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Deep Earth Dynamical Processes and the Development of Topography

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The topography of the continents is shaped by erosion, but erosion can act only when elevation differences are created by lateral variation in crustal or lithospheric thickness or density, with density determined by intrinsic composition and temperature. Topography changes with time in response to evolution of the thermal profile, or in response to a structural re-arrangement of the mass in the lithospheric column, caused for example by extension, convergence, underplating, intrusion or surface loading. Convection in the mantle also produces variable stresses that act on the base of the lithosphere and drive time-variable development of topography. We can make some simple order of magnitude estimates of the drivers for topography. Most of the topographic variation on the Earth is directly attributable to variations in crustal thickness, e.g., the difference between 37 km of crust in the continental cratons and 7 km of crust in the ocean basins produces about 4 km of relief (if we correct for the water loading). If the crustal thickness is increased by a further 30 km as in Tibet, we get an additional 4 km of relief. The greatest possible lithospheric thermal anomaly (complete reheating of the lithosphere as at the mid-ocean ridge) accounts for about 2.5 km of water-corrected topographic relief in the oceans. Topographic relief of order 1 to 2 km is also found in the continents where major reheating of the lithosphere is implied (as for the Colorado Plateau or the Basin and Range of the Western USA). Reheating of the lithosphere beneath Tibet also evidently contributes to the 5 km average elevation of that plateau. Away from subduction zones, the direct dynamical effect of mantle plumes or convection currents in the mantle is apparently smaller. The largest mantle plume, Hawaii, is associated with a topographic amplitude anomaly on the order of 1 km. Yet subtle epeirogenic movements caused by flow in the mantle have affected large areas of the continents and are significant in the evolution of continental regions like Central Australia. Most of the topographic signature on the Earth's surface

is directly attributable to intra-lithospheric effects caused by crustal thickness variation and lithospheric thermal anomaly. Where these effects are greatest in the continents, however, they are typically produced by convergent and extensional orogeny caused by the tectonic plates focussing stresses that originate in the mantle convection system. The European Alps and the Indian-Asian continental collision illustrate such processes. More enigmatic, however, is the possibility that the continental lithosphere can locally drive its own orogeny by the development of gravitational instability of a relatively dense mantle lithosphere. We argue that the Pannonian-Carpathian system of Miocene Europe is one example of this process.