***Environmental Geology*, 2e  
Answers to End-of-Chapter Questions**

**Chapter One  
Review Questions**

1. Scientists trying to understand the reduction of mountain glaciers can study ice cores removed from the glaciers. Scientists can study global climate and weather to understand glacier changes. They can also study local events that would affect glaciers in a region, such as volcanic eruptions that would deposit ash on the glacier. The stock of ice in a glacier is a balance between ice lost by melting and sublimation and ice gained by precipitation.

Mt. Kilimanjaro is located in tropical Tanzania with an elevation of about 5800 meters. Scientists have been documenting the retreat of its glaciers; the glaciers now cover a smaller area and are thinner. To determine whether climate change or other factors are responsible, in the year 2000 C.E. ice cores were taken. These ice cores contain a record going back 12,000 years. Climate scientists discovered that the glaciers were not retreating in the distant past, only in the recent past. This was interpreted to support the hypothesis that recent climate change is responsible. A different group of scientists proposed an alternative hypothesis. They proposed that deforestation and forest fires changed the local weather patterns, causing less moisture to be available. Further research was done, including climate modelling and analysis of satellite data. The modelling indicates that global warming has a greater effect on Kilimanjaro than local deforestation.

Understanding glacial retreat is an issue that involves more than tourist income for a region. For many parts of the world, glaciers provide freshwater during times of low precipitation.

1. The Earth systems are considered to be open because both matter and energy are exchanged among the systems. Water provides an excellent example. Water is transferred among all of Earth’s spheres. As water moves through all of Earth’s spheres it undergoes phase transitions, taking up or releasing energy. Water is also necessary for life and takes part in respiration and photosynthesis reactions. Water is a major factor in rock weathering, the creation of the pedosphere.

The whole Earth system is considered to be closed because energy is transferred between Earth and solar system. This is why Earth is not an isolated system. Earth does accrete small amounts of extraterrestrial material and does lose some gas from the top of the atmosphere. These fluxes are small relative to the mass of Earth, so Earth is best modeled as a closed system.

1. A stock is the content of a reservoir. The flow of material from one reservoir to another is called a flux. The solar radiation (energy) coming to Earth is a flux, also called a flow rate. The solar energy is leaving the sun and being deposited on Earth. The rates of solar radiation at different locations falling on Earth vary with time of day, season and other factors. Earth’s solar energy is not stored as solar energy, although it is converted. For example, the biosphere is driven by solar energy. Kinetic solar energy is converted to biomass, that is, plant material, by photosynthesis. The potential energy stored in plants is an example of a stock of solar energy. See Figure 1-3.
2. Earth formed 4.6 billion years ago. Portions of the five spheres are continuously being created and destroyed via plate tectonics, solar energy and gravity.

**Atmosphere**: Earth has had several atmospheres. Earth’s original atmosphere did not contain free oxygen. Photosynthetic life in the oceans is the origin of Earth’s current oxygen-bearing atmosphere. Our current oxygen-bearing atmosphere is a couple of billion years old.

**Biosphere**: The chapter mentions that clear fossil evidence of life is 3.5 billion years old. Given the incompleteness of the fossil record, it is likely that life evolved earlier. The biosphere is characterized by constant change, that is, evolution. There have been many changes in the biosphere since its start.

**Hydrosphere**: The hydrosphere is believed to have formed about 4.4 billion years ago by outgassing of magma.

**Geosphere**: Earth formed when the solar system formed 4.6 billion years ago. The chapter states that the layering of the geosphere was complete about 4.4 billion years ago. Plate tectonics has been greatly reworking Earth since then.

**Pedosphere**: Geologically speaking, the pedosphere is very young. The pedosphere is weathered bedrock which forms by interaction of the bedrock with the biosphere, hydrosphere and atmosphere. There is a large range in the rates of soil formation. Soil formation depends on climate, rock type, vegetation, and topography among other factors. It takes thousands to millions of years to form soils. In natural ecosystems, soil erosion often occurs on the same timescale.

