The thermal structure and composition of Tibetan crust and upper mantle

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Surface-wave tomography studies by a number of groups shows that material with high shear-wave velocity is currently present everywhere beneath the Tibetan Plateau. A variety of other seismic observations such as regional Sn propagation and teleseismic S-wave delays support the surface-wave observations. These seismic observations suggest that most of the plateau has been underthrust by high wave-speed Indian mantle from the south and possibly, to a lesser extent, high wave-speed Asian mantle from the north.

Low shear-wave velocities in the upper mantle beneath northern Tibet have previously been noted and these, along with the recent volcanism in northern Tibet, led one of us to propose that the lithosphere beneath Tibet had delaminated as a result of a convective instability caused by shortening (Houseman, McKenzie and Molnar, 1981). However, more recent seismic observations show that these low shear-wave velocities are a relatively shallow feature (less than about 130 km) and conversion of the shear-wave velocity structure to temperature (Priestley and McKenzie, 2006) demonstrate that at deeper depths the Tibetan upper mantle is cool with respect to the surrounding mantle. Therefore, the lithosphere extends to almost 300 km depth beneath most, if not all, the plateau. Consequently, the delamination proposed by Houseman et al is wrong. Thermal modeling suggests that the low velocity sub-Moho mantle beneath central and northeast Tibet results from radioactive heating of the thickened Tibetan crust. With increasing time, this crustal radioactive heating causes a temperature inversion which heats the lower crust and uppermost mantle, thus lowering the sub-Moho shear velocity. Therefore, cold lithosphere has not been removed by delamination, and, at least in the northern part of the plateau, the mantle beneath the Moho is hotter than that at greater depths.

This unexpected behavior can be understood if the density of the lithosphere is a function of both its temperature and its composition. Mantle nodules brought to the surface by melts show that much of the continental lithosphere has been depleted by melt removal, leaving a harzburgite whose density is substantially less than that of the fertile mantle. The trace element composition of basaltic rocks from northern Tibet shows that their source rocks were harzburgites that had been enriched by a few percent of metasomatic melt. The melting must be occurring in the mantle, probably at shallow depths beneath the Moho, where the shear wave velocity is low and where the temperature is increasing because of downward conduction of heat generated by radioactive decay within the crust. The density of the harzburgitic source rock for the magmas is about 63 kilograms per cubic meter less than the density of fertile mantle. Therefore, while the Tibetan lithosphere has been thickened by shortening, it is stabilized by its lower density relative to the density of the fertile upper mantle. A similar upper mantle lithosphere is currently forming beneath the Zagros compressional belt in western Iran and trace element analysis of the volcanics within the compressional belt indicate a similar depleted and low density source for the magmas. However, gravity and GPS observations demonstrate that the Tibetan lithosphere is mobile and where it is not constrained by old, strong lithosphere, it flows and thins.

References

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