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Revisiting State of Stress and Geodynamic Processes in Northeast India Himalaya and Its Adjoining Region

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Abstract The paper investigates to study components of seismicity and prevailing tectonic stress regimes of the considered region by analyzing the earthquake data that occurred during the last 200 years (from 1808 to 2008). For the purpose, northeast India Himalaya and its adjoining regions have been divided into five active regions namely Eastern Syntaxis, Arakan-yoma fold belt, Shillong plateau, Himalayan Frontal arc and Southeastern Tibet by taking into consideration the spatial distribution of seismicity its tectonic complexity. The minimum compressive stress is almost horizontal in the Tibet which indicates that the earthquake generation process is due to the flow of materials in east-west direction. The prevailing regional stress conditions at shallower levels in compression as well as in extension zones extend up to the deeper levels in to the upper mantle especially in southeastern Tibet and Arakan-yoma region. The present findings provide additional information on the seismicity, tectonics, the faulting pattern and the associated ongoing geodynamic processes in the region.

Keywords Extension Regime, Compression Regime, Syntaxis

1. Introduction

Focal mechanism solution determines the nature and orientation of the stress field that prevailed in the preliminary generation of an earthquake. It is the analytical result of waveforms generated by an earthquake which eventually provide information about the mode in which the seismic energy is released in the hypocentral zone and facilitates to understand the physical and the tectonic conditions. It commonly refers to fault orientation, the seismic slip in relation to plate movement, stress release patterns and the geodynamic process of seismic wave generation. To understand the stress pattern and the geodynamic processes in the eastern segment of Himalayan collision zone and its adjoining regions, a total of 94 focal mechanism solutions have been considered in the present research work. Thirty four focal mechanism solutions have been determined in present work. The remaining 60 solutions are compiled from already published literatures (e.g.[3],[4],[5],[15],[17],[18],[20],[22],[26], Centroid Moment Tensor (CMT) solution). Rastogi et al.[22] determined eleven focal mechanism solutions of earthquakes occurred in Assam-Burma region using P-wave first-motion direction data and reported that the dominant modes of deformation are thrust faulting in the region. Chandra[3] determined eighteen focal mechanism solutions for the earthquakes occurred in Himalayan region using P-wave first motion data and reported thrust faulting pattern in northeast India region. Singh and Shanker[25] have stated that the effect of Tibetan plateau on Burmese Arc tectonics and seismicity distribution cannot be ignored.

Several thrusts, lineaments, folded belts are found to be responsible for the earthquake generation in this region. It is believed that high seismic activity in the region is due to northward as well as eastward movement of the Indian plate toward the Eurasia and Burma plates, respectively.

2. Physiographic Location of Study Region

The Himalayan mountain belt extends from Nanga Parbat (8138 m) in the west to Namche Barwa (7775 m) in the east[14]. This belt trends mostly in NW-SE with a length 2400 km and width vary from 200 to 250 km covering Nepal and some parts of India, China, Bangladesh, Bhutan and Burma. The Himalaya is bounded by Tibetan plateau to the north and Indus- Ganga -Brahmaputra plain to the south. Northeast India Himalaya and its adjoining regions, the eastern part of Himalaya, are focused here to identify the present state of geodynamic processes by using focal mechanism solutions (Fig 1). This region has been considered as complex from geologic and tectonic points of view[1, 7, 9, 19]. The region is seismically potential zone as

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several large/great damaging earthquakes have occurred in the past. The earthquakes in this region are reported to be associated with MCT, MBT, thrusts, faults and lineaments. The main Himalayan seismic belt is mostly confined with the MCT and MBT[20]. The Indo-Burma region forms complex geology and tectonics. On the basis of physiographic structure, Burma territory has been divided as Eastern Highlands, Central lowlands and Indo-Burma mountain belt (called Indo-Burma Range). Bengal basin lies to the west of Indo-Burma range. The Arakan-Yoma, Manipur, Naga Hills, Lushai and Patkai are the most prominent structure in the Indo-Burma range. The northernmost part of Indo-Burma arc joins with the Himalayan belt and the joint region is outlined a complex structure that forms Syntaxis called Eastern Syntaxis.

