

Eco-Link

Linking Social, Economic, and Ecological Issues

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By: Lacey McCray

Geology 101

What is it and how does it affect our daily lives?

Introduction

The processes that create physical geology determine the Earth's landscape, the distribution of metals, mineral and energy resources, and the types of plant and animal life within a given area. Geology determines the places that are prone to volcanoes, floods, and other natural disasters. The study of geology teaches us what Earth was like in the past, allows us to understand the present and predict future events. It also provides us with pertinent information and resources regarding fossil fuels, water, food, and the climate.

This *Eco-Link* explores the basics of geology and how it impacts communities and the lives of individuals. Linkages of geology to energy availability, climate, natural disasters, water resources, soils, natural resource availability, and even space exploration are considered.

Geology Basics

History of Earth and Life

Geology is defined as the study of the dynamic processes occurring on the planet's surface and in the interior.¹ Geology includes the study of Earth's history, plate tectonics, plant and animal evolution, climate, mineral exploration, water resources, natural hazards, and remediation of environmental problems. Geologists estimate the Earth to be 4.5 billion years old. Carbon dating and geologic records formed through fossilization indicate that life on earth started about 3.5 billion years ago.

¹ Miller, Tyler G., and Scott Spoolman. Environmental Science Problems, Concepts, and Solutions. 12th ed. California: Brooks/Cole Cengage Learning, 2008. Page 262

Earth's Composition

The Earth has three main layers (Figure 1). The first layer consists of continental and oceanic crust, and the uppermost solid mantle; this layer is called the *lithosphere*. The next layer of the Earth is called the *mantle* and consists of hot dense semi-solid rock. The inner layer is called the *core* and is made up of iron-nickel alloy, with a liquid layer in the most outer core and a solid inner core.²

Earth's Tectonic Plates and Their Movement

Earth's continents did not always look like they do today. The crust of the earth is composed of fifteen major tectonic plates.³ These plates are constantly moving, though slowly, and their movement can result in earthquakes, eruption of volcanoes, formation of mountains, and even movement of entire continents.⁴ Through time, the tectonic plates have moved and reformed landmasses. Figure 2 shows how continents have moved over millions of years reforming the Earth's surface.⁵

Plate tectonic movement has influenced life's evolution, physical geography, and climate change throughout the planet's history. It is also the underlying cause of earthquakes and volcanoes on continents and in the oceans. Such events can change the Earth's surface. For example, eruption of a volcano beneath the ocean surface can create a new landmass in the form of an island.

