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The July 11, 1995 Myanmar–China earthquake: A representative event in the bookshelf faulting system of southeastern Asia observed from JERS-1 SAR images

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ABSTRACT

On July 11, 1995, an Mw 6.8 earthquake struck eastern Myanmar near the Chinese border; hereafter referred to as the 1995 Myanmar–China earthquake. Coseismic surface displacements associated with this event are identified from JERS-1 (Japanese Earth Resources Satellite-1) SAR (Synthetic Aperture Radar) images. The largest relative displacement reached 60 cm in the line-of-sight direction. We speculate that a previously unrecognized dextral strike-slip subvertical fault striking NW–SE was responsible for this event. The coseismic slip distribution on the fault planes is inverted based on the InSAR-derived deformation. The results indicate that the fault slip was confined to two lobes. The maximum slip reached approximately 2.5 m at a depth of 5 km in the northwestern part of the focal region. The inverted geodetic moment was approximately Mw = 6.69, which is consistent with seismological results. The 1995 Myanmar–China earthquake is one of the largest recorded earthquakes that has occurred around the "bookshelf faulting" system between the Sagaing fault in Myanmar and the Red River fault in southwestern China.

1. Introduction

On July 11, 1995 at 21:46 UTC, an Mw 6.8 earthquake struck eastern Myanmar near the Chinese border (Global Centroid Moment Tensor (GCMT) database) (Figs. 1 and 2; Table 1). The focal mechanism was a strike-slip fault (Fig. 1; Table 1). The mainshock damaged a large area in eastern Shan State, Myanmar and southwestern Menglian County, China, killed 11 people in China and caused more than 205 million Yuan in damage in China (http://www.csi.ac.cn/manage/html/4028861611c5c2ba0111c5c558b00001/zhenli/zeren/html/zhenli146.htm). According to the Yunnan Seismic Network Center catalogue, the 1995 Myanmar–China earthquake was preceded by two moderately-sized foreshocks of M_L 5.5 and M_L 6.2. Over the following 100 days, the mainshock was followed by 872 aftershocks with local magnitudes over 2.0. The largest aftershock, with M_L 5.1, occurred just 8 min after the mainshock. Most of the recorded aftershocks occurred within 100 days of the mainshock (Fig. 3). Fig. 3 shows the decay rate of the aftershocks, which falls within the typical range for aftershock sequences (Utsu and Ogata, 1995). The cumulative moment released by the aftershocks in the 100 days following the mainshock was 5.3×10^{17} Nm, which is equivalent to 4% of the energy released by the mainshock.

Study of the fault geometry and slip distribution associated with the 1995 Myanmar–China earthquake can elucidate the deformation style of this seismically active area. For this study, coseismic deformation associated with thisis detected using synthetic aperture radar (SAR) interferometry (InSAR) based on Japanese Earth Resources Satellite-1 (JERS-1) data. Slips on fault planes are documented and investigated using InSAR-derived deformation data. The results indicate that the 1995 Myanmar–China earthquake was associated with a previously unmapped fault. This earthquake was one of the strongest events recorded in the "bookshelf faulting" system of southwestern China and eastern Myanmar.

2. Tectonic setting

The Indian plate converges with Eurasia at a rate of approximately 40 mm/yr; half of this motion is accommodated by shortening across the Himalayas (e.g., Paul et al., 2001; Bettinelli et al., 2006). On the eastern edge of the Indian subcontinent, half of

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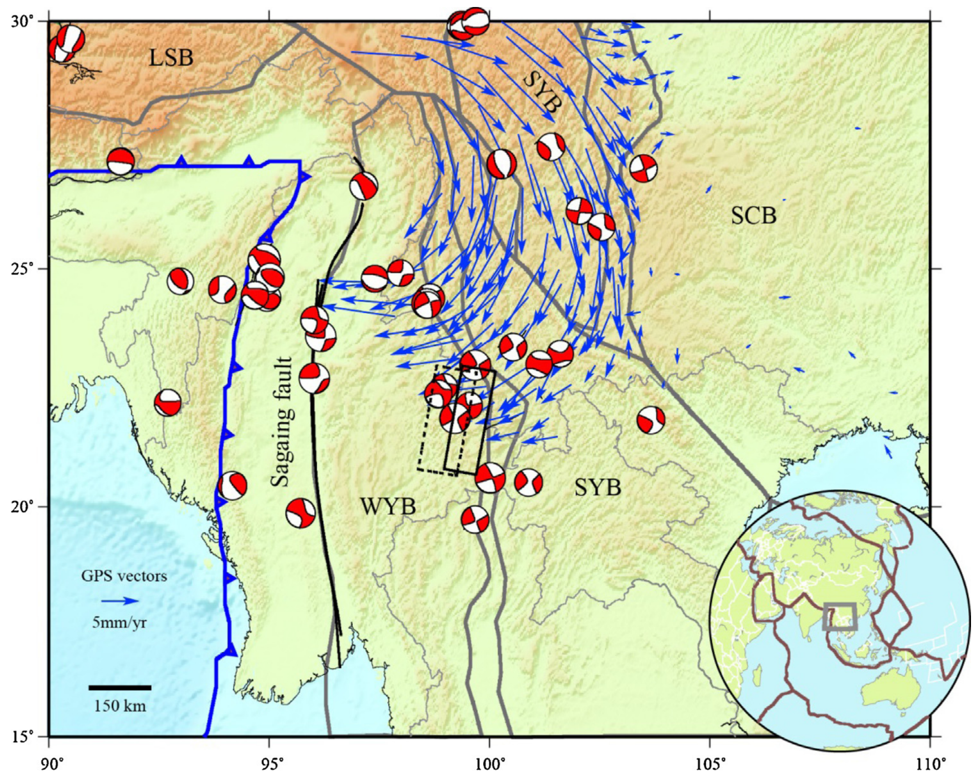