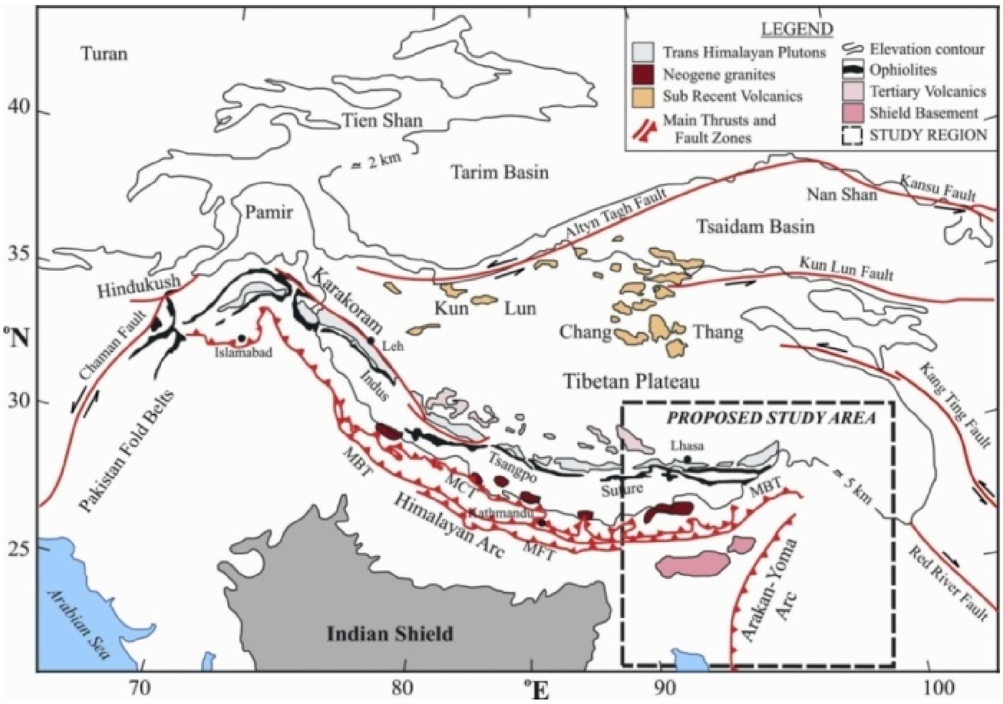

Figure 1. Map of the Northeast India Himalaya and its adjoining regions (modified after[20]). The map includes the Himalayan arc, Tibetan plateau and surrounding regions showing major tectonic– structural features. MCT (Main Central Thrust); MBT (Main Boundary Thrust); MFT (Main Frontal Thrust)

3. Seismicity and Stress Pattern

The Northeast India and the Eastern segment of the Himalaya is seismically one of the most active regions in the world where several large and two great earthquakes have occurred during the past hundred years. Several thrusts, lineaments, folded belts are found to be responsible for the earthquake generation in this region. A total of 560 earthquakes have been listed in the database during the period 1808 to 1962 in the considered region. Gupta et al.[10] have considered the great Shillong earthquake (1897) as the demarcation between the historical and recent seismicity of northeast India region. The seismicity pattern of this region has been studied by a number of researchers[10, 12, 13, 23, 25]. Considering the spatial distribution of earthquakes for the period 1808-2008 and using the information from[8], five seismically active zones are delineated in the northeast India Himalaya and its adjoining regions (Fig. 2.) as: Eastern Syntaxis (I), Arakan Yoma Fold Belt (II), Shillong Plateau (III), Himalayan Frontal Arc (IV) and Southeastern Tibet (V).

The seismicity and stresses acting in Himalayan region are very complex. Eastern and western Syantaxis of the Himalaya show comparatively high seismic activity to that of the central section. Four great earthquakes have occurred in this Himalayan belt during the last one hundred years which are 1897 (M 8.7, Shillong), 1905 (M 8.6, Kangra), 1934 (M 8.4, Bihar –Nepal border) and 1950 (M 8.7, Assam). The high seismic activity in the region is due to northward as well as eastward movement of the Indian plate toward the Eurasia and Burma plates respectively.

Chouhan and Srivastava[6] studied the focal mechanism solutions of earthquakes in northeastern India region using P-wave first motion directions data only for two years (1965-1966) and reported strike-slip faulting in northern part and thrust faulting in the southern part of Burmese mountains, and strike-slip faulting with Dauki fault and Disang thrust. Verma et al.[27] determined six focal mechanism solutions and observed normal as well as thrust faulting in Burma region and reported compressive stress axis nearly vertical than horizontal. Pure thrust faulting in Shillong area and pure thrust and strike faulting in Tura area were observed by composite focal mechanism of microearthquakes[12]. Singh and Shanker[25] determined six focal mechanism solutions in Bengal Basin using P-wave first motion data and observed thrust faulting.

