8.4: The Geosphere

As illustrated in Figure 8.5, the **geosphere** is the solid Earth (which sometimes is not so solid when earthquakes or volcanic eruptions occur). The geosphere is an enormous source of natural capital. It provides the platform upon which most food is grown and is the source of plant fertilizers, construction materials, and fossil fuels that humans use. As part of its natural capital, the geosphere receives large quantities of consumer and industrial wastes. Past and current practices of using the geosphere as the anthrosphere's waste dump are ultimately unsustainable. As shown in Figure 8.5, the geosphere interacts strongly with the hydrosphere, atmosphere, biosphere, and anthrosphere. Managing and preserving Earth's natural capital are of utmost importance to sustainability.

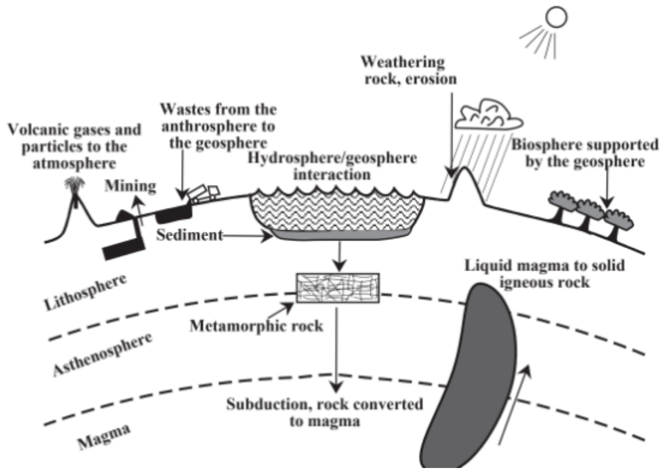

Figure 8.5. The geosphere. The "solid earth" consists of a surface layer of rock about 100 km thick on average floating on top of molten magma. Rock cycles occur within the geosphere. It is an enormous source of natural capital including essential minerals and provides a thin surface of soil upon which most food is grown

Earth is in the shape of a geoid defined by the levels of the oceans and a hypothetical sea level beneath the continents. It is slightly pear-shaped rather than being a perfect sphere because of differences in gravitational attraction in different parts of Earth. Although humans have flown hundreds of thousands of km into space, they have been unable to penetrate more than a few km into Earth's crust.

The geosphere is a layered structure most of which is hot enough to melt rock. Earth's core is a huge ball of iron at a temperature above the normal melting point of iron, but solid due to the enormous pressure that it is under. Above this core is the **mantle** composed of rock and ranging in depth between 300 km and 1,890 km. The deeper inner mantle, though hot enough for the rock to be liquid under ordinary pressures is solid because of the enormous pressure to which it is subjected. On top of the inner mantle is the outer mantle at a depth between 10 km and 300 km composed of hot molten rock called **magma**. Floating on the magma is the solid **lithosphere** composed of relatively strong rock, varying in thickness from just a few to as much as 400 km, averaging about 100 km. The transition layer between the molten magma and the lithosphere is the **athenosphere** composed of hot rock that is relatively weak and plastic. Earth's **crust** is the outer layer of the lithosphere, which is only 5-40 km thick.

Introduced to much controversy in the mid-1900s, the theory of **plate tectonics** views Earth'ssurface as consisting of huge lithospheric plates upon which the continents and Pacific Ocean rest, behaving as units. Earth's crust is a dynamic system in which the lithospheric plates move relative to each other by, typically, a few centimeters per year. When abrupt plate movement occurs, an earthquake results. Magma coming to the surface along plate boundaries results in emissions of hot and molten rock, ash, and gases in the form of **volcanoes**.

There are three kinds of boundaries between tectonic plates

- **Divergent boundaries** on ocean floors between tectonic plates that are moving apart are where hot magma undergoes upwelling and cooling to form new solid lithospheric rock, creating ocean ridges.
- **Convergent boundaries** where plates move toward each other forcing matter downward into the asthenosphere in subduction zones, eventually to form new molten magma and in some cases forcing matter upward to produce mountain ranges
- **Transform fault boundaries** where two plates move laterally relative to each other creating fault lines along which earthquakes occur

The conditions outlined above drive the **tectonic cycle**. In this cycle, there is upwelling of molten rock magma at the boundaries of divergent plates. This magma cools and forms new solid lithospheric material. At convergent boundaries, solid rock is forced downward and melts from the enormous pressures and contact with hot magma at great depths, reforming magma. This cycle and the science of plate tectonics explain once puzzling observations of geospheric phenomena including the opening and spreading of ocean floors that create and enlarge oceans, the movement of continents relative to each other, formation of mountain ranges, volcanic activity, and earthquakes.

Earth's Composition

Characterized by definite chemical composition and crystal structure, about 2000 known minerals compose Earth. Most rocks in the crust are composed of only about 25 common minerals. With a composition of 49.5% oxygen and 25.7% silicon, Earth's crust is largely composed of chemical compounds of these two elements with smaller amounts of aluminum, iron, carbon, sulfur, and other elements. Other than aluminum and iron, only about 1.6% of Earth'scrust consists of the kinds of rock that must serve as important resources of metals, phosphorus required for plant growth, and other essential minerals. Careful management of this resource of essential minerals is one of the primary requirements for sustainability.

As molten magma penetrates to near the top of Earth's crust then cools and solidifies, it forms igneous rock. Exposed to water and the atmosphere, igneous rock undergoes physical and chemical changes in a process called **weathering**. Weathered rock material carried by water and deposited as sediment layers may be compressed to produce secondary minerals, of which clays are an important example. Molded and heated to high temperatures to make pottery, brick, and other materials, clays were one of the first raw materials used by humans and are still widely used today.

A part of the crust crucial for the existence of humans and most other non-aquatic life forms is the thin layer of weathered rock, partially decayed organic matter, air spaces, and water composing **soil** (see Chapter 11) that supports plant life. Were Earth the size of a geography classroom globe, the average thickness of the soil layer on it would be only about the size of a human cell! The to player of soil that is most productive of plants is topsoil, which is often only a few centimeters thick in many locations, or even non-existent where poor cultivation practices and adverse climatic conditions have led to its loss by wind and water erosion. The conservation of soil and enhancement of soil productivity are key aspects of sustainability (see Chapter 11).

The Geosphere in Relation to Other Environmental Spheres

Virtually all things and creatures commonly regarded as parts of Earth's environment are located on, in, or just above the geosphere. Major segments of the hydrosphere including the oceans, rivers, and lakes rest on the geosphere, and groundwater exists in aquifers underground. Water dissolves minerals from the geosphere that nourish aquatic life. These minerals and rock particles eroded by moving water from the geosphere are deposited in layers and transformed into rock again. The atmosphere exchanges gases with the geosphere. For example organic carbon produced by photosynthetic plants from atmospheric carbon dioxide may end up as soil organic matter in the geosphere, and the photosynthetic processes of plants growing on the geosphere put elemental oxygen back into the atmosphere. The majority of biomass of organisms in the biosphere is located on or just below the surface of the geosphere. Most structures that are parts of the anthrosphere are located on the geosphere, and a variety of wastes from human activities are discarded to the geosphere. Modifications and alterations of the geosphere can have important effects on other environmental spheres and vice versa.