Fig. 1. Seismotectonic map of the interaction between the Indian plate to the southwest and the Eurasian plate to the northeast. Shaded relief topography is derived from the Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) at a 90-m resolution. Earthquake focal mechanisms, retrieved from the GCMT catalogue, are Mw 6.0+ from the period 1976–2015. The blue barbed line indicates the plate boundary between the Indian plate and the Eurasian plate. Gray lines show block boundaries as mapped by Zhang et al. (2003): LSB, Lasa block; WYB, western Yunnan block; SYB, southern Yunnan block; SYB, Sichuan–Yunnan block; and SCB, South China block. GPS vectors (blue arrows) are relative to the stable SCB. Boxes represent the radar scenes (Table 2; Fig. S1) used in this study (the left box, dotted, indicates Track 133, and the right box, solid, indicates Track 132). The black line represents the Sagaing fault as mapped by Tapponnier et al. (2001). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Focal mechanism solutions of the 1995 Myanmar–China earthquake from the catalogues of the NEIC and GCMT, and from Ma and Hao (1997).

Source	Magnitude(Mw)	Depth(km)	NP1 (Strike, Dip, Rake)	NP2 (Strike, Dip, Rake)
NEIC	6.7	13.0	59°, 86°, −9°	149°, 81°, −176°
GCMT	6.8	15.0	60°, 85°, 1°	330°, 89°, 175°
Ma and Hao (1997)	6.8	12.0	62°, 90°, 2°	332°, 88°, 180°

the northward component of this motion relative to South China is accommodated by the Sagaing fault, a major dextral strike-slip fault around the eastern Himalayan syntaxis (e.g., Socquet et al., 2006; Wang et al., 2014a) (Fig. 1). The remaining motion between the Indian plate and the South China block is accommodated by southeastward/southward/southwestward movement of three blocks, including the Sichuan–Yunnan block (SYB), the western Yunnan block (WYB) and the southern Yunnan block (SYB). GPS measurements suggest an approximate relative velocity of 10 mm/yr between the SYB, WYB, SYB and the SCB (Fig. 1). Several strong earthquakes (Mw ≥ 6.0) have occurred near the Myanmar–China border between 1976 and 2015 (Fig. 1), which shows that the SYB, WYB and SYB have accommodated a portion of the broad zone of deformation between the Indian plate and the South China block. For instance, on March 24, 2011, a large earthquake (Mw = 6.8) occurred in eastern Myanmar near its borders with Thailand and Laos (e.g., Sun et al., 2013; Zhou et al., 2013; Wang et al., 2014b; Phodee et al., 2015).

3. InSAR observations

Because of the sparseness of the geodetic arrays, coseismic deformation associated with the 1995 Myanmar–China earthquake was not previously identified. Moreover, because fieldwork investigation was not carried out following the earthquake, the seismogenic fault was not identified. The application of satellite-based monitoring techniques, such as InSAR, is therefore highly advisable in this case. InSAR has been an important tool for imaging coseismic displacement and estimating source parameters since its first use for the June 1992 M 7.3 Landers earthquake (Massonnet et al., 1993; Wright et al., 2004; Biggs et al., 2010; Li et al., 2011; Elliott et al., 2012; Amighpey et al., 2014; Motagh et al., 2015). For the 1995 Myanmar–China earthquake, coseismic deformation was successfully captured by the JERS-1 radar sensor, which has allowed for construction of three interferograms with favorable temporal and spatial baselines (Table 2), despite the vegetation and high relief of the area.