OBSERVATIONS RELATED TO PLATE TECTONICS

It is useful to assess the global data sets that are most relevant to plate tectonics. Below are a series of global maps that help to confirm various aspects of plate tectonic theory. Plate boundaries are classified as ridges, transform faults, or subduction zones based on basic observations of topography (Figure 1) and seismicity (Figure 2). Remarkably, nearly all seafloor spreading ridges lie at a depth of 2500-3000 m below sea level which is the level of isostasy for hot thin lithosphere. Depths gradually increase away from the ridges because of cooling and thermal contraction so old ocean basins are commonly 4500 - 5000 m deep. Fracture zones and aseismic ridges also show up on these maps. Global seismicity (magnitude > 5.1 Figure 2) highlights the plate boundaries and reveals their tectonic style. Shallow normal-faulting earthquakes (< 30 km deep) are common along slow-spreading ridges but largely absent along faster-spreading ridges where the plates are too thin and weak to retain sufficient elastic energy to generate large earthquakes. Transform faults are characterized by relatively shallow (< 30 km) strike-slip earthquakes and they are common along both fast- and slow-spreading ridges. The deeper earthquakes (green and blue dots in Figure 2) occur only in subduction zones where sheets of seismicity (i.e., Benioff zones) are critical evidence that relatively cold lithosphere is subducting back into the mantle. But even convergent boundaries are characterized by shallow extensional earthquakes on the ocean side of the trenches. Some regions (e.g., Africa. Asia, western North America, Indian ocean) have distributed earthquake activity, indicating broad deformational zones. Topography and seismicity provide strong evidence for tectonic activity but little or no information on the rate of plate motion.

Marine magnetic anomalies, combined with relative plate motion directions based on satellite altimeter measurements of fracture-zone trends, have been used to construct a global age map (Figure 3) of the relatively young (< 180 Myr) oceanic lithosphere. Finally the distribution of off-ridge volcanoes that have been active during the Quaternary mainly occur directly behind trenches where wet subducting slabs reach asthenospheric depths and trigger back-arc volcanism (Figure 4). A few active volcanoes occur in the interiors of the plates and in diffuse extensional plate boundaries.

The geoid (Figure 5) shows little correlation–at long wavelengths– with surface tectonics and primarily reflects mass anomalies deep in the mantle. It is expected that the dynamic topography–the topography not due to crustal and near-surface variations–and the stress-state of the lithosphere at long wavelengths will also reflect deep density differences. Insofar as volcanoes correlate with high surface elevations and extensional stress one expects correlation of volcanoes with deep mantle structure, even if there is no material transfer.

Acknowledgements: The data provided in these figures represent decades of data collection by thousands of scientists. Figures were constructed using Generic Mapping Tools [*Wessel and Smith*, 1995]