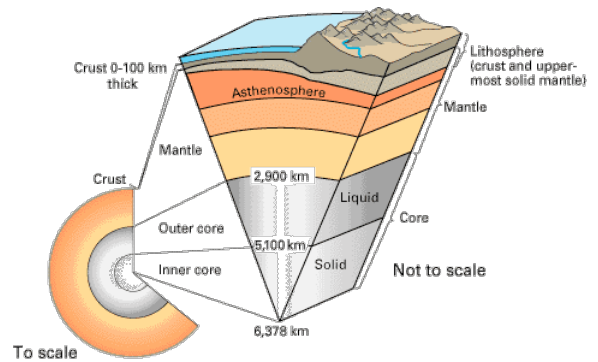


Figure 1: Layers of the Earth

Source: United States Geologic Survey

<http://pubs.usgs.gov/gip/dynamic/inside.html>

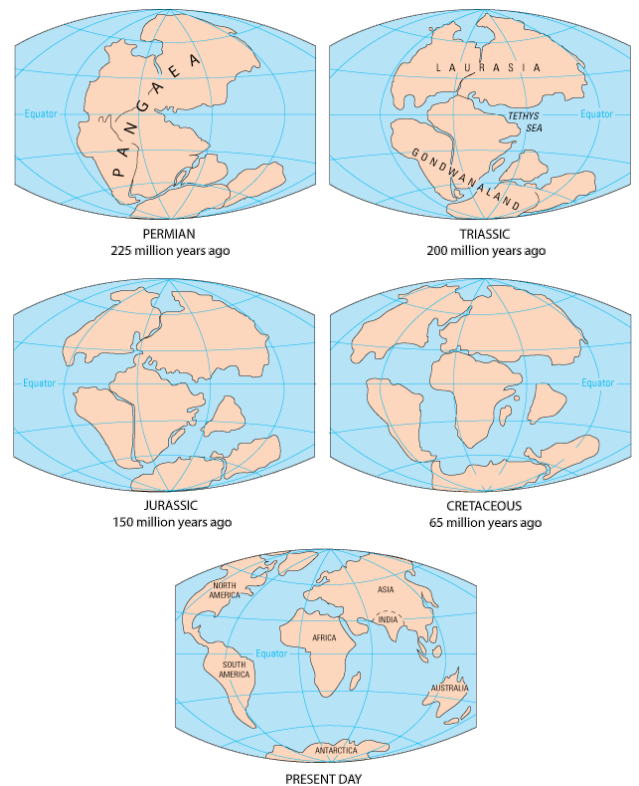


Figure 2: The Earth over 225 million years

Source: United States Geologic Survey

<http://pubs.usgs.gov/gip/dynamic/historical.html>

² Watson, J. Inside the Earth. 5 May 1999. United States Geologic Survey. 27 Oct. 2011
<<http://pubs.usgs.gov/gip/dynamic/inside/html>>.

³ Withgott, Jay, Scott Brennan. Environment: The Science Behind The Stories. 3rd ed. California: Pearson Benjamin Cummings, 2008. Page 200

⁴ "Plate Tectonics." Cambridge Dictionaries Online. 2011. Cambridge University Press. 21 Dec. 2011
<<http://dictionary.cambridge.org/dictionary/british/plate-tectonics>>.

⁵ Watson, J. Historical Perspective. 9 Sept. 2011. United States Geologic Survey. 27 Oct. 2011
<<http://pubs.usgs.gov/gip/dynamic/historical.html>>.

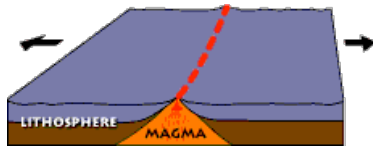


Figure 3: Divergent Plate Boundary



Figure 4: Transform Plate Boundary

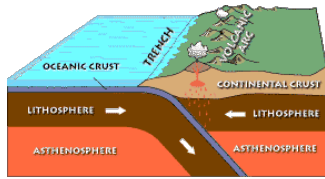


Figure 5.1: Convergent Plate Boundary
Oceanic Plate vs. Continental Plate

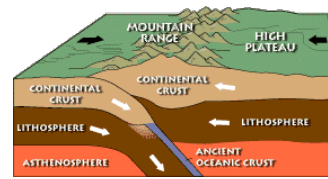


Figure 5.2: Convergent Plate Boundary
Continental Plate vs. Continental Plate

Source: Unites States Geologic Survey; *Understanding plate motions (This Dynamic Earth, USGS)*
<http://geomaps.wr.usgs.gov/parks/pltec/pltec3.html#divergent>

Plate tectonics can occur in different ways. Movement of two plates away from one another occurs along what is called a *divergent plate boundary*, wherein magma from the core of the Earth can rise to the surface and form a new crust as it cools and spreads (Figure 3). When plates are close together and move in opposite directions, they can slip or slide along one another. If this happens it creates a *transform plate boundary* (Figure 4). Friction created from movement of these plates can cause earthquakes. An example of this can be found in California where the Pacific North American Plates rub against one another along a plate boundary known as the San Andreas Fault. If tectonic plates collide, the point of contact is called a *convergent plate boundary*. Different things can occur when plates collide. When a continental plate collides with an oceanic plate, one plate may be pushed under the other creating a subduction zone. When this happens the plate that was subducted (or pushed downward) into the crust is heated, which can result in magma being sent to the Earth's surface (Figure 5.1). An example of this is Mount Saint Helens in Washington, where an eruption in 1980 dramatically changed the landscape. When a continental plate converges with another continental plate, material from both plates may lift, forming mountains, such as the Himalayas (Figure 5.2).

