Heating the Over-Thickened Lithosphere, downward from Crust or upward from Mantle?

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Surface wave tomography shows that the thickness of the lithosphere beneath Tibet plateau is now about 300 km (Priestley and McKenzie, 2006). Their result suggests that the process that generated the thickened crust beneath Tibet plateau has resulted in thick lithosphere that extends beneath the whole plateau. Meanwhile, there is no evidence of large scale lithospheric removal since the formation of the plateau; thus, the thick lithosphere must be stabilized against convective instability, most probably by depletion (McKenzie and Priestley, 2008). They argued that the thick depleted lithospheric mantle to have been produced by shortening, to transport the depleted material downwards to form the mantle "keel". The downward conduction of heat generated by radioactive decay within the over-thickened crust causes the increasing of temperature and melting in the deep crust and the shallow mantle, and results in regional metamorphism and magmatism. When the crustal temperatures exceed the granite solidus, melting will occur, and the upward movement of melt will transport the elements that generate heat to the upper part of the crust. After the upper 30–40 km of this thickened crust has been removed by erosion, the Tibet will eventually become a craton. However, we find that the heat production rate used in the modelling of McKenzie and Priestley (2008) is too high. In their model, the upper and lower crustal thickness are 20 km and 5 km, with heat production rates of 2 $\mu W/m^3$ and 0.4 $\mu W/m^3$ respectively. This means that the average heat production rate of crust is 1.68 $\mu W/m^3$, two times of the global average for continental crust (Rudnick and Gao, 2003; Wang, 2006). Accordingly, crustal heating model can not explain the lithospheric thermal evolution of Tibet plateau.

Instead we propose the mantle heating model in here. If lithospheric removal has not occurred beneath Tibet, the only other heat source available should be mantle radioactivity. The lithospheric mantle beneath Tibet had been enriched from poly-phase subduction. Thus, after shortening the entire lithosphere, the radioactive elements fertile mantle became very thick, and the heat generation within the lithospheric mantle contributed a rather large portion of mantle heat flow. If the fertile mantle has average heat production rate are 0.1 $\mu W/m^3$, the mantle heat flow by radioactive decay in the 120 – 150 km thick mantle varies from 12 mWm^{-2} to 15 mWm^{-2}. This enhanced mantle heat flux can produce the same thermal effects as the crustal heating model suggested by McKenzie and Priestley (2008). The upward conduction of heat generated by radioactive decay within the over-thickened fertile lithospheric mantle will cause the increasing of temperature in the deep crust and the shallow mantle, and results in the decrease of seismic velocity in the shallow mantle, which is observed in the north part of Tibet plateau. When the temperatures in shallow mantle exceed the peridotite solidus, melting will occur, and the upward movement of melt will transport the heat-producing elements to the crust. Eventually, the over-thickened lithospheric mantle loses a lot of heat-producing elements, and cools down. Compared to the Archean undifferentiated crust, heat-producing elements are enriched in upper part of the Phanerozoic continental crust. Thus, we prefer the mantle upward heating rather than the crust downward heating to explain the thermal evolution of the over-thickened continental lithosphere formed in Phanerozoic epoch, such as Tibet plateau.

This study is supported by China 973 Program (Grant No. 2008CB425704), the National Natural Science Foundation of China (40572128, 40376013, 40104003), and the Fundamental Research Funds for the Central Universities (No. 2010ZD15 and 2010ZY23).

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