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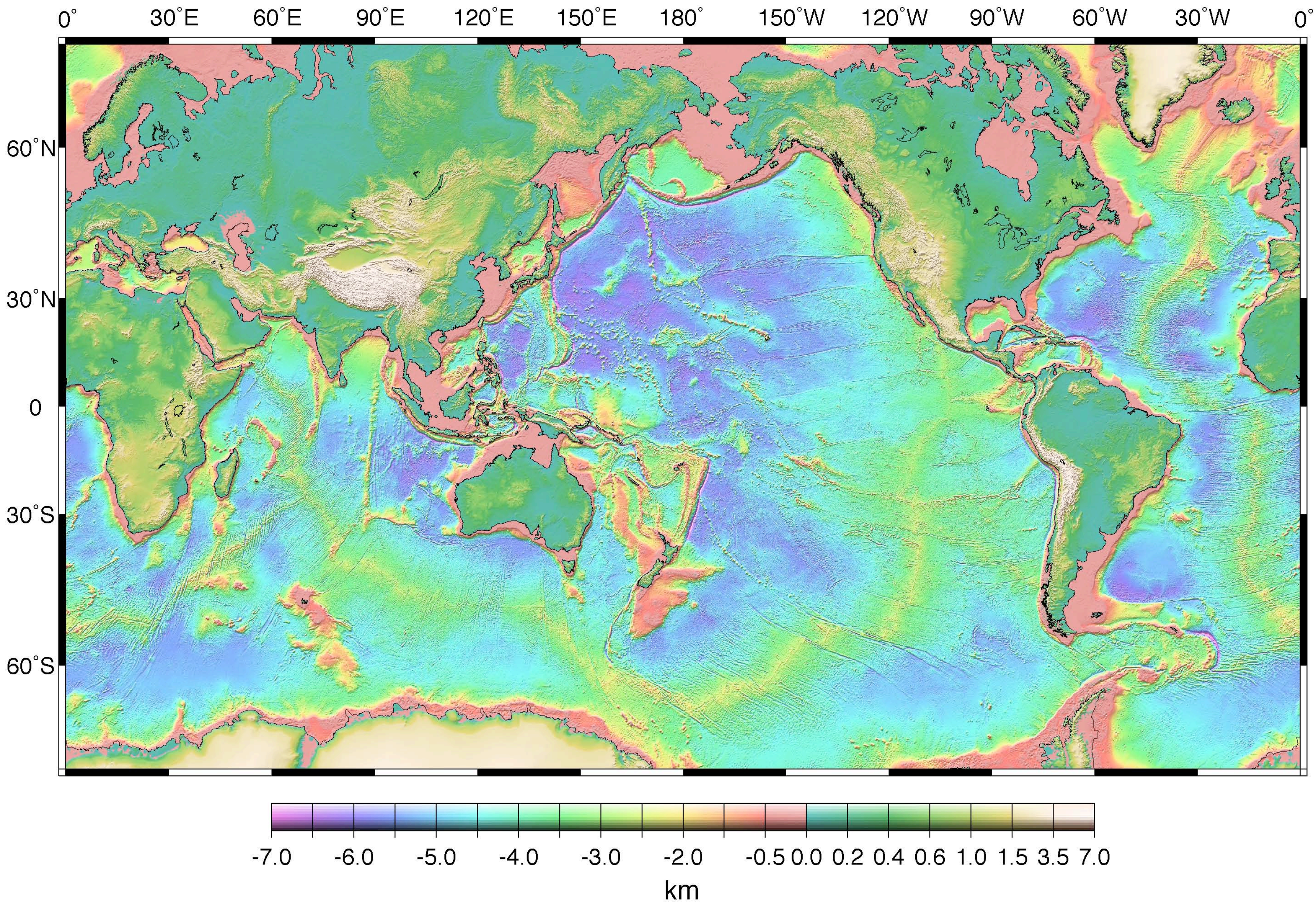

Figure 1. Topography of the Earth based on a global compilation of land data (GTOPO30 http://edcdaac.usgs.gov/gtopo30/README.html), and ocean data from a combination of sparse ship soundings and marine gravity anomalies derived from satellite altimetry [*Smith and Sandwell*, 1997].

