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Gravity and GPS Measurements Reveal Mass Loss beneath the Tibetan Plateau - Geodetic Evidence of Increasing Crustal Thickness

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The Tibetan Plateau, the highest and largest plateau on Earth with mean elevation of 4.5 km and width of about one km, began rising about 50 million years ago [Tapponnier et al., 2001]. The continued northward movement of the Indian subcontinent deformed a large part of the plateau crust through folding and various faulting mechanisms. The high rate of seismicity along the Himalaya reflects that a collision between India and Asia is still thrusting the Tibetan Plateau upward. The huge mass of Asia to the west and north blocks the northward movement of the plateau crustal material. Consequently, northward movement on deep-seated thrust faults is transferred laterally to the east and southeast roughly along the eastwest trending strike-slip faults. The nearly northsouth trending strike-slip faulting in eastern Tibet and western Sichuan and the rotation of Indochina southeastward into the South China Sea can be interpreted as eastward and southeastward extrusion of Tibetan crustal blocks. The horizontal displacements obtained by GPS measurements in China show that crustal shortening accommodates most of the Indian penetration into Eurasia [Wang et al., 2001]. The Tibetan Plateau undergoes substantial internal shortening at the contraction rate of ca. 38 mm/yr between northern India and the rigid Alashan block. A continuum deformation appears to characterize the active tectonics of the Tibetan Plateau. However, this continuum deformation is apparently confined to the plateau itself. It is absorbed by crustal thickening, which causes vertical crustal movement, i.e., elevated topography of the Tibetan Plateau and a subsided crustal bottom at depth. The seismological tomographic evidence showing that the lithospheric crust under south Tibet has doubled to 80 km thickness [Chen and Yang, 2004] supports this hypothesis.

This report presents geodetic evidence of the increasing crustal thickness by gravity observations in the plateau area: a gravity change can reflect material transport accompanying vertical movements at the surface and on the crustal bottom, as described above. The vertical displacements add an additional gravity change; they must therefore be eliminated from the observed gravity at the surface to isolate the signal from mass changes. Combined absolute gravity and GPS measurements at three stations in southern and southeastern Tibet during two decades reveal uplifting of the Tibetan Plateau, but its underlying mass is diminishing. As the crust thickens, the mass of a column of rock beneath the station decreases because mantle is displaced by crust, causing a reduction in gravity. Continuous GPS measurements during 9-12 years reveal uplift, and negative gravity change rates are shown for 13-17 years. Removing the contribution of surface vertical displacement, gravity values on the deformed earth surface are transformed to those of a fixed point. Thereby, residual gravity changes reflect only the interior mass distribution.