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The Stability of Tibetan Mantle Lithosphere

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The large area of thickened crust beneath the Tibetan Plateau is a consequence of sustained continental convergence between India and the Eurasian land mass during the last ∼50 m.y. Although the Tibetan crust has thickened, there has been much debate about the consequences for its sub-crustal mantle lithosphere. The onset of crustal thinning in the late Miocene appears to require an increase in the gravitational potential energy of the plateau at that time. One explanation for that increase depended on the idea that the mantle lithosphere beneath Tibet had been replaced by asthenosphere, either by some form of convective thinning or by a delamination process akin to retreating subduction acting on the unstable lithospheric mantle layer. Such ideas seem consistent with the history of magmatism and volcanism on the plateau. However, the dispersion of surface waves crossing the plateau implies that a relatively cold and fast layer of mantle remains beneath the plateau to depths of at least 250 km. Because the surface wave data appear inconsistent with the idea that mantle lithosphere has been removed, we investigate an alternative explanation that could explain the apparent increase in gravitational potential energy of the Tibetan lithosphere. If that mantle lithosphere has remained largely in place due to an intrinsic compositional buoyancy but, on thickening, has become unstable to an internal convective overturn, then: (1) mantle material at near asthenospheric temperatures would be emplaced below the crust, and (2) colder mantle from beneath the Moho could become stranded above about 250 km depth. This mechanism is feasible if the Tibetan sub-continental mantle lithosphere is depleted and intrinsically less dense than the underlying asthenosphere. The mechanism is broadly consistent with the surface wave analyses (which cannot resolve the short horizontal wavelengths on which overturn is likely to occur), and it predicts the kind of short-wavelength variations that are revealed by body-wave tomography. The thermal re-equilibration of the disturbed lithosphere may take 100s of m.y. but there is a rapid transient transfer of heat as the coldest parts of the mantle lithosphere are juxtaposed with the asthenosphere and the hotter parts juxtaposed with the base of the crust. Heat transfer at the base of the lithosphere could explain a short-term uplift of the surface (∼500 m in ∼10 m.y.). Heat transfer at the Moho could cause lower-crustal melting and volcanism, and could trigger retrograde metamorphic reactions in the lowermost crust that would contribute to further uplift. The increase in gravitational potential energy of the lithosphere associated with surface uplift thereby can explain the onset of extension in the plateau.