Structure and Evolution of Continents and their Margins: A Global Synthesis

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Introduction

The Earth's crust preserves the record of the evolution of our planet, provides our natural resources, and presents social challenges in the form of natural hazards, such as earthquakes and volcanoes. Here I summarize the key accomplishments of the 100 years of research (with a focus on recent results), and highlight the remaining outstanding problems in crustal evolution. The Earth's crust has profound implications for all aspects of the planet's physical state and evolution. The process of crustal formation led to the complementary formation of an underlying mantle lithosphere. The physical properties of the crust plus mantle lithosphere (oceanic and continental) modulates the rate at which heat is released to the Earth's surface, regulates mantle convection, and more generally defines the rules for plate tectonic processes. Geological, geochemical and geophysical studies define crustal properties. Here I discuss the key processes that have dominated the evolution of the Earth's crust and sub-crustal lithosphere as inferred from a new synthesis of global seismic data for the crust.

Eurasian Crust

The thickness of the Earth's crust in Eurasia and surrounding oceanic regions is depicted in Figure 1. Normal oceanic crust is 5-10 km thick (not including water), but the oceanic crust becomes 30 km thick beneath island arcs, such as Japan, and at the edge of continents, such as eastern China. Continental interiors are generally 40 +/- 10 km thick, but the closure of the Tethyan Ocean has led to a zone of continent-continent collision and crustal thickness of 70-80 km. However, continental crust that is subducted to depths greater than 80 km would undergo metamorphism to eclogite facies, and would then have a density and seismic properties like mantle rocks (peridotite). For this reason, geophysical measurements cannot easily detect the presence of crustal rocks at depths greater than 80 km. Eclogite might be inferred from anomalous high P-wave velocity and a lack of seismic anisotropy.

African Crust

The Moho contour map for Africa (Fig. 2) is much smoother than the Moho map for Eurasia (Fig. 1) because no young continent-continent orogeny is present. The average crustal thickness is 38 km for land above sea level and is 36 km when submerged continental crust is included. The crust is locally thinned to 20 km in the East African rift in northern Kenya and Ethiopia, and along the rifted continental margins.

Continental Tectonics

The contour maps of Eurasia and Africa illustrate some important points. Oceanic crust maintains a thickness of 5-10 km except when invaded by a volcanic island arc, such as the Aleutians, or when thick sediments are deposited, such as the Bay of Bengal. Continental margins feature transitional crust that thins from 30 km (at the coast) to 5-10 km (oceanic crust) over a lateral distance of about 200 km. Continental margins are formed during continental breakup and pass through an evolutionary stage that is similar to the East African rift and the Red Sea rift. Continental interiors stabilize with a crustal thickness of 40 km.

Our contour maps of crustal thickness of Eurasia and Africa cross many paleo-suture zones where continent-continent collisions have occurred, such as the east-west oriented Dabei Shan suture at 32° N in central and eastern China and older sutures in Africa. However, we do not find thick crust at these locations, which indicates that the crust has undergone post-orogenic thinning. Three processes may have thinned the orogenic crust: (1) isostatic uplift and erosion; (2) crustal extension, and (3) lateral crustal flow. The first two of these processes can be distinguished by geological field studies that provide evidence for erosion or extension. However, to date it has been difficult to use geophysics to document lateral crustal flow. Crustal seismic anisotropy may hold the promise to measure deformation associated with crustal flow.