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Multi-layered azimuthal anisotropy beneath Tibet, constrained by broadband Rayleigh-wave dispersion

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The mechanism of the internal deformation that characterises the Tibetan Plateau is debated. A record of deformation at depth can be obtained from strain-induced anisotropy in crustal and mantle rocks. Studies of shear-wave splitting (birefringence of shear waves) have revealed strong anisotropy beneath Tibet. The distribution of the fast-propagation directions shows a broad regional trend, with the directions rotating around the eastern Himalayan syntaxis. A detailed examination, however, reveals that, in many locations, measurements from stations close to one another show different fast directions and split times, the latter ranging from null to >2 seconds. The origins of these apparent inconsistencies are still unclear. Furthermore, most shear-wave splitting analyses to date have been performed under the assumption that the splitting originates within a single anisotropic layer.

Surface waves provide depth resolution of seismic-velocity structure and anisotropy in the entire lithosphere-asthenosphere depth range. Understanding the depth dependence of anisotropy is essential in order to determine the mechanisms of Tibet's deformation, because the deformation itself is likely to be strongly depth-dependent. In this study we use inter-station measurements of phase velocities of Rayleigh surface waves. Using a few tens of highly accurate, broadband dispersion curves from across central and eastern Tibet, we apply a number of alternative surface-wave analysis approaches and determine robust patterns of phase-velocity anisotropy as a function of period. We then use these results to constrain the direction and amplitude of shear-velocity anisotropy as a function of depth and infer the dominant deformation mechanisms that operate in the crust and upper mantle beneath Tibet.

The crustal azimuthal anisotropy shows W-E and NW-SE fast-propagation directions in central and eastern Tibet, respectively. Special focus is given to northeastern Tibet, where the inferred fast directions are aligned southeast rather than northeast, as would be expected from an elevation-gradient induced flow. The fast azimuths are parallel to the extensional component of the current strain rate across Tibet, strongly suggesting similar deformation through the entire crust despite the mid-crust's greater susceptibility to deformation and flow. Furthermore, the close agreement of anisotropy and the extensional component of the current strain rate field with the traces of sutures (which are not active geological boundaries any longer but serve as markers of how the plateau has deformed) implies that the dominant deformation mechanism within the plateau has not changed since the initiation of continental collision and is still governed by the northward push of India.

The dynamics of the warm Tibetan asthenosphere beneath the northeastern plateau is characterised by a fast SSW-NNE shear-wave propagating direction. The amplitude of the anisotropy increases from south to north and its azimuth is parallel to that of India's plate motion. This suggests that the flow is associated with India's northward subduction beneath the Tibetan lithosphere and asthenosphere under the central and eastern plateau. The multi-layered anisotropy beneath Tibet with different azimuths in the crust and asthenosphere, accounts for the complexity of published shear-wave splitting observations.