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Global Continental Residual Topography

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Convective circulation in the mantle supports some fraction of Earth's topography. It is challenging to observe this topographic expression of mantle convection because it is contaminated by crustal and lithospheric isostatic processes. In the oceanic realm, residual bathymetry has been calculated by removing the effects of sedimentary and crustal thickness variations and comparing to the well-known plate cooling trend, revealing sub-plate topographic support that is up to 1–2 km in amplitude and varies on wavelengths of ~1000 km. On the continents, crustal thickness and density variations support a much larger fraction of topography. Similarly, the density and thickness of the lithospheric mantle do not follow a simple predictive relationship. It is therefore significantly more challenging to calculate the component of sub-plate topographic support in the continental realm. Here, we assemble a database of > 20,000 continental crustal thickness estimates from published active and passive source seismic experiments with a goal of exploring the topographic expression of crustal, lithospheric, and sub-plate mantle structure. A subset of these studies provides constraints on crustal seismic velocity structure which can be used to estimate local density structure of the continental crust. We exploit a database of laboratory-determined density and velocity measurements of crustal rocks to develop a velocity to density conversion scheme. We use these constraints on crustal structure to remove the effects of crustal thickness and density variations and calculate an estimate of residual topography that arises from mantle processes. We compare these values of residual topography to an independent, tomographically derived map of lithospheric thickness. We find that residual topography is negatively correlated with lithospheric mantle thickness, which is expected and consistent with oceanic lithospheric observations. Next, we exploit a pressure and temperature-dependent density parametrisation to calculate and remove the expected topographic contribution of the lithospheric mantle. This approach demonstrates that up to 3 km of residual topography is positively correlated with lithospheric thickness even after removing the effects of cooling and thickening of the plate, indicating that compositional factors may lead to decreasing density with increasing lithospheric thickness. This relationship is in broad agreement with constraints on lithospheric mantle composition from xenoliths. Our analysis demonstrates the importance of accounting for lithospheric structure in the continental realm in constraining the sub-plate, dynamic contribution to Earth's topography. An important corollary is that changes to the density and thickness of lithospheric mantle drive rapid vertical motions of the Earth's surface which are increasingly recognised as causes of regional epeirogenic uplift.