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Oceanic crustal structure from seismic measurements

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The primary source of our knowledge of the structure of oceanic crust is the interpretation of seismic refraction experiments. The first classic compilation of seismic data of Raitt (in The Sea, 1963) subdivided the crust into three distinct layers, which have formed the reference basis for seismic profiles for the last decades. Today we know that the upper igneous crust (layer 2) is a region of strong velocity gradients, while the lower crust (layer 3) is relatively homogeneous, although it does show an increase in velocity with depth. Further, the upper crust has been sub-divided the in Layer 2A, composed of extruded basalts, and Layer 2B, formed by basaltic sheeted dikes. The lower crust, or Layer 3, often called the "oceanic layer", is inferred to be composed of gabbros. As crust ages, sediments accumulate on the igneous basement, creating layer 1.

The velocity structure of the oceanic crust formed by seafloor spreading is inherently related to the process of mantle melting. The amount of melt produced by adiabatic decompression of the mantle and the composition of the resultant igneous crust depend on the temperature, composition, and water content of the mantle source. Normal oceanic crust with a thickness of 6-7 km and Mid-Ocean Ridge Basalt (MORB) like composition is the result of decompressional melting of a mantle source composed of dry pyrolite with a mantle temperature of $\sim$1300°C. Thus, crustal formation occurs as passive response to seafloor spreading (i.e. passive upwelling). Higher mantle temperatures or compositional anomalies may cause buoyant upwelling of the mantle (i.e. active upwelling). The combination of active upwelling and higher mantle temperatures, or the presence of a more fertile mantle source, will produce larger amounts of melting and, likely, a thicker crust. Steady state mantle melting models can be used to investigate the relationship between mantle temperature, upwelling, and mantle composition on one hand and lower crustal seismic velocity and crustal thickness on the other hand. Here I use a new compilation of modern seismic refraction data to survey the relationship between crustal thickness and average layer 3 seismic velocity structure to test the hypothesis that mantle temperature is governing the variability of the oceanic crust.

Indeed, relating lower crustal seismic velocities to crustal thickness is extremely successful. Thus, the seismic structure of crust generated at the East Pacific Rise is consistent with that expected for a crust generated by passive decompression melting of dry pyrolitic mantle with a potential temperature of 1250–1300°C. However, thinner crust found in some parts of the Indian Ocean indicates along with reduced velocities in the lower crust that crust has been formed at lower mantle temperatures, while thicker crust found near hotspots suggests higher mantle temperatures. Furthermore, focused mantle upwelling along the Mid-Atlantic Ridge suggests that along axis variations of mantle temperature control crustal structure.