

Basic Principles of Geology Earth Structure

To appreciate the finer features of this marvelous planet we call Earth, one must first master—or at least acquire a competent comprehension of—the basic concepts of the general field of science that we know as geology. However, geology is not an isolated discipline, set apart from all other scientific inquiries. Quite to the contrary, all the sciences are intimately associated at their most fundamental levels.

A casual glance outside your livingroom window reveals a wonderous world of *billowing clouds* climbing high into the *blue sky*; rain soaking into the front lawn *dissolves* compounds, *breaks down* rocks, and transports the sediment to the *ocean* to become the future generation of *geologic formations* in an endless cycle of creation and destruction that defines our dynamic planet. Meteorology, optical physics, chemistry, weathering, oceanography, stratigraphy . . . these are just a sampling of the many fields that collectively define the natural sciences, only a part of which is geology.

The study of *geoscience* is a narrow discipline within **natural science**, which itself is divided into the branches of *life science* and *physical science*. *Geology* is a specialized field within the broader term *earth science* that focuses on the structure, composition, and the processes that affect both over time, but encompasses far more than simply the physical aspects of the planet we live on.

Reading geologic features in the field is like reading a novel. First one learns the alphabet and the sounds the individual letters represent; letters combine into words; words into sentences, sentences into stories. Likewise, understanding basic geologic concepts reveals answers to the grander manifestations of the world around us, and allows us to better appreciate—and formulate educated postulations—what we're seeing and how they came to be over large expanses of time that otherwise are too mundane for our minds to understand on such large and slow-moving scales.

In this pursuit, basic geologic principles will be addressed starting with this issue, and continue with increasingly comprehensive scientific theories that define and explain the unique celestrial rock we live on. These include, but are not limited to, *geophysics* (Earth's structure, heat flow, electricity, magnetism, radioactivity, orbit, gravity, et al), *plate tectonics* (seafloor spreading and continental drift), *climate change*, geologic time scales, and relative/absolute dating methods.

We will also explore related fields, such as *petrology* (study of rocks), *mineralogy* (study of minerals), *stratigraphy* (study of sedimentary layers), and *structural geology* (study of positions of rock units and their deformation), among others.

Studying the outer layer of the Earth—that is, the crust—is a relatively simple matter through observation of geologic features, core drilling, mining, etc. However, our understanding of the earth's interior must be inferred by evidence gathered from seismology, mineral physics, et al, to determine the planet's composition, density, temperature, and pressure. The structure of the Earth is composed of "shells" that can be described by either their chemical or mechanical properties. From the mechanical viewpoint, Earth's layers include the lithosphere, asthenosphere, mesopheric mantle, outer core, and inner core. These spheres can be differentiated according to characteristic variations such as temperature, density, rigidity, seismic velocity, and rheologic behavior (pertaining to the flow of liquids or deformation of solids). By comparison, chemical qualities distinguish the crust, upper mantle, lower mantle, outer core, and inner core. These are outlined in the following graph and outline.

(This series will continue in the next issue with: Earth's Dynamo)

Layers of the Earth

(Crust, Mantle, Core)

(a mechanical discription, i.e. how physical bodies behave under stress) The outermost Lithosphere shell of a rocky-type planetary body. On Earth, this layer is composed of the rigid outer crust and upper mantle, and is divided into numerous tectonic plates that essentially

accommodate the effects of mantle conection.

Crust The paper-thin (relative to the planet's mass), rigid shell that forms the outermost of Earth's many layers,

Continental Crust Igneous, sedimentary, and metamorphic rocks form the continents, including

> portions called *shelves* that extend below sea level beyond the shorelines. Derived from fractional differentiation of oceanic crust. Generally *granitic* in

composition. Roughly 25 miles average

Felsic: Light-colored, lower-density (specific gravity 2.7 g/cm³), high-silica rocks rich in

elements that combine to form feldspars and quartz, primarily silicon, oxygen,

sodium, potasium, and aluminum.

Oceanic Crust Igneous rocks erupted from the mantel and covered with various sediments

> eroded from land or accumulated from calcareous/siliceous shells of marine organisms form Earth's crust below the ocean. Generally basaltic in composition.

Up to 6 miles in thickness.

Mafic: Darker-colored, higher-density (specific gravity 2.9 g/cm³), low-silica rocks rich

in iron and magnesium minerals such as biotite mica, olivines, pyroxenes, and

amphiboles.

Mohorovicic (Moho) Discontinuity: A <u>chemical boundary</u> between crust and mantle. Lies almost entirely

within the lithosphere about 3-6 miles below the ocean floor, and 10-60

miles below continental crust.

Lithosphere-Athenosphere-Boundry: A <u>rheological boundary</u> (how liquids or soft solids flow in a plastic

manner rather than deforming elastically) that delineates the mechanical

differences between the lithosphere and asthenosphere.



Mantle

The solid, but plastic, interior of the Earth that lies between the crust and the outer core, and is itself divided into several layers based on densities determined by variations in seismic velocities that represent changes in mineral composition (primarily atomic restructuring of olivine due to temperature and pressure differences). These layers are known as the *upper mantle*, the *transition zone*, and the *lower mantle*, plus an indefinite core-mantle boundary called the D" zone. At nearly 2000 miles thick, the mantle encompasses about 84% of the Earth's volume.

Upper Mantle

Comprises the rigid lower *lithosphere* starting at the Moho (up to 75 miles thick), and the plastic inner *asthenosphere* (about 120 miles thick).

Asthenosphere

(a mechanical discription) The plastic portion of the upper mantle lies below the Earth's lithosphere between about 50 and 120 miles under the surface. Although mostly solid, it is both highly viscous (describes a fluid's resistence to flow) and ductile (describes a material's ability to be stretched without breaking).

Transition Zone

A physical zone separating the upper and lower mantles that extends from about 250 miles below the surface down to about 400 miles. Consists primarily of an ultramafic rock called peridotite. May contain up to three times the amount of water (in the form of hydroxyl ions) as in all the oceans combined!

Mesosphere

(a mechanical discription) An archaic term that refers to the portion of the mantel below the lithosphere and above the outer core; thus it comprises the transition zone, lower mantle, and the so-called D" zone.

Lower Mantle

This seismically homogenous region of the mantle starts abou 400 miles below the surface and extends down to a depth of about 1800 miles. It is likely that olivine at this depth has been recrystallized into silicates structurally similar to perovskite (an oxide) due to immense temperature and pressure. Nevertheless, this region is still mostly solid due to enormous lithostatic pressure.

D" Zone

At roughly 120 miles thick, this region of high-density matter separates the mantle from the core.

Core-Mantle Boundary (CMB):

A <u>chemical boundary</u> that lies between the solid silicate mantle and the liquid iron-nickel outer core at a depth of about 1,800 miles.

Outer Core

Located between the mantle and inner core about 1,800 miles below the surface, this fluid 1,400-mile-thick layer composed of iron-nickel alloy (with some sulfur and oxygen) is, despite the exceptionally high pressure at this depth, still liquid due to temperatures that exceed 7,000 degrees F at the boundary with the mantle! It is this layer of molten iron-nickel that is responsible for producing Earth's life-protecting magnetic field.

Inner Core

A solid ball of iron-nickel alloy with a radius of about 760 miles. The surface of this layer, some 3,200 miles below the surface, experiences temperatures exceeding 13,000 degrees F!

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(not to scale; numbers are approximate)