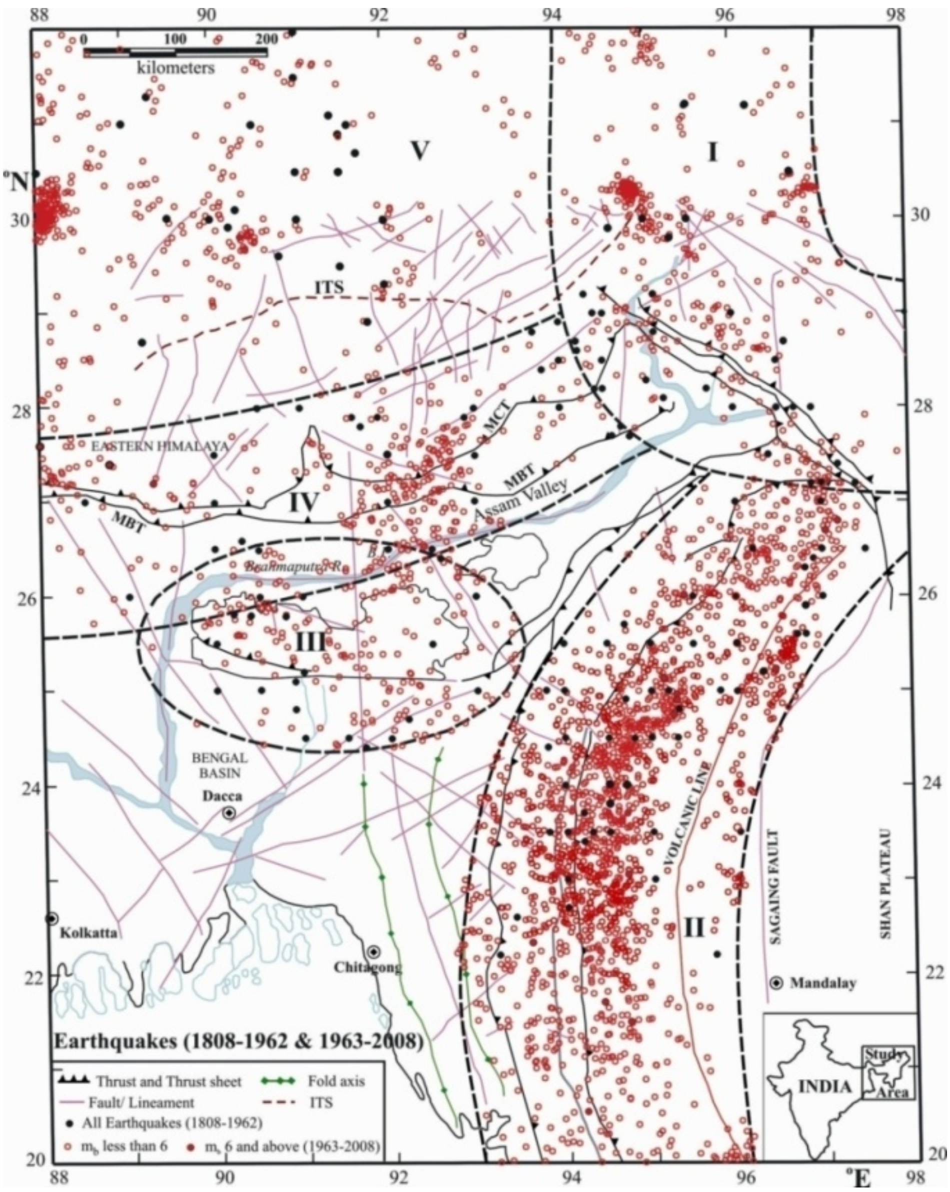

Figure 2. Seismicity of Northeast India Himalaya and its adjoining regions from 1808 -2008 over the major tectonic features MCT, MBT, IBR, and Shillong plateau. Roman letters I to V indicate seismically active regions delineated in the present study

4. Data Analysis

Focal mechanism solutions are determined by using P-wave first motion directions data of short as well as long periods from the catalogue of the International Seismological Centre (ISC) bulletin for the earthquakes with magnitudes mb 4.7-6.1 occurred from 1964-2008 in northeast India Himalaya and its adjoining regions. P-wave velocity structure model of Bhattacharya et al.[2] for the region is used to estimate the angle of incidence at each seismological station. Data related to ray parameter is taken from P–wave table of Herrin et al.[11] and estimated the angle of incidence of the ray at each recording station. The first motion directions of P–wave were plotted on an equal area projection of the lower hemisphere using the estimated values of angle of incidence (i) at the azimuth (Az) of each seismological station. The orientations of the nodal planes and the direction of P (pressure), T (tension) and B (null) axes were determined by using Wulff's stereographic projection net. The azimuth and the plunges of the P, T and B axes and the orientation of nodal planes were measured in degrees from the north and the horizontal, respectively. For all the solutions, a double couple source has been assumed for the interpretation of earthquake mechanism.

To investigate the current geodynamic status and stress pattern in northeast India Himalaya and its adjoining regions considering 94 focal mechanism solutions (Fig. 3). And source parameters and focal mechanism solution parameters for these earthquakes are furnished in Table 1. The distribution of inferred faulting patterns from focal mechanism solution of these earthquakes, in relation to major tectonic features, is shown in Fig. 4 at their epicenter locations.

