Seismicity and Seismotectonics of Nepal and its Neighbouring Regions

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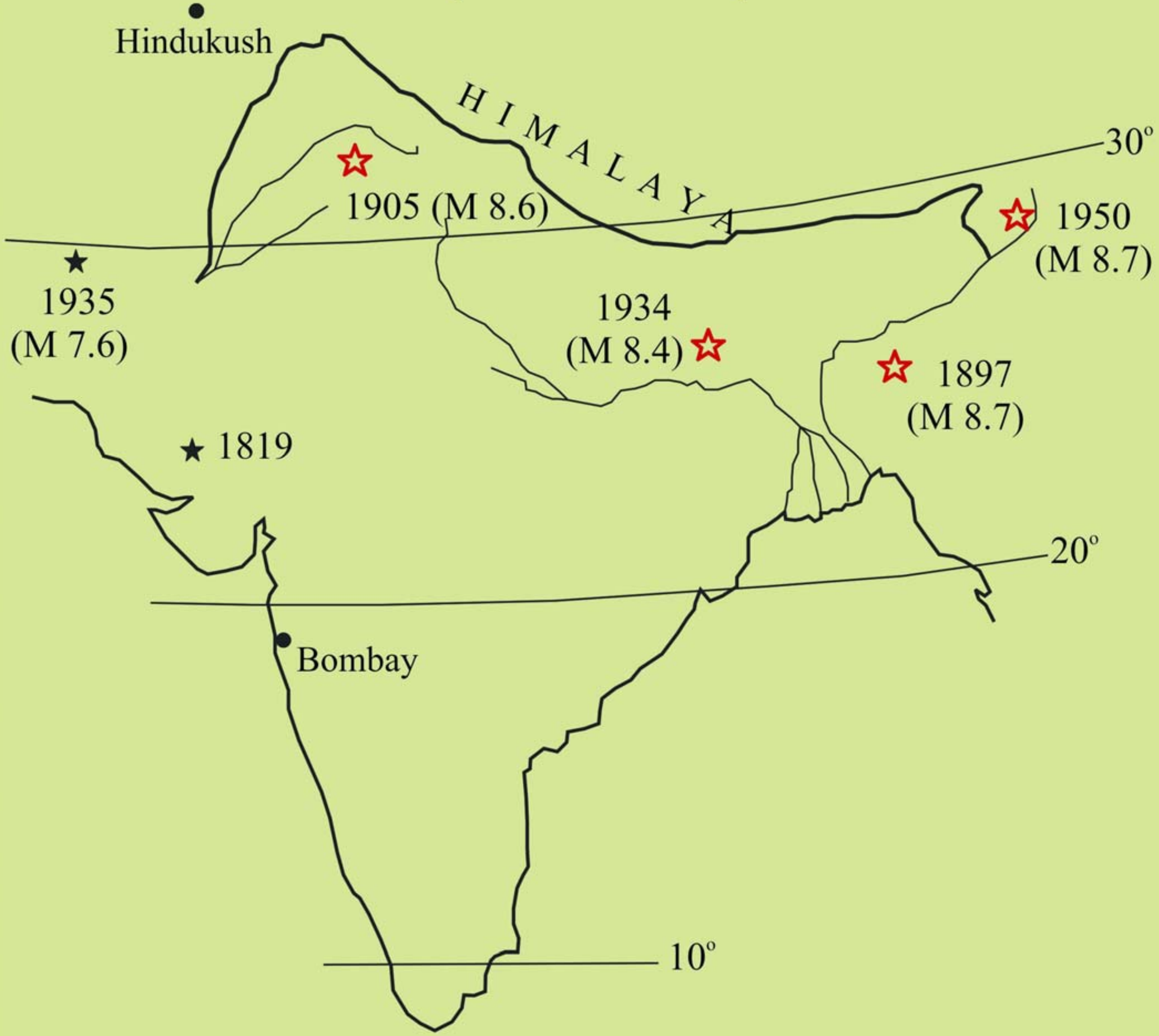
Great Earthquakes in Central Himalayas (1897-1950)



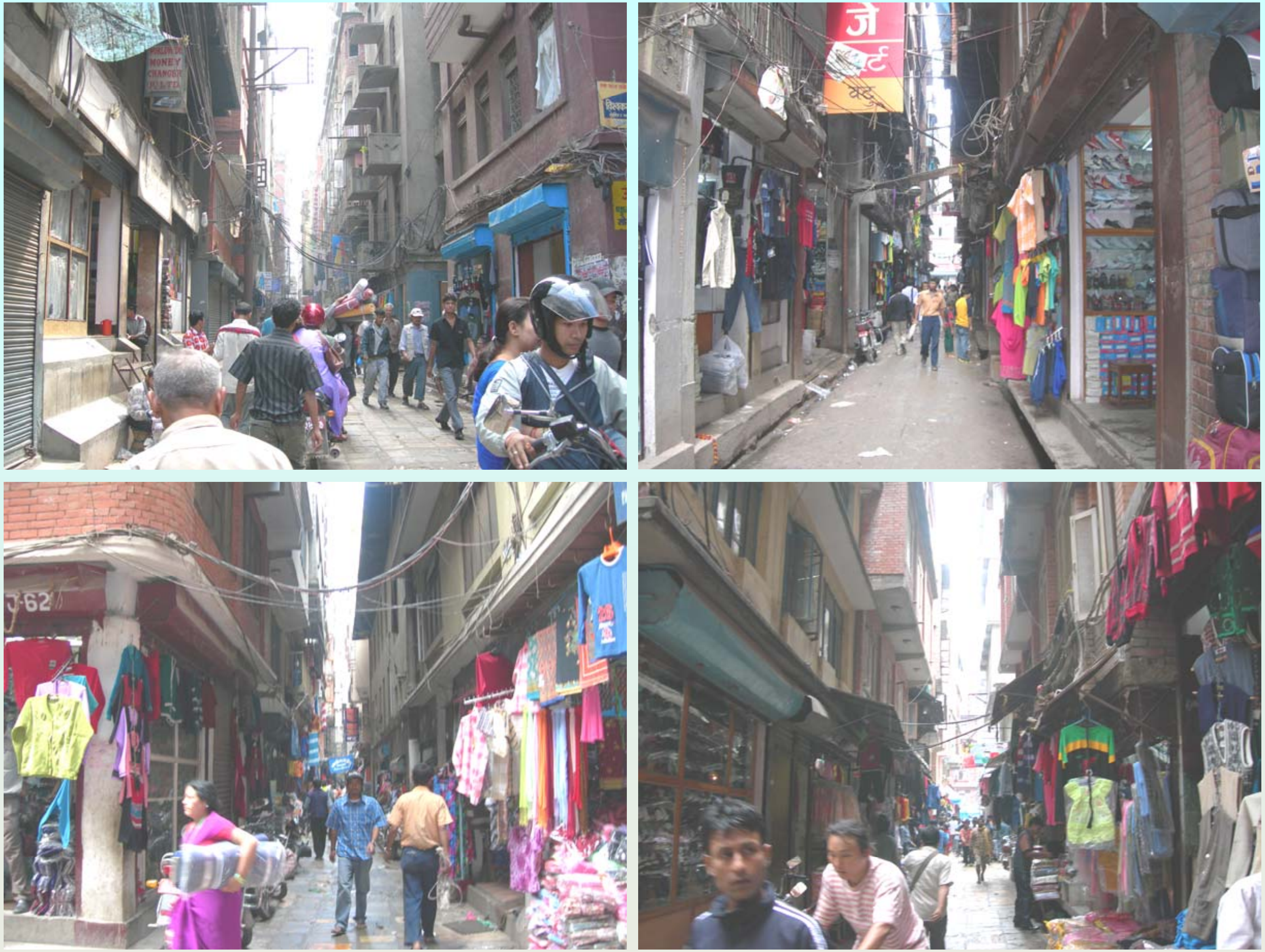
Distribution of Probable rupture zones of great earthquakes along the Himalayan arc during last century.

