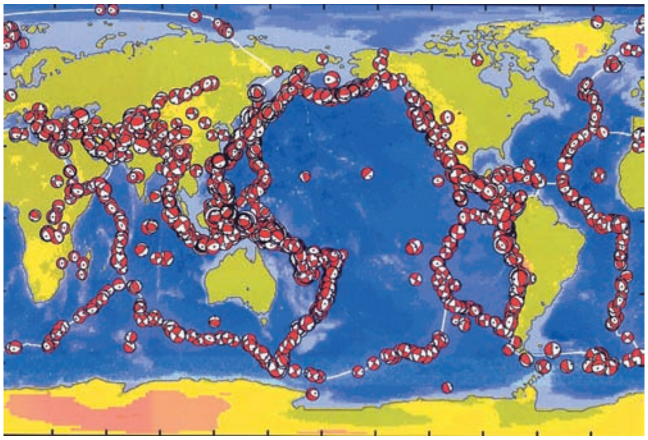

FIGURE 19 Source mechanisms of approximately 4,000 earthquakes from 1993 to 1997 obtained through the CMT analysis. The center of a beach ball is plotted at the epicenter. Only a small fraction of earthquakes are visible. Note the preponderance of earthquakes occurring on plate boundaries (Figure 18) and their mechanism corresponding closely to the type of the boundary (convergent, thrust faulting; divergent, normal faulting; transform, strike-slip faulting). Some earthquakes occur away from plate boundaries. They are particularly numerous in Asia and Africa along the east African rift system, but there are some in eastern North America and the center of the Pacific.

hence the term "subduction zones." At a plate boundary where the red arrows diverge, there is normal faulting and creation of a new crust: midocean ridges. For boundaries that slip past each other in the horizontal plane (green arrows), also called the transform faults, there is strike-slip faulting.

Figure 19 shows the source mechanism of approximately 4000 shallow earthquakes from 1993 through 1997 determined at Harvard University using the centroid-moment tensor (CMT) method; the center of each beach ball is at the epicenter—many earthquakes have been plotted on top of each other. It is easy to see that thrust faulting is dominant at the converging boundaries (subduction zones), there are exceptions related to bending of the plates, plate motion oblique to the boundary and other causes.

At midocean ridges, we see predominantly normal faulting, the faults where a midocean ridge is offset, show strike-slip faulting, in accordance with the plate tectonic theory. The exception is where the fault is complex. Along the San Andreas Fault, the most famous transform fault, we see many complexities that led to earthquakes other than the pure strike slip. For example, the Northridge earthquake of January 1994 was a thrust, and the Loma Prieta earthquake of October 1989 was half-thrust, half-strike slip. There are also earthquakes away from the plate boundaries. These are called intraplate earthquakes and their existence demonstrates the limits of the validity of the plate tectonic theory, as there should be no deformation within the plates. A very wide zone of deformaton is observed in Asia; the rare large earthquakes in eastern North America are sometimes associated with isostatic adjustment following the last glaciation. If we compare the distribution of earthquakes along a midocean ridge, including its transform faults, with that of the Alpide belt, we notice that for the oceanic plates the region in which earthquakes occur is very narrow, while in Eurasia it may be 3000 km wide. A part of the reason that the theory of plate tectonics has been put forward is because of observations (bathymetry, magnetic stripes, and seismicity) in the oceans.

There are also deep earthquakes, with the deepest ones just above 700 km depth; earthquakes with a focal depth from 50 to 300 km are said to be of an intermediate depth and are called "deep" when the focal depth is greater than 300 km. Intermediate and deep earthquakes are explained as occurring in the subducted lithosphere and are used to map the position of the subducted slab at depth. Not all subduction zones have very deep earthquakes; for example, in Aleutians, Alaska, and Middle America the deepest earthquakes are above 300 km depth. The variability of the maximum depth and the mechanism of deep earthquakes have been attributed in the late 1960s to the variation in the resistance that the subducted plate encounters; more recent studies indicate more complex causes, often invoking the phase transformations (change in the crystal structure) that the slab material subjected to the relatively rapidly changing temperature and pressure may undergo.

6. Earth's Radial Structure

A spherically symmetric Earth model (SSEM) approximates the real Earth quite well; the relative size of the three-dimensional part with respect to SSEM varies from several percent in the upper mantle to a fraction of a percent in the middle mantle and increases again above the CMB.

A concept of an SSEM, often referred to as an "average" Earth model, is a necessary tool in seismology. Such models are used to compute functionals of the Earth's structure (such as travel times), and their differential kernels are needed to locate earthquakes and to determine their mechanism. Knowledge of the internal properties of the Earth is needed in geodesy and astronomy. Important inferences with respect to the chemical composition and physical conditions within the deep interior of the Earth are made using information on radial variations of the elastic and anelastic parameters and density.

An SSEM is a useful mathematical representation that is not necessarily completely representative of the real Earth. This is most obvious at the Earth's surface, where one must face the dilemma of how to reconcile the occurrence at the same depth, or elevation, of water and rocks; the systems