Journal of Asian Earth Sciences 109 (2015) 29–37

Contents lists available at ScienceDirect

Journal of Asian Earth Sciences

journal homepage: www.elsevier.com/locate/jseaes

M_W 4.9 earthquake of 21 August, 2014 in Kangra region, Northwest Himalaya: Seismotectonics implications

Mithila Verma [a], Anup K. Sutar [b], Brijesh K. Bansal [b,*], B.R. Arora [b], G.M. Bhat [c]

[a] National Center for Seismology, Ministry of Earth Sciences, New Delhi 110003, India
[b] Geoscience Division, Ministry of Earth Sciences, New Delhi 110003, India
[c] Department of Geology, Jammu University, Jammu 180016, India

ARTICLE INFO

Article history:
Received 8 December 2014
Received in revised form 24 April 2015
Accepted 11 May 2015
Available online 19 May 2015

Keywords:
Kangra Himalaya
1905 Kangra earthquake
Chamba nappe
Earthquake source parameters
Seismotectonics

ABSTRACT

A moderate earthquake (M_L 5.0, M_W 4.9) occurred in the Kangra region of Himachal Pradesh on 21 August, 2014 (08:11 UT). The earthquake attains significance as it occurred immediately northeast of the source zone of the large Kangra earthquake of 1905 (M_W 7.8), the source mechanism of the later earthquake remains a subject of debate. Further, the seismic event is nucleated in a narrow block, where intense clustering of small and moderate events has been indicated by earlier campaign mode surveys. Taking advantage that recent earthquake is well recorded by a regional BBS network, the source parameters are estimated and interpreted to provide fresh constraint on the elements of seismotectonic model. The earthquake with its epicenter at 32.34°N and 76.52°E is seated on the Panjal Thrust, boundary between Panjal imbricate zone and the Chamba nappe. The travel time inversion and wave form inversion technique suggest focal depth no more than 5 km. A stress drop of 92 bars and a source radius of 1.1 km. The moment magnitude (M_W) for this event is calculated as 4.9. The anomalous high value of stress drop compared to the generally low values prevailing over much of the Kangra–Chamba region indicates that the earthquake of 21 August 2014 is rooted in crustal blocks characterised by strong material strength to support accumulation of high strain during the earthquake building cycle. Fault plane solution of the event under study suggested that source fault is striking 323° with dip of 34°. The rake value of 105° indicated thrust movement with a very negligible right lateral movement. Synthesis of source parameters, especially the shallow focal depth, strike paralleling the Panjal thrust/MBT with steep dip, favour the seismotectonic model where moderate magnitude earthquake of 21st August 2014 is a typical example caused by the reverse fault displacement on the Panjal thrust fault. In the compressive regime of the Kangra Himalaya, such movements are facilitated by the stresses resulting in response to the southward sliding of the Chamba nappe and thus activating the contact zone between the nappe and Panjal imbricate zone.

1. Introduction

A moderate magnitude earthquake (M_L 5.0, M_W 4.9) occurred on 21st August, 2014 (8:11 UT) in the Kangra–Chamba region of the Himachal Pradesh (Fig. 1). The earthquake was felt in Kangra, Chamba, Mandi and Shimla districts of Himachal Pradesh with no loss to life reported from anywhere. However, the earthquake drew attention as it is located in the close proximity, only 25 km northeast, of the 1905 Kangra earthquake that accounted death toll of about 20,000 and about 100,000 buildings were destroyed (Middlemiss, 1910). This earthquake was of exceptional scientific interest due to development of two high intensity seismic zones-one in Kangra and the other in Dehradun-Musoorie region. Srivastava et al. (2010) showed that the later meizoseismal area was a site response effect and not due to two earthquakes as suggested by Hough et al. (2005). In the absence of instrumental records, epicenter and magnitude of the 1905 Kangra earthquake were estimated by the intensity and extent of damage patterns (Middlemiss, 1910). Magnitude was initially estimated at M 8, but later downgraded to M 7.8 (Ambraseys and Douglas, 2004). The source parameters, including length of the rupture, fault mechanism, strain budget continue to be subject of debate (e.g. Hough et al., 2005; Wallace et al., 2005; Srivastava et al., 2010; Verma et al., 2014). Since 1905, the region is seismically quiet in terms of large magnitude earthquake; no earthquake of $M > 7$, six earthquakes of magnitude 6 occurred during the period 1900–1950; the

* Corresponding author.
E-mail addresses: bansal.moes@gmail.com, bansalbk@nic.in (B.K. Bansal).