Bhaktapur Darbar Square before and after 1934 Earthquake

Clock tower and Tri-Chandra College, Kathmandu

After 1934 event

Reconstruction in same fashion



Kathmandu: vulnerable mega city

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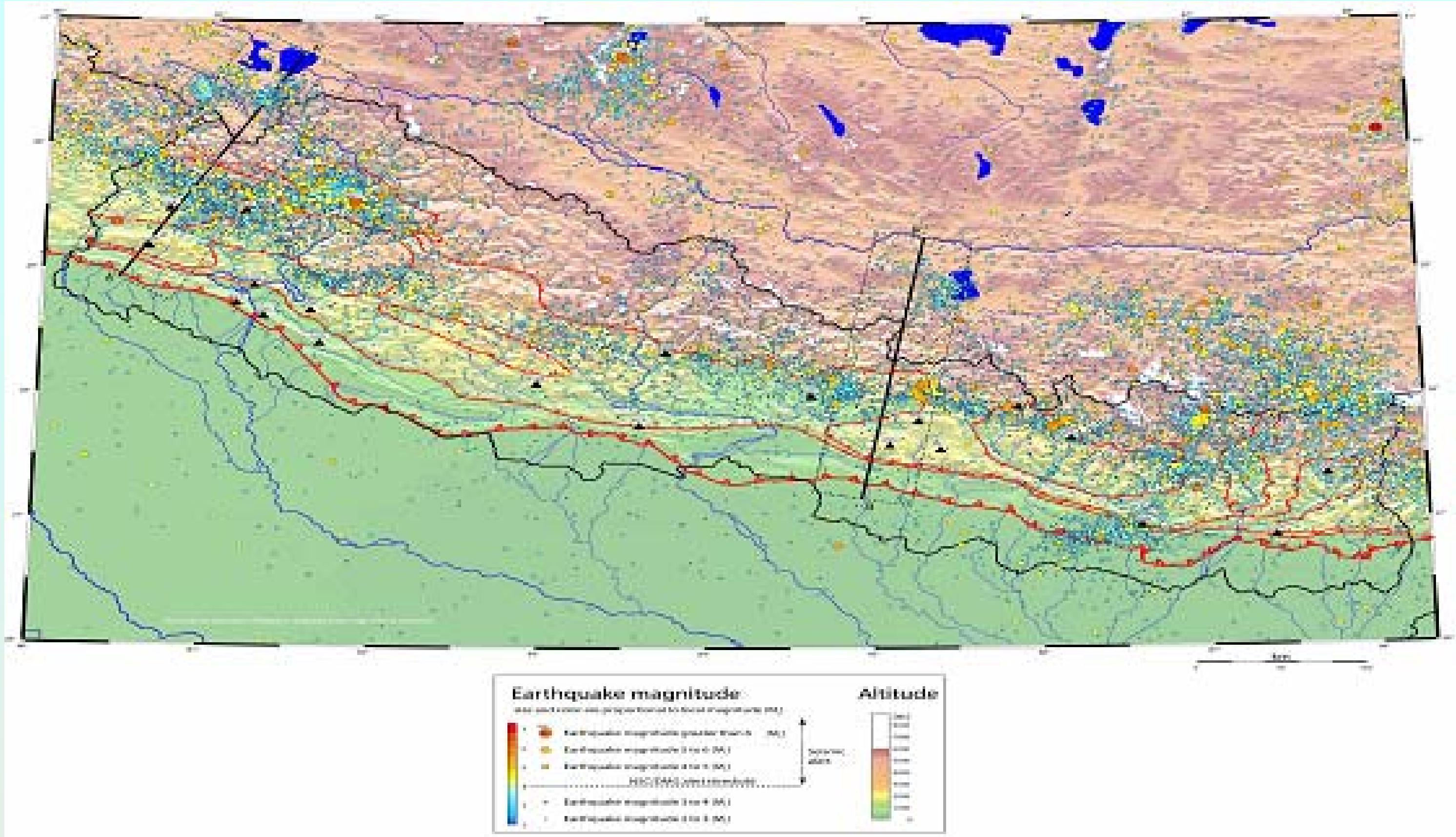
Seismic stations in Nepal

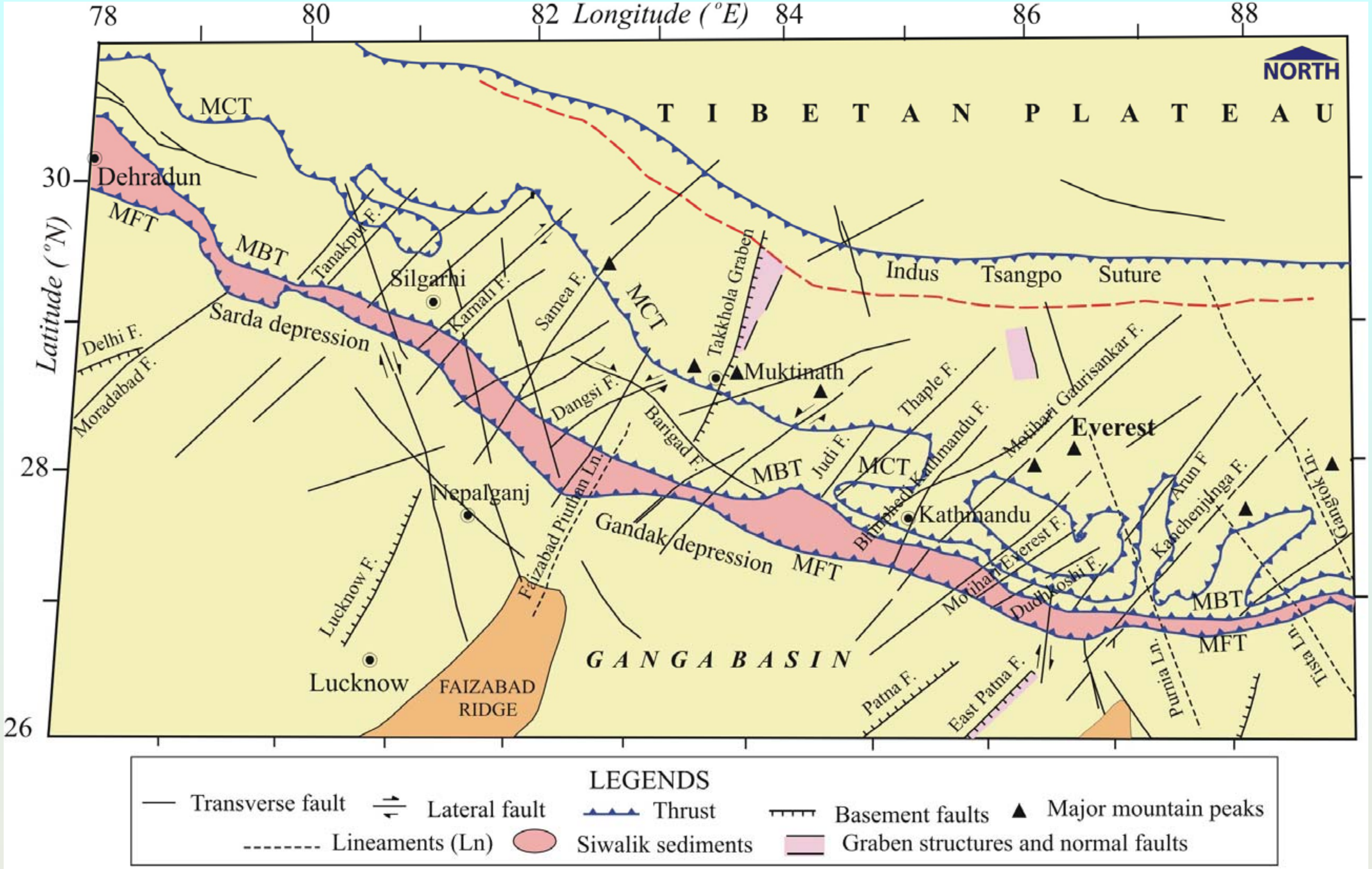
In Brief: 1978 First seismic station at Phulchowki

