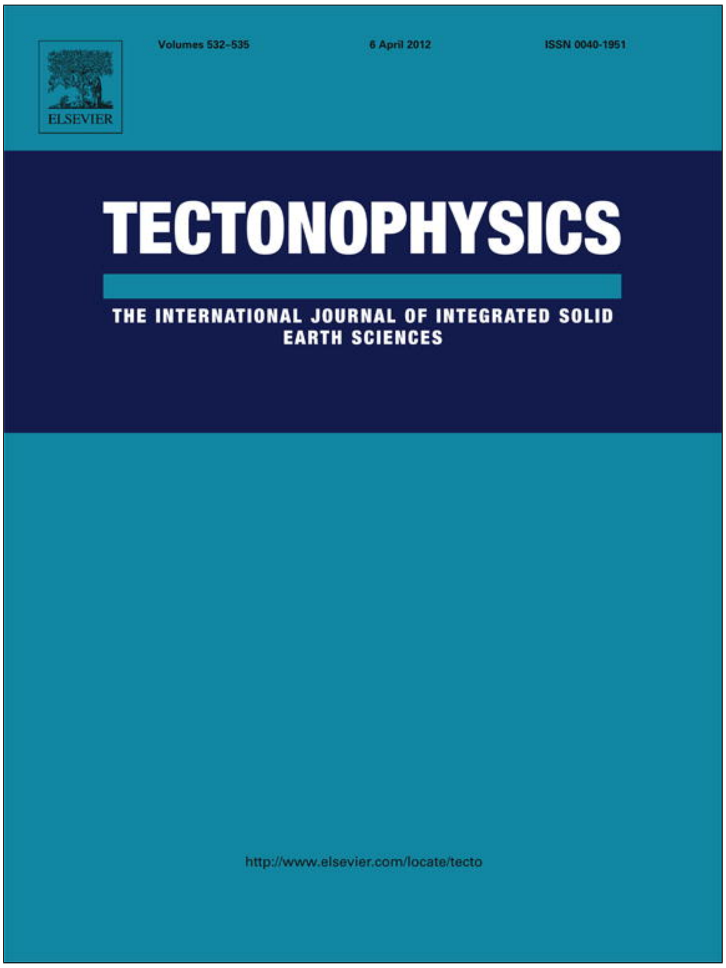
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Large and great earthquakes in the Shillong plateau–Assam valley area of Northeast India Region: Pop-up and transverse tectonics

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ABSTRACT

The tectonic model of the Shillong plateau and Assam valley in the northeast India region, the source area for the 1897 great earthquake (Ms~8.7) and for the four (1869, 1923, 1930 and 1943) large earthquakes (M.≥7.0), is examined using the high precision data of a 20-station broadband seismic network. About 300 selected earthquakes M≥3.0 recorded during 2001–2009 are analysed to study the seismicity and fault plane solutions. The dominating thrust/reverse faulting earthquakes in the western plateau may be explained by the proposed pop-up tectonics between two active boundary faults, the Oldham–Brahmaputra fault to the north and the Dapsi–Dauki thrust to the south, though the northern boundary fault is debated. The more intense normal and strike-slip faulting earthquakes in the eastern plateau (Mikir massif) and in the Assam valley, on the other hand, are well explained by transverse tectonics at the long and deep rooted Kopili fault that cuts across the Himalaya and caused the 2009 Bhutan earthquake (Mw 6.3). It is conjectured that the complex tectonics of the Shillong plateau and transverse tectonics at the Kopili fault make the region vulnerable for impending large earthquake(s).

1. Introduction

The Shillong plateau in the northeast India region is a part of the Indian shield (Evans, 1964). The long E–W trending Dauki fault separates the plateau to the north and the Bengal basin to the south (Fig. 1). The Dapsi thrust, a western segment of the Dauki fault, separates the Achaean gneisses and the Tertiary meta-sediments within the plateau, and it is seismically active (Kayal, 1987; Kayal and De, 1991). The Brahmaputra river to the north, on the other hand, separates the Shillong plateau from the Himalaya, and is named Brahmaputra river fault (Nandy, 2001). The Mikir massif, a fragmented part of the Shillong massif, moved to the northeast; the nearly 400 km long NW–SE trending Kopili fault separates them (Nandy, 2001) (Fig.1). Based on the observation of intense seismicity, fractal dimension and b-value, the long Kopili fault is identified as the seismically most active fault in the region (Bhattacharya et al., 2002). Two large earthquakes (M>7.0) were caused by this fault in 1869 and in 1943, respectively. Recently it is argued that the Kopili fault cuts across the Himalaya and caused displacement and curvilinear structure at the Main Boundary Thrust and Main Central Thrust zones (Kayal et al., 2010). Further, the plateau is delimited to the west by the north–south Dhubri fault which generated a large earthquake (M 7.1) in 1930 (Fig. 1). In addition to these geologically as well as seismically mapped known tectonic faults, Bilham and England (2001), based on geodetic and Global Positioning System (GPS) data, identified a hidden fault at the northern boundary of the plateau; they named it Oldham fault (Fig.1). They further proposed that the 1897 great earthquake (modified to Mw 8.1) occurred by pop-up tectonics of the plateau between the south dipping Oldham fault and north dipping Dauki fault by reverse faulting.