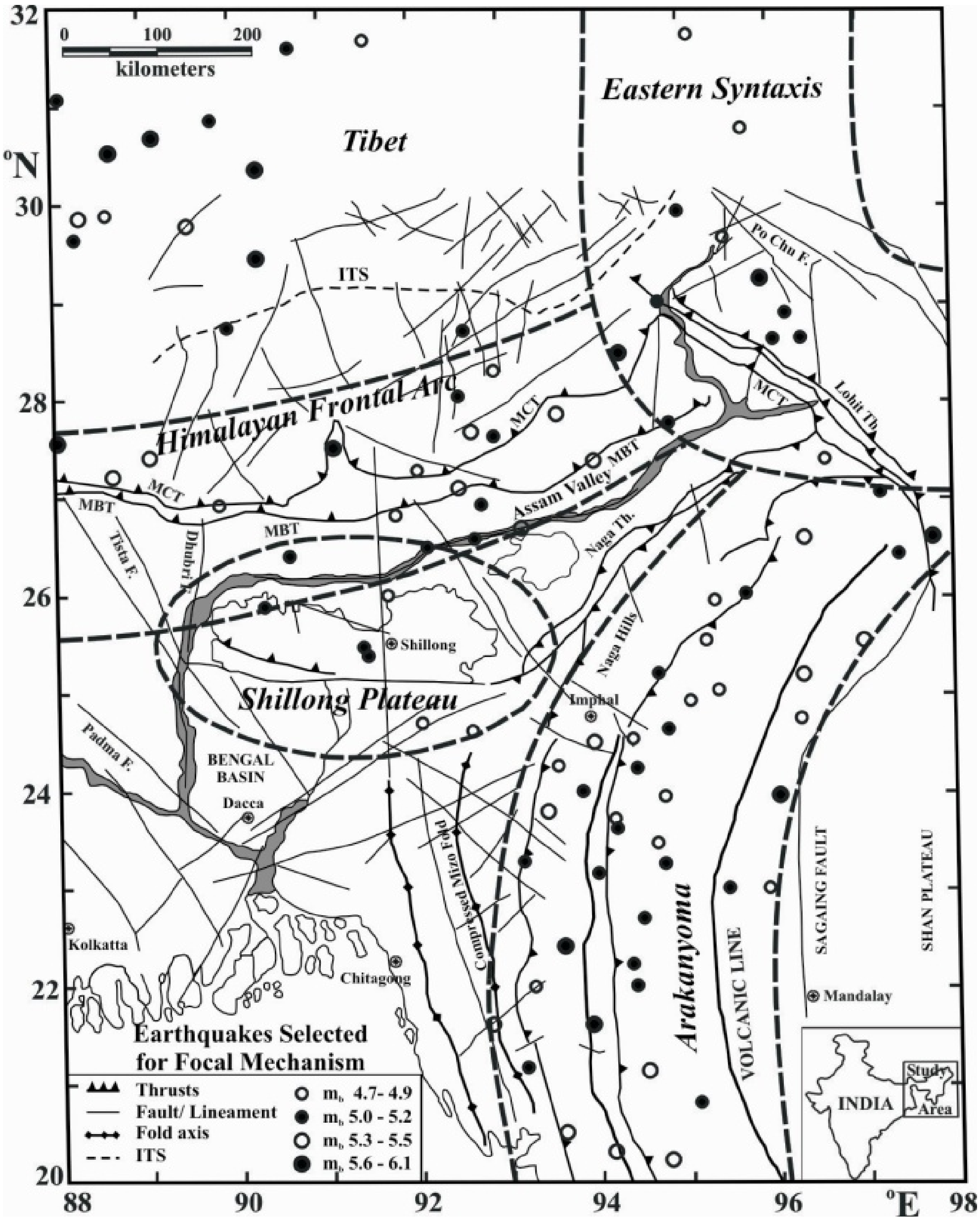

Figure 3. Spatial distribution of ninety-four mainshocks occurred during 1963-2008 in Northeast India Himalaya and its adjoining Southeast Tibet region selected for focal mechanism solutions and seismotectonic studies

5. Statistic of Faulting Patterns

The tectonics of Northeast India and its adjoining Eastern Himalaya, Southeastern Tibet and Burma regions is quite complex in which mixed faulting pattern is observed. It may be seen from Table 2. that the thrust environment is very much dominant in all the regions except Southeastern Tibet which is dominated by normal faulting. The tectonics of Arakan-yoma region is even more complex in which almost equal percentage of normal as well as thrust faulting occurs from shallow to intermediate depths. The nodal planes of thrust events orient predominantly in N to NE directions, and it is NW-SE to E-W direction of nodal planes for normal faulting events similar to that of the Southeastern Tibet. Thrust environment is predominant in Himalayan Frontal arc, Shillong plateau and Eastern Syntaxis regions but a few normal and strike-slip faulting have also occurred. The different tectonic regimes as observed from north to south are (1) extensional in Tibet region, (2) compression in Eastern Himalaya; and (3) both extensional and compressional in Arakan-yoma region to the south. The faulting pattern in the adjoining Tibet is totally different than Himalayan compression belt where normal faulting is predominant with north-south trending nodal planes leading to east-west flow of materials. The data furnished in Table 2 also suggest that most predominant mode of energy release in Eastern Himalaya is due to thrust faulting, and due to both normal as well as thrust faulting in Arakan-yoma regions, whereas mechanism for energy release in the Southeastern Tibet is solely due to normal faulting.