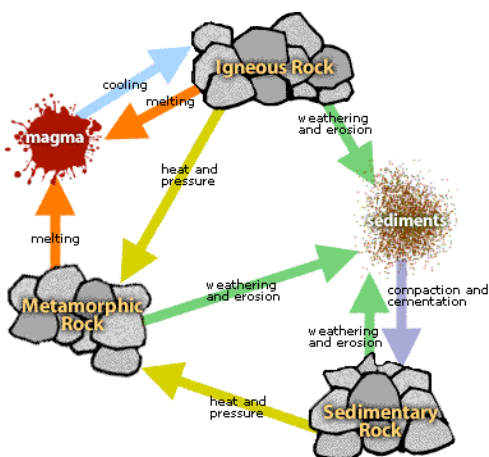


Figure 6: Simple Rock Cycle
 Source: Center for Educational Technologies
<http://www.cotf.edu/ete/modules/msese/earthshv>

Rocks and Minerals

The processes that create plate movement and affect the layers of the Earth form rocks and minerals. Through geology we are able to understand their composition and learn their origin. Rocks, and the minerals that compose them, change slowly over time through heating, melting, cooling, and sometimes breaking down. There are three different classifications of rocks (Figure 6). *Igneous* rocks are formed from extremely high temperatures that melt the material into a liquid state known as magma. When the magma cools a rock is formed; an example of this is basalt lava. *Sedimentary* rocks are created through lithification, which happens when sediments are compacted together and dissolved minerals bind the particles together. Common sedimentary rocks are sandstone and slate. Lastly there are *metamorphic* rocks. These rocks undergo high temperatures and great pressure that change their form. In this case

the heat that is exerted on the rock is not hot enough to melt it but the crystals that make up the rock itself are reshaped. This changes physical properties as well as appearance. An example of a metamorphic rock is marble.⁶

Geologists are able to study different rocks and minerals to determine what the climate was like in the past, the time and location of the existence of fossilized life forms, as well as other major earth forming events. For example, through discoveries of the same types of fossils on more than one continent, and analysis of sediment layers in rock formations, geologists have been able to learn how continents were formed.

Rocks can have a major influence on soil chemistry and can influence the ecosystem in a region. Soil is one of the most important natural resources we have and is vital for agriculture, grassland and forestry.⁷ Plants, forests, and grasses help protect soil from natural erosion processes. Important ways to protect soils are to practice farming techniques such as terracing crops, crop rotation, and the use of windbreaks or no-till practices. Soil protection is also important in forest management and other land management activities.

Natural Hazards

Geological influences and physical processes contribute to natural disasters such as earthquakes, volcanic eruptions, floods, landslides, and tsunamis. Though geological features may cause or contribute to natural disasters, it is through geology that we are better able to understand and predict outcomes of these events and determine high-risk locations. With monitoring stations all over the world, seismic geologists (or seismologists) and government organizations, such as the U.S. Geological Survey, are able to study tectonic plate movements and fault zones associated with earthquakes and other disasters. For instance, a geologist can use a geological fault map to help predict the most likely areas for earthquakes. They can also provide early warning when a volcano is likely to erupt. Geologists cannot stop natural disasters but they can help determine levels of risk and inform decision-making regarding the types of uses and activities for a given location.

Natural Resources and Energy

Mining and Hydraulic Fracturing

Mineral resources and energy are fundamental to modern day life. Extraction of mineral and energy resources involves the study of almost all parameters of geology, including mineralogy, plate tectonics, deformation processes, groundwater movement and sedimentary environments. Energy resources include oil, coal, natural gas, and nuclear fuels, as well as renewable energy such as solar, wind, hydro, geothermal, and biomass energy (Table 1). What are known as fossil fuels are most commonly used - oil, natural gas and coal.⁸ These resources were formed in the past, making them nonrenewable as we deplete their finite supply. Geologists searching for oil or other fossil fuels drill rock core samples and conduct air, ground and seismic surveys to create maps of underground rock formations. This provides an understanding of the geologic history of the area being studied and helps predict where the mining or drilling should occur.⁹ Geology is essential to the mining of many critical resources, including iron ore and taconite, copper, aluminum, lead, coal, gold, silver, uranium, zinc and phosphate.¹⁰

⁶ “Exploring the Environment.” *Earth Floor Cycle*. 28 April 2005. Center of Educational Technologies. 1 Nov. 2011 <<http://www.cotf.edu/ete/modules/msese/earthsysflr/rock.html>>.

⁷ Withgott, Jay, Scott Brennan. *Environment: The Science Behind The Stories*. 3rd ed. California: Pearson Benjamin Cummings, 2008.

