Large contrasts in crustal structure and composition between the Ordos plateau and the NE Tibetan plateau from receiver function analysis

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Abstract

The Ordos plateau located in the western side of the North China craton is a distinct aseismic block. The plateau is bounded on the south and east, respectively, by the Paleozoic-Mesozoic Qinling orogenic belt and the Taihangshan mountain range. A series of graben systems were developed late in Cenozoic around the southern and eastern margins of the plateau. The Ordos is also bordered on the southwest by the northeastern (NE) margin of the Tibetan Plateau formed by the Cenozoic India-Eurasia collision. Tapponnier et al. (2001) suggested that the rise of the Tibetan plateau occurred progressively from south to north, and that crustal thickening was accommodated by shortening along the compressional direction. On the other hand, Clark and Royden (2000) proposed that the topographic relief along the eastern and NE margins of the plateau is maintained by dynamic pressure from a lower crust flow. Injection of lower crustal material from the central plateau to the edges inflated the crust along the borders of the plateau. In other words, crustal thickening occurred mainly in the lower crustal level. In general mafic rocks have higher Vp/Vs ratios than felsic rocks (Zandt and Ammon, 1995; Christensen, 1996). Thus seismic measurements of Vp/Vs ratio across the area could be used to diagnose whether the crustal shortening model or the lower crustal flow model is a more appropriate explanation for the crustal thickening observed along the NE corner of the Tibetan plateau.

We analyzed thousands of receiver-function data recorded by 182 national and regional stations of the broadband seismic network operated by the China Earthquake Administration to study the crustal structure beneath the Ordos plateau and the northeastern margin of the Tibetan plateau. Crustal thickness and average crustal Vp/Vs ratio were measured at each station. The Ordos plateau is underlain by a moderate thick crust with an average Moho depth ~40 km. The Trans-North China Orogen east to the Ordos is featured by a thin crust varying from 25-35 km. The Weihe Graben at the southern border of the Ordos plateau is lying above a ~30-km thin crust, while its southern neighbor, the Qinling orogenic belt has a thick root extending to as much as 45 km deep. Crust beneath the northeastern margin of the Tibetan plateau varies from 55 to 65 km (Figure 1).

We found a remarkable contrast between the Tibetan and Ordos plateaus in the measured Poisson’s ratio: the Ordos plateau is featured by a high Poisson’s ratio \( \frac{V_p}{V_s} = 1.761, \sigma = 0.261 \) while the Tibetan margin has a very low Poisson’s ratio.
$V_p/V_s = 1.714, \sigma = 0.240$. Laboratory studies indicated that the Poisson’s ratio is a good indicator of crustal composition (e.g., Christensen, 1996). Pressure and temperature appear to have little effect on it. The relative abundance of quartz ($V_p/V_s = 1.49, \sigma = 0.090$) and plagioclase ($V_p/V_s = 1.87, \sigma = 0.300$) has a dominant effect on the Poisson’s ratio of common igneous rocks and their metamorphosed equivalents. An increase in plagioclase content or a decrease in quartz content can increase the Poisson’s ratio of a rock. For example, the Poisson’s ratio increases from 0.240 for granitic rock, to 0.269 for diorite, and to 0.300 for gabbro (Tarkov and Vavakin, 1982). The mafic/ultramafic igneous rocks generally have high Poisson’s ratios because they usually contain gabbro and peridotite or dunite, which originate from magmatic differentiation. The measured lower ratio thus indicate that the crustal column beneath the NE margin of the Tibetan Plateau is rather felsic and is inconsistent with the lower-crust injection model. This lower crustal flow model also has difficulty in explaining the thin crust beneath the Weihe Graben. The observed contrast in the Poisson’s ratio, on the other hand, agrees with the observed surface deformation that indicates the Ordos plateau is mechanically stronger than the Tibetan plateau.

Figure 1. (a) Moho relief map inverted from observations at stations shown as black triangles.
Note the gradual increase of Moho depth from east to west. Also note the thin crust beneath the Weihe graben at the southern edge of the Ordos plateau. (b) Map of lateral variations for the Poisson’s ratio. The color contour is calculated from observations at stations shown by black triangles.

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