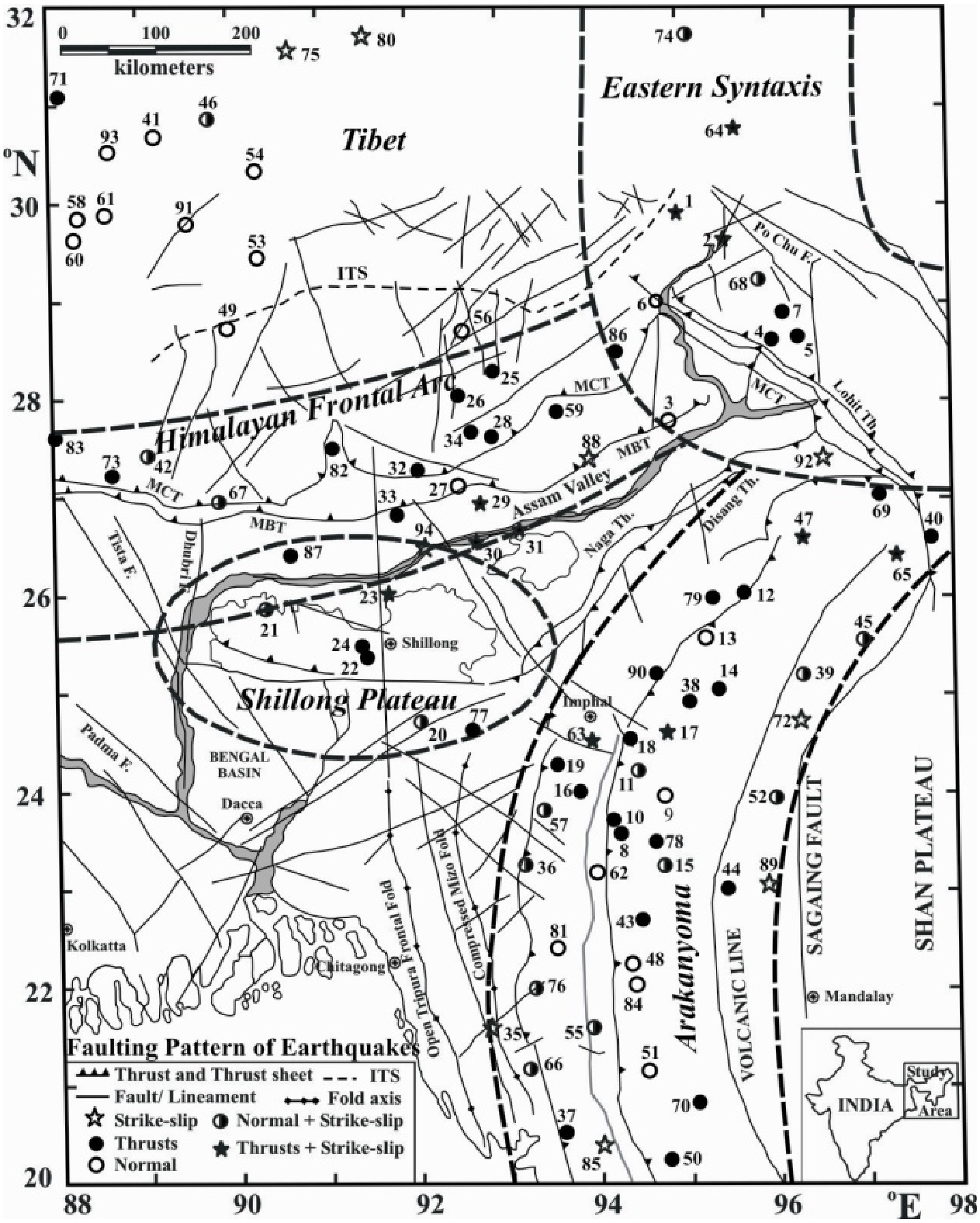

Figure 4. Spatial distribution of faulting patterns of the ninety-four mainshocks occurred in Northeast India Himalaya and its adjoining regions during 1963-2008

6. Discussion and Conclusions

It has already been established that the great Himalayan mountain range was formed as a result of the collision of two mega tectonic plates India and Eurasia. This collision, which happened some 65 million years ago, was brought about by the northward movement of the Indian plate that resulted in closing of the vast intervening Tethyan Ocean. Many scientists have already pointed out that collision of the Indian plate with the Eurasian plate, which occurred in the Late Tertiary[16, 21], is the sole cause for the faulting pattern being observed in the Himalaya and its adjoining region.

Table 1. List of ninety-four earthquakes occurred during 1963-2008 in northeast India Himalaya and its adjoining Tibet region are considered for seismotectonic studies using focal mechanism parameters derived through focal mechanism solutions of these earthquakes. Focal mechanism solutions for the first 34 mainshocks (Sl. No. 1-34) have been done in the present work, and the remaining 60 solutions (Sl. Nos. 35-94) and their source parameters are taken from different published literatures. The strikes, dips, dip directions (dip dir.) and slips of both the nodal planes; and azimuths (Az) and plunges (Pl) of P, T and B-axes for each of the mainshocks are estimated/ taken and these are furnished in degrees. Dip directions are considered for both of the nodal planes related to the first 34 mainshocks, whereas it is slip angle for the remaining 60 mainshocks

Sl. No.	Mainshocks					Nodal Plane I			Nodal Plane II			P axis		T axis		B axis		Ref.
	Date dd/mm/yyyy	Long. (°E)	Lat. (°N)	Mag. (m_b)	Depth (km)	Strike	Dip	Dip dir. (Slip)	Strike	Dip	Dip dir. (Slip)	Az.	Pl.	Az.	Pl.	Az.	Pl.	
1	22.04.1982	94.99	29.94	5.0	15	41	69	135	122	66	32	171	2	262	22	78	58	TS
2	29.05.1982	95.5	29.67	4.9	35	29	61	300	96	59	188	304	1	63	46	241	45	TS
3	26.11.1982	94.86	27.77	5.1	28.6	52	40	141	52	60	323	140	75	322	15	52	0	TS
4	01.03.1983	96.04	28.63	5.1	26.7	176	15	87	176	76	265	266	32	86	60	176	0	TS
5	20.01.1984	96.35	28.64	5.0	27	9	20	101	9	70	280	280	26	102	65	9	0	TS
6	09.05.1988	94.76	29.01	5.1	29	97	19	187	97	71	6	188	64	7	27	97	0	TS
7	24.05.1993	96.18	28.9	5.0	41	51	62	140	77	30	346	150	16	294	70	57	12	TS
8	13.12.1975	94.26	23.61	5.2	81	75	25	165	75	66	346	345	21	164	69	75	0	TS
9	09.02.1978	94.75	23.94	4.8	117	35	70	306	35	20	125	126	65	306	26	35	0	TS
10	20.05.1980	94.19	23.71	4.8	85	131	76	40	131	16	221	41	32	222	60	131	0	TS
11	03.01.1983	94.44	24.23	5.1	81.7	24	50	116	148	51	239	346	57	90	7	183	33	TS
12	25.04.1984	95.69	26.02	5.0	108	160	6	71	160	84	252	251	41	71	51	160	0	TS
13	17.02.1985	95.24	25.54	4.8	92	20	16	111	20	74	292	112	71	292	29	20	0	TS
14	10.07.1988	95.37	25.03	4.9	131	82	26	172	82	64	350	351	19	173	71	82	0	TS
15	27.12.1988	94.74	23.25	5.1	139	55	63	146	158	67	250	18	36	287	4	193	53	TS
16	07.12.1991	93.83	23.99	5.1	65	103	25	193	103	66	12	13	32	194	69	103	0	TS
17	09.04.1994	94.8	24.63	5.1	91	24	60	115	81	46	350	139	9	242	60	44	31	TS
18	06.03.1998	94.4	24.53	4.7	66	133	27	223	133	64	44	44	20	226	71	133	0	TS
19	27.07.1998	93.56	24.25	4.8	59	46	10	147	46	80	315	310	35	147	71	82	0	TS
20	11.01.1982	92.05	24.69	4.9	48	48	60	317	116	59	206	83	45	351	2	260	45	TS
21	06.07.1982	90.31	25.88	5.0	17	75	68	343	143	48	233	119	47	14	13	274	41	TS
22	31.08.1982	91.46	25.38	5.0	38	35	67	127	35	23	306	125	23	306	61	35	0	TS
23	30.12.1982	91.69	26	4.9	50	3	80	274	90	80	180	137	5	45	21	245	88	TS
24	12.12.1992	91.41	25.47	5.0	43	69	39	169	69	52	339	339	6	160	83	69	0	TS
25	24.04.1982	92.91	28.3	4.8	82	97	20	185	97	70	6	6	26	184	65	97	0	TS
26	02.10.1983	92.51	28.04	5.0	38.3	46	32	136	40	29	317	317	13	138	77	46	0	TS
27	12.10.1985	92.51	27.11	5.3	7	80	22	171	80	68	350	172	67	350	13	80	0	TS
28	24.01.1987	92.9	27.63	5.0	24.4	9	19	100	9	80	282	281	28	100	62	9	0	TS
29	08.03.1989	92.75	26.93	5.1	63	56	62	146	125	58	38	180	2	274	46	88	44	TS
30	09.02.1990	92.67	26.58	5.2	48	24	71	116	102	58	12	152	10	247	40	50	42	TS
31	23.06.1991	93.18	26.58	5.4	36	10	70	101	115	55	206	67	11	327	42	167	48	TS
32	12.12.1993	92.04	27.28	4.8	29.9	163	13	74	163	78	293	254	34	74	58	163	0	TS