The northeast India region is jawed between the two arcs, the Himalayan arc to the north and the Indo-Burmese arc to the east and seismically very active (Kayal, 2001, 2008) (Fig.1). The region, bounded by latitude 22–29°N and longitude 90–98°E, produced two (1897 and 1950) great earthquakes (Ms~8.7) and about 20 large earthquakes (M>7.0) since 1869 (Fig.1). Among these, there had been two large earthquakes, M 7.5 in 1923 and M 7.1 in 1930, and one great event Mw 8.0 in 1897 in the Shillong plateau, and two large

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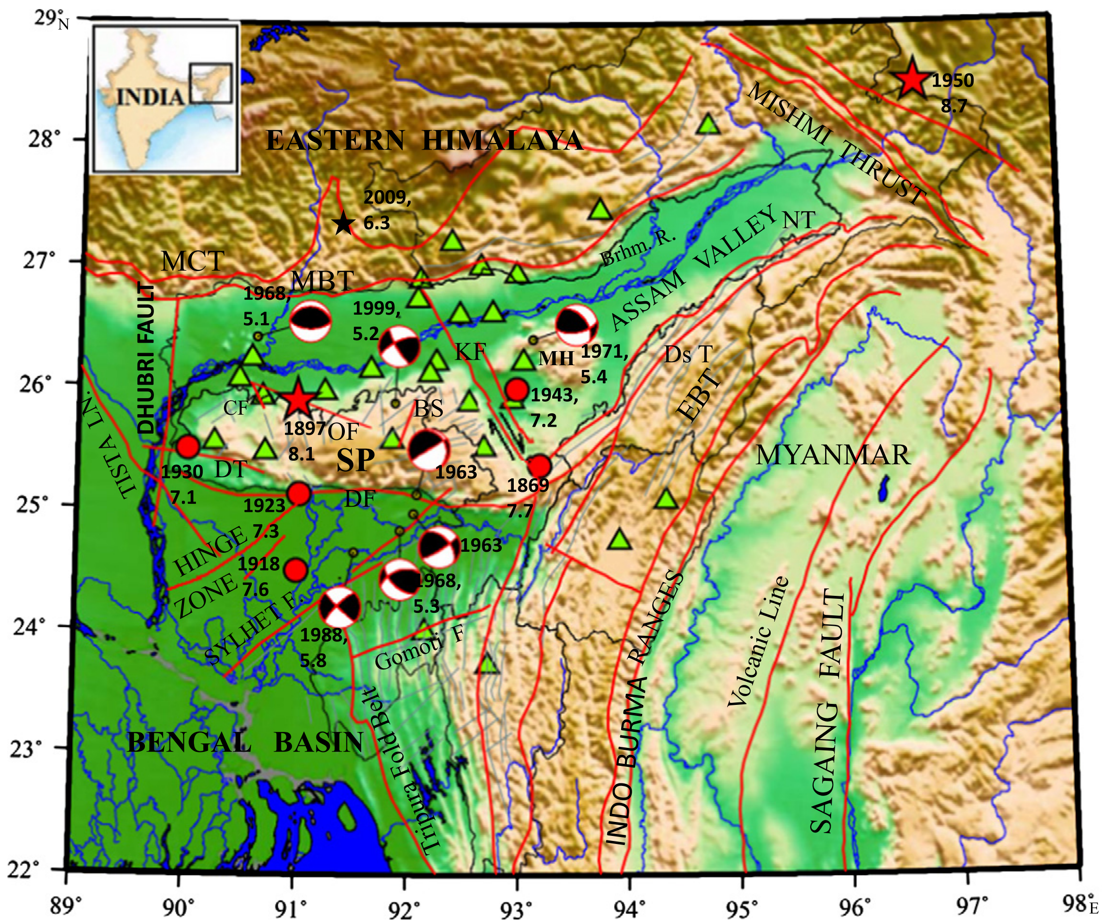

Fig. 1. Map showing major tectonic features of northeast India region (modified from Kayal et al., 2006). Two great earthquakes ($Ms \sim 8.7$) in the region are shown by stars, and the large earthquakes ($8.0 > M > 7.0$) in the study area by circles; the years of occurrences and magnitudes are annotated. The digital seismic stations are shown by triangles. The published fault plane solutions are shown by conventional beach balls; the dark area indicates compression and open area dilatation (see Table 2). The major tectonic features in the region are indicated; MCT: Main Central Thrust, MBT: Main Boundary Thrust, DF: Dauki Fault, DT: Dapsi Thrust, OF: Oldham Fault, CF: Chedrang Fault, BS: Barapani Shear, KF: Kopili Fault, NT: Naga Thrust, DsT: Disang Thrust and EBT: Eastern Boundary Thrust. The right lateral movement of the Kopili fault is shown by small arrows. Inset: map of India showing the study region in rectangle.

earthquakes, M 7.7 in 1869 and M 7.2 in 1943 at the Koipili fault in Assam valley (Kayal, 2008). The 1923 event at the southern boundary of the plateau is, however, argued to have occurred at the northern edge of the Hinge zone in the Bengal basin (Nandy, 2001). Magnitude of the 1869 earthquake at the southeast end of the Kopili fault is estimated to be M 7.7 by Szeliga et al. (2010).

