Geophysical Research Abstracts
Vol. 20, EGU2018-11077, 2018
EGU General Assembly 2018

Seismic tomography of the Qilian Orogenic Belt in Northwestern China and its geodynamic implications

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The Qilian Orogenic Belt is an important tectonic unit located in the northeastern margin of the Tibetan Plateau. The detailed three-dimensional (3-D) seismic velocity structure of the crust and uppermost mantle under the Qilian Orogenic Belt (QLOB) is important for better understanding the Cenozoic deformation mechanism of the QLOB [U+FF0C] the deep tectonic relationship between the QLOB and the North China Craton and the causal mechanism of the large crustal earthquakes occurred in the study region. In this work, we determine a high-resolution 3-D tomographic model of the crust and uppermost mantle beneath the QLOB applying a state-of-the-art tomographic method to the data set used in this study, which consists of 75,999 P-wave and 72,178 S-wave arrival times of 7485 local earthquakes recorded at 72 seismic stations during 2009 to 2015.
Our tomographic results reveal strong lateral and vertical variations of Vp and Vs in the crust and uppermost mantle under the QLOB. The velocity images at 2-10 km depths in the upper crust are generally consistent with the surface geological features, which show that the low-V and high-V anomalies in the upper crust are generally distributed in sedimentary basins and mountainous areas, respectively. Obvious low-velocity (low-V) anomalies are revealed in the lower crust beneath the Qilian Orogenic Belt and the low-V zones extend to the uppermost mantle in a few local areas. Combining with other geophysical evidences, these features are interpreted as mechanically weakened zones caused by fluids and melt related to the northward extension of the Tibetan Plateau and local hot upwelling in the upper mantle. The weakened zones in the lower crust are capable of ductile flow on a geological timescale, and the distribution of the low-V zones indicates that the scale of the ductile flow is not very large. High-V anomalies exist in the deep crust and uppermost mantle beneath the Northern Qilian belt and the Corridor Transition belt, which may represent the subducted lithosphere of the Alashan Block beneath the Qilian Orogenic Belt related to the Indo-Eurasia collision. Most of the large crustal earthquakes in our study region occurred in large fault zones where Vp and Vs change drastically in a short distance. Beneath the source areas of the large earthquakes, low-V anomalies exist widely in the lower crust and uppermost mantle. These results indicate that the occurrence of large earthquakes may be attributed to faults, stress and fluids and are strongly affected by the dynamic processes in the lower crust and uppermost mantle. A single model cannot explain all of the geologic and geophysical observations in the northeastern margin of the Tibetan Plateau. Rather, several processes (e.g., continental lithosphere subduction, lower crust ductile flow and hot upwelling in the upper mantle) operated together throughout the orogen and changed in relative importance through time and space.