Sl. No.	Mainshocks					Nodal Plane I			Nodal Plane II			P axis		T axis		B axis		Ref.
	Date dd/mm/yyyy	Long. (°E)	Lat. (°N)	Mag. (m_b)	Depth (km)	Strike	Dip	Dip dir. (Slip)	Strike	Dip	Dip dir. (Slip)	Az.	Pl.	Az.	Pl.	Az.	Pl.	
33	18.07.1997	91.79	26.82	4.9	47	18	27	108	18	64	290	290	30	110	71	18	0	TS
34	25.01.2000	92.65	27.68	5.3	4.4	22	20	115	22	70	296	295	26	116	65	22	0	TS
35	12.05.1977	92.8	21.6	5.4	40	216	72	3	125	87	162	172	10	79	15	295	72	CMT
36	13.10.1977	93.2	23.3	5.2	60.8	145	41	-171	48	84	-49	354	37	107	27	223	41	CMT
37	01.01.1979	93.6	20.5	5.3	95	93	32	62	305	62	106	23	16	248	69	117	14	CMT
38	29.05.1979	95.1	24.9	4.9	108	109	30	134	241	69	68	348	21	120	60	250	20	CMT
39	25.11.1979	96.3	25.2	5.5	10	357	79	-175	266	85	-11	221	11	312	5	63	78	CMT
40	21.12.1979	97.8	26.6	5.8	10	119	42	72	323	51	106	42	4	292	77	133	12	CMT
41	22.02.1980	89.2	30.7	6	10	7	39	-84	180	51	-95	62	83	273	6	183	4	CMT
42	19.11.1980	89.1	27.4	5.3	44.1	209	51	-2	301	89	-141	172	28	68	25	302	51	CMT
43	20.11.1980	94.5	22.7	5	20	208	19	131	345	76	78	85	30	239	57	348	12	CMT
44	30.06.1981	95.5	23.0	5.1	10	7	40	142	128	67	57	242	15	355	55	143	30	CMT
45	16.08.1981	97.0	25.5	5.3	37	298	66	-7	30	83	-156	257	22	162	12	45	65	CMT
46	22.01.1982	89.8	30.9	5	10	139	36	-132	7	64	-64	318	62	78	15	174	23	CMT
47	16.11.1983	96.4	26.6	5.3	144	177	58	147	286	62	37	51	3	144	44	318	45	CMT
48	03.07.1988	94.4	22.2	5.2	86	133	18	-104	327	72	-85	244	63	54	27	146	4	CMT
49	09.04.1989	89.9	28.7	5.2	15	330	43	-119	187	53	-65	155	70	260	5	352	19	CMT
50	24.09.1989	94.8	20.2	5.3	144	83	59	145	192	61	36	317	1	48	45	226	45	CMT
51	27.03.1992	94.5	21.1	5.4	86.2	159	12	-85	334	78	-91	242	57	65	33	334	1	CMT
52	15.06.1992	96.0	24.0	5.7	22.9	8	69	-173	275	83	-21	229	20	323	10	78	68	CMT
53	30.07.1992	90.3	29.5	6	15	10	42	-94	196	49	-86	141	86	283	3	13	3	CMT
54	18.01.1993	90.3	30.3	5.7	15	25	48	-57	161	51	-121	7	66	272	2	181	23	CMT
55	03.08.1994	93.9	21.6	5.6	64.5	216	73	0	306	90	-163	173	12	80	12	307	73	CMT
56	09.06.1996	92.6	28.7	5.1	83	12	23	-117	221	69	-79	149	64	303	24	37	10	CMT
57	31.07.1997	93.4	23.8	5.5	41.8	330	16	40	201	80	103	280	34	126	54	19	12	CMT
58	25.08.1998	88.3	29.9	5.3	15	14	46	-67	162	48	-112	1	74	268	1	177	16	CMT
59	26.09.1998	93.6	27.9	5.4	33	233	26	118	22	67	77	122	21	270	65	27	12	CMT
60	30.09.1998	88.3	29.6	5.1	33	139	32	-112	345	60	-76	286	71	65	14	158	12	CMT
61	05.10.1998	88.6	29.9	4.8	33	26	29	-77	191	62	-97	84	72	287	17	195	6	CMT
62	22.02.1999	94.0	23.2	5.1	51	47	35	-103	242	56	-81	180	77	326	11	57	7	CMT
63	05.04.1999	94.0	24.5	5.3	65.1	86	62	16	348	76	151	39	9	304	30	144	58	CMT
64	26.01.2000	95.7	30.8	4.9	33	95	70	11	1	80	160	49	7	317	21	156	67	CMT
65	08.06.2000	97.4	26.4	5.1	18.8	126	33	67	333	60	104	53	14	276	71	146	12	CMT
66	16.10.2002	93.2	21.2	5.1	45.9	310	43	-128	177	57	-60	140	64	246	8	339	25	CMT
67	25.03.2003	89.8	26.9	4.8	55.8	40	70	-21	137	71	-159	358	29	268	1	177	61	CMT
68	18.08.2003	95.9	29.3	5.6	33	65	77	-6	156	84	-167	21	14	290	5	179	75	CMT
69	24.05.2004	97.2	27.1	5	26.5	339	45	107	136	48	74	238	2	335	78	147	12	CMT

