Crustal Thickness Variations in the Central Andes and the Origin of the Andean Altiplano

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A lively debate is raging about the role of geologic processes in the lower crust and uppermost mantle in mountain building and plateau uplift. Magmatic injection, lower crustal flow, lithospheric instabilities, and upper mantle small-scale convection are postulated as important mechanisms that control some of the earth's most important tectonic features. Seismic imaging of the inaccessible lower crust and upper mantle is the key to determining which, if any, of these processes are occurring. Three-component broadband seismic recordings of natural earthquakes provide a powerful source of data to study the structure of the crust and lithosphere. We can map crustal thickness variations, measure crustal and mantle anisotropy, map large-scale lithospheric structure, delineate attenuating zones, and determine Vp/Vs ratios to provide constraints on bulk composition. I am currently working on lithospheric-scale structure in the Central Andes in South America.

The Altiplano, in southern Peru, western Bolivia, and northern Chile, and the Puna of northwestern Argentina together form one of the world's highest and largest plateaus, second only to the Tibetan Plateau. The Altiplano has an average elevation of nearly 4 km, a crustal thickness of ~65 km, and encompasses an area of over 600,000 km2. The Altiplano is part of the central Andean mountain belt and is clearly associated with subduction of the Nazca plate beneath the South American plate. However, the origin of the Altiplano remains controversial. To test several hypotheses of formation of the Altiplano and to understand the mountain building processes of the Central Andes, we are conducting a transportable broadband seismic transect across the Central Andes to record teleseismic, regional, and local earthquakes. A multifaceted approach is clearly necessary to fully understand the crust and upper-mantle structure of a region. Variations in the thickness and internal structure of the crust, lithospheric thickness changes, and the seismic properties of the upper mantle need to be investigated using a variety of seismological techniques, including shear-wave splitting, receiver functions, regional surface waves, travel times, and Pnl waveform modeling. My goal in these studies is to combine the seismological information with regional geology and tectonics to understand the process of lithospheric deformation in both compressional and extensional regimes.

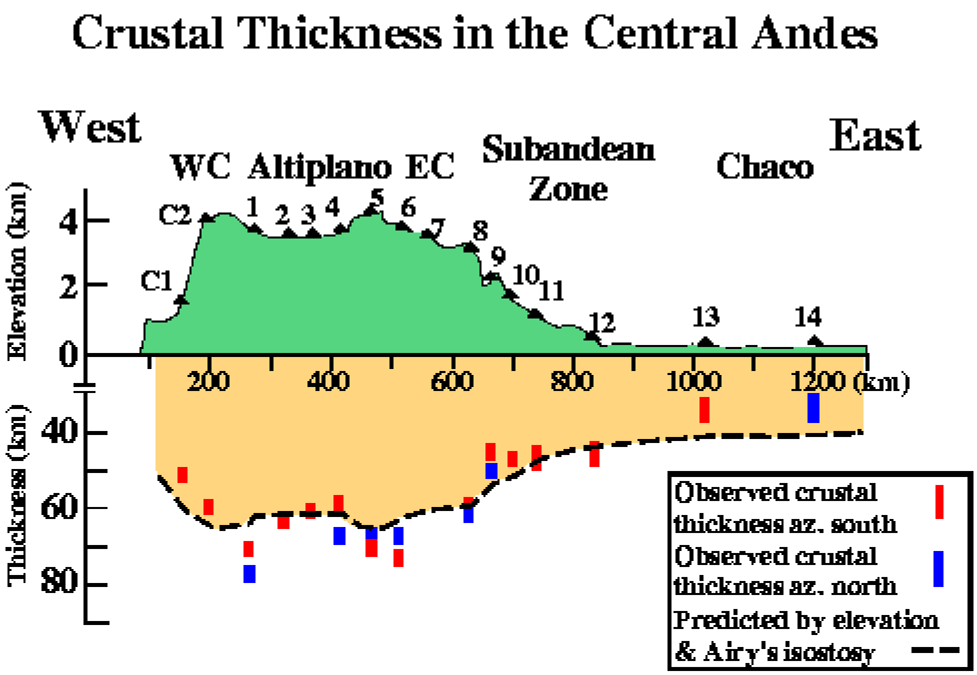

Figure 1. The Altiplano, the high intermountain plateau in the central Andes, is bordered on the west by the Western Cordillera (an active volcanic arc) and on the east by the Eastern Cordillera (high mountain range dominated by folding and thrusting), the Sub-Andean zone (a thin-skin fold and thrust belt), and the Chaco Plain (a platform underlain by the Brazilian shield). We estimated the crustal thickness along a east-west transect across the Andes at 20 degrees S and along a north-south transect along the eastern edge of the Altiplano from data recorded on two arrays of portable broadband seismic stations (BANJO and SEDA). Waveforms of deep regional events in the down-going Nazca slab and teleseismic earthquakes were processed to isolate the P-to-S converted phases from the Moho. Depth to the Moho and, in some cases, the average crustal Poisson's ratio were computed from the delay times of Ps conversions and crustal multiples. We found crustal thickness variations using this technique of nearly 40 km across the Andes. Maximum crustal thicknesses of 70-74 km under the Western and Eastern Cordilleras thin to 32-38 km 200 hundred km east of the Andes in the Chaco Plain. The central Altiplano at 20!S has crustal thicknesses of 60 to 65 km. The crust also appears to thicken from north (La Paz, 55-60 km) to south (Los Frailes volcanic field, 70 -74 km) along the Eastern Cordillera. The Sub-Andean zone crust has intermediate thicknesses of 43 to 47 km. Crustal thickness predicted from the topography of the Andes for an Airy type isostatic behavior shows remarkable overall correlation with observed crustal thickness in the regions of high elevation. In contrast, in the transition from the Eastern Cordillera to the Sub-Andean zone and in the Chaco Plain, the crust is thinner than predicted, suggesting the crust in these regions is supported in part by the flexural rigidity of a strong lithosphere. With additional constraints, we conclude the observation of Airy-type isostasy is consistent with thickening associated with compressional shortening of a weak lithosphere squeezed between the stronger lithosphere of the subducting Nazca plate and the cratonic lithosphere of the Brazilian shield.