Now 20 Short Period and 10 GPS Stations operation from 1994

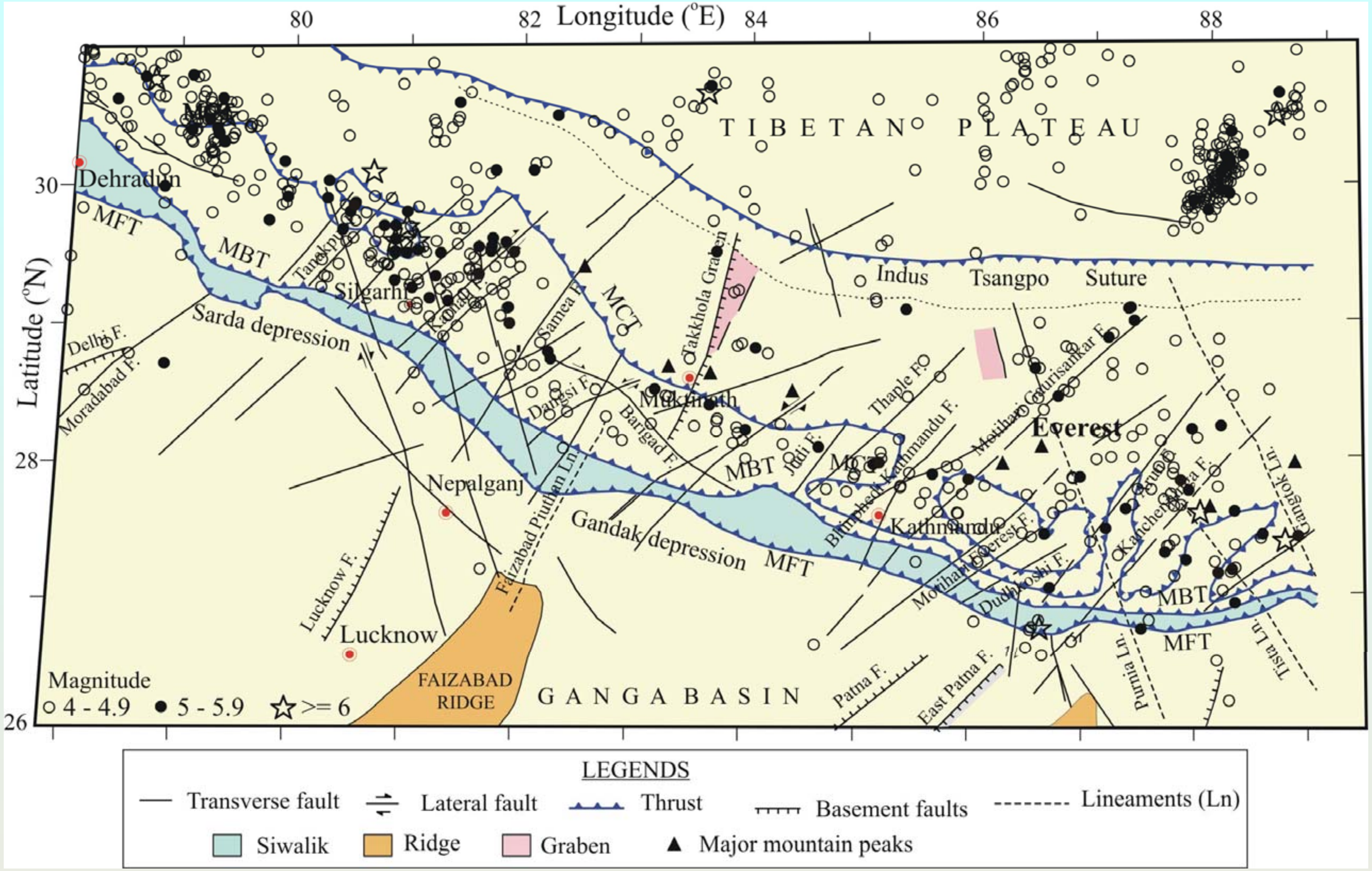


Seismicity map of Nepal with epicenter M>2 for the period of 1995 -1998 (*by DMG, Kathmandu*).

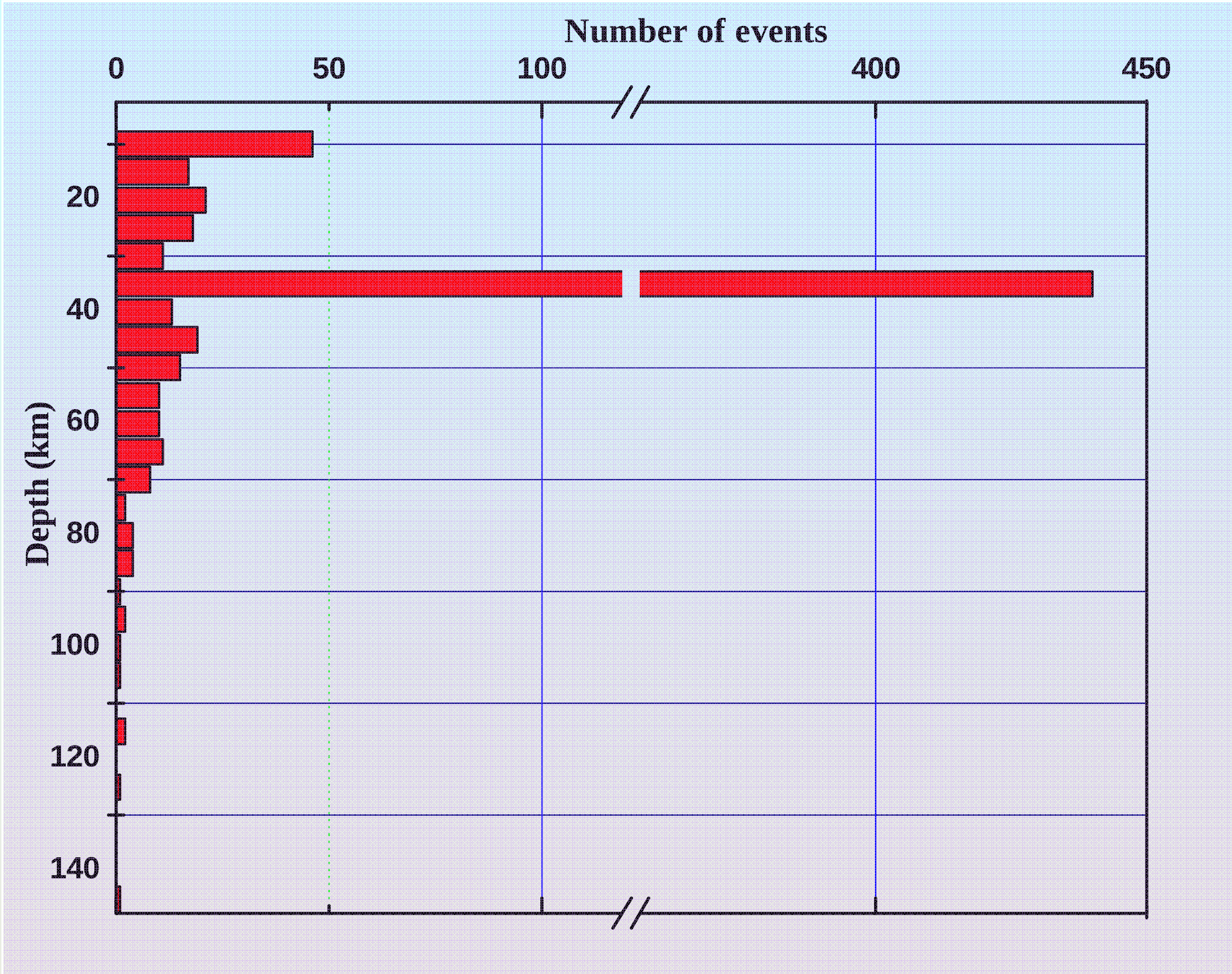
Tectonics elements of Nepal and adjoining regions