1. Earth’s crust overlies the mantle. The crust is defined by its chemical composition; it is rich in oxygen, silicon, aluminum, iron, magnesium, calcium, sodium and potassium. The lithosphere is defined by its physical properties. The lithosphere is rigid and consists of both the crust and the rigid top portion of the mantle. The mantle is rich in oxygen, silicon, magnesium and iron. See Figure 1-9.
2. The major processes that operate in the lithosphere and rock cycle are plate tectonics and the creation of igneous, sedimentary and metamorphic rocks. Plate tectonics is the creation and destruction of the rigid lithospheric plates. New plate material is created by igneous activity at divergent plate boundaries. Igneous rock breaks down by weathering to form sedimentary rock. Both sedimentary and igneous rocks are converted to metamorphic rock by changes in heat and pressure. Subduction of oceanic plates back into the mantle starts the process anew. See Figure 1-11.
3. Solar energy heats the oceans, causing water to evaporate. The water vapor moves through the atmosphere and falls as precipitation, rain, or snow. In some locations, rain falls. Some water forms groundwater, other water runs off and flows into rivers and lakes. In some locations glaciers form, storing water on land. Eventually, the water returns to the ocean. The biosphere is intertwined with the hydrosphere. Plants use photosynthesis to convert water and carbon dioxide into plant material. Respiration uses oxygen to break down plant material to release energy, carbon dioxide and water. Water is also heavily involved with rock weathering. Additionally, plate tectonics subducts some water into the mantle with the subducting plate. Igneous activity returns the subducting water to the hydrosphere and atmosphere.
4. The two most abundant substances in Earth’s atmosphere are nitrogen gas (N2) and oxygen gas (O2). In dry air, nitrogen gas has an abundance of 78 percent and oxygen has an abundance of 21 percent.
5. The three main sources of energy on Earth are solar, internal and gravitational. Solar energy is the largest at 99.98 percent and is the major driver of surface processes. The primary source of internal energy is radioactive decay. This drives plate tectonics. The energy from the gravitational attraction among Earth and solar system bodies, primarily the sun and moon, is less than internal energy. Gravitational energy is responsible for ocean tides and solid Earth tides.

Thought Questions

1. If the flux of rock from Earth’s mantle were to increase more igneous rock would be created. The igneous rock that reached the surface would become volcanic rock. More gases from the mantle would enter the atmosphere, which would affect climate. Greater rates of seafloor spreading could cause a rise in sea level, due to the greater volume of warm, buoyant rock in ocean basins. Rock weathering rates would likely increase, leading to the eventual formation of sedimentary rock. This formation of sedimentary rock would lead to sequestration of atmospheric carbon dioxide into the sedimentary rock, leading to climate change. Greater igneous activity on land would also lead to the formation of more metamorphic rock via the rock cycle and by contact with preexisting rock.
2. Deforestation of tropical rainforest generating an increase in soil erosion is a reinforcing feedback. Since the change leads to an increase of the magnitude of the change, it is a reinforcing feedback.
3. Almost every aspect of human society is affected by the Earth systems, so modeling the Earth systems affects almost everything. As humans change Earth, the risk of passing thresholds that could put the Earth systems into completely different states could be very destructive to human society.

When human population was small and consisting of migrating hunter gatherers, human impact on Earth was readily absorbed by natural processes. As human population has increased to over 7 billion people, this is no longer the case. Humans are having a huge impact on almost every part of Earth’s surface. For humans to live with enough resources to thrive, human societies need to become sustainable. Currently our use of nonrenewable resources is unsustainable. When a population exceeds the carrying capacity of the land, the population crashes. Many scientists fear that human societies are approaching a tipping point, beyond which the Earth systems may switch into a mode we cannot predict. Rockström and his colleagues have developed a planetary boundaries model to determine how close human society is to a tipping point. See Figure 1-26.

1. Many plants require the presence of soil to grow. If the soil is removed, the plants can’t grow. Soil is the major component of Earth’s critical zone which is the interface between organisms and the resources needed to live. Soil contains organic matter and the weathered bedrock. The organic component of soil contains the carbon, hydrogen, nitrogen, sulfur, and phosphorus needed for life.
2. Changes in the amount of water in the oceans will lead to sea level changes. The water in glaciers, originated as water evaporating from the oceans. As more water is stored in glaciers, sea level will drop, assuming no change in ocean temperature. As more glaciers melt, the glacial meltwater eventually returns to the ocean, raising sea level. Cycles of Ice Ages have occurred over the last couple of million years. The glacial periods were accompanied by drops in sea level. The interglacial periods were accompanied by melting glaciers, with the resulting rise in sea level.

Additionally, as humans store more water behind dams, ocean water amounts decrease.