Earthquakes and Seismic Waves as Clues to the Earth's Interior

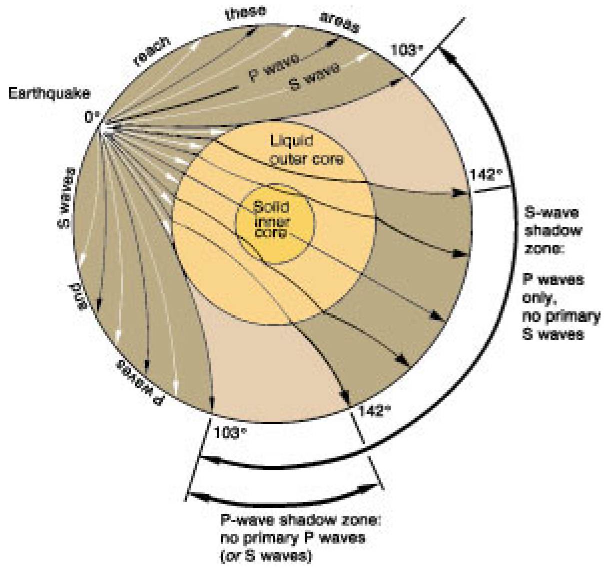

Figure 1 - The seismic shadow zone phenomenon.

The behavior of seismic body waves in the earth has allowed geologists to deduce information about the earth's internal structure. For example, the existence of the asthenosphere was discovered in part from the fact that seismic-wave velocities drop when they pass through it. Generally, rocks become denser and seismic waves travel faster with increasing depth in the earth. At a depth of 50 to 100 kilometers (which geologists now recognize as the base of the lithosphere), S-wave velocities decrease. Shear waves cannot travel through a liquid; they are slowed down and propagate less efficiently in the asthenosphere because of its plastic behavior and tendency to deform under stress, rather than store and release energy elastically.

S waves cannot travel through the earth's liquid outer core at all. When a major earthquake occurs, P waves from the quake are detected all over the earth, but S waves do not reach the part of the world on the opposite side from the earthquake. Figure 1 shows representative P-wave and S-wave paths in the earth; the arrows indicate the directions in which the seismic waves are traveling. A "seismic shadow" is being cast by the liquid outer core. Both the core's size and its liquid state can be determined from the existence and size of the shadow zone. Even P waves have a (more limited) shadow zone, due to deflection by the outer core.

Nearer the surface, seismic data have helped to confirm plate tectonics, not only because earthquakes are concentrated in belts that we now recognize as plate boundaries. Detailed examination of focal depths in subduction zones reveals a pattern of earthquake foci dipping away from the trench into the mantle, in a feature known as a Benioff zone (figure 2). The earthquakes occurring in the *Benioff zone* reveal the presence of the slab of cold, brittle lithosphere being subducted.

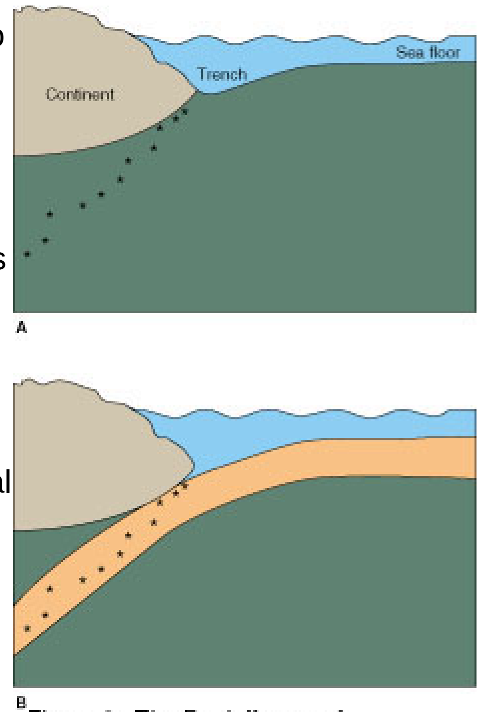

Figure 2 - The Benioff zone of progressively deeper earthquakes dipping away from a trench along the subducted slab. (A) The data. (B) The interpretation in plate-tectonic terms.

Most recently, a new technique-*seismic tomography*-uses high- precision data on seismic-wave velocities in and propagation through the earth to reveal temperature variations and other features of the earth's interior (figure 3). One unexpected discovery has been that the core/mantle boundary appears not to be smooth, but to have considerable relief on it. Why this should be so is not yet understood. Seismic tomography is helping to clarify patterns of mantle convection also.