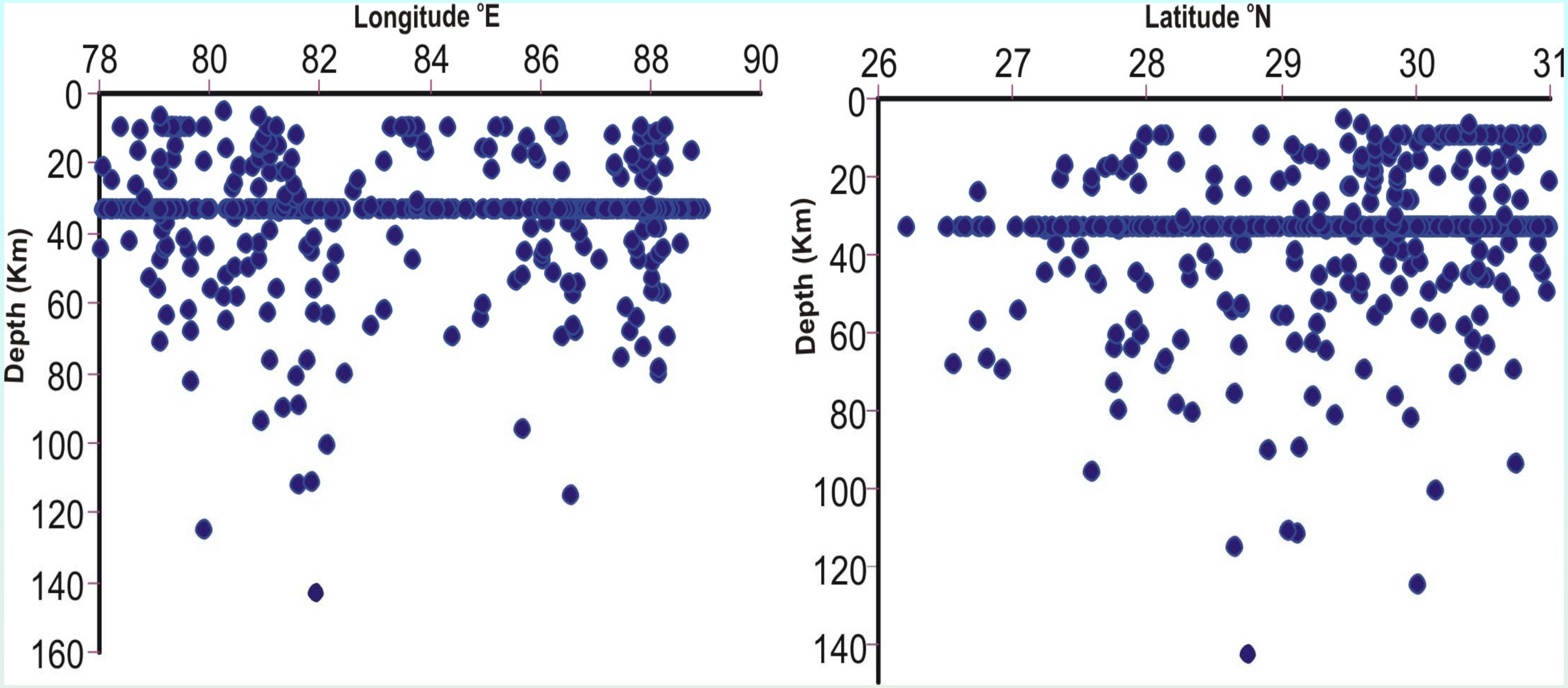


Seismicity map for m≥4 (1963-2004)



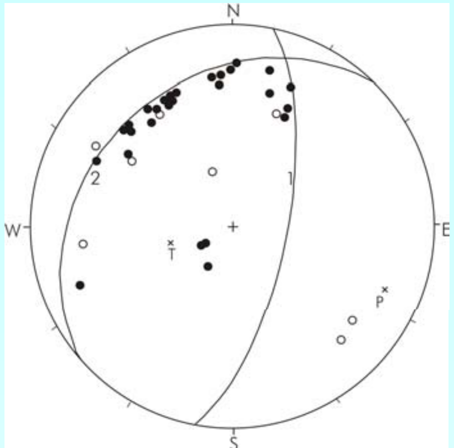
Variation of number of events with focal depth