⁸ Reynolds, Stephen J., et al. *Exploring Geology*. 2nd ed. New York: McGraw-Hill Companies, Inc., 2010.

⁹ Withgott, Jay, Scott Brennan. *Environment: The Science Behind The Stories*. 3rd ed. California: Pearson Benjamin Cummings, 2008. Page 552

¹⁰ Withgott, Jay, Scott Brennan. *Environment: The Science Behind The Stories*. 3rd ed. California: Pearson Benjamin Cummings, 2008. Table 19.1, page 543.

Table 1: Energy Sources Used in the United States

Energy source	Description	Type of energy
Crude oil	Fossil fuel extracted from ground (liquid)	Nonrenewable
Natural gas	Fossil fuel extracted from ground (gas)	Nonrenewable
Coal	Fossil fuel extracted from ground (solid)	Nonrenewable
Nuclear energy	Energy from atomic nuclei of uranium	Nonrenewable
Biomass energy	Energy stored in plant matter from photosynthesis	Renewable
Hydropower	Energy from running water	Renewable
Solar energy	Energy from sunlight directly	Renewable
Wind energy	Energy from wind	Renewable
Geothermal energy	Earth's internal heat rising from core	Renewable
Tidal and wave energy	Energy from tidal forces and ocean waves	Renewable

Source: *Environment The Science Behind The Stories*, Page 543

Mining can cause negative effects on the environment both during mining and well after it. Mining in an area can cause erosion following the removal of vegetation, and mining processes can result in acidic runoff and pollution of waterways. Some metals known to have negative effects on human health, including arsenic, lead, mercury and acids from mining are often found in runoff. Streams near old mines may also show higher amounts of aluminum, manganese, zinc, and barium. A recent study in the San Juan Mountains of Colorado found that rocks from mines dumped in or near streams have released chemicals to the water and soils, with some of these then absorbed by plant life. In addition to releases to water, mining, and smelting of metal ores are major causes of chemical oxidation processes that generate acid in the Earth's surface environment. The same is true of burning of coal to produce energy.