Recently two felt earthquakes, Mw 5.1 in the Assam valley on August 19, 2009 and Mw 6.3 in the Bhutan Himalaya on September 21, 2009, have drawn special attention to better understand the source processes and vulnerability of occurrence of large earthquakes in the Shillong plateau and in the Assam valley area. In this study, we have analysed about 300 selected earthquakes $M \geq 3.0$, recorded by a 20-station broadband seismic network during 2001–2009 in the study area to examine the proposed pop-up tectonic model of the Shillong plateau (Bilham and England, 2001) and to examine the role of the Kopili fault in the recent two felt earthquakes (Mw 5.1 and 6.3), and their vulnerability of generating larger earthquake(s) in the area.

2. Data analysis

The seismic network covers the area of our interest fairly well to monitor the Shillong plateau and the Assam valley seismicity (Fig.1). About 2000 events ($M \geq 1.0$) are recorded during the period 2001–2009. We have selected about 300 earthquakes ($M \geq 3.0$) that are recorded by at least four broadband seismic stations with minimum seven precise P- and S-phases. These events are relocated by double-difference tomography method developed by Zhang and Thurber (2003). This method uses both the absolute and relative arrival times in inversion. The events are relocated with an average rms 0.09 s, epicentre and depth error <3 km (Fig.2).

Out of these 300 relocated events, we have examined fault plane solutions of 42 events $Mw \geq 3.5$ by waveform inversion. In waveform inversion, the Green's function approach is applied for generation of synthetic seismograms using the software AXITRA (Coutant, 1989). The inversion is carried out using a frequency band (0.01–0.2 Hz) that is free of noise or with a high signal to noise ratio, and falls below the corner frequency. Final validation of the best fitting solutions was accomplished by comparing the observed and synthetic amplitude spectra and first motion polarities. The fault plane solutions are shown in Fig. 2; other details are given in Table 1. We examined the published as well as HRVD (Harvard) CMT (Centroid Moment Tensor) solutions available in the study area. No HRVD CMT solution is available for the study period 2001–2009; only one HRVD CMT solution is available for an earthquake Mw 5.2 that occurred in May 1999, and some six solutions are published by Chen and Molnar (1990) for earthquakes $M > 5.0$. Solutions of these events are shown in Fig. 1, and other details are given in Table 2.

3. Results and discussion

Although the seismic activity in the Shillong plateau and Assam valley is categorised as intra-plate seismicity, it differs from the typical shallow (>10 km) intra-plate shield seismicity in depth as well as

