In-Situ Rheology from Isostatic Strength and Geophysical Constraints of Lithospheric Properties

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Measurements of effective elastic thickness, T_e, from flexural isostatic modeling are sensitive to flow rheology of the lithosphere. Nevertheless, T_e has not been widely used to estimate in-situ rheology, partly owing to methodological controversies regarding the measurement of T_e, and partly because of uncertainties in other in-situ properties such as temperature, lithology, water content and state-of-stress of the lithosphere. Dense seismic and other geophysical arrays such as EarthScope's USArray are providing a wealth of new information about the physical state of the lithosphere, however, and relationships of these data to T_e promise new insights into lithospheric rheology and deformation processes. For example, new estimates of subsurface mass distributions derived from seismic data enable us to examine controversial assumptions about the nature of lithospheric loads. Variations in crustal lithology evident in bulk crustal velocity ratio, v_P/v_S, contribute a surprisingly large fraction of total loading. Perhaps the most interesting new information on physical state derives from imaging of uppermost mantle velocities using refracted mantle phases, P_n and S_n, and depths to negative velocity gradients imaged as converted phases in receiver functions (so-called seismic lithosphere-asthenosphere boundary, "LAB", and mid-lithosphere discontinuity, "MLD"). Reconciling seismic estimates of temperature variations with T_e measurements in the western US requires that we invoke variations in lithology, water concentrations, and/or membrane stress. Cordilleran T_e and P_n are best-reconciled using a wet quartz crustal lithology, wet olivine mantle lithology, and large membrane stress. More stable lithosphere to the east is best-modeled with a dry feldspar or pyroxene crustal lithology, dry olivine in the mantle and smaller membrane stress. Greater crustal quartz abundance in deforming regions (and in older orogens further east) is observed independently in measurements of bulk-crustal v_P/v_S, and independent evidence also supports the inference of variable water concentrations. Taken together, these lines of evidence suggest that lithology and water abundance are equally as important as geothermal variation in determining the rheological behavior of the lithosphere.

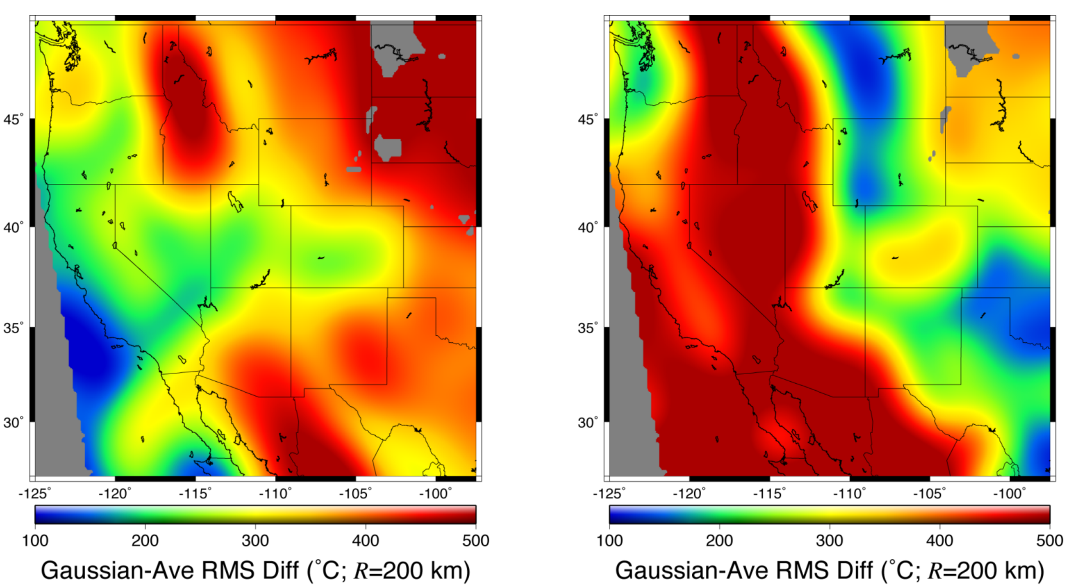

Figure 1. Gaussian-averaged RMS-difference in Moho temperatures estimated from P_n tomography versus modeled from T_e. Left panel modeled T_e with a wet quartz crust, wet olivine mantle and membrane stress; right panel used dry anorthite crust, dry olivine mantle and no membrane stress.