Shear-Velocity Profiles Across the Tibetan Plateau from Broadband, Surface-Wave, Phase-Velocity Measurements

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In order to constrain variations in the crustal and lithospheric structure across Tibet, we measure phase velocities of seismic surface waves. The data are seismograms recorded by broadband instruments of permanent and temporary networks within and around the plateau. Phase-velocity measurements are performed in broad period ranges using an elaborate recent implementation of the 2-station method. A combination of the cross-correlation (Meier and others, 2004) and multimode-waveform-inversion (Lebedev and others, 2005) measurements using tens to hundreds of seismograms per station pair produces robust, accurate phase-velocity curves for Rayleigh and Love waves.

We use our new measurements to infer phase-velocity variations and to constrain S-velocity profiles in different parts of the plateau, including radial anisotropy and depths of lithospheric discontinuities. S-velocity profiles are computed using a non-linear gradient search and show a distinct crustal low-velocity zone (LVZ) in the 20–45 km depth range across the plateau, both in the south and in the north. We perform a series of targeted test inversions and show that the dispersion data constrains S velocity in this mid-crust low velocity layer to be within a 3.2–3.5 km/s range. This LVZ coincides with a low-resistivity layer inferred from magnetotelluric studies, interpreted as evidence for partial melting in the middle crust (Nelson and others, 1996, Unsworth and others, 2004). Surface-wave data are, also, consistent with strong radial anisotropy in this layer, indicative of horizontal flow (Royden and others, 2008). At the north-eastern boundary of the plateau, past the Kunlun Fault, S-velocity in the lower middle crust increases, although still relatively low. The mid-crustal LVZ, in the sense of an S-velocity decrease with depth in the 15–25 km depth range, is not required by the surface-wave data outside the plateau.

The mantle-lithosphere structure shows a pronounced contrast between the southern - south-western and central-northern parts of the plateau. The south and south-west are underlain by a thick, high-velocity, craton-like lithospheric mantle. Beneath the north, in contrast, the average S velocity between the Moho and 200 km depth is close to the global continental average (4.5 km/s). In order to investigate the finer detail of the lithospheric structure in the north, and keeping in mind the non-uniqueness of the S-velocity models, we perform an extensive series of test inversions. We find that surface-wave dispersion alone is consistent both with models that have low S velocity just beneath the Moho, increasing with depth below (McKenzie and Priestley, 2008), and with models that display a thin high-velocity mantle lid underlain by a low-velocity zone (asthenosphere). This non-uniqueness implies that a joint analysis of surface-wave data with data of other types may be necessary in order to determine the thickness of the lithosphere in the central and northern Tibet.

We combine our surface-wave measurements in the Qiangtang Block in central Tibet (Hi-Climb experiment area, north of the Banggong-Nujiang suture) with receiver-function constraints on the Moho depth (Tseng and others, 2009) and Sn constraints on the uppermost-mantle S velocities (Pei and others, 2007). We show that the data is matched significantly better with models that contain a thin, high-velocity lithosphere (up to 90 km thick) underlain by a low-velocity zone than by models with no wave-speed decrease between the Moho and ~100 km depth. In the deeper upper mantle (below ~150 km depth), S velocity increases and is likely to exceed the global average value.

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