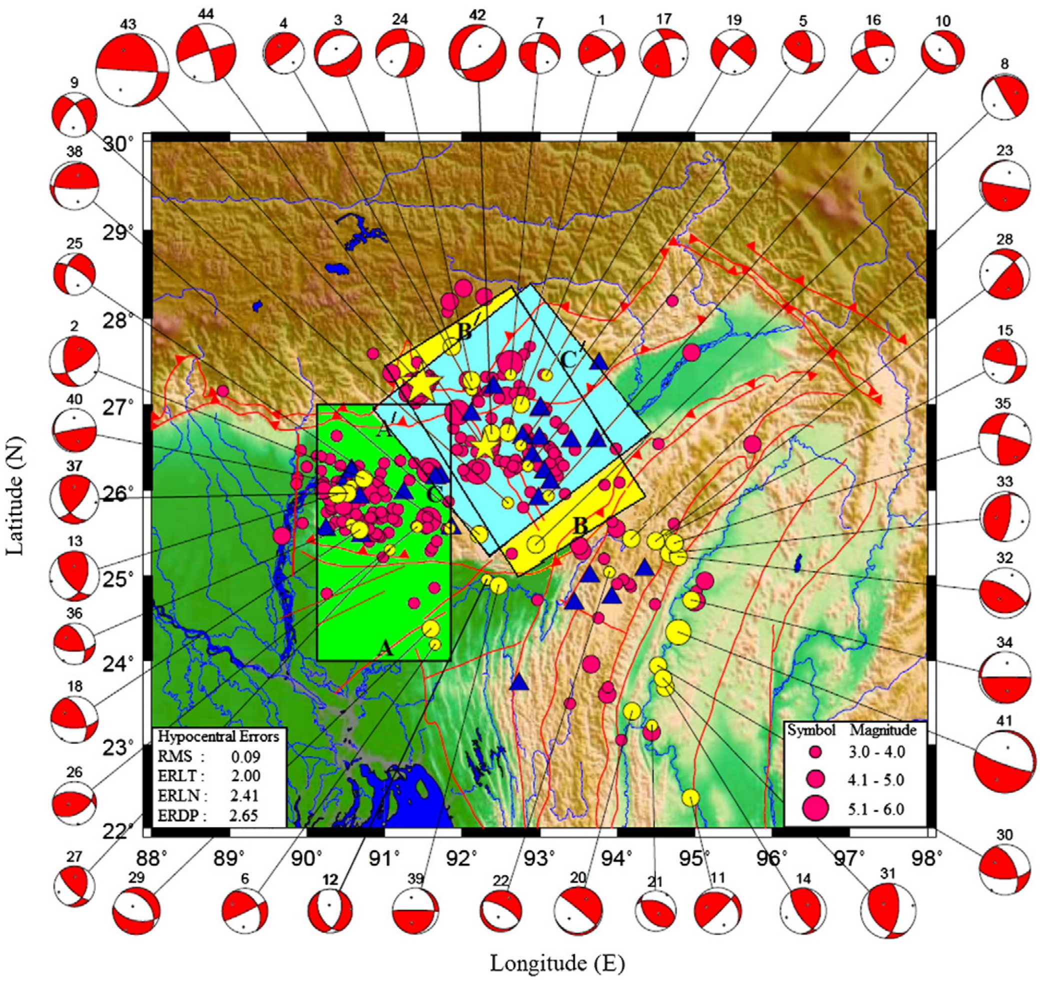

Fig. 2. Map showing epicentres of 300 well-located earthquakes. Fault plane solutions of 44 selected events (M > 3.5) including the solutions of two recent (2009) felt events (Mw 5.1 and 6.3) are shown (see Table 1). The shaded areas show the area of considered epicentres for the cross sections (Figs. 3 and 4).

in frequency of occurrence (Kayal, 2008). The earthquakes in the Shillong plateau and Assam valley are much deeper, down to 50 km, and the seismic characteristics, b-value and fractal dimension, are much similar to a seismically active zone (Bhattacharya et al., 2002) rather than the central India shield zone (Kayal, 2008). A north–south cross section of the events in the plateau is examined. The section is taken across the Dauki–Dapsi, and Oldham–Brahmaputra faults (Fig. 3); the considered events are shown by a shaded zone A–A′ in the western part of the plateau (Fig. 2). The proposed pop-up tectonic model is shown in Fig. 3a and the cross section of the events in Fig. 3b. The section shows that the earthquakes in the Shillong plateau are mostly confined within a depth of ~50 km and may be bounded by two boundary faults, the Dapsi thrust to the south and the Brahmaputra river fault to the north. The events for which the fault plane solutions are obtained are numbered, and the inferred dipping fault planes are plotted in the section using the software RAKE (Louvari and Kiratzi, 1997) (Fig. 3c). The fault planes are inferred to the known geological information as mentioned above. The section shows that beneath the plateau area eight fault-plane solutions are obtained (Fig.3c) and these are dominated by thrust/reverse faulting (Fig. 2). The inferred fault planes seems to be compatible with the two boundary faults, the north dipping Dapsi thrust and the south dipping Brahmaputra river fault (Fig.3c). It is interesting to note that the solution of the event 27 at a much deeper depth (~55 km) that occurred below the Dauki fault zone shows a south dipping plane. The events 6 and 29 in the considered shaded area (Fig.2) fall in Sylhet fault zone in the Bengal basin (Fig.1), and these events show strike slip and normal faulting respectively.

Bilham and England (2001) argued that the 1897 great earthquake was produced by a south dipping hidden fault at the northern boundary of the Shillong plateau (Fig. 3a); they named it 'Oldham fault' that extends from a depth of about 9 km down to 45 km. They further suggested that the plateau earthquakes are caused by the 'pop-up' tectonics between two boundary faults, the north dipping Dauki fault and the south dipping Oldham fault. Rao and Kumar (1997), however, first suggested the pop-up tectonics of the Shillong plateau, and they argued that the pop-up mechanism is facilitated by the Dauki fault to the south, Brahmaputra fault to the north, Dhubri fault to the west and Disang thrust to the east (Fig. 1). They and later Nandy (2001) defined the E–W segment of the Brahmaputra river to the north of plateau as the Brahmaputra fault. Evans (1964) and Nandy (2001) also argued that the Dauki fault is a near vertical gravity fault or a south dipping strike-slip/normal fault, not a north dipping thrust fault as envisaged in the pop-up tectonic model. Nandy (2001) further argued that the large (~20 km) difference in basement between the Shillong plateau and the Bengal basin cannot be in any way explained by a thrust movement. The south dipping structure is conformable with the E–W segment of the Brahmaputra river fault at the northern boundary of the plateau. In this study, we observe that the surface projection of the Oldham fault and the surface trace of the Brahmaputra river fault are very close, within say 20 km at the 1897 great earthquake epicentre. In a recent geological field investigation Tapponnier (2011, pers. comm.), however, argued that the Dapsi thrust seems to be north dipping but geologically, geomorphologically and topographically there is no evidence of the Oldham fault or the Brahmaputra fault.

Table 1
List of earthquakes used for focal mechanism solution in this study.

