

d6 Lithosphere, asthenosphere, mesosphere < plastic zone >

The terms *lithosphere* and *asthenosphere* stem from Joseph Borell's 1914-15 papers on isostasy, entitled *The Strength of the Earth's Crust*, in the *Journal of Geology*.¹

In the 1960s, seismic studies revealed a zone of rock weakness worldwide near the top of the upper part of the mantle. This zone of weakness is called the **asthenosphere** (Gk. *asthenes*, weak). The asthenosphere turned out to be of revolutionary significance for historical geology (see Topic d7, plate tectonic theory). Within the asthenosphere, rock behaves plastically at rates of deformation measured in cm/yr over lineal distances of thousands of kilometers. Above the asthenosphere, at the same rate of deformation, rock behaves elastically and, being brittle, it can break (fault).

The shell of rock above the asthenosphere is called the **lithosphere** (Gk. *lithos*, stone). The lithosphere as its name implies is more rigid than the asthenosphere. It is important to remember that the names *crust* and *lithosphere* are not synonyms. The crust, the upper part of the lithosphere, is continental rock (granitic) in some places and is oceanic rock (basaltic) elsewhere. The lower part of lithosphere is mantle rock (peridotite); cooler but of like composition to the asthenosphere.

The asthenosphere's top (**Figure d6.1**) has an average depth of 95 km worldwide below 70+ million year old oceanic lithosphere.² It shallows below oceanic ridges to near seafloor at oceanic ridge crests. The rigidity difference between the lithosphere and the asthenosphere exists because downward through the asthenosphere, the weakening effect of increasing temperature exceeds the strengthening effect of increasing pressure. This is so to a depth of about 210 km. Of known stony planets and moons, Earth is unique in its temperature gradient that maintains an asthenosphere, and this state has existed since at least the Late Archean (see Topic L5).

The entire layer of rock below the asthenosphere down to the core is called the **mesosphere** (Gk. *meso* means *middle*). The rock of the mesosphere evidently creep-yields to stress but is stiffer than the asthenosphere as the strengthening effect of increasing rock pressure through its depth exceeds the weakening effect of increasing temperature. The boundary between the asthenosphere and the underlying mesosphere is gradational. The chemical composition of the mesosphere, likely, does not change much with depth. However, to be in equilibrium with the existing temperature and pressure, its mineral composition must. Narrow plumes of hot mantle associated with hotspot volcanism arise from deep within the mesosphere (**Footnote d6.1**). □

Figure d6.1 Cross section showing movements (arrows indicate directions) of lithosphere and (streamlines indicate flow) of asthenosphere. Vertical exaggeration is about twenty times horizontal scale. At convergent plate boundaries, andesitic volcanism occurs on nonsubducting plate margins and basaltic "petite spot" (named by Naoto Hirano in 2006)³ volcanism, which evidently taps shallow depths of the asthenosphere, occurs on an upflexed part of a subducting plate margin. At divergent margins, basaltic volcanism produced by decompression melting taps shallow depths of the asthenosphere. At intraplate hotspots, basaltic volcanism produced by decompression melting taps mantle rock that has risen from deep within the mesosphere.