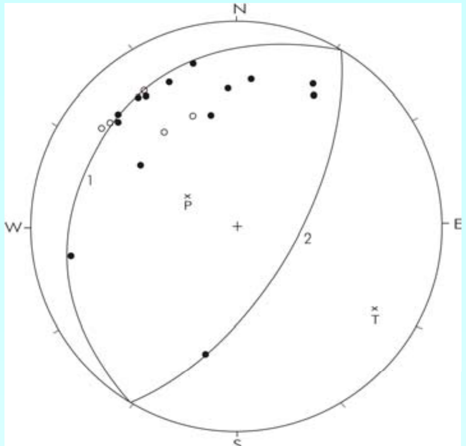


Variation of focal depth (Km) with Longitude and Latitude

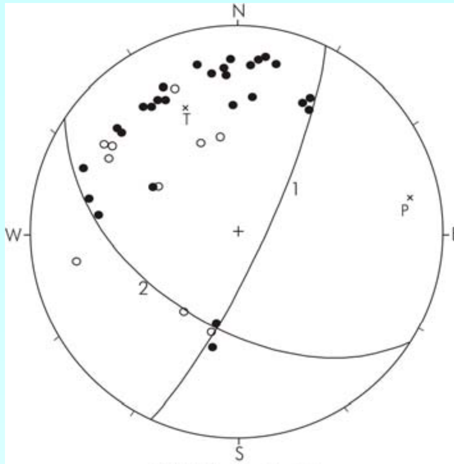
Samples of FPS calculated in this study



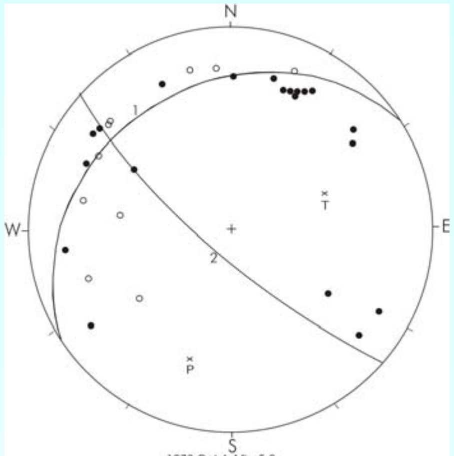
1970 Feb. 26 Mb 5.0



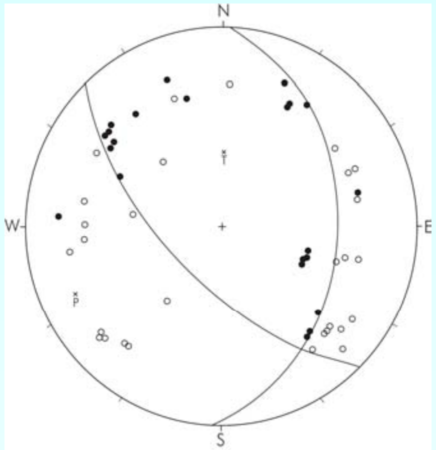
1975 Sep 6 Mb 5.1



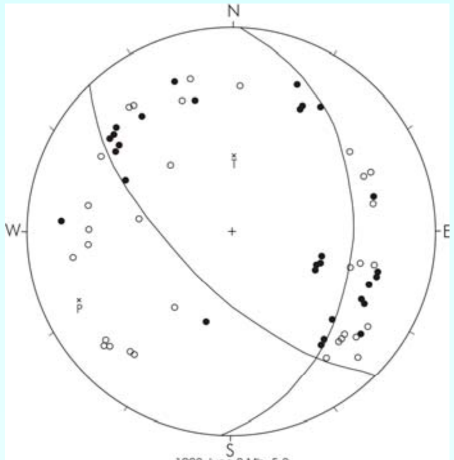
1970 Feb. 12 Mb 5.3



1978 Oct 4 Mb 5.2

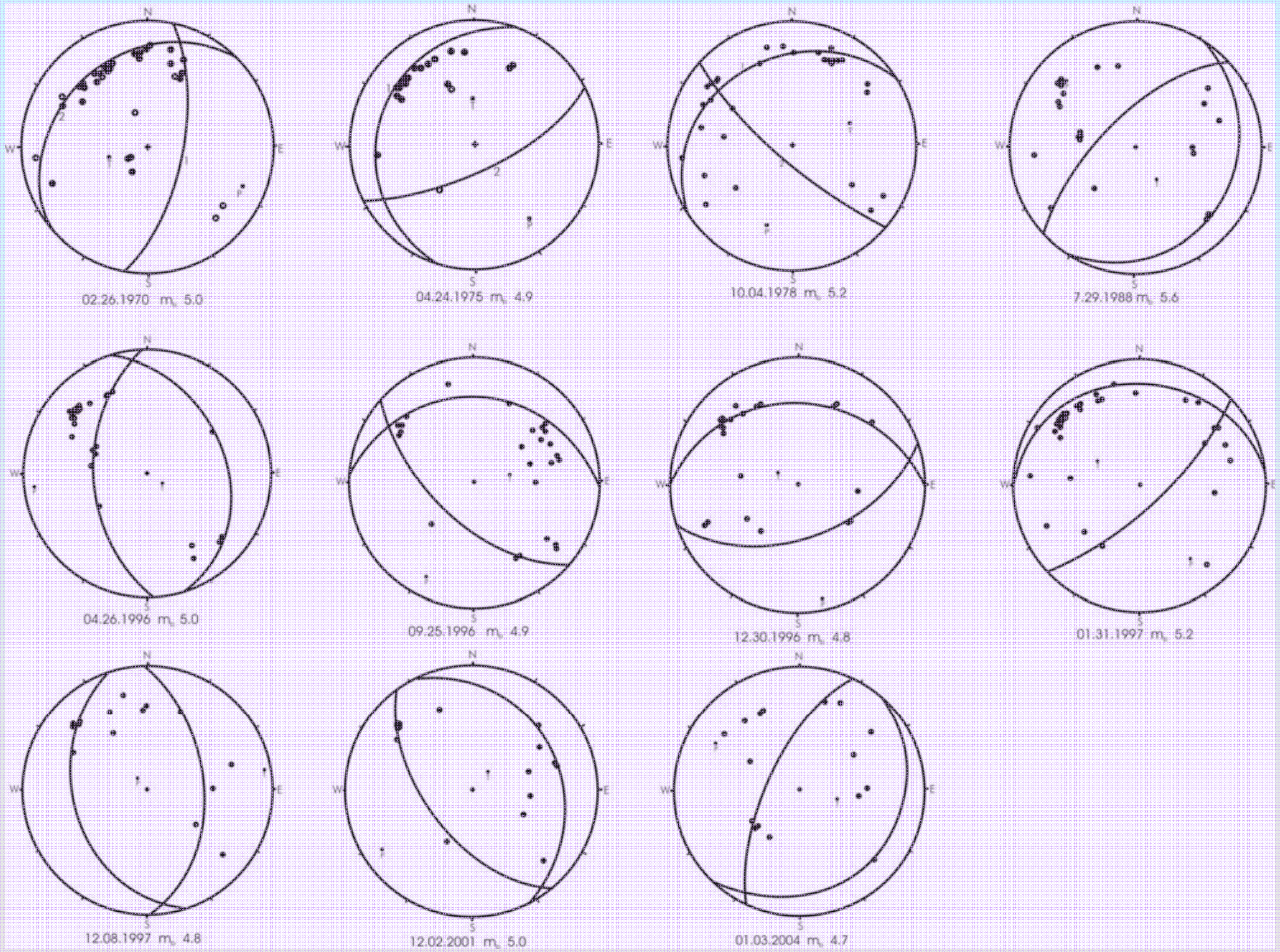


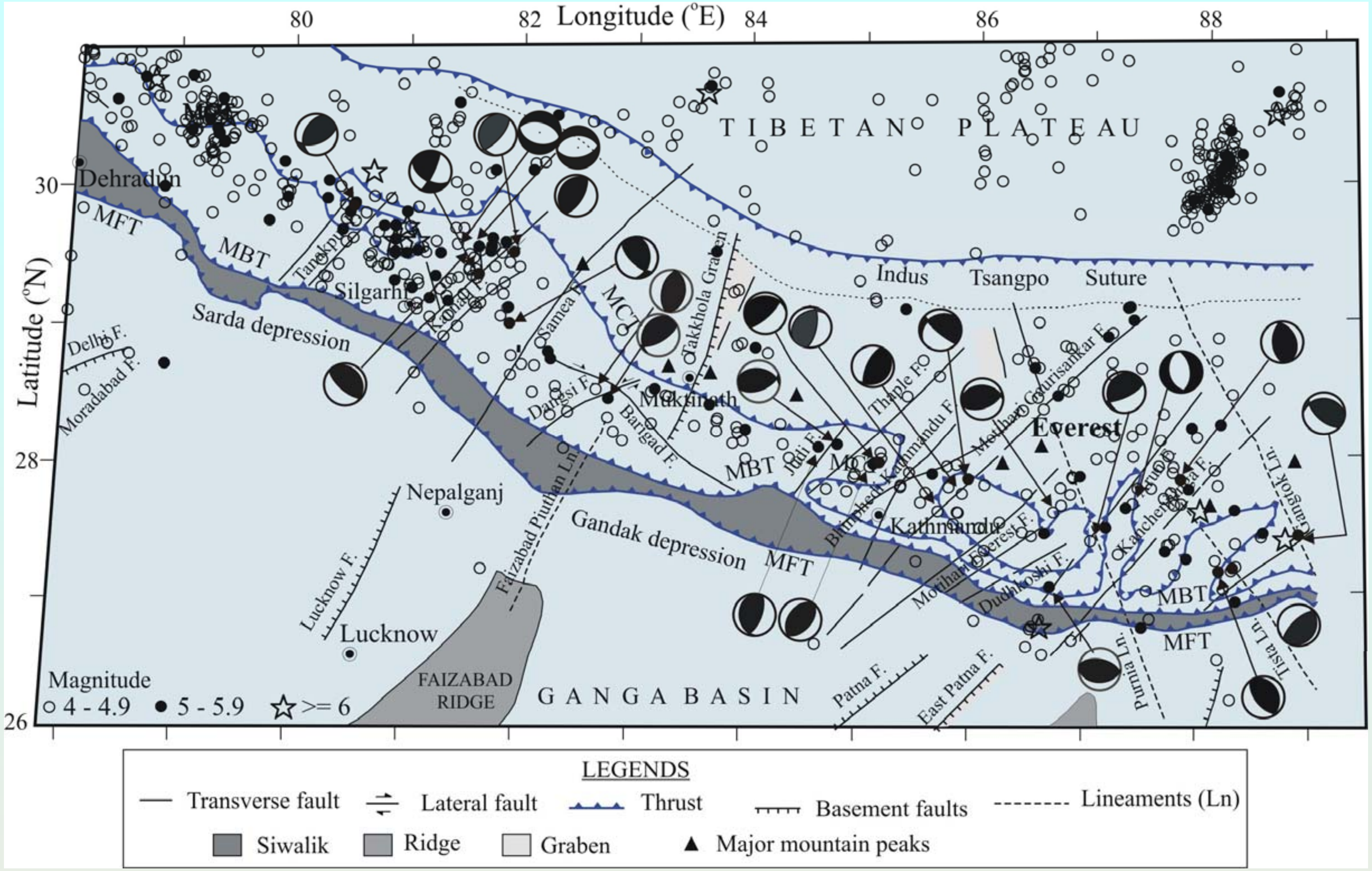
06.02.1992 m_b 5.2



1992 June 2 Mb 5.2

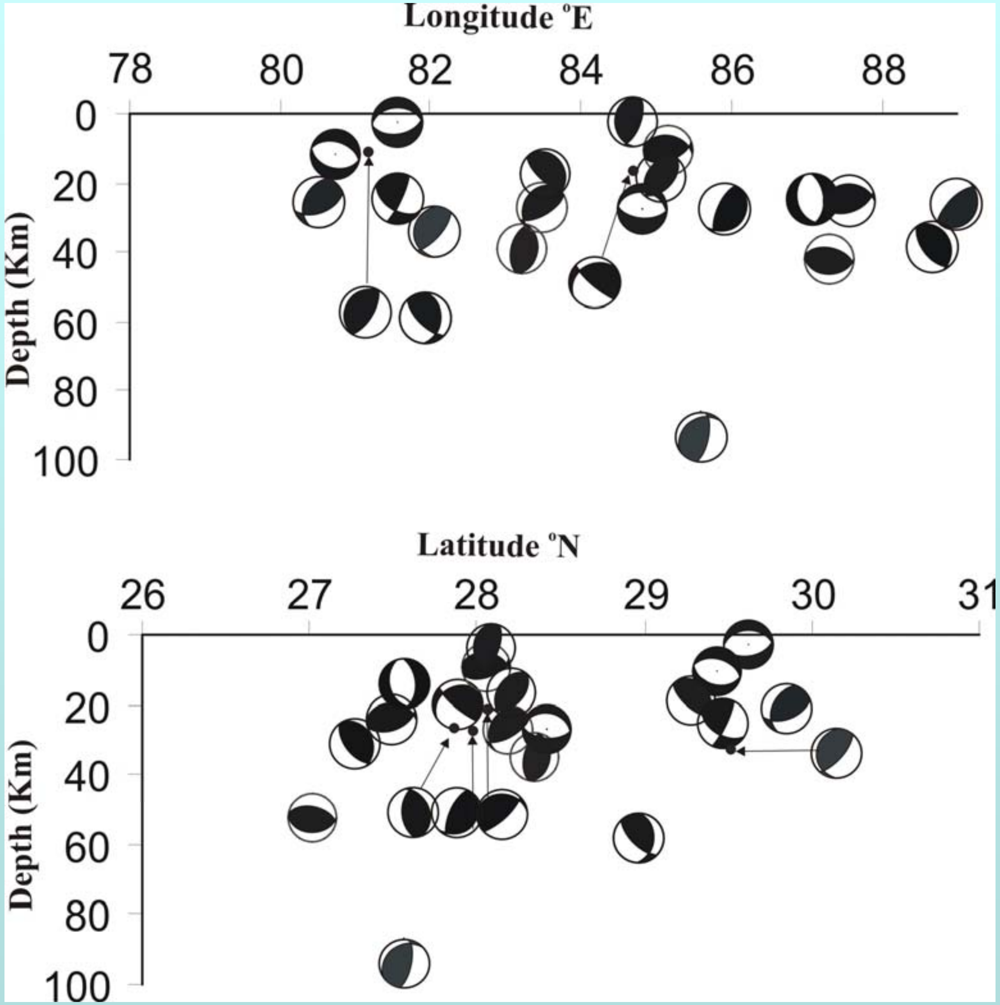
More samples …





Seismotectonic map with fault plane solutions of 25 events (1970-2004) calculated in this study.

Variation for orientation of fault plane with depth



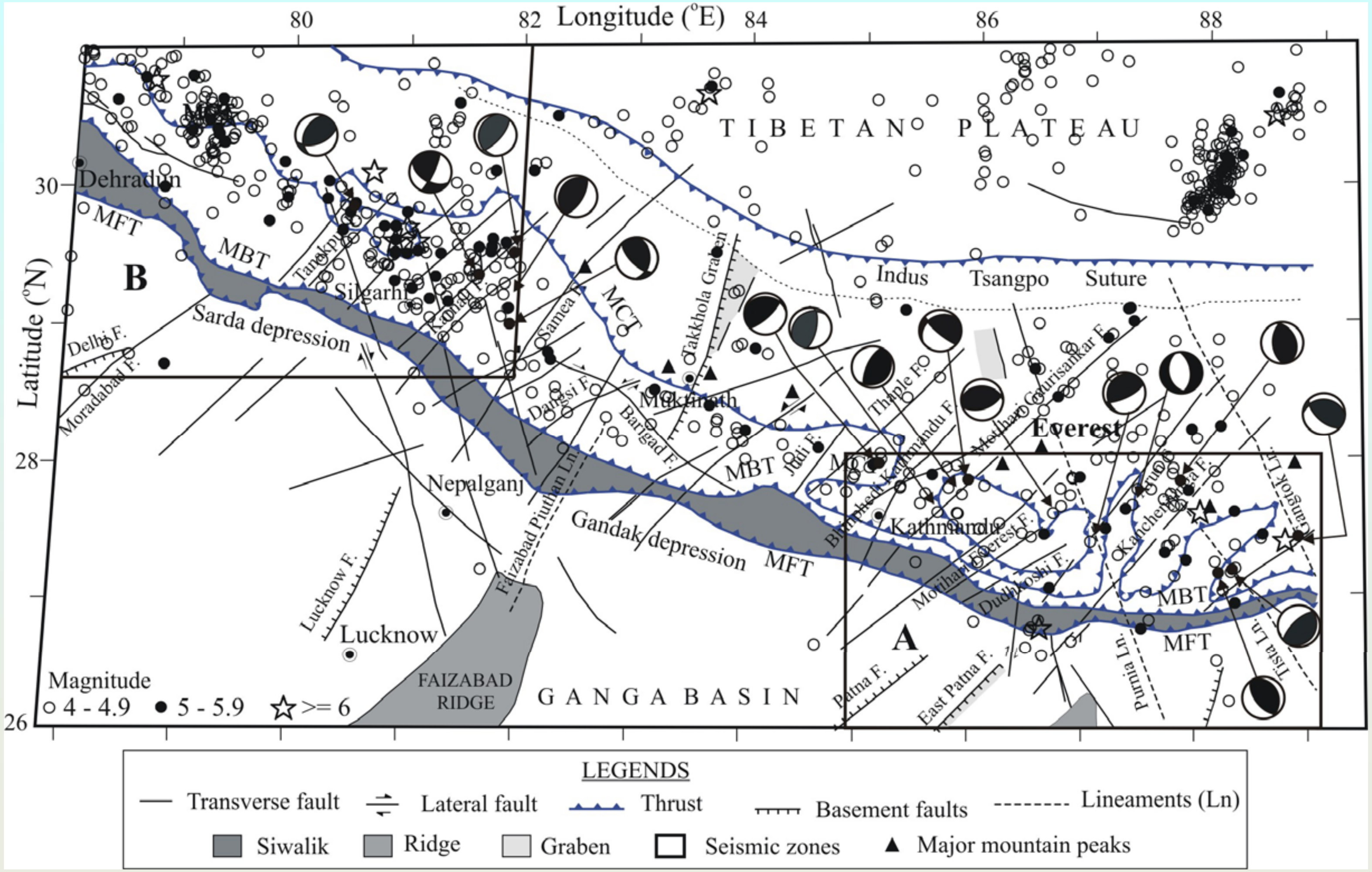
Stress Pattern in Two Prominent Seismogenic Sources in Nepal region

- Two seismic zones:
- zone A (26^0 - 28^0 N, 85^0 – 89^0 E) in south eastern Nepal and adjoining areas and

- zone B (28.5^0 - 31^0 N, 78^0 – 82^0 E) in western Nepal and vicinity, have been delineated using available historical records as well as current seismic events in Nepal and the adjoining regions.

- Data used
- Focal mechanism solution of earthquakes occurred in the region have been collected from published literature and 16 new focal mechanism solution for the period 1970 – 2004 with M 4.7 to 5.6 have been calculated using P – wave first motion data

Seismo-tectonic map of Nepal and its adjoining regions, Central Himalaya. Two zones A and B are delineated using spatial distribution of earthquakes that have occurred in this region from 1964 to 2004.