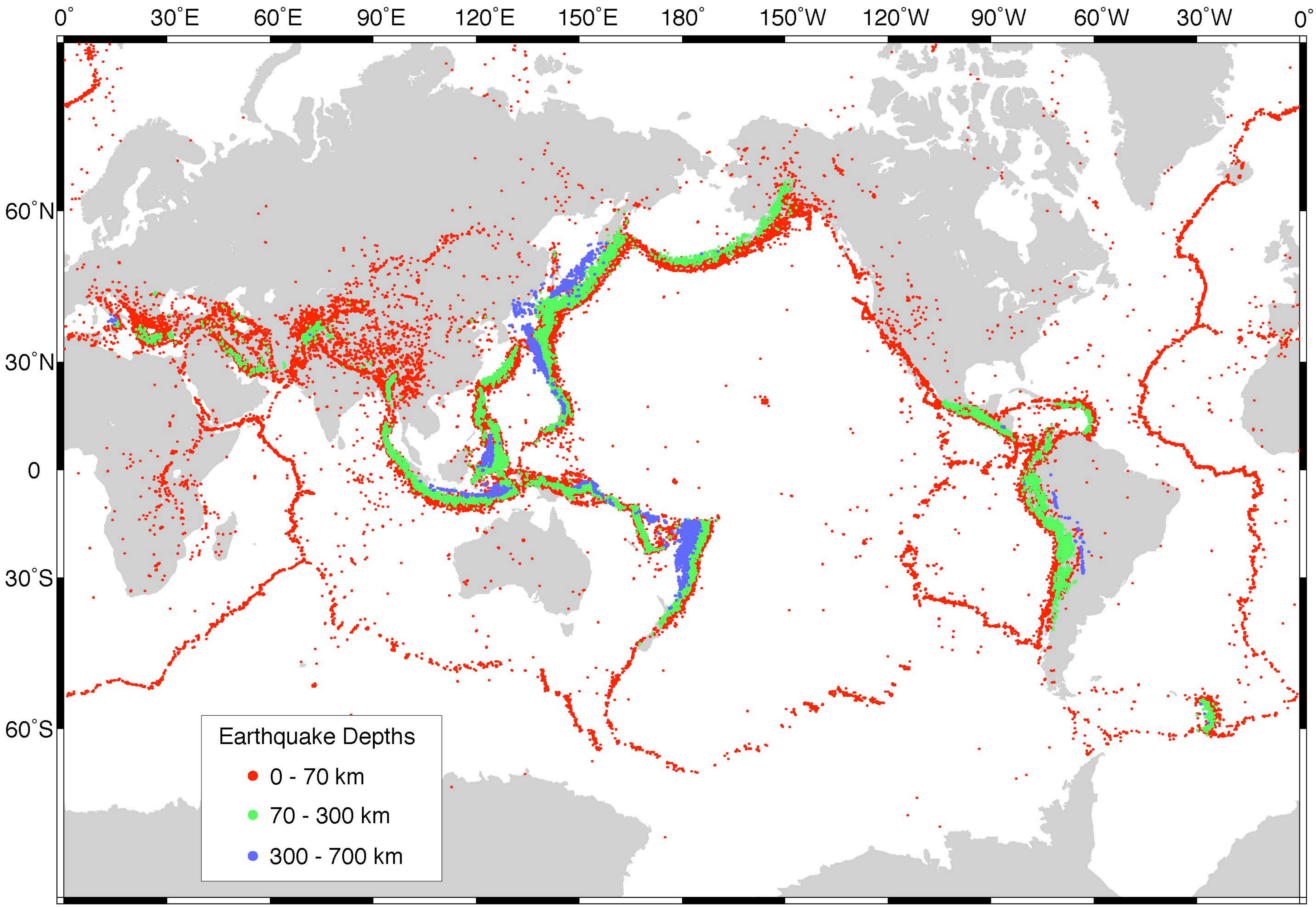

Figure 2. Well-located earthquakes with magnitude > 5.1 reveal the global plate boundaries [*Engdahl et al.*, 1998]. Shallow earthquakes (0-70 km – red) provide clear definition of the boundaries of the oceanic plates but have a more diffuse distribution on the continents. Intermediate (70-300 km - green) and deep (300-700 km - blue) earthquakes occur in subduction zones and are the primary evidence for lithospheric subduction to at least 670 km.

