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Some Features of Continental Lithospheric Deformation

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Plate collision is one of the principal drivers of lithospheric deformation; gravitational collapse of relatively thick crust is another. The broad consistency of GPS velocity fields in regions as diverse as Central Asia, western USA, and Anatolia – Aegea provides strong support to the concept that in such regions the lithosphere basically behaves as a thin viscous sheet, producing spatially coherent deformation patterns over distances of 1000's of km. The general validity of the thin viscous sheet approximation implies that (1) the lithosphere is typically stable with respect to vertical motions in the upper mantle that impact the deforming plate and (2) the response of the lithosphere to stress is strongly non-linear; measurable deformation is activated only when the regional stress differences exceed some threshold that is locally variable and presumably depends on the thermal state of the lithosphere. The non-linear response is explicable in terms of the deformation mechanisms that are activated within the lithosphere. The stability to vertical motions is apparently due mainly to the compositional buoyancy of continental crust and possibly of depleted lithospheric mantle. Nonetheless vertical motions in the upper mantle, often near plate boundary zones, occur on a spectrum of length-scales and geometrical configurations. Where oceanic lithosphere remains, subduction may persist as at the Hellenic trench, and the length scale is typically defined by the along-strike length of the subducting plate fragment. Downwelling of mantle lithosphere at rates of $\sim$ 20 mm/yr beneath the SE Carpathians provides one of the clearest examples of short length-scale ($\sim$ 300 km) vertical motion beneath an apparently plate-like lithosphere. The cause of this activity is clearly shown by regional seismic tomography; a well-defined high velocity anomaly is inferred to correspond to a mass anomaly which drives an unusual level of seismic activity in the upper mantle above the mass. The seismicity in the structure beneath the SE Carpathians is unusual when compared to seismic anomalies beneath the eastern Alps and beneath the western USA that do not show comparable seismic activity. It seems likely that an additional factor like fluid mobilisation might be needed to explain the high rates of seismicity beneath the SE Carpathians. Where they are not seismically active, such velocity anomalies can only be detected and mapped using detailed regional seismic tomography, as for example the Isabella anomaly of California. In most other locations the data are not adequate to observe such structures. As with the broader-scale regional deformation of the lithosphere, there is a strong suggestion that the development of lithospheric gravitational instability requires a finite-amplitude disturbance consistent with the non-linear constitutive law for olivine at lithospheric temperatures. Abrupt lateral discontinuity of lithospheric structure produced by convergent, strike-slip, or extensional lithospheric deformation fields could produce the conditions for such instability, resulting in downwelling beneath the edge of thicker lithosphere.