Geophysical Research Abstracts
Vol. 20, EGU2018-1690-1, 2018
EGU General Assembly 2018

High-resolution topography-derived slip distribution along the South Heli Shan fault at the northeastern Tibetan Plateau in China

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Constraining the along-fault slip distribution provides an insight into the rupture process and strain release pattern on the fault, thus enabling us to make more accurate estimates of its potential future behavior, greatly benefitting seismic hazard assessment. Recently, with the increasing availability of high-resolution topographic data, both the accuracy and spatial density of the offset measurements can be significantly improved compared to traditional field surveys, which will greatly enhance our understanding of fault behavior. The South Heli Shan fault is a reverse fault located on the northern margin of the Hexi Corridor. It is an important component of the latest active faults on the northeastern Tibetan Plateau, and also suggested to be the causative fault of some historical earthquakes. In this study, a 2 m DEM of the South Heli Shan fault was built from the high resolution stereo images of the GeoEye-1 satellite. Based on the high resolution topographic data, we made detailed tectono-geomorphic interpretations and then acquired a total of 302 vertical displacement measurements along the fault strike, increasing the observation density by nearly a factor of 5 compared to previous field surveys.

Our results show that the vertical displacements display a generic asymmetric shape along the fault strike with a clear increasing trend from the west to the east, indicating that the fault may has been propagating westward over its whole history, and the maximum slip of each rupture may has been produced on the eastern part of the fault where the fault structural maturity is much greater. The good consistence between the vertical displacement distribution and the topographic relief suggests that the uplift of the Heli Shan may mainly be controlled by the long-term activity of the South Heli Shan fault. The vertical displacements fall into different clusters on different segments of the fault, indicating that the fault has been ruptured by large earthquakes for several times. Based on the displacement clusters on different segments, we conclude that at least four large earthquakes have ever occurred on the South Heli Shan fault, resulting in the variation of cumulative displacements on different geomorphic units. These events do not recur as the characteristic earthquake model along the whole fault, but may follow a characteristic slip pattern on each individual segment. The smallest clusters on the middle and east segments, corresponding to the scarps with a height of about 0.4∼0.6 m discovered on the youngest geomorphic unit, may be attributed to the most recent 756 A.D. Zhangye-Jiuquan earthquake. The first cluster of about 0.4∼0.6 m on the west segment and the second cluster of about 0.9∼1.7 m on the middle and east segments may be associated with the prior 180 A.D. Biaoshi earthquake. By constraining slip-length distribution of the two historical earthquakes, and applying scaling relationships between the moment magnitude and each of the rupture length and the maximum slip, we obtain Mw 6.9 and Mw 6.5 for the 756 A.D. Zhangye-Jiuquan earthquake, and Mw 7.1 and Mw 6.7 for the 180 A.D. Biaoshi earthquake, respectively.