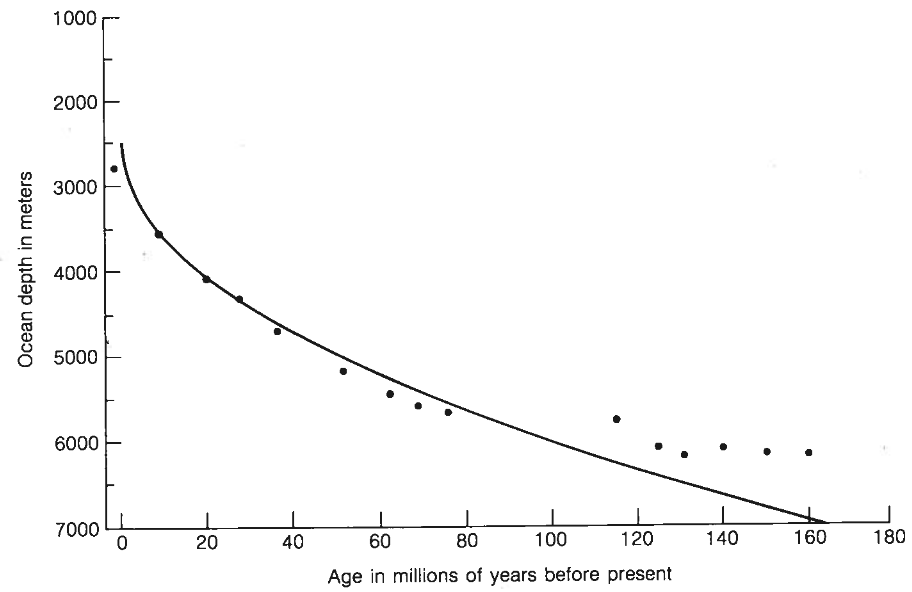

Figure 19-4
Mean ocean depths for the North Pacific plotted as a function of age of the sea floor. Theoretical curve assumes depth is proportional to the square root of age. [After B. Parsons and J. G. Sclater.]

When a cold plate is subducted it remains cooler than the surrounding hot mantle for about 12 million years, only gradually heating up as it penetrates more deeply. Slow-moving plates will of course heat up and be assimilated at shallow depths, perhaps 400 km, compared to fast-moving plates, which can penetrate to about 700 km before heating to the point of assimilation. The process of subduction involves very large forces, and in a general way these forces must be responsible for the deep-focus earthquakes that occur only in downgoing plates (see Chapter 17). The sudden failure associated with earthquakes can take place until the plates become so warm that stress is relieved by slow plastic deformation rather than faulting. This seems to be the likely explanation for the fact that earthquakes are absent below 700 km (Fig. 19-5).

Rates of Plate Motion. The velocities of moving plates are measured by dating ocean-floor magnetic anomalies (using the time scale of magnetic stratigraphy) and dividing the age of each anomaly into the distance between it and the ridge axis. The procedure was outlined graphically in the preceding chapter (Figs. 18-17, 18-18, 18-21, 18-22).

The worldwide pattern of sea-floor spreading is being worked out by using a combination of magnetic, seismic, and bathymetric data. The charts used earlier (Fig. 18-22 and inside front cover) map the world's zones of spreading, subduction, and fracture; their geographic locations were obtained from the positions of ocean ridges, deep-sea trenches, earthquake epicenters, and other indications of activity. On the basis of spreading rates determined from magnetic data, isochrons (contours that connect points of the same age) were drawn to show the age of the sea floor in millions of years. The distance from a ridge axis to a 50-million-year isochron, for example, indicates the extent of new ocean floor created in the period of time represented by the isochron. In Figure 18-21, note how the isochrons are closely spaced in the Atlantic and widely spaced in the Pacific, where the spreading rate is higher. The fracture zones offset the isochrons, so that upon crossing one of these great faults there is an abrupt change in the age of the sea floor. A summary of the rates and directions of plate motions, measured in centimeters/year relative velocity, is given in Figure 19-6. The largest spreading velocity, 18.3 centimeters/year, occurs between the Pacific and Nazca plates.