Sl. No	Date (YYYY: MM:DD)	Origin time (h:min:s)	Latitude (°N)	Longitude (°E)	Depth (km)	Magnitude Mw	Focal mechanism solution NP1 Strike	NP1 Dip	NP1 Rake	NP2 Strike	NP2 Dip	NP2 Rake
1	20010215	22:39:07.00	26.68	92.59	44.0	4.0	60	80	35	323	56	168
2	20010227	01:46:08.00	26.14	90.73	17.0	4.4	170	55	30	62	66	141
3	20010310	00:20:16.00	27.67	91.87	11.0	4.1	235	30	−95	61	60	−87
4	20010320	16:15:12.00	27.17	92.12	21.0	3.6	50	80	95	203	11	64
5	20010406	03:32:09.00	26.53	92.76	48.0	3.7	0	55	140	116	58	42
6	20010418	20:47:48.00	24.19	91.65	56.9	4.0	330	40	175	64	87	50
7	20011123	15:41:18.00	27.35	92.62	20.2	3.6	290	50	−160	187	75	−42
8	20021012	18:30:50.43	25.37	92.95	29.5	4.0	260	10	20	150	87	99
9	20030104	19:39:44.10	25.86	92.59	23.0	3.9	222	62	−30	327	64	−148
10	20030115	10:41:50.60	25.94	93.11	23.5	3.7	120	45	−110	327	48	−71
11	20030120	12:54:38.00	22.37	94.95	10.0	4.1	45	85	65	304	25	168
12	20030125	22:57:18.90	24.96	92.32	48.0	3.8	15	50	−60	153	49	−121
13	20030215	21:37:33.84	25.96	90.39	36.6	4.3	240	60	150	346	64	34
14	20030325	04:30:04.00	23.68	94.62	22.7	4.0	5	25	125	147	70	75
15	20030419	04:36:24.70	25.48	94.63	73.0	3.8	0	45	165	101	80	46
16	20030511	17:19:40.20	26.29	92.85	53.2	3.8	160	70	−20	257	71	−159
17	20030530	10:27:53.30	27.01	92.76	57.5	4.2	240	50	160	343	75	42
18	20030717	20:28:25.28	25.54	90.68	20.8	4.1	90	60	40	337	56	143
19	20030820	14:05:52.40	27.34	93.09	20.8	3.9	220	70	0	130	90	160
20	20040103	15:44:57.80	23.40	94.19	28.2	4.2	70	10	−150	310	85	−81
21	20040106	19:29:08.33	23.23	94.45	14.2	3.5	290	50	70	140	44	112
22	20040108	23:28:32.00	25.05	93.90	44.9	3.6	130	20	−80	299	70	−94
23	20040108	23:35:47.14	25.44	94.18	45.0	4.4	100	90	−80	190	10	−180
24	20040113	23:16:56.85	27.28	92.12	15.3	4.2	10	60	−140	257	56	−37
25	20040120	21:40:02.21	25.56	91.84	41.9	3.6	300	70	−140	194	53	−25
26	20040124	20:50:50.25	25.58	91.42	52.5	3.8	60	50	60	282	48	121
27	20040128	13:06:45.00	25.31	91.07	62.3	3.5	20	40	150	134	71	54
28	20040206	04:21:55.70	25.41	94.50	86.6	4.3	320	40	10	222	84	130
29	20040209	22:13:14.81	24.38	91.60	40.9	4.1	320	40	−60	103	56	−113
30	20040320	19:20:35.20	23.94	94.53	85.1	4.4	90	60	40	337	56	143
31	20040325	12:57:24.80	23.79	94.59	110.5	4.8	140	40	50	8	61	118
32	20040421	13:54:05.35	25.23	94.79	13.6	4.4	300	70	100	93	22	65
33	20040423	23:38:26.76	25.27	94.67	21.8	4.3	220	20	120	8	73	80
34	20040524	01:39:53.10	24.72	94.96	43.0	4.5	170	10	170	270	88	80.15
35	20040603	13:01:17.80	25.39	94.74	24.8	4.5	190	70	170	284	81	20
36	20040604	17:32:21.48	25.61	90.57	49.9	3.6	90	60	40	337	56	143
37	20040804	01:09:12.10	25.97	90.52	19.4	4.2	320	50	−130	193	54	−53
38	20041102	08:23:23.10	25.49	92.22	25.0	4.2	210	20	30	92	80	108
39	20041209	08:48:58.90	24.89	92.47	43.7	4.0	10	20	10	271	87	110
40	20090404	19:19:04.52	26.06	90.57	8.6	3.8	150	10	160	260	87	81
41	20090811	21:43:47.60	24.34	94.79	102.1	5.4	330	10	−50	110	82	−97
42	20090819	14:57:24.10	26.67	92.38	10.0	4.9	200	40	−120	57	56	−67
43	20090921	08:53:10.55	27.24	91.47	14.0	6.3	1	32	177	94	88	58
44	20090819	10:44:44.10	26.49	92.30	10.0	5.1	342	80	−175	251	85	−10

The pop-up tectonic model of the Shillong plateau was supported by Kayal et al. (2006) with smaller magnitude (M>2.0) earthquake data for the period 2001–2003, but there was a debate whether the smaller magnitude earthquakes and their fault plane solutions can represent or support the model. In this study, we are able to select a substantial data set with higher magnitude (M 3.0–6.0) events for the period 2001–2009, and examined some 44 fault plane solutions of events M>3.5 for a more comprehensive observation. Eight fault plane solutions are obtained in the Shillong plateau, three events (2,13 and 18) are with Mw 4.1–5.0 and five events with Mw 3.5–4.0 (Fig. 3c). These solutions are comparable with the published solutions (Chen and Molnar, 1990) and with the HRVD CMT solution of the event Mw 5.2 of 1999 in the plateau area. The inferred fault planes are compatible with the two boundary faults, the north dipping Dapsi thrust and the south dipping Oldham–Brahmaputra fault. The north dipping Dapsi thrust was well identified as an active fault by Kayal (1987), Kayal (2001) and Kayal and De (1991). They also reported that the Dapsi thrust, western segment of the Dauki fault,

Table 2
List of published focal mechanisms solutions in the study area.