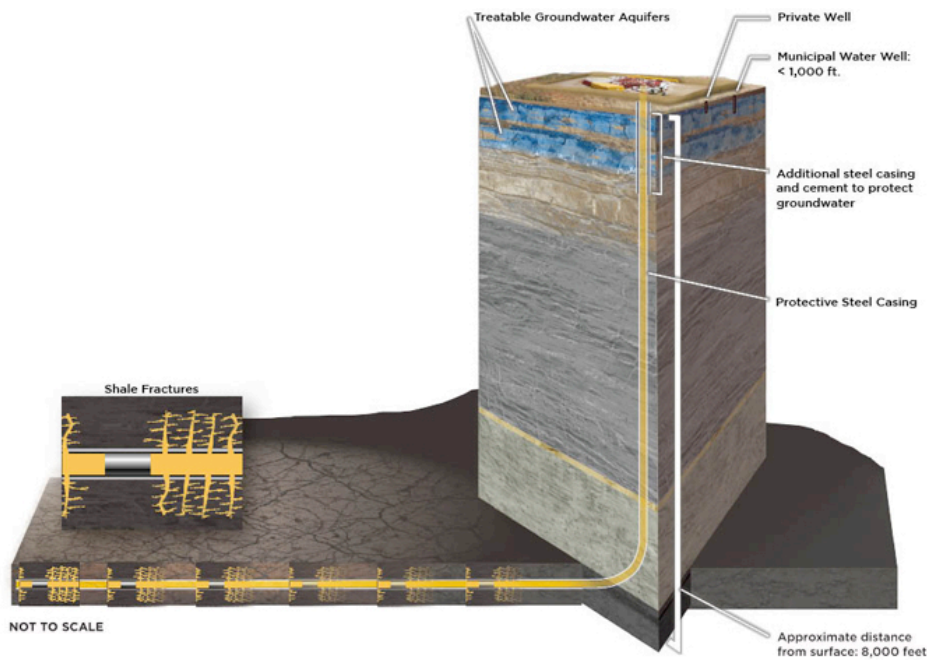


Figure 7: Hydraulic Fracturing

Source: Chesapeake Energy Corporation's

<http://www.hydraulicfracturing.com/Process/Pages/information.aspx>

Geologists are involved in the use of hydraulic fracturing (or fracking), a practice begun in the 1940s, as another way to recover natural gas and oil from rock formations deep underground (Figure 7). The objective of hydraulic fracturing is to maximize the extraction of oil, natural gas, and geothermal energy. Hydraulic fracturing occurs thousands of feet below the Earth's surface in shale rock beds. Fractures are created in an underground formation by pumping water, sand and various additives at high pressures. After the rock is fractured, sand is injected into resulting cracks to hold the rock open, allowing trapped natural gas and oil to flow. The natural gas and oil is then brought to the surface and collected.¹¹ Operators currently use fracking on as many as 35,000 wells each year. According to the Interstate Oil and Gas Compact Commission, 90% of oil and gas wells in the United States undergo fracturing to stimulate production.¹²

The U.S. Environmental Protection Agency (EPA) is evaluating the potential negative impacts of expanded fracturing, including potential risks to drinking water, public health and the environment around hydraulic fracturing areas. Potential problems arise when some of the fluids that are injected underground at high pressures to allow the oil and gas to flow more freely remain trapped underground. Twenty to 85% of fracturing fluids may remain in the formation and some of the chemicals used can be a source of groundwater contamination. In addition, the amount of water used for fracturing can be significant. For example, extraction of coal bed methane utilizes about 5,000 to 35,000 gallons of water per well, and 2 to 10 million gallons of water is used annually for shale beds. In 2010 the U.S. EPA estimated that 70 to 140 billion gallons of water are used to fracture oil and gas wells in the United States each year.¹³ The findings of on-going EPA research into the environmental impacts of hydraulic fracturing are expected in late-2012.¹³ One potential strategy for minimizing negative environmental impacts from hydraulic fracturing would be to use sand and water in the formation without the use of additives.

Nuclear power is the second largest source of electricity in the United States and relies on the mining of uranium.¹⁴ The mining of uranium is highly regulated and involves materials that can contaminate water, land, and air around the mining areas if all the materials are not handled properly. There have been cases of miners and mill workers becoming gravely ill due to radioactive exposure. An example of this is in Moab, Utah, where a uranium mine is located in close proximity to the Colorado River.¹⁵

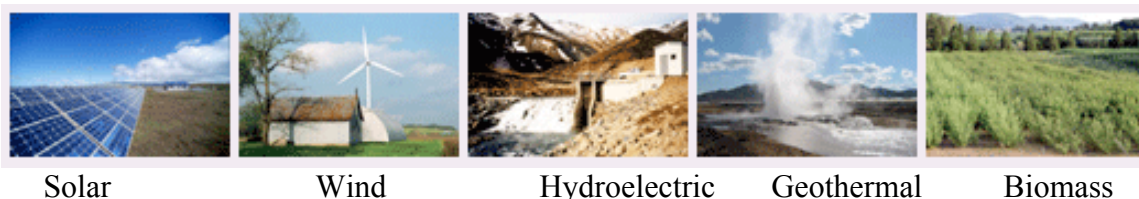


Figure 8: Renewable Energy Sources

Source: National Atlas http://nationalatlas.gov/articles/people/a_energy.html#one

Renewable Energy

Several types of energy resources do not require high-impact mining and are renewable sources of energy. Solar, wind, water, geothermal and biomass are diversified and renewable sources of energy. The movement of water can generate electrical energy, and ten percent of the country's electrical energy comes from hydroelectric

¹¹ Chesapeake Energy. 2011. 1 Nov. 2011 <<http://www.hydraulicfracturing.com/Process/Pages/Information.aspx>>.

¹² "Hydraulic Fracturing 101." Earthworks. 16 Dec. 2011. <http://test.earthworksaction.org/index.php/issues/detail/hydraulic_fracturing_101>.

¹³ "Hydraulic Fracturing Background Information." 31 Oct. 2011. United States Environmental Protection Agency. 1 Nov. 2011 <http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/wells_hydrowhat.cfm>.