Sl. No.	Mainshocks					Nodal Plane I			Nodal Plane II			P axis		T axis		B axis		Ref.
	Date dd/mm/yyyy	Long. (ºE)	Lat. (ºN)	Mag. (m_b)	Depth (km)	Strike	Dip	Dip dir. (Slip)	Strike	Dip	Dip dir. (Slip)	Az.	Pl.	Az.	Pl.	Az.	Pl.	
70	17.07.2005	95.1	20.8	5	121	241	36	53	105	62	114	178	14	57	64	273	21	CMT
71	20.08.2005	88.1	31.1	5.1	96.3	89	44	74	290	48	105	10	2	268	79	100	11	CMT
72	29.12.2005	96.3	24.7	4.9	18.5	104	72	-1	195	89	-162	61	13	328	12	197	72	CMT
73	14.02.2006	88.6	27.2	5.4	19.2	287	27	126	68	68	73	170	21	311	63	74	16	CMT
74	21.02.2006	95.1	31.8	4.9	14.5	70	36	-13	171	82	-125	48	42	289	28	177	35	CMT
75	19.04.2006	90.7	31.6	5.2	23.2	325	80	-179	235	89	-10	190	8	281	6	47	80	CMT
76	03.11.2006	93.3	22.0	4.9	34.5	216	70	2	126	88	160	173	13	79	15	302	70	CMT
77	10.11.2006	92.6	24.6	4.9	31.8	141	46	154	249	72	47	9	16	116	46	266	40	CMT
78	07.12.2007	94.7	23.5	4.8	108	135	42	120	277	54	65	24	6	131	69	292	20	CMT
79	07.07.2008	95.3	26.0	4.9	70	137	45	135	262	60	55	16	9	121	59	281	30	CMT
80	26.08.2008	91.5	31.7	4.8	21.4	150	82	-179	60	89	-8	15	7	105	5	231	82	CMT
81	22.01.1964	93.6	22.4	6.1	88	236	25		19	70		266	63	120	23	24	14	a*
82	18.02.1964	91.1	27.5	5.6	30	122	50		302	40		212	5	32	85	302	0	b*
83	12.01.1965	88.0	27.6	6.1	23	91	78		271	12		181	33	1	57	271	0	b*
84	15/12.1965	94.4	22	5.2	109	299	84		128	6		208	50	28	40	299	1	c*
85	15.02.1967	94.1	20.3	5.5	19	179	12		83	30		134	29	38	11			d
86	14.03.1967	94.3	28.5	5.8	12	276	6		96	84		186	39	6	51	96	0	b*
87	18.08.1968	90.6	26.4	5.1	29±3	90	60	90				180	15	0	75			e
88	19.02.1970	94.0	27.4	5.5	18	129	51		19	67		77	10	337	46	176	42	b*
89	10.10.1971	95.9	23	4.9	46	324	78	54	47	60	317	189	29	92	12	343	57	f
90	29.12.1971	94.7	25.2	5	46	152	58		130	56		90	88	186	55	181	36	g*
91	14.09.1976	89.5	29.8	5.4	90±10	215	52	292	2	43	244	185	72	290	5	21	17	h
92	25.04.1979	96.6	27.4	4.8	24	316	70	46	34	60	304	178	36	84	6	346	53	i
93	22.02.1980	88.65	30.5	5.8	14	185	48		339	44		172	76	262	40	352	24	j
94	22.09.1984	92.14	26.4	5.2	29	301	86	31	34	60	124	351	17	253	23	113	60	i

a: Chandra[4]; b : Chandra[3]; c : Verma et al[27]; d : Rastogi et al[22]; e: Chen and Molnar[5]; f : Mukhopadhyay and Dasgupta[17]; g : Tandon and Srivastava[26]; h : Molnar & Chen[15]; i :Nandy & Dasgupta[18]; j: Ni & Barazangi[20], TS- This Study, CMT-Centroid Moment Tensor Solution; *estimated strike of the nodal planes from dip directions as given in the originally published research papers