Focal mechanism solutions of the earthquakes in zone A, south eastern Nepal and its vicinity

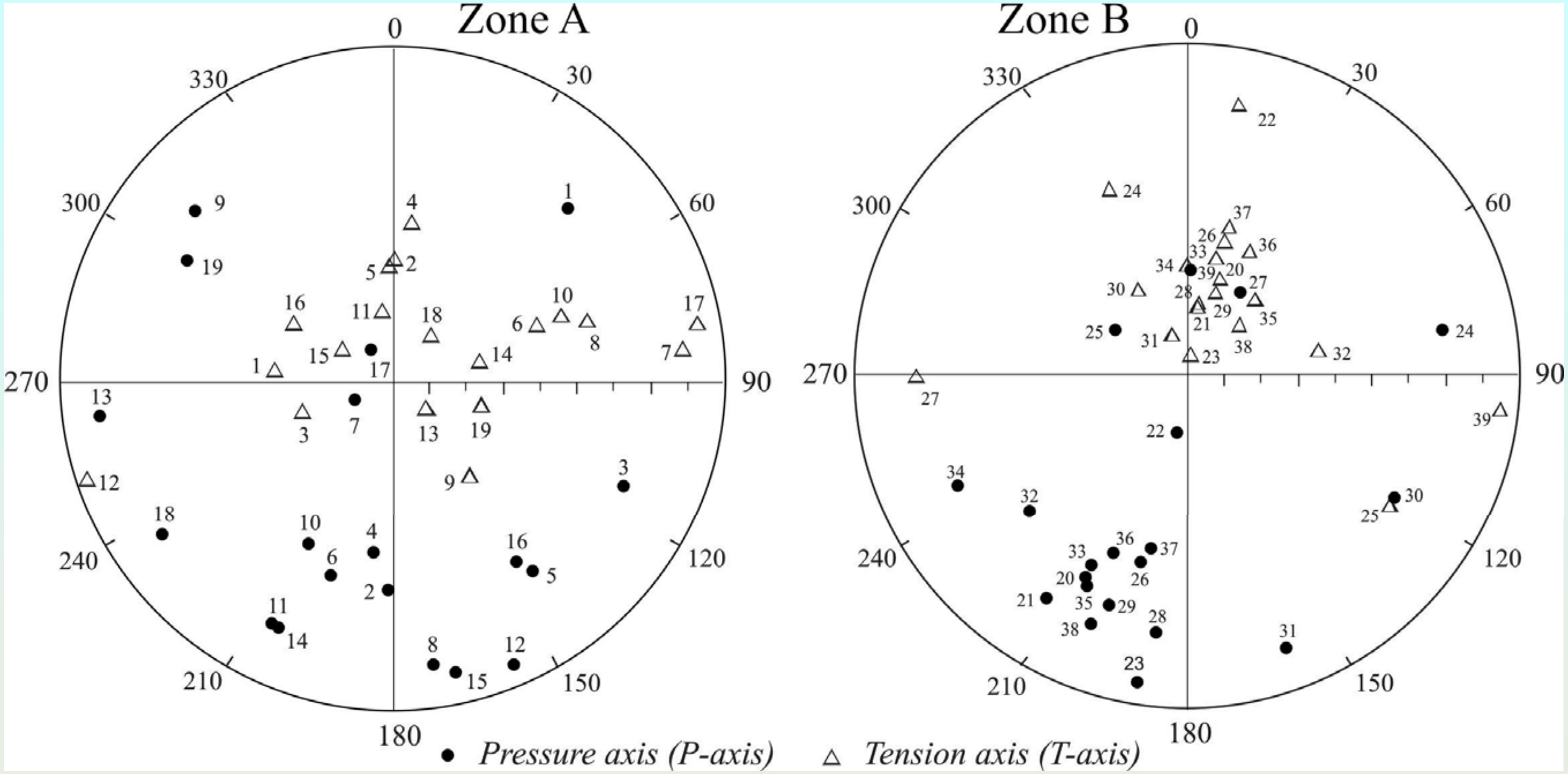
Sl. Nos.	Date	Origin time	Lat. (ºN)	Long. (ºE)	Depth km	M	P-Az	P-Pl	T-Az	T-Pl	Ref.
1	1/15/1934	08:43:18	26.5	86.5	20	8.4**	46	24	275	58	SG
2	1/12/1965	13:22:24.1	27.38	87.85	23	6.1	181	33	1	57	CH
3	2/26/1970	19:30:14.5	27.6	85.7	96	5	115	21	251	64	TS
4	3/24/1974	14:16:01.	27.66	86.00	20	5.4	187	43	7	47	MT
5	4/24/1975	01:35:51.2	27.43	87.04	25.5	4.9	144	26	358	59	TS
6	10/4/1978	13:53:50.7	27.82	85.93	19	5.2	197	34	69	48	TS
7	6/19/1979	16:29:12.4	26.29	87.57	24	5*	243	78	84	11	CMT
8	11/19/1980	19:00:45	27.4	88.8	17	6	172	12	73	35	NB
9	7/29/1988	19:10:10.3	27.19	88.36	27.5	5.6	314	24	148	65	TS
10	8/20/1988	23:09:15.9	26.52	86.64	35	6.9*	207	40	69	41	CMT
11	10/29/1988	09:11:0.8	27.39	85.76	18	5.2*	205	16	352	71	CMT
12	12/21/1991	19:52:45.9	27.9	88.14	70	4.9*	157	6	252	3	ZH
13	4/26/1996	16:30:57.6	27.85	87.8	24.9	5	263	10	130	78	TS
14	9/25/1996	17:41:17.5	27.60	88.80	31.7	4.9	206	16	78	66	TS
15	12/30/1996	11:08:19.05	27.49	86.76	33	4.8	168	9	301	74	TS
16	1/31/1997	20:02:14.22	27.98	85.20	7	5.2	146	30	300	59	TS
17	12/8/1997	02:03:55.9	27.49	87.26	33	4.8	320	80	80	6	TS
18	12/2/2001	22:41:13.06	27.21	88.17	24.5	5	236	15	40	74	TS
19	1/3/2004	13:14:28.7	27.77	85.95	27.4	4.7	300	25	106	65	TS

Ref: TS:This Study, CH:Chandra (1978), SG: Singh and Gupta (1980), CMT: Centroid Moment Tesor solution, NB: Ni and Barazangi (1984), ZH: Zhu and Helberger (1996).

Focal mechanism solutions of the earthquakes in zone B, western Nepal and its vicinity

Sl. Nos.	Date	Origin time	Lat. (ºN)	Long. (ºE)	Depth Km	M	P-Az	P-Pl	T-Az	T-Pl	Ref.
20	9/26/1964	00:46:02.6	29.96	80.46	50	5.8	207	28	19	62	CH
21	6/27/1966	10:41:08.6	29.62	80.83	37	6.1	212	18	9	71	CH
22	8/15/1966	02:15:29	28.67	79.39	53	5.6	191	75	11	15	CH
23	12/16/1966	20:52:16.3	29.62	80.79	15	5.8	190	6	10	84	CH
24	2/12/1970	01:51:48.4	29.24	81.57	25	5.3	80	18	337	35	TS
25	9/6/1975	04:44:33.1	29.21	81.94	12.3	5.1	302	66	122	24	TS
26	5/20/1979	22:59:14.7	29.58	80.32	16	5.8*	194	38	16	52	CMT
27	6/22/1980	14:38:58.4	30.1	81.59	15	5.1*	31	63	270	15	CMT
28	7/29/1980	12:23:15.9	28.96	81.11	10	5.5*	188	20	9	70	CMT
29	7/29/1980	14:58:51.4	29.42	80.95	22.3	6.6*	199	24	19	66	CMT
30	5/15/1981	17:22:43.4	29.46	81.92	33	5.1	121	24	330	63	TS
31	2/19/1984	15:46:25.9	29.84	80.54	21	5.1	160	11	340	78	TS
32	7/16/1986	22:03:12.4	30.48	78.19	15	5.5*	231	33	79	53	CMT
33	10/19/1991	21:23:21.6	30.22	78.24	15	6.8*	207	32	14	57	CMT
34	6/2/1992	22:07:45.3	28.93	81.90	56.4	5.2	245	20	0	60	TS
35	1/5/1997	08:47:31.6	29.43	80.29	15	5.6*	206	27	42	62	CMT
36	3/28/1999	19:05:18.1	30.38	79.21	15	6.6*	203	38	27	52	CMT
37	11/27/2001	07:31:57.1	29.61	81.75	15	5.5*	192	42	16	48	CMT
38	11/27/2001	08:53:59.4	28.91	81.49	15	5.4*	202	18	46	70	CMT
39	6/4/2002	14:36:8.5	30.13	81.25	15	5.6*	0	61	96	3	CMT