Sl no.	Date YYMMDD	Lat (°N)	Long (°E)	Depth (km)	Mag.	St, dip, rake (°)	Azm/Plng (P-axis)	Azm/Plng (T-axis)	Reference
1	19630619	24.97	92.06	52±6	–	57,80,42	181, 20	286, 36	Chen and Molnar (1990)
2	19630621	25.13	92.09	38±4	–	238,88,−70	167, 44	310, 40	Chen and Molnar (1990)
3	19680612	24.83	91.94	41±4	5.3	132,60,135	192, 5	96, 52	Chen and Molnar (1990)
4	19680818	26.42	90.62	29±3	5.1	90,60,90	180, 15	0, 75	Chen and Molnar (1990)
5	19710717	26.41	93.15	36±5	5.4 (m_b)	79±10,60±7,46±10	198, 5	295, 53	Chen and Molnar (1990)
6	19880206	24.65	91.52	31±3	5.8 (m_b)	225±10,77±6,5±7	180, 6	89, 13	Chen and Molnar (1990)
7	19991005	25.88	91.89	33	5.2 (M_w)	244,68,12			HRVD catalog

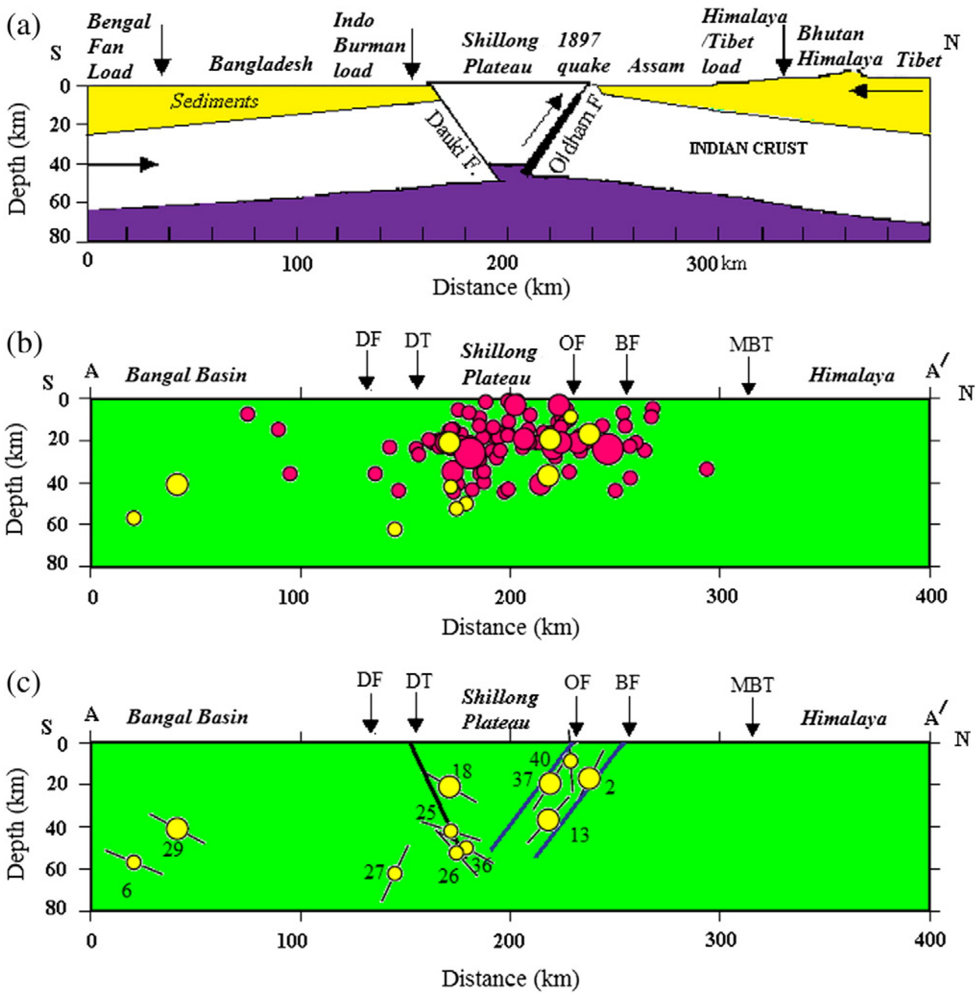

Fig. 3. (a) The pop-up tectonic model of the Shillong plateau (after Bilham and England, 2001). (b) Cross section of the events across the Dauki, Dapsi, Oldham, and Brahmaputra fault zones; the considered events are shown in the shaded zone A–A′ (Fig. 2). (c) Cross-section of the inferred fault planes of the selected solutions. Tectonic features are as explained in Fig. 1.

truncated the maximum isoseismal (XII) of the 1897 great earthquake (Fig.1), and it delimits the seismicity to its north in the western plateau. They further identified that the eastern part of the Dauki fault is dormant; possibly presently locked or the maximum stress is taken up by the Dapsi thrust. It is worth noting that only one event (event 27) occurred below the Dauki fault in the Bengal basin at much deeper depth (~55 km) and its fault plane solution shows a south dipping plane (Fig.3c). We believe that Dauki–Dapsi thrust is the southern boundary fault for the pop-up tectonics and or it accommodates the back thrust from the Himalaya and cause the plateau earthquakes. The seismological data, with inferred south dipping nodal planes as the fault planes, though illustrate that the Brahmaputra fault could be the northern boundary fault for the pop-up tectonics, we need more data from the Himalayan foredeep (lower Assam valley) to establish the northern boundary fault. In a recent field investigation Tapponnier (2011, pers. comm.) ruled out any geological fault like the so called Oldham fault or the Brahmaputra fault to the north of Shillong plateau. The Himalayan back thrust could be the main cause of the Shillong plateau earthquakes as envisaged by Kayal and De (1991) and by Oldham (1899).