http://dx.doi.org/10.1016/j.jseaes.2015.05.006
1367-9120/

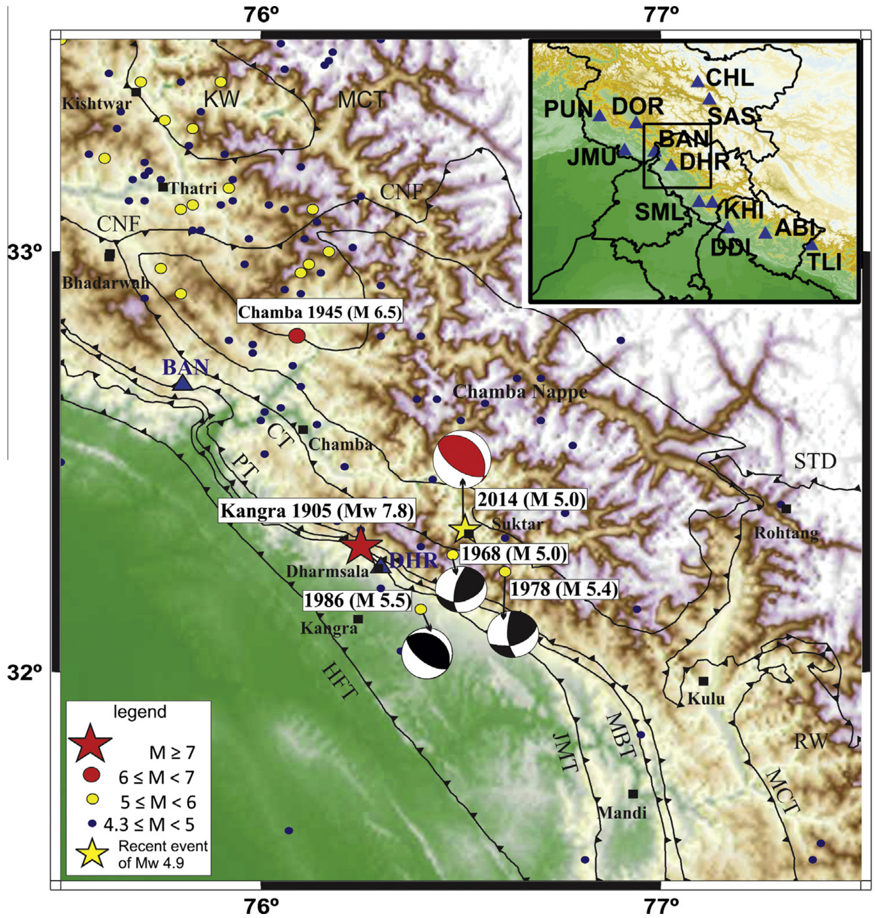

Fig. 1. Topographic map of Kangra–Chamba sector of northwest Himalaya overlapped by the major tectonic elements of the region (after Thakur, 1998); Labels used are: STD: Southern Tibetan Detachment; CNF: Chenab Normal Fault; CT: Chamba Thrust; MCT: Main Central Thrust; PT: Panjal Thrust, MBT: Main Boundary Thrust; JMT: Jawala Mukhi Thrust and HFT: Himalayan Frontal Thrust. Epicenter (yellow star) of the recent earthquake (M_W 4.9) of 21st August, 2014 is shown in relation to the devastating 1905 Kangra (M7.8) earthquake and other moderate magnitude earthquakes (labelled). The spatial distribution of earthquakes ($M > 4.3$) for the period of 1964–2010 (ISC catalogue) are also shown. The beach ball representing the fault plane solution of the recent event of 21 August 2014 is shown along with 1968, 1978 and 1986 earthquakes adopted from published literature. The inset map shows the location of stations used in the present study to estimate the source parameter of the earthquake of 21st August, 2014.

last M 6.5 earthquake occurred near Chamba in 1945. Again, due to the lack of sufficient instrumental data, the fault plane solutions could not be estimated and source mechanisms and knowledge on the causative faults remained obscure. However, seismogenic potential of the region is evidenced by the wide spread occurrence of small events (>4.3), located by local network of stations that were setup by India Meteorological Department post 1964. These data showed clustering pattern (Fig. 1) encompassing a couple of moderate magnitude earthquakes, notably Himachal earthquake of 1968 (M_L 5.0), 1978 (M_L 5.4) and Dharamshala earthquake of 1986 (M_b 5.5). A specially designed seismological experiment undertaken to constrain the seismotectonics of the Kangra–Chamba region (Fig. 2), identified a close clustering of seismic events immediately northeast of the epicenter of the 1905 Kangra earthquake (Kumar et al., 2009). Improved spatial-depth distribution of hypocentres in conjunction with velocity structure and distinctive focal mechanisms helped to identify multiple sources and mechanisms of seismic events in this clustered seismicity (Kumar et al., 2009, 2013a). As seen in Fig. 2 that recent M_L 5.0 event of 21 August, 2014 is nucleated in this localised cluster. Further, recognising that as a result of continued improvement in seismic monitoring network, the event is well recorded. The source parameters and fault plane mechanism for the recent earthquake are determined to place independent constraints on the seismotectonic model for the Kangra region.

2. Geology and tectonic setting

The Chamba–Kangra region comprises of complex system of major tectonic structures and related seismicity. It, in general, consists of four tectonic zones from south to north namely; Sub-Himalaya (SH), Panjal Imbricate Zone (PIZ) of the Lesser Himalaya, Chamba Nappe (CN) and Higher Himalaya (HH). The Himalayan Frontal Thrust (HFT) demarcates the tectonic boundary between the folded Tertiaries of Sub-Himalaya and the alluvium of Indo-Gangetic plains, whereas, the Main Boundary Thrust (MBT) separates the Tertiary rocks of the Sub-Himalaya from the PIZ of the Lesser Himalaya (Figs. 1 and 2). The Chamba Nappe is the significant tectonic unit. The nappe basically comprises of weakly metamorphosed sediments that are similar in facies to the THS and are considered to have resulted by the southwestward sliding of the THS from the north over the metamorphic HHC. This migration took place along the south dipping Chenab Normal Fault (CNF) that defines the present day northern boundary of the CN. The northern border of the Chail formation was diagnosed to represent the southern limit of the CN, particularly west of the Chamba Township (Singh, 1994). In contrast, Rautela and Thakur (1992) and Thakur (1998) indicated that the CN extended right up to the PT/MBT particularly in the eastern part along the Kangra. It is further argued that due to this southward transgression of the nappe, the LH sequence on the eastern part is pinched out to a