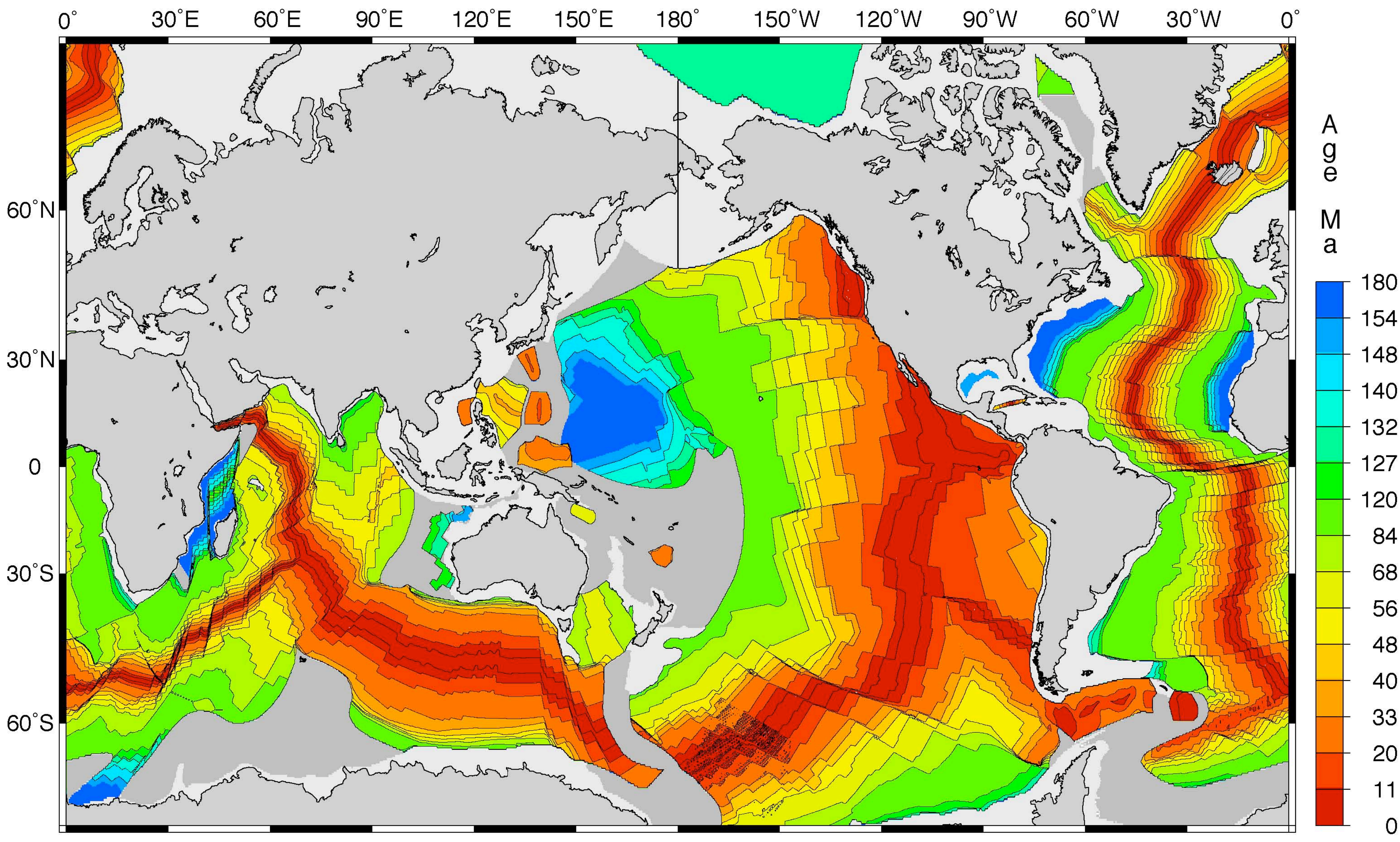

Figure 3. Seafloor age [*Mueller et al.*, 1997] based on identified magnetic anomalies and relative plate reconstructions along trends identified in satellite altimeter measurements of marine gravity. Ages in the Cretaceous quiet zone (64 - 127 Ma) have poor control.

