The 22 June 2020 Mizoram, India earthquake (M_w 5.5): an unusual intra-wedge shallow earthquake in the Indo-Burmese Wedge

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Earthquakes in the Indo-Burmese arc occur due to interaction of India and Sunda plates along the Indo-Burmese Wedge and Sagaing Fault. Majority of the moderate to major magnitude earthquakes in the Indo-Burmese Wedge occur within the Indian slab and very few of them occur on the plate interface. Earthquakes within the wedge are rare and the 22 June 2020 earthquake of magnitude 5.5 (M_w) on the India–Myanmar border in Mizoram, India, at shallow depth is probably one such earthquake. The earthquake caused moderate damage (maximum intensity VIII on MSK scale) in remote border villages (Vaphai and Chawngtui) with sparse population without any fatality. The earthquake did not seem to be related with the Mat Fault, which was transverse to the north–south trending wedge, as various estimates of mainshock and the region of maximum damage was ~20 km northeast of the surface trace of the Mat Fault. It appeared to be associated with almost north–south oriented Churachandpur Mao Fault (CMF) with dextral slip which mapped extensively and monitored geodetically in the neighbouring regions of Manipur and Nagaland to the north. Occurrence of this shallow depth earthquake may imply that some segment of the CMF might be seismically active, unlike in the north, where it appears to be predominantly aseismic. This implies that the seismic hazard along the CMF may vary along its length.

Keywords: Churachandpur Mao Fault, earthquakes, Indo-Burmese arc, tectonics.

THE tectonics and earthquake occurrence processes in the North East India are more complicated due to the presence of several distinct yet interacting tectonic domains in the region. In the north, the Indian plate subducts beneath the Eurasian plate along the east–west oriented Himalayan arc. Majority of these earthquakes occur at shallow depth on the Main Himalayan Thrust (MHT). The 1950 Assam earthquake (*M* 8.6) which occurred in Arunachal Pradesh and adjoining Tibet region, is the largest earthquake in that region[1,2]. Immediately south of the Himalayan arc, there is another anomalous region, the Shillong plateau on the Indian plate, which hosted the great 1897 Shillong plateau earthquake (*M* 8.1). It is considered that the intraplate earthquakes in this region occur on the Dauki and Oldham faults in response to the plateau pop up[3]. The north–south oriented Indo-Burmese arc which joins the Himalayan arc along the North East Himalayan syntaxial bend, accommodates the plate motion between the India and Sunda plates. The predominantly northward motion of the India plate with respect to the Sunda plate is actually partitioned between the Sagaing Fault and Indo-Burmese Wedge[4]. The north–south oriented Sagaing Fault is a dextral strike–slip fault which has witnessed several strong and damaging earthquakes. In the Indo-Burmese Wedge, majority of the motion is accommodated through dextral slip along the Churachandpur Mao Fault (CMF), albeit in predominant aseismic manner, at least in Manipur and south Nagaland region, as brought out by the GPS measurements in the region[4]. The remaining arc's normal motion in the Indo-Burmese Wedge is accommodated on the plate boundary interface that lies west of CMF, and is considered to be active seismic[5,6], though some investigators have argued against it[7]. At depth of ~40–60 km, CMF merges with the plate boundary interface, below which the interface is aseismic, as at other plate margins, but experiences intraslab earthquakes at depths of up to ~150 km. Majority of the earthquakes in the Indo-Burmese Wedge occur below the plate interface (depth >25 km) and are considered as intraslab earthquakes[8]. This is also evident from their focal mechanism solutions exhibiting motion on steep planes which are not consistent with the plate interface geometry. The region has witnessed several strong earthquakes in the past, e.g. 1988 India–Burma (*M* 7.3) which was the largest instrumentally recorded earthquake, and the recent 2015 Tamenglong (M_w 6.7) (ref. 9) and 2017 Manu earthquake (M_w 5.6) (ref. 10). It has been opined that even the famous Cachar earthquake of 1869 was also an intraslab earthquake of the India plate which occurred below the Indo-Burmese Wedge[8]. The wedge is generally devoid of moderate or even strong magnitude earthquakes and hence it is rare to find earthquakes within the wedge with focal depth shallower than 25 km. The 22 June 2020 Vaphai earthquake in Mizoram is one such rare earthquake.