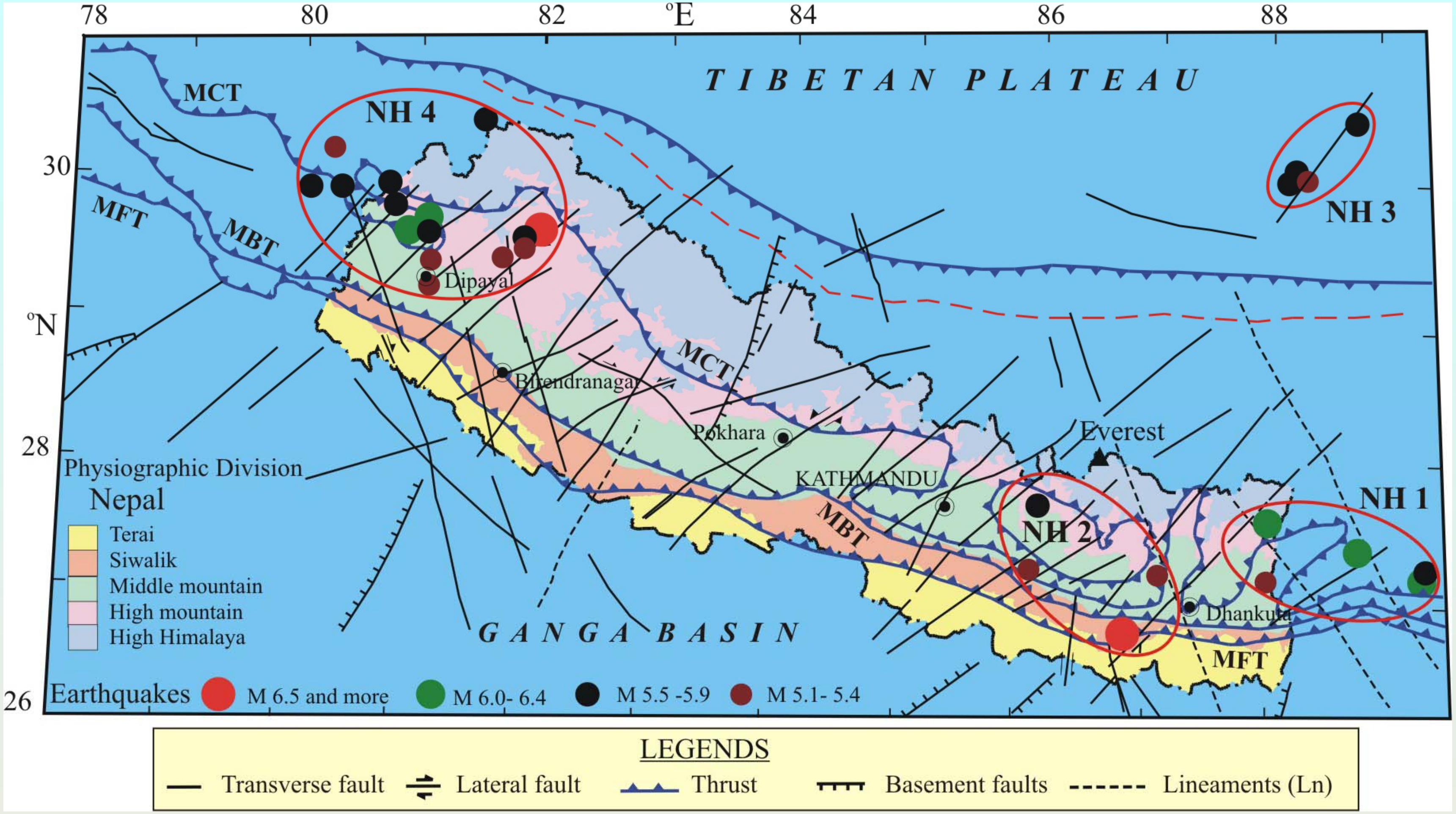
Composite plot of P- and T- axes for Eastern Nepal (Zone A) for 19 events and Western Nepal (Zone B) for 20 events.



The stress pattern study shows:

- 1. The western and eastern portion of Nepal region shows a compressive stress regime. Such information could not be obtained for Central Nepal due to lack of seismic data.
- 2. The greatest compressive stress direction in inferred to be NE – SW to NNE - SSW in western and eastern Nepal region. The direction of tensile stress is found nearly horizontal E – W in eastern Nepal where as NW – SE in western Nepal. This also suggest that the direction of extensional force changes from east west in eastern Nepal to approximately NW – SE in the western region which are separated approximately by 750 km in NW – SE direction.
- 3. Our study supports existing idea of approximately east west mass movement to the north of MCT.

Seismogenic sources in Central Himalaya



- Based on inter event times of main shocks in the four seismogenic sources of Central Himalayan region; the time and magnitude predictable relationships has been established as:

$$\log T_t = 0.25\ M_{min} + 0.03\ M_p - 0.43 \log m_0 + 10.05 \qquad (1)$$

- with a correlation coefficient of 0.92 and standard deviation of 0.19. Similarly the values of parameters of (4) were calculated by the use of all available information from Table 1, and the following formula is derived:

$$M_f = -\ 0.48\ M_{min} + 1.19 M_p + 1.13 \log m_0 - 26.27, \qquad (2)$$

- This equation has multi-correlation coefficient, R=1.13 and standard deviation 0.74.The positive correlation between the repeat time and the magnitude of the preceding main shock in (X) infers that the time-predictable model hold in the area under study.

Long-term prediction of the next shallow main shock

The conditional probability, P, may be calculated, for main shock with M ≥ Mmin during the next Δt years (from present), when the previous such event with magnitude Mp occurred t years ago (from now), by using the following relation (Papazachos and Papaioannou, 1993):

$$P(\Delta t) = \frac{F\left(\frac{X_2}{\sigma}\right) - F\left(\frac{X_1}{\sigma}\right)}{1 - F\left(\frac{X_1}{\sigma}\right)}$$

where

$$X_2 = \log\frac{(t + \Delta t)}{T_t}, \qquad X_1 = \log\left(\frac{t}{T_t}\right)$$

In above equation, F is the complementary cumulative value of the normal distribution with mean equal to zero and standard deviation σ

Expected magnitude, Mf, and the corresponding probabilities, P_{10}, P_{20} and P_{30}, for the occurrence of large ($M_{min} \geq 5.5$) shallow shocks during the Periods **2006-2015**, **2006-2025** and ***2006-2035*** in the Nepal and adjoining Central-Himalaya (NCH).

Name of Seismogenic Sources	$M_f \pm 0.09$	P10	P20	P30	M_{min}	M_p	t_p (Year of Mp)	$\log m_0$
NCH-1	5.3	0.59	0.94	0.99	5.5	5.5	2003	24.46
NCH-2	6.9	0.90	0.99	1.00	5.7	6.6	1988	24.85
NCH-3	6.1	0.84	0.98	1.00	5.9	6.0	1998	24.83
NCH-4	6.4	0.96	1.00	1.00	5.8	5.8	2002	25.31

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Thank you