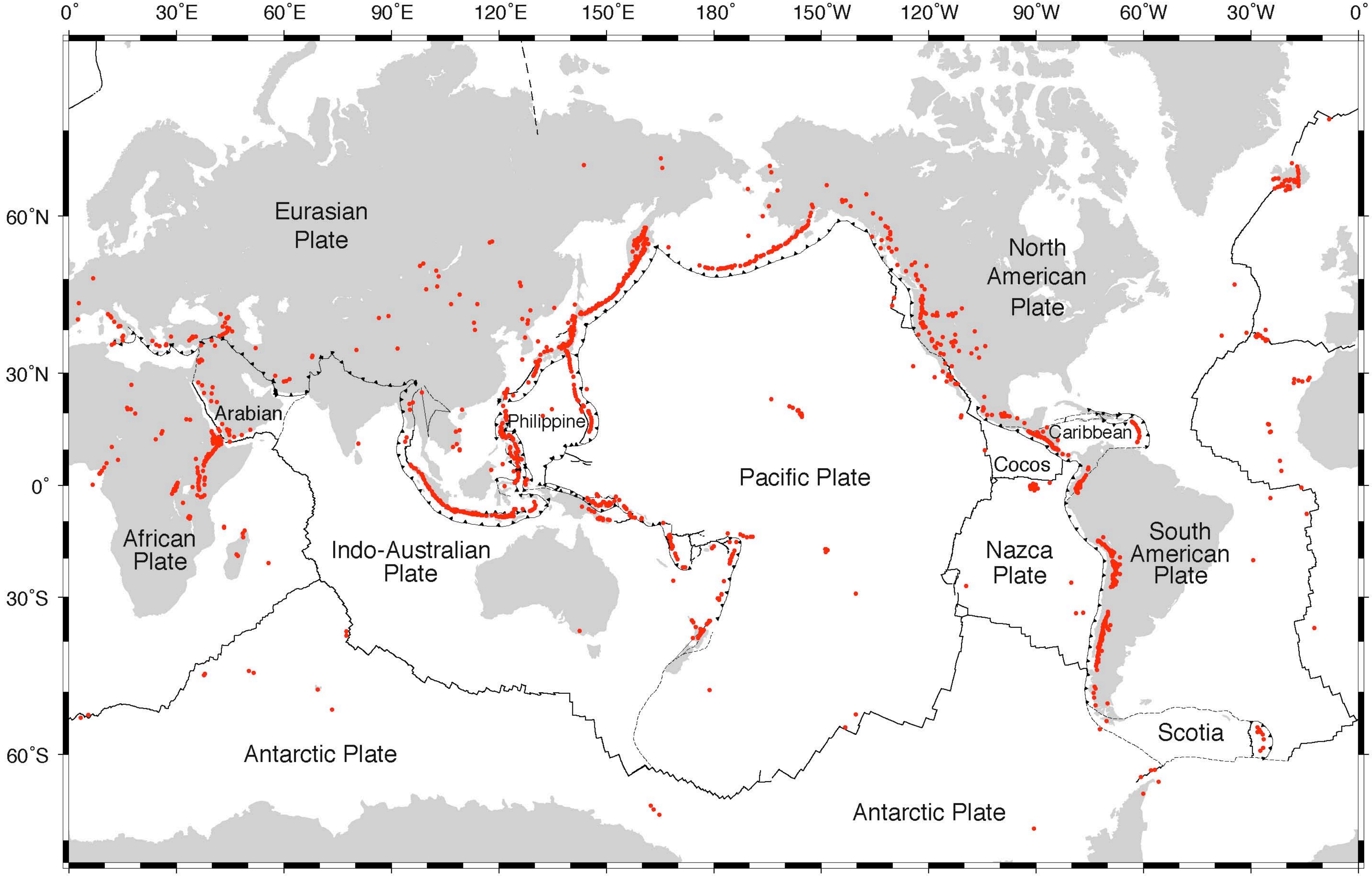

Figure 4. Plates, plate boundaries, and subaerial Quaternary volcanoes. The dozen or so tectonic plates are separated by spreading centers (solid lines), transform faults (dashed lines), and subduction/thrust faults (triangular fronts). The majority of active or recently active volcanoes [*Siebert and Simpkin,* 2002] are associated with convergent plate boundaries.