The 22 June 2020 Vaphai earthquake occurred at 4:10 am (IST). The Indian national network operated by the National Center for Seismology (NCS, Ministry of Earth Sciences, New Delhi) along with all the global earthquake reporting agencies reported shallow depth for this earthquake (e.g., United States Geological Survey, European–Mediterranean Seismological Centre and GEOFOrschungsNetz reported focal depth between 10

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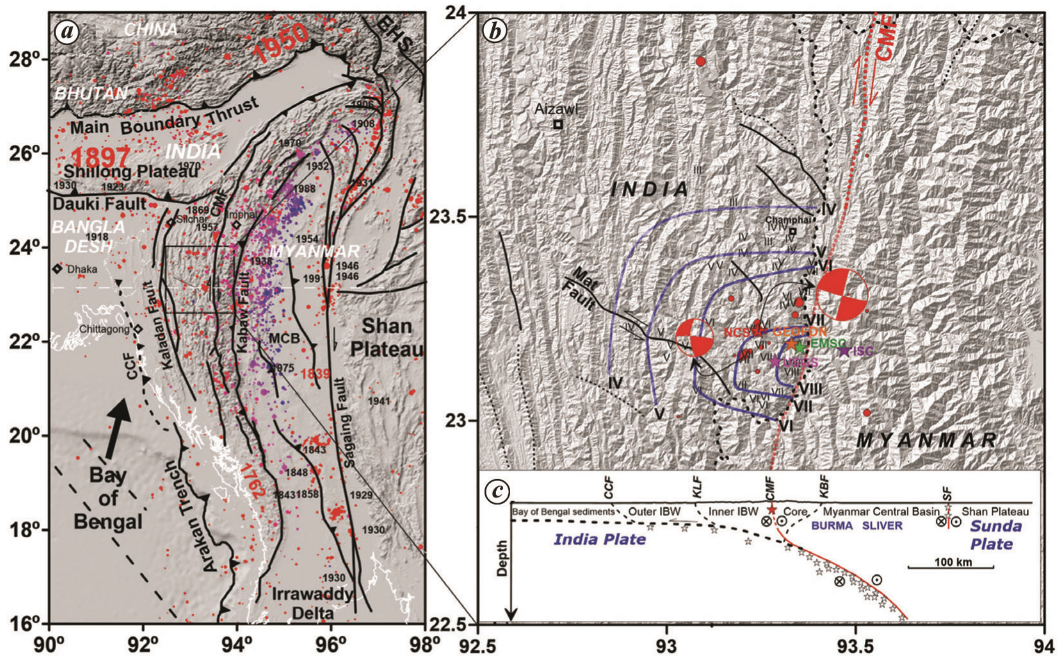

Figure 1. ***a***, Earthquakes in the North East region which includes tectonic domains of Himalayan arc, Shillong plateau, Eastern Himalayan Syntaxis (EHS) and Indo-Burmese Wedge (IBW). Earthquakes are plotted as per their size and depth (magnitude from 4.5 to 7 and depth up to 200 km, colour changing from red to blue with increasing depth). The 1897 Shillong Plateau and 1950 Assam earthquakes are also marked with red text. Significant and historical earthquakes are also marked with their year of occurrence. The background tectonic information is partly based on Maurin and Rangin[12]. MCB, Myanmar Central Basin; CMF, Churachandpur Mao Fault; CCF, Chittagong Coastal Fault. ***b***, Earthquakes in India–Myanmar border (marked by black dotted line) region of Mizoram from 22 June 2020 to 31 August 2020. Estimates of mainshock (stars) by National Center for Seismology (red), European–Mediterranean Seismological Centre (green), United States Geological Survey (magenta), GEOForschungsNetz (GEOFON) (orange), and ISC (purple) are shown. Focal mechanism solutions of the 22 June 2020 (M_w 5.5) and 27 August 2020 (M_w 5.3) are also shown (from GEOFON). The inferred intensity on Medvedev–Sponheuer–Karnik (MSK) scale from our field survey is shown by blue contours along with the assessed estimate of intensity (roman numbers) at more than 30 places/villages. ***c***, A schematic west to east depth section across the Indo-Burmese arc. Red star on CMF marks the location of the 22 June 2020 earthquake. KLF, Kaladan Fault; KBF, Kabaw Fault; SF, Sagaing Fault.