The northern boundary of the proposed pop-up tectonics for the Shillong plateau earthquakes is still an enigma; the pop-up tectonic model is yet to be verified by some more geological and geophysical investigations. We also need more seismic stations in the lower Assam valley of the Himalayan foredeep region, to the north of the Shillong plateau, to monitor seismicity.

Average elevation of the Shillong plateau is about 1 km, and its uplift is continuing due to the regional tectonic stresses from the north and from the east (Angelier and Baruah, 2009; Kailasam, 1979; Kayal, 2001). Recent GPS data also show rapid shortening of the plateau (Banerjee et al., 2008; Bilham and England, 2001). Although the palaeo-seismological evidences suggest that recurrence period of great events (M≥8.0) in the Shillong plateau is of the order of 500± 100 years (Sukhija et al., 1999), but such complex tectonics and the tectonic stress due to rapid shortening may cause a large earthquake (M≥7.0) any time, if not a great earthquake (M>8.0) immediately as envisaged by Bilham and England (2001).

The other most seismically active zone in the region is the Kopili fault (Fig.1). The most intense seismicity along the Kopili fault is examined taking two cross-sections of the events, one NW–SE section along the fault and the other NE–SW section across the fault zone (Fig. 4). The corresponding considered events are shown in the shaded zones B–B′ and C–C′ in Fig. 2. The section B–B′ shows an intense seismic activity down to a depth of ~50 km beneath the Kopili fault, and the activity continues to the Main Central Thrust (MCT) in the Bhutan Himalaya (Fig. 4a). The section C–C′ across the Kopili fault shows that the fault zone is about 50 km wide and dips to the northeast (Fig. 4b). The cross section of the inferred fault planes of 15 fault plane solutions in the considered zone (Fig. 2) is shown in Fig. 4c; there are seven events of Mw 3.5–4.0 and six events Mw 4.1–5.0, and two events Mw 5.1 and 6.3 respectively (Fig.4c). One event (38) falls outside the Kopili fault zone. The inferred fault planes for