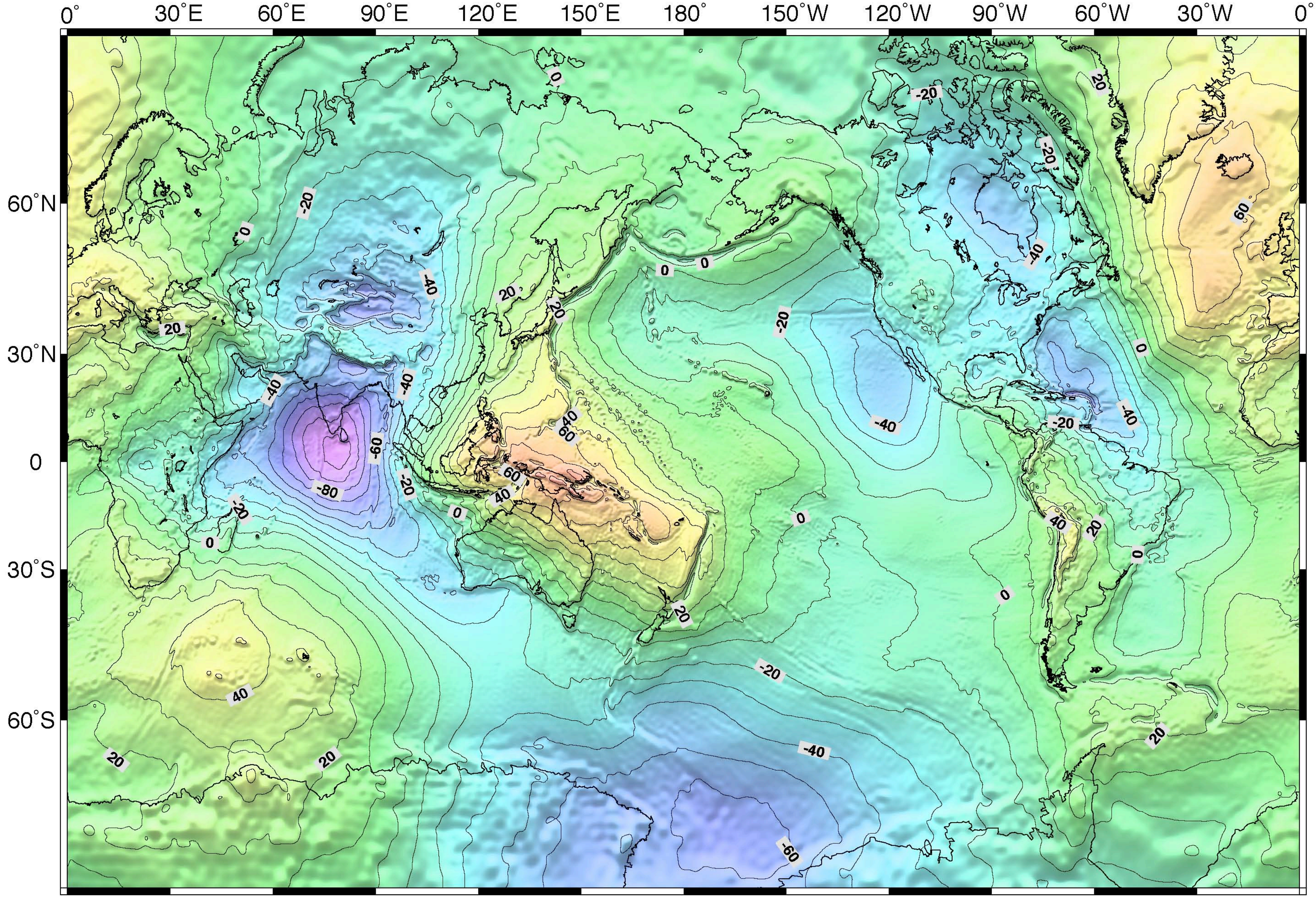

Figure 5. Geoid height (EGM96) above reference ellipsoid WGS84 [*Lemoine et al.*, 1998] based mostly on satellite tracking data and some terrestrial gravity anomaly measurements. Unlike topography, seismicity and age, shown in the other maps, the geoid is poorly correlated with surface tectonics except in areas where mature lithosphere has subducted.