and 13 km while NCS reported a default depth of 20 km). Even the aftershocks (at least 20, of magnitude more than 3 till 10 September 2020; seismo.gov.in), also had similar shallow depth. It implies that this earthquake occurred within the wedge and is not an intraslab Indian plate earthquake which usually occur at depths deeper than 30 km (ref. 8). The available focal mechanism solution for earthquakes of 22 June and 26 August 2020 exhibit strike–slip motion on steep planes (Figure 1), i.e. either dextral motion on the predominantly north–south oriented plane or sinistral motion on the east-southeast (ESE) to west-northwest (WNW) oriented plane (GEOFON, https://geofon.gfz-potsdam.de/). Interestingly, there is a prominent ESE-WNW to SE-NW oriented transverse fault with sinistral motion in the vicinity of this region, known as the Mat Fault[11]. However, Mat Fault is about 20 km south of the available estimates of the epicentre of the 22 June 2020 earthquake, reported by various agencies (Figure 1). Our studies suggested that this fault was probably not active as there was no relative motion across it, at least at shallow depth[11]. Thus, we opined that the 22 June 2020 earthquake (M_w 5.5) and its aftershocks, including the recent one on 26 August 2020 (M_w 5.3), were not associated with the Mat Fault. To confirm this further, we (authors from Mizoram University) undertook a detailed field survey to identify the region of maximum damage, to document coseismic surface fractures/cracks, if any, and to draw the isoseismals for the mainshock. The field survey was conducted during 25–31 June 2020 in the Champhai district of Mizoram state. The team visited about twenty villages within 20–30 km of the reported epicentre and assigned the intensity of damage due to earthquake on MSK (Medvedev–Sponheuer–Karnik) scale in the region. The buildings in the region were mostly single-storey light weight RCC structures. The maximum damage due to the earthquake occurred ~10 km southeast of the reported epicentre of NCS. Because of the nearby India–Myanmar international border, the team could survey villages only on the Indian side. The maximum intensity of VIII was assigned in the sparsely populated villages of Vaphai and Chawngtui. Cracks in the buildings were extensive and at some places, the unsupported boundary walls collapsed. Cracks on the ground were observed at a few places near Vaphai and Chawngtui villages, which were oriented in the approximately northeast-southwest direction but did not extend more than a few tens of metre and also were not deep. Thus these cracks were probably surficial and were not part of the primary coseismic rupture. The region of maximum damage and surface cracks was close to the international border and due to the prevalent restriction we could only visit the Indian side and not the Myanmar side, so the information about the extent of damage and ground cracks was not available from the Myanmar side. The intensity varied from VIII to III in the surveyed region of 50 × 50 sq. km. Thus it seemed that the attenuation of the intensity appeared to be fast which confirmed the shallow depth of this earthquake. Although the region was sparsely populated and the extent of region of maximum intensity was very small, the intensity contours appeared to be elongated in the north–south direction. Our damage survey confirmed that the maximum damage occurred ~20 km north of the Mat Fault. Thus we suggest that this earthquake and its aftershocks did not occur on the Mat Fault. Unfortunately, CMF, which has been mapped and characterized extensively in Manipur and Nagaland, has not been investigated in this region, neither on Indian, nor on Myanmar side. Even the surface trace of CMF in this region is not mapped. However, the trend of the CMF further north, suggested that it could be extending along the India–Myanmar border or close to the border in Myanmar. Thus it is possible that this earthquake occurred on CMF or on a plane parallel to it, but because of the limited accessibility of the region, we could not verify whether this earthquake caused any primary coseismic surface rupture on the CMF. The nearest permanent GPS sites at Siaha (~80 km SSW of the epicentre) and Aizwal (~90 km NW of epicentre) do not show any coseismic offset because of this earthquake which would have been useful in constraining the rupture plane of this earthquake. Nevertheless, such an interpretation is consistent with the focal mechanisms of the earthquakes of 22 June and 26 August 2020. We acknowledge that it is possible that these earthquakes might have occurred on transverse faults similar to Mat Fault, however, since they are not evident on satellite imageries and have not been mapped yet, we prefer the above interpretation.

Occurrence of such earthquake, though not frequent, has implications on the slip behaviour on CMF. It appears that the slip behaviour CMF within the wedge varies from predominantly aseismic in the north to active seismic in the region of 22 June 2020 earthquake, which has been seen in several cases (e.g. the San Andreas Fault). Thus, occurrence of this earthquake adds a new dimension in the slip behaviour of CMF and the associated seismic hazard, as earlier it was considered as predominantly aseismic[4]. It implies that the seismic hazard along the CMF due to its slip, may vary significantly along its length, i.e. high hazard in region where CMF accommodates slip seismically through earthquakes (e.g. region of current investigations), and low, where it accommodates slip aseismically (e.g. Manipur and southern Nagaland in the north). It also confirms the earlier view that the hyper oblique motion in the Indo-Burmese Wedge is accommodated through slip partitioning in which the arc parallel motion (dextral strike–slip) occurs on the CMF, and arc normal (i.e. thrust) motion occurs on the decollement, also referred as the Blind Mega Thrust (BMT)[5–7] that lies to the west of CMF. The remaining motion of about 20 mm/year between the India–Sunda plate is accommodated on the Sagaing Fault through active dextral slip. However, in view of the uncertainty of the rate and mode of slip accommodation at BMT[7], it is difficult to compare the seismic hazard associated with BMT and CMF.

Competing interest. The authors declare no competing interests.

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