Lithospheric Structure and Dynamics of Tibet: Constraints from Shear-Velocity Distribution

Sergei Lebedev[1], Matthew R. Agius[1]

[1] Geophysics Section, Dublin Institute for Advanced Studies, Dublin 2, Ireland, sergei@cp.dias.ie

Seismic-velocity structure of the crust and underlying upper mantle of Tibet reflects the physical state of the rock at depth and can offer essential constraints on the dynamics and evolution of the plateau. Data from a number of broad-band seismic experiments conducted in recent years, together with data from permanent stations in the region, produce dense coverage of the plateau and its surroundings. In spite of the intensive seismic study, however, even the basic elements of the lithospheric structure of Tibet are still disputed. The mid-crustal low-viscosity layer is thought to play a key role in the dynamics of the plateau (e.g., Royden and others, 2008), but both its lateral extent and its depth range in different parts of the plateau still need to be mapped in detail. Thick, cold mantle lithosphere is present beneath the Himalaya and southern Tibet but not in northern Tibet, according to a number of recent studies. The nature of the lithosphere, however, in particular in the north, has been debated.

We study seismic-velocity structure of Tibet using primarily surface waves and combine two main approaches: regional-scale multimode tomography (Lebedev and others, 2006, Lebedev and van der Hilst, 2008) and broadband inter-station analysis (Meier and others, 2004, Lebedev and others, 2005, Lebedev and others, 2009). We detect strong north-south variations in the seismic-velocity (and, by inference, thermal) structure of the lithosphere. Whereas the south-southwestern part of the plateau is underlain by thick, seismically fast, craton-like mantle lithosphere, the central-northern part, in contrast, displays *S* velocities that are close to the global continental mean, when averaged over the depth range from the Moho to ~200 km.

The north-south contrast in the lithospheric wavespeeds is a clear first-order feature, and can be seen in published tomographic models (e.g., Friederich, 2003, Priestley and others, 2006, Li and others, 2008). The finer seismic-velocity layering within the top 100-200 km of the mantle is more difficult to resolve, however. A series of targeted test inversions of our broadband phase-velocity curves shows that surface-wave dispersion data can be fit equally well with substantially different shear-velocity profiles. In particular, the models with a thin high-velocity lid (and a moderate low-velocity zone beneath it) and the models with a low-velocity layer just below the Moho (and an increase in shear velocity beneath it) can fit surface-wave data equally well. By combining the surface-wave data with additional constraints on the Moho depth and on the uppermost-mantle seismic velocities from receiver functions and *S*n mapping, respectively (e.g., Pei and others, 2007; Tseng and others, 2009), we are able to resolve the ambiguity, at least in some locations. For example, in the central Qiangtang Block in west-central Tibet (north of the Banggong-Nujiang suture in the Hi-Climb experiment area), the joint seismic data set can be matched significantly better with models with thin (<100 km) seismic lithosphere underlain by a low-velocity asthenosphere, compared to models without a low-velocity zone at 100-150 km. Our analysis can reconcile published tomographic models and other seismic evidence. It suggests that the lithosphere is, indeed, substantially thinner in the middle than it is in the south of Tibet.

Regional tomography and broadband dispersion data also agree regarding the presence of a mid-crustal low-velocity layer across the plateau. We show that the layer, with isotropic-average shear speeds in the range of 3.2-3.5 km/s between 20 and 45 km depths, is present both in the South and in the North of Tibet. Our results have important implications relating to the geodynamic evolution of the Tibetan Plateau.

References

Friederich, W., 2003, The S-velocity structure of the East Asian mantle from inversion of shear and surface waveforms, Geophys. J. Int., 153, 88-102.

Lebedev, S., Boonen, J. and Trampert, J., 2009, Seismic structure of Precambrian lithosphere: New constraints from broadband surface-wave dispersion, Lithos Special Issue, 109, 96-111.

Lebedev, S., Meier, T. and van der Hilst, R.D., 2006, Asthenospheric flow and origin of volcanism in the Baikal Rift area, Earth Planet. Sci. Lett., 249, 415–424.

Lebedev, S., Nolet, G., Meier, T. and van der Hilst, R.D., 2005, Automated multimode inversion of surface and S waveforms, Geophys. J. Int., 162, 951-964.

Lebedev, S. and van der Hilst, R.D., 2008, Global upper-mantle tomography with the automated multimode inversion of surface and S-wave forms, Geophys. J. Int., 173, 505–518.

Li, C., van der Hilst, R.D., Meltzer, A.S. and Engdahl, E.R., 2008, Subduction of the Indian lithosphere beneath the Tibetan Plateau and Burma, Earth Planet. Sci. Lett., 274, 157-168.

Meier, T., Dietrich, K., Stöckhert, B. and Harjes, H.P., 2004, One-dimensional model of shear wave velocity for the eastern Mediterranean obtained from the inversion of Rayleigh wave phase velocities and tectonic implications, Geophys. J. Int., 156, 45-58.

Pei, S., and others, 2007, Upper mantle seismic velocities and anisotropy in China determined through Pn and Sn tomography, J. Geophys. Res., 112, B05312.

Priestley, K., Debayle. E., McKenzie, D. and Pilidou, S., 2006, Upper mantle structure of eastern Asia from multimode surface waveform tomography, J. Geophys. Res., 111, B10304, doi:10.1029/2005JB004082.

Royden, L. H., Burchfiel, B. C. and van der Hilst, R. D., 2008, The Geological Evolution of the Tibetan Plateau. Science, 321, 1054-1058.

Tseng, T.L., Chen, W.P. and Nowack, R.L., 2009, Northward thinning of Tibetan crust revealed by virtual seismic profiles, Geophys. Res. Lett., 36, L24304.

Cite as: Lebedev, S. and Agius, M.R., 2010, Lithospheric structure and dynamics of Tibet: Constraints from shear-velocity distributions, *in* Leech, M.L., and others, eds., Proceedings for the 25th Himalaya-Karakoram-Tibet Workshop: U.S. Geological Survey, Open-File Report 2010-1099, 2 p. [http://pubs.usgs.gov/of/2010/1099/lebedev/].