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A combined analysis of basaltic melting and shear wave velocity anomalies to constrain dynamic support of western North America

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The region of western North America that encompasses the Basin and Range Province, the Snake River Plain and the Colorado Plateau is about 2 km higher than cratonic North America. This topographic difference broadly coincides with variations in lithospheric thickness (i.e. <120 km beneath Colorado Plateau, ∼220 km beneath the Great Plain). Thermochronologic observations from the Grand Canyon area, sedimentary flux estimates from the Gulf of Mexico, and inverse modeling of regional drainage networks together suggest that this regional uplift occurred during Cenozoic time in at least two discrete phases. Earthquake tomographic models have imaged low velocity material beneath the bulk of western North America, including a ring-shaped anomaly encompassing the Colorado Plateau itself. Basaltic magmatism coincides with these low velocity zones and indicates an overall increase in melt volume at ∼40 Ma, as well as an abrupt change from lithospheric to asthenospheric signatures at ∼5 Ma. To investigate the quantitative relationship between seismic velocity anomalies and basaltic magmatism, we have analyzed >260 samples from volcanic centers throughout western North America for major, trace and rare earth elements using ICP-MS and XRF techniques. For asthenospheric samples, we observe a correlation between slow shear wave velocity anomalies and basaltic geochemistry. Using a combination of petrologic observations, forward and inverse modeling of major and rare earth elements, and shear wave velocity anomalies from tomographic models, we determine depth of melting and melt fraction. We explore the possibility that volatiles, anomalous source composition and/or temperature can give rise to basaltic magmatism and regional uplift. We then calculate mantle temperatures from shear wave velocity profiles beneath each volcanic field. In this way, we exploit a variety of approaches to constrain lithospheric thickness and mantle potential temperature. Our combined geochemical and geophysical results yield excess temperatures of 50-80 °C beneath a ∼60 km thin lithospheric plate. A dynamic topographic model of progressive lithospheric erosion over anomalously hot upper mantle can account for regional uplift as well as the temporal and spatial distribution of magmatism across western North America.