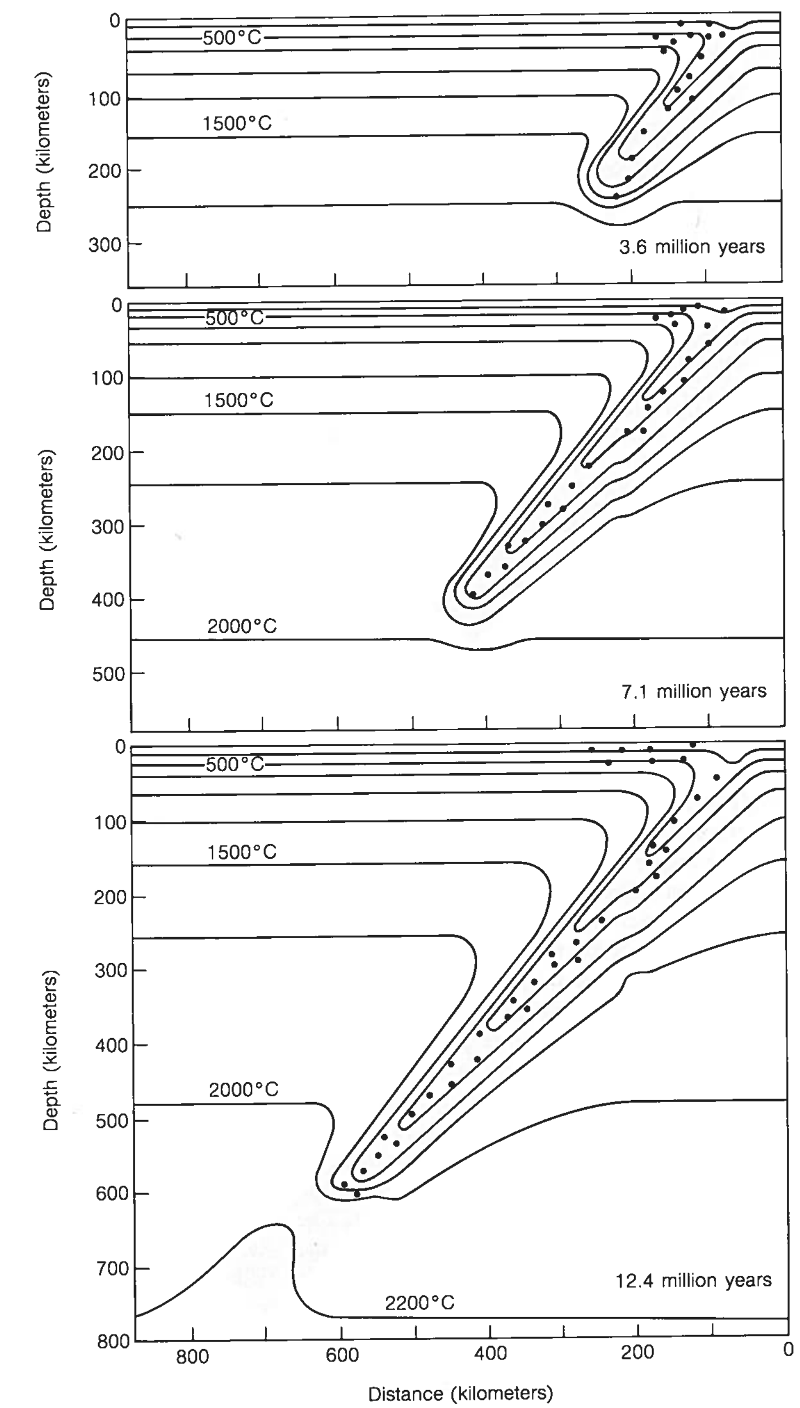

Figure 19-5
Evolution of descending slabs is described by computer models made by M. N. Toksöz. These diagrams depict the fate of a plate subducted at a rate of 8 cm/year. Contours show computed temperatures in plate and adjacent mantle. Note that temperatures in plate are several hundred degrees cooler than the adjacent mantle. After 12 million years, the plate reaches the temperature of the surrounding mantle at a depth of 600–700 km and loses its original identity. At shallow depths, earthquakes (dots) occur in the shear zone between the colliding plates and in the overriding plate. The deeper earthquakes occur in the cooler, brittle, center of the slab, but no deeper than 700 km, where the plate is assimilated.