¹⁴ Reynolds, Stephen J., et al. Exploring Geology. 2nd ed. New York: McGraw-Hill Companies, Inc., 2010. Page 540

¹⁵ . "Leetso, the Yellow Monster: Uranium Mining on the Colorado Plateau." Canyons, Cultures and Environmental Change An Introduction to the Land Use History of the Colorado Plateau. 14 Feb. 2012. <<http://cpluhna.nau.edu/Change/uranium.htm>>

dams.¹⁶ The moving water through the dam turns turbines or blades in electrical generators. This allows dam operators to regulate how much water goes through the dam to produce the electricity as needed. Geology is an important factor in hydroelectric power plans and designs. Geologists determine if the site for the dam is sustainable. They look to see if there is a deep enough canyon or valley, what type of rock the canyon or valley is made up of, and the geologic history of the area. Geologists can also help determine where some of the best sites are for other types of energy-production, such as geothermal plants and wind turbines.¹⁷

Climate Change

The U.S. EPA defines climate change as, “change in temperature, precipitation, moisture content, barometric pressure, solar radiation and wind.”¹⁸ Geology can affect climate through plate movement and deformations that alter the land elevation. Climate can also be influenced by emissions of volcanic ash, rearrangement of landmasses, and changes in ocean currents and sea level.¹⁹

Through geology and more specialized fields such as paleoclimatology, we are able to study the Earth’s past and present climates to help predict future changes and conditions. Natural factors of climate change are normally small changes that happen over decades or centuries. A large volcanic eruption or meteorite event can cause events that will cool the planet for a period of time. This can happen from the particles that are produced from these events and reflect the sunlight back out to space. The United Nations Environmental Program and World Meteorological Organization established the Intergovernmental Panel on Climate Change (IPCC) in 1988 to bring scientists and government officials together to conduct research on climate change to help us better understand trends and potential impacts.²⁰

Water Resources

Geology plays a major role in water management. Managing water resources is extremely important because water can be depleted or availability limited if not properly managed. Geologists focus on the maximum sustainability yield, without depletion. Drinking water is an essential and limited resource for humans.²¹

Freshwater that is found in the ground is held in aquifers that are generally porous rock, sand and gravel. The need to focus on sustainable practices to help maintain water quality is important for providing drinking water, irrigating crops, and wetland habitats for wildlife.

Space

Through planetary geology we are able to study other planets and their moons to understand what processes are reshaping the surfaces and if conditions exist that may support life. Evaluation can also be made of the potential for extracting mineral resources. Scientists are able to use radar and other techniques that can penetrate the atmosphere of a planet to show topographic features and surface conditions. Geologists and engineers work

¹⁶ Renewable Energy Sources in the United States. 26 Jan. 2011. National Atlas of the United States. 9 Nov. 2011 <http://nationalatlas.gov/articles/people/a_energy.html#one>.

¹⁷ “Climate Change.” 15 Sept. 2011. U.S. Environmental Protection Agency. 24 Oct. 2011 <<http://www.epa.gov/climatechange/>>.

¹⁸ “Climate Change.” 14 Oct. 2011. U.S. Environmental Protection Agency. 24 Oct. 2011 <<http://www.epa.gov/climatechange/basicinfo.html>>.

¹⁹ “Frequently asked question about global warming and climate change.” Back to Basics. 15 Sept. 2011. United States Environmental Protection Agency. 27 Oct. 2011 <<http://www.epa.gov/climatechange/>>.

²⁰ Withgott, Jay, Scott Brennan. Environment: The Science Behind The Stories. 3rd ed. California: Pearson Benjamin Cummings, 2008. Page 234

²¹ Perlman, Howard. How much water is there on, in, and above the Earth? 9 Feb. 2011. United States Geologic Survey. 9 Nov. 2011 <<http://ga.water.usgs.gov/edu/earthhowmuch.html>>.

together to develop new instruments that allow for observation and inferences to be made about a planetary body's temperature and composition. The continued exploration of other planetary bodies and their moons will allow us a better understanding of space and the processes that form these bodies.

The Bottom Line

Geology is the science that deals with the Earth's physical structure, its history, and the processes that act on it and by which it evolves. The world's land formations, climate, resources, and environment are always changing and geology allows us insight into all of it. Understanding how the Earth's processes work, how different interactions may affect water, soils, and other natural resources is important to the sustainable management of these resources. The study and comprehension of our world through geology can help us find answers to questions and solutions to problems.

Resources

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