
Mining geology consists of the extractions of mineral resources from the Earth. Some resources of economic interests include gemstones, metals, and many minerals such as asbestos, perlite, mica, phosphates, zeolites, clay, pumice, quartz, and silica, as well as elements such as sulfur, chlorine, and helium.

Petroleum geology
Petroleum geologists study locations of the subsurface of the Earth which can contain extractable hydrocarbons, especially petroleum and natural gas. Because many of these reservoirs are found in sedimentary basins, they study the formation of these basins, as well as their sedimentary and tectonic evolution and the present-day positions of the rock units.

Engineering geology
Engineering geology is the application of the geologic principles to engineering practice for the purpose of assuring that the geologic factors affecting the location, design, construction, operation and maintenance of engineering works are properly addressed.

In the field of civil engineering, geological principles and analyses are used in order to ascertain the mechanical principles of the material on which structures are built. This allows tunnels to be built without collapsing, bridges and skyscrapers to be built with sturdy foundations, and buildings to be built that will not settle in clay and mud.

Hydrology and environmental issues
Geology and geologic principles can be applied to various environmental problems, such as stream restoration, the restoration of brownfields, and the understanding of the interactions between natural habitat and the geologic environment. Groundwater hydrology, or hydrogeology, is used to locate groundwater, which can often provide a ready supply of uncontaminated water and is especially important in arid regions, and to monitor the spread of contaminants in groundwater wells.

Geologists also obtain data through stratigraphy, boreholes, core samples, and ice cores. Ice cores and sediment core are used to for paleoclimate reconstructions, which tell geologists about past and present temperature, precipitation, and sea level across the globe. These data are our primary source of information on global climate change outside of instrumental data.
Natural hazards

Geologists and geophysicists study natural hazards in order to enact safe building codes and warning systems that are used to prevent loss of property and life.[57] Examples of important natural hazards that are pertinent to geology (as opposed those that are mainly or only pertinent to meteorology) are:

- Avalanches
- Earthquakes
- Floods
- Landslides and debris flows
- River channel migration and avulsion
- Liquefaction
- Sinkholes
- Subsidence
- Tsunamis
- Volcanoes

Fields or related disciplines

- Earth science
- Economic geology
  - Mining geology
  - Petroleum geology
- Engineering geology
- Environmental geology
- Geoarchaeology
- Geochemistry
  - Biogeochemistry
  - Isotope geochemistry
- Geochronology
- Geodetics
- Geography
- Geological modelling
- Geometallurgy
- Geomicrobiology
- Geomorphology
- Geomythology
- Geophysics
- Glaciology
- Historical geology
- Hydrogeology
- Meteorology
- Mineralogy
- Oceanography
  - Marine geology
- Paleoclimatology
- Paleontology
  - Micropaleontology
• Palynology
• Petrology
• Petrophysics
• Plate tectonics
• Sedimentology
• Seismology
• Soil science
  • Pedology (soil study)
• Speleology
• Stratigraphy
  • Biostratigraphy
  • Chronostratigraphy
  • Lithostratigraphy
• Structural geology
• Volcanology

Regional geology

By mountain range
• Geology of the Alps
• Geology of the Andes
• Geology of the Appalachians
• Geology of the Himalaya
• Geology of the Rocky Mountains

By nations
• Geology of Australia
  • Geology of the Australian Capital Territory
  • Geology of Tasmania
  • Geology of Victoria
  • Geology of the Yilgarn Craton
• Geology of China
• Geology of Hong Kong
• Geology of Europe
  • Geology of Iberia
  • Geology of the Netherlands
  • Geology of Norway
  • Geology of Sweden
    • Geology of Gotland
• Geology of the United Kingdom
  • Geology of England
    • Geology of Cheshire
    • Geology of Cornwall
    • Geology of Lizard, Cornwall
  • Geology of Dorset
- Geology of Gloucestershire
- Geology of Hampshire
- Geology of East Sussex
- Geology of Hertfordshire
- Geology of Shropshire
- Geology of Somerset
- Geology of Yorkshire
- Geology of Scotland
  - Geology of Orkney
- Geology of Wales
- Geology of Jersey
- Geology of Guernsey
- Geology of South America
  - Geology of Bolivia
  - Geology of Chile
  - Geology of Colombia
  - Geology of the Falkland Islands
- Geology of India
  - Geology of Sikkim
- Geology of Japan
- Geology of the Philippines
- Geology of New Zealand
- Geology of Vietnam
- Geology of the United States of America
  - US geology by state:
    - Geology of Alabama
    - Geology of Connecticut
    - Geology of Delaware
    - Geology of Georgia
    - Geology of Idaho
    - Geology of Illinois
    - Geology of Iowa
    - Geology of Kansas
    - Geology of Minnesota
    - Geology of New Jersey
    - Geology of Oklahoma
    - Geology of Pennsylvania
    - Geology of Tennessee
    - Geology of Texas
    - Geology of West Virginia
  - US Geology by region or feature:
    - Geology of the Appalachians
    - Geology of the Pacific Northwest
    - Geology of the Bryce Canyon area (Utah)
    - Geology of the Canyonlands area (Utah)
    - Geology of the Capitol Reef area (Utah)
• Geology of the Death Valley area (California)
• Geology of the Grand Canyon area (Arizona)
• Geology of the Grand Teton area (Wyoming)
• Geology of the Lassen area (California)
• Geology of Mount Adams (Washington)
• Geology of Mount Shasta (California)
• Geology of the Yosemite area (California)
• Geology of the Zion and Kolob canyons area (Utah)
• Glacial geology of the Genesee River (New York, Pennsylvania)

By planet
• Geology of Mars
• Geology of Mercury
• Geology of the Moon
• Geology of Venus

See also
• Agrogeology
• Digital geologic mapping
• Geologic modeling
• Glossary of geology terms
• International Union of Geological Sciences (IUGS)
• List of fossil sites (with link directory)
• List of geology topics
• List of Russian geologists
• List of important publications in geology
• List of minerals
• List of rock textures
• List of rock types
• List of Russian geologists
• List of soil topics
• Paleorrota
• Timeline of geology

Notes
[2] Fielding H. Garrison wrote in the History of Medicine:

"The Saracens themselves were the originators not only of algebra, chemistry, and geology, but of many of the so-called improvements or refinements of civilization, such as street lamps, window-panes, fireworks, stringed instruments, cultivated fruits, perfumes, spices, etc."

[57] USGS Natural Hazards Gateway (http://www.usgs.gov/hazards/)

External links

- GeologyForum.org (http://geologyforum.org) an online community for fans of everything Geologic!
- James Hutton's Theory of the Earth (http://records.viu.ca/~johnstoi/essays/Hutton.htm)
- Charles Lyell's Elements of Geology (http://books.google.com/books?id=AcKAAAAAIAAJ&printsec=frontcover&dq=Charles+Lyell&ei=YMOLSa_GE4uiyATW_Zy6BQ&client=firefox-a#PPR5,M1)
- Charles Lyell's Principles of Geology, or the Modern Changes of the Earth and its Inhabitants, Considered as Illustrative of Geology (http://books.google.com/books?id=O2YNAAAAYAAJ&printsec=frontcover&dq=Charles+Lyell&ei=YMOLSa_GE4uiyATW_Zy6BQ&client=firefox-a#PPR3,M1)
- American Geophysical Union (http://www.agu.org)
- European Geosciences Union (http://www.egu.eu/)
- Geological Society of America (http://www.geosociety.org)
- Earth Science News, Maps, Dictionary, Articles, Jobs (http://geology.com)
- Geological Society of London (http://www.geolsoc.org.uk)