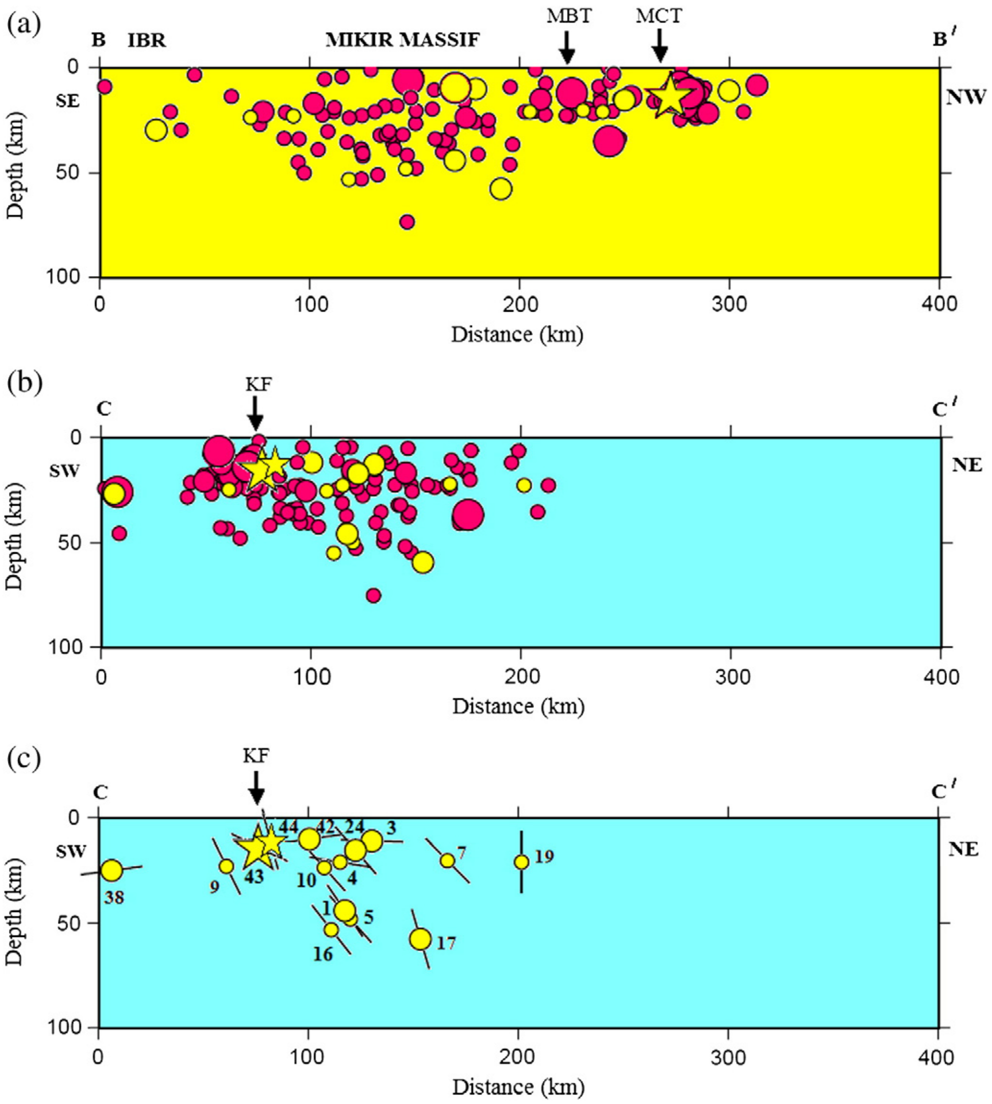

Fig. 4. (a) Cross-sections of the events, (a) along the Kopili fault, and (b) across the Kopili fault; the considered events are shown in the shaded zones B–B′ and C–C′ (Fig. 2), respectively. (c) Cross-section of the inferred fault planes of the selected solutions across the Kopili fault zone, shaded zone C–C′ in Fig. 2. The tectonic features are as explained in Fig. 1.

all the events are conformable with the northeast dipping Kopili fault, except the event 19 which shows a near vertical dipping plane. The events 43 and 44 are the Bhutan Himalaya and the Assam valley felt earthquakes of September 21 and August 19, 2009, respectively; the fault plane solutions of these two events are taken from Kayal et al. (2010). The continuity of seismicity trend along the Kopili fault indicates that the fault cuts across the Himalaya causing the curvilinear structure at the MCT. Such transverse seismogenic structures in the Himalaya with curvilinear MCT are reported in the eastern and north-eastern Himalaya by several authors (e.g. De and Kayal, 2004; Hazarika et al., 2010; Kayal, 2001; Mukhopadhyay, 1984). The fault plane solutions of these two medium/strong felt earthquakes are very much in conformity with the transverse tectonics of the Kopili fault. In addition to these solutions, a few different solutions are observed in the Indo-Burma ranges (Fig.2), which reflect subduction zone tectonics; we are not focussing our discussion to these solutions.

The Kopili fault had been the source zone of two past large earthquakes (M > 7.0); the 1869 large earthquake (M 7.7) occurred at the south-eastern end of the fault and the 1943 earthquake (M 7.2) occurred at the centre of the fault zone within a span of about 75 years (Kayal, 2008) (Fig.1). Both these two events caused severe damages and loss of lives in the Assam valley. Bhattacharya et al. (2008) relocated the local network events that were recorded by analogue recorders during 1993–99, and identified the intense seismic activity along the Kopili fault, that continues to the MCT in the Bhutan Himalaya. The August 19, 2009 felt earthquake (Mw 5.1) in the Assam valley occurred at the centre of the Kopili fault zone and the September 21, 2009 strong Bhutan Himalaya earthquake (Mw 6.3) occurred at the northern end of the Kopili fault where it hits the MCT, and the MCT shows a curvilinear shape (Fig.1). The past two large earthquakes M > 7.0 (1869 and 1943) and the recent two felt earthquakes along with the intense seismicity at the Kopili fault zone warrant close monitoring of this ~400 km long and ~50 km wide active zone, which may be vulnerable for an impending large earthquake in the region.

4. Conclusions

We have examined two large earthquake source zones, the Shillong plateau and the Kopili fault, in the northeast India region using recent digital seismic data. The Shillong plateau generated the 1897 great (M ~ 8.0) earthquake and the 1930 Dhubri earthquake (M 7.1), and the Kopili fault caused the 1869 (M ~ 7.7) and 1943 (M ~ 7.2) large earthquakes. The Shillong plateau shield earthquakes are deeper, down to 50 km, and may be explained by pop-up tectonics between two boundary faults; the earthquakes occur by thrust/reverse faulting with strike slip component. The known geological and the present seismological evidences show that these two boundary faults could be the north dipping Dapsi–Dauki thrust and the south dipping Oldham–Brahmaputra fault. The north dipping Dapsi–Dauki fault is well defined, but the south dipping Oldham–Brahmaputra fault needs to be re-examined by more geological, geophysical and seismological data. A recent geological investigation does not support the south dipping Oldham and or Brahmaputra fault (Tapponnier, 2011, pers com.). The seismological network to the north of the plateau, in the lower Assam valley, is poor due to thick Brahmaputra river sediments. The seismological data from the Bhutan Himalaya network, however, when in operation, could be used in future study.

The other source zone, the ~400 km long Kopili fault that fragmented the Shillong plateau into two, Shillong massif and Mikir massif, extends from southeast to northwest across the Assam valley and hits the MCT in the Himalaya. Intense seismic activity down to 50 km is recorded along this fault. The earthquakes occur mostly by normal/strike slip faulting. This fault generated two past (1869 and 1943) large (M > 7.0) earthquakes and two recent (2009) felt earthquakes, one (Mw 5.4) in the Assam valley and the other (Mw 6.3) in the Bhutan Himalaya; both the felt events occurred by strike slip faulting. The Shillong plateau as well as the Kopili fault zone is under compressional stress from the Indo-Burma arc to the east and from the Himalayan arc to the north, and both are equally potential for impending large earthquake(s) in the region.

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