Table 2. Frequency distribution of different types of faulting observed in five delineated seismogenic regions in the Northeast India Himalaya and its surrounding Tibet region using ninety four focal mechanism solutions

Delineated Seismogenic Regions	Focal depth range (km)	Number of focal mechanism solutions		Frequency of different faulting patterns				
				Thrusts	Normal	Strike-slip	Strike-slip with	
		shallow	Intermediate				Thrusts	Normal
Eastern Syntaxis (Region I)	12-41	12	0	4	2	1	3	2
Arakan-Yoma (Region II)	10-145	24	19	18	7	4	4	10
Shillong Plateau (Region III)	29-50	8	0	4	--	1	1	2
Himalayan Frontal Arc (Region IV)	7-82	16	1	10	1	1	3	2
Southeast Tibet (Region V)	10-96	11	3	1	11	2	--	--
Total		71	23	37	21	9	11	16

Orientations of pressure (P) and tension (T) axes derived through focal mechanism solutions Table. 1 and Fig 4, help in understanding the stress pattern of a region. The azimuth and dip of the P- and the T- axes are determined through focal mechanism solutions of earthquakes. In general, the tension is related with the normal faulting and the compressive stress with the thrust faulting and measurement of P- and T-plunge determines the stress regime of a region. The following criterion are considered to infer about different stress regimes: (1) Extension Regime if T <45° and P >45° (if T- plunge is less than 45° and P- plunge is greater than 45°, the region is said to be an extension regime); (2) Compression Regime if P <45° and T >45° (if P - plunge is less than 45° and T- plunge is greater than 45°, the region is said to be compressive regime); and (3) if both the axes of P- and T- plunge are around 45°, the focal mechanism solutions are said to be strike-slip in which motion occurs past each other). In order to study the general characteristic of the stress field of a region, the composite plot of P- and T -axes will be more meaningful than deriving inferences using individual event mechanisms. Such composite solutions provide direct evidence for the main compressive stress field in a region like Northeast India Himalayan region.

In the Eastern Syntaxis the events have shallow dipping nodal planes striking NW-SE to E-W. Normal faulting is observed at a depth of 29 km (events 3 and 6) with nodal planes oriented along NE-SW to E-W indicating resultant extension along NW-SE. It may be inferred that the Eastern Syntaxis region of Himalayan range is under compression from northwest and south directions. The general trend of direction of extension from NW-SE to E-W is observed in Arakan-yoma region by analyzing a total of 17 normal faulting solutions (shallow as well as intermediate). Majority of normal solutions (~65%) provided predominantly E-W direction of extension which is especially confined in the central portion of the fold belt bounded by 21° to 25.5° N latitude along north-south direction whereas it is predominantly NW-SE towards east and west of it. It is also observed that the deeper level of extensional regime in the central portion changes to shallow depths on either sides of it (east and west). This trend suggests that the extensional tectonic regime occur from shallow to intermediate depths (up to 140 km) in the region which may be indicative of presence of extensive fluid (magma chamber) at these depths. The analysis of focal mechanism parameters reveals NE oriented compression and E-W oriented extension pattern in Arakan-Yoma region and these patterns exist right from shallow to intermediate depths up to 140 km.

It is inferred that N to NE is the predominant direction of compressive stresses currently acting in the Arakan-yoma region whereas direction of extension is predominantly from NW-SE to E-W. Compression and extension regimes observed at different depth levels may be due to internal relative motion of different blocks along the transverse faults coupled with intermittent upward rise of magmatic materials due to partial and differential melting in the subsurface of the leading edge of the plate subducting into the asthenosphere. The Shillong Plateau region consists of several faults with three main directions of orientation i.e. NW-SE, NE-SW and N-S. Several major faults are mapped in the Shillong plateau region such as Dauki fault to the south, Chedrang fault and Oldhan fault to the north, Kopili fault to the east and Dhubri and Tista fault to the west. Seismic activity is observed to be very feeble along these faults and strong activity is found to occur slightly away from these faults. The region is also traversed by several other faults/ lineaments especially in the eastern, southern and western portions that surround the plateau. Focal mechanism solutions of eight earthquakes have been considered to study the stress pattern in Shilllong plateau of which five solutions (events No. 20-24) of the earthquakes (1982 -1992) are determined in the present work. Majority of events with thrust faulting have moderate to steep dipping nodal planes towards NW to N. Steep dip is observed towards northwest and southeast of the plateau whereas it is moderate dip within the plateau region. From the interpretation of observed faulting patterns in Shillong plateau, it can be inferred that the region is under compression due to the stresses acting in N to NE directions.

The present geotectonic activity in the Himalayan collision zone is the result of post collisional incident. The results derived through focal mechanism solutions confirm that the geological processes, that were responsible for the formation of Himalaya, are still continuing. The orientation of minimum compressive stress, reveal that the earthquake generation process in Tibet is entirely different than that of the Himalayan compression zone. And almost horizontal minimum compressive stress in the Tibet is responsible for the earthquake generation process due to the flow of materials in east-west direction.

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