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ON THE SEISMICITY AND SEISMIC HAZARD ESTIMATION OF THE KUMAUN HIMALAYA

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ABSTRACT

A considerable part of the Kumaun region in the Himalaya lies in zone V of the seismic zoning map of India (IS; 1893-1984). A Digital Telemetered Seismic Network (DTSN) has been deployed in the Kumaun Himalaya to monitor local and regional activity. The network comprises a Central Recording Station (CRS) and four remote stations. The present paper incorporates the analysis of the data recorded between May 1999 and December 2001. The epicentral location map indicates that the region in close proximity to the Main Central Thrust is seismically more active. The stress drop values have been calculated using the Brunes's model of the earthquake source. The low stress drop values indicate that the crust of the region has low strength to withstand the accumulated strain energy. An endevour has been made to empirically correlate the stress drop with the magnitude. The region also shows evidence of tectonic movements in recent past especially along the boundary and subsidiary thrusts, and transverse faults. The peak ground acceleration (PGA) of two moderate earthquakes in the recent past have been compared with the PGA recorded at Nainital.

Key words : Seismicity, Hazard Estimation, Kumaun Himalaya.

INTRODUCTION

Seismic activity of the Himalaya in the Garhwal-Kumaun region has been monitored since 1974 by various organizations. Most of these networks were located in the Garhwal Lesser Himalayan region. The epicentral locations of the earthquakes show the existence of a seismic belt, running almost parallel to the surface trace of Main Central Thrust (MCT) lying between Yamuna and Alaknanda valleys (Gaur *et al.*, 1985; Khattri *et al.*, 1989). Another study, based on the observations of more than 350 microearthquakes by Wason *et al.* (1999), shows that the seismicity in Garhwal Himalaya is concentrated close to MCT.

To monitor the regional seismic activity, a duplex telemetered seismic network has been deployed in the Kumaun Himalaya (fig.1). It has two-way communication link between the Central Recording Station (CRS) and the remote stations with full error correction features. The CRS is located at Nainital close to the Main Boundary Thrust (MBT) and the remote stations are located at Kalakhet, Kausani, Dhaulchhina and Almora (fig.1). The aperture of the network is about 51 km. The network became operational since May 1999 and about one thousand two hundred events have been recorded. The hypocentral parameters have been determined using Hypo 71, and Brune's model has been used for computing stress drop values. Also, the peak ground acceleration recorded at Nainital has been compared with that of Chamoli earthquake of March 1999 and Uttarkashi earthquake of 1991.

TECTONIC SETUP

The Himalaya Mountain extending for over 2500 km from Nanga Parvat in the west to Namcha Barwa in the east constitutes one of the tectonically most active regions of the Indian subcontinent. The orogen has witnessed some of the biggest earthquakes recorded in

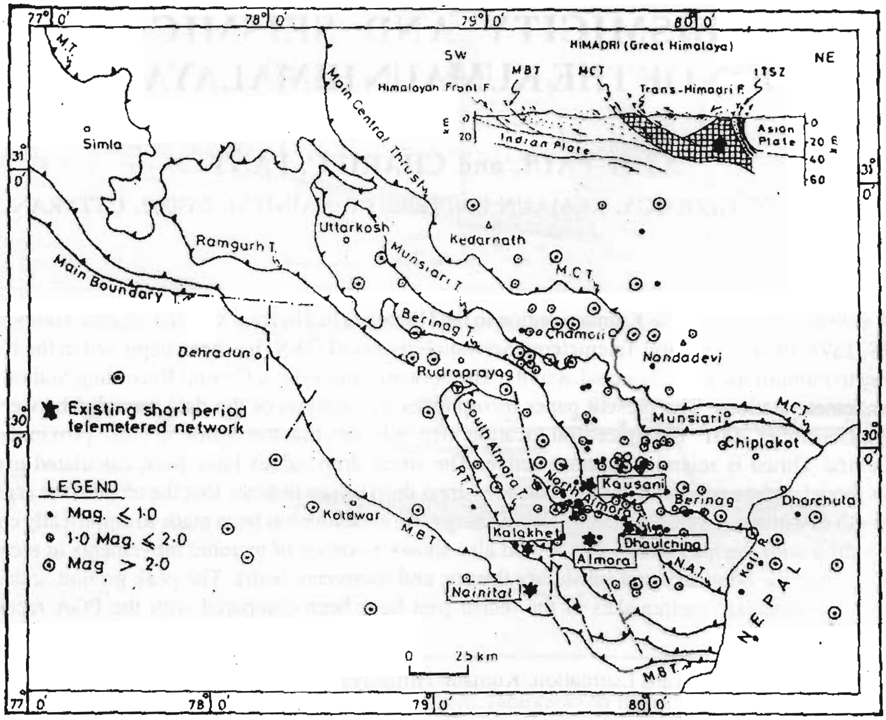

Fig. 1. Tectonic map of the Kumaun Himalaya showing epicentral location of the earthquake recorded by the network. Inset shows geological cross-section and tectonic disposition of the different blocks. (modified after Valdiya, 1980)

the history. The origin of this mountain and its neotectonic rejuvenation continue to be subjects of debate and speculation among seismologists despite considerable efforts directed towards their studies in recent years. The large amount of data and its analysis manifest complex geological processes being operative in the region. (Heim and Gansser, 1939; Le Fort, 1975; Valdiya, 1980).

The Kumaun Himalaya, seismotectonically an active region of the Himalayan arc, shows development of all the major five lithotectonic units bound by the boundary thrusts. These subdivisions from south to north are (i) Sub Himalaya consisting of Cenozoic sediments of the uplifted foreland basin (ii) Lesser Himalaya comprising thick platform type sedimentaries covered mostly by crystalline thrust sheets (iii) Greater Himalaya, made up of thick crystallines of Precambrian age intruded by younger granites (iv) Tethys Himalaya comprising sedimentary pile of late Precambrian to lower Eocene (v) Indus suture zone, consisting of Cretaceous flysch, ophiolitic mélange and post-orogenic molasses. In general, the region has a very complex geological set-up as the rocks are involved in polyphase deformation and constitute many thrust sheets and nappes. The main thrusts and faults of the Kumaun Himalaya are shown in fig.1.

The Main Central Thrust (MCT) at the base of crystalline zone (Gansser, 1964), dipping 30^0-45^0 northwards, is a zone of intense shearing. Along the MCT there are many geological evidences suggestive of neotectonic movem-ents (Valdiya, 1980; Gansser, 1982). Seeber *et al.* (1981) proposed the existence of a detachment surface, representing the upper surface of the subducting Indian plate, underlying the entire Himalaya (Inset, fig. 1). The MCT merges with this surface at depth. Ni and Barazangi (1984) observed that the majority of epicenters lie just south of the surface trace of the MCT and excepting a few, almost all the fault plane solutions indicate thrust movements along a north–dipping (shallow depth, 10-15 km) plane quite different from the MCT, but possibly delineating the interface between the underthrusting Indian plate and overlying Himalayan mass. They also pointed out that the geometry of the detachment surface beneath the Higher Himalaya is not constrained by the seismicity of this region rather than the steepening of the Moho, implies a sharp bending of the Indian plate and a steeper dip of the detachment surface below the Higher