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Causes and Consequences of Time-Varying Dynamic Topography

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Convective circulation of the Earth's mantle maintains plate motion but we know little about the spatial and temporal details of this circulation. Accurate maps of the spatial and temporal pattern of dynamic topography will profoundly affect our understanding the the relationship between surface geology and deep Earth processes. A major difficulty is the 'tyranny of isostasy'. In other words, dynamic topography is difficult to measure because crustal and lithospheric thickness and density changes are the dominant control of surface elevation. Some progress can be made along continental margins by measuring residual depth anomalies of the oldest oceanic floor on newly available seismic reflection and wide-angle profiles. These estimates of dynamic topography have amplitudes of ± 1 km and wavelengths of 10^2–10^4 km. They mostly, but not always, correlate with long wavelength free-air gravity anomalies. Correlation with seismic tomographic images is much poorer. The distribution of dynamic topography throughout the rest of the oceanic realm can be supplemented by using ship-track data in regions with sparse sedimentary cover and by exploiting the mid-oceanic ridge system. On the continents, it is more difficult to measure dynamic topography with the same accuracy since the density structure of continental lithosphere is so variable but progress can be made on three fronts. First, long-wavelength gravity anomalies which straddle continental margins are an obvious and important guide. Secondly, stratal geometries across continental shelves contain information about positive and negative surface elevation changes. In several cases, 2- and 3-D seismic surveys calibrated by boreholes can be used to constrain spatial and temporal patterns of dynamic topography. In the North Atlantic Ocean, examples of buried ephemeral landscapes suggest that dynamic topography can grow and decay on timescales as short as a few million years. Recognition of positive and negative vertical motions, which cannot be accounted for by global eustasy, is encouraging and suggests that we are on the verge of creating global dynamic topographic maps which can be used to test predictive global models.