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Channel flow, pure-shear crustal thickening, and the growth of Tibet: Evidence from azimuthal and radial seismic anisotropy

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Of the two debated, end-member models for the late-Cenozoic thickening of Tibetan crust, one invokes “channel flow” (rapid viscous flow of the mid-lower crust, driven by topography-induced pressure gradients and transporting crustal rocks eastward) and the other—“pure shear” (faulting and folding in the upper crust, with viscous shortening in the mid-lower crust). Deep-crustal deformation implied by each model is different and would produce different anisotropic rock fabric. Observations of seismic anisotropy thus offer a discriminant. We use broadband phase-velocity curves (1) —each a robust average of tens to hundreds of measurements—to determine azimuthal and radial anisotropy in the entire lithosphere-asthenosphere depth range and constrain its amplitude (2, 3). Inversions of the differential dispersion from path pairs, region-average inversions and phase-velocity tomography yield mutually consistent results, defining two highly azimuthally anisotropic layers with different fast-propagation directions within each: the middle crust and the asthenosphere. The distribution and complexity of published shear-wave splitting measurements can be accounted for by the different anisotropy in these two layers.

Fast-propagation directions in the mid-lower crust align with the directions of extension and flow. In southern and central Tibet, azimuthal anisotropy in the middle crust (20–45 km depths) is 3–5% and 4–6%, respectively, with E–W fast-propagation directions, parallel to the current extension at the surface (3). The rate of the extension is relatively low, however, whereas the large radial anisotropy in the middle crust requires strong alignment of mica crystals, implying large finite strain and consistent with high-rate horizontal flow (2). Together, radial and azimuthal anisotropy indicate eastward, mid-crustal channel flow in central Tibet, along the regional topography gradient.

In northeastern high Tibet, mid-crustal azimuthal anisotropy is 4–8% and has WNW–ESE and NW–SE fast-propagation directions, perpendicular to the net compression and parallel to the net extension at the surface. These fast directions are inconsistent with channel flow following the SW–NE regional topography gradient. Instead, they suggest similar net deformation in the deep and shallow crust. In the brittle upper crust, it is accommodated by strike-slip faulting; in the ductile mid-lower crust—by shear oriented at 45 degrees to the faults. Motions in the middle crust are thus decoupled from those in the upper crust. Although mid-crustal flow beneath NE Tibet may transport some material towards the plateau periphery at a low region-average rate, the dominant mid-crust deformation pattern is shear parallel to the plateau boundary. This implies that channel flow from central Tibet is not the main mechanism of the on-going crustal thickening in northeastern Tibet.

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