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Coseismic and postseismic slip ruptures for 2015 Mw 6.4 Pishan earthquake constrained by static GPS solutions

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ABSTRACT

On 3 July 2015, a Mw 6.4 earthquake occurred on a blind fault struck Pishan, Xinjiang, China. By combining Crustal Movement Observation Network of China (CMONOC) and other Static Global Positioning System (GPS) sites surrounding Pishan region, it provides a rare chance for us to constrain the slip rupture for such a moderate event. The maximum displacement is up to 12 cm, 2 cm for coseismic and postseismic deformation, respectively, and both the deformation patterns show a same direction moving northeastward. With rectangular dislocation model, a magnitude of Mw6.48, Mw6.3 is calculated based on coseismic, postseismic deformation respectively. Our result indicates the western Kunlun range is still moving toward Tarim Basin followed by an obvious postseismic slip associated with this earthquake. To determine a more reasonable model for postseismic deformation, a longer GPS dataset will be needed.

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1. Introduction

On 3 July 2015, at 01:07 UTC (local time at 09:07), an earthquake of Mw6.4, at a depth of 15 km, occurred at the north front of western Kunlun Mountain, about 133 km SE of Shache and 162 km WNW of Hetian. The epicenter, located only about 15 km southwest of Pishan city (USGS). In the first few days, after the main shock, there were thousands of aftershocks ($M \geq 2$) in the adjacent area; most of these aftershocks reveal an approximately fault strike direction (Fig. 1). According to the field geological investigation [1], no surface rupture was found which indicated the seismogenic fault was a blind fault beneath the surface ground. In spite of a moderate buried-rupture event, there were six people killed, hundreds of people injured, and more than 5000 housed destroyed [2]. In the past 40 years, only a couple of reverse-faulting earthquake ($M < 5.6$) occurred in this area, and none above M6.0 was recorded, implying that the seismicity is low [2,3]. This 2015 Pishan event significantly exceeded the expected seismic magnitude, which would lead a serious damage for the local constructions with their low antiseismic level. However, the detailed mechanisms of history earthquakes were unclear in consequence of few adequate geodetic observations in this area.

This 2015 Pishan earthquake just located between southwest boundary of the Tarim Basin and north front of western Kunlun range. According to the previous studies [3,6], the western Kunlun Mountain was one of the most important tectonic syntaxis of Tibetan Plateau, which extends along the range front, and there is a fast shortening of the upper crustal

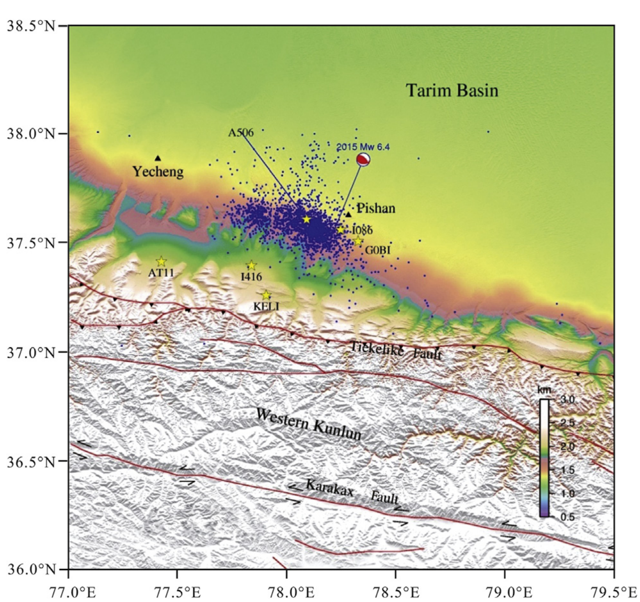

Fig. 1 – Active tectonics of the western Kunlun Mountain superimposed on a 3-arcsecond SRTM Digital Elevation Model (DEM). Red lines depict active faults [4]. Beachballs represent fault-plane solutions from the Harvard CMT catalogue, while the blue points show the aftershocks from the GCMT catalogue [5]. Yellow stars were the re-surveyed GPS sites.

nappe since approximately 12 Ma has been well attested. There are three main fault segments including in this active area (Fig. 1), such as the left-slip Karakax Fault, an echelon left-lateral fault, and this western thrust system [3]. Geodetic observations indicate no more than 5 mm/yr coverage between western Tibet and Tarim [7]. Due to a thick desert covered, it is difficult to determine the rupture deformation for an earthquake through a field geological survey in this area [8]. Moreover, there is approximately 50 km region surrounding Pishan earthquake with no active Holocene faults found, according to the active tectonic map of China.

As a rare chance to gain insights into the interaction between western Tibetan and Tarim, many studies focus on this event with different datasets, such as seismic reflection profile [1,8], Synthetic Aperture Radar Interferometry (InSAR) [9], and the Global Positioning System (GPS) [3]. All of them suggest that this event occurred at depth of 10–15 km on a buried fault except for slightly different dip angle. Seismic reflection profile is helpful to delineate the subsurface geometry of each fault segment in the fold belt, but which could not give a surface deformation and slip rupture produced by the seismogenic fault. InSAR is a powerful relative measurement tool with wide surface coverage which has been successfully used for many earthquakes, but atmospheric disturbance limits its precision at level of 1–2 cm [3,9]. In contrast to the above two measurements, GPS is an absolute measurement means which could provide 3-D surface displacement with high precision, especially in horizontal direction. Thanks to the resurvey GPS work of our group, it provides a chance for us to independently discuss both the coseismic and postseismic process for this event with only GPS observations.

In this article, both the coseismic and postseismic displacements associated with Pishan event are observed by “in-situ” static GPS measurements. Due to pre-earthquake surveys of these sites were carried out in different years by different agencies, the interseismic deformation must be considered before the coseismic deformation acquired. With another resurvey 5 months after the main shock, a postseismic deformation is estimated. Based on those GPS observations, both the coseismic and postseismic slip ruptures are constrained, and then potential seismic hazards in this area are discussed.

2. GPS data and processing

2.1. Data set

Usually, it is hard to find enough GPS sites in near-field to constrain the slip rupture for a moderate thrust event, because of its low surface deformation magnitude. It could be seen in Fig. 1 and Table 1 there are only two GPS sites in Crustal Movement Observation Network of China (CMONOC) near the epicenter of Pishan event. Fortunately, several groups implemented a GPS campaign based on the geodetic triangular point in Xinjiang Province around 2000 (Table 1), which makes it possible to improve the GPS site density and capture enough observations for this event in near-field region. There are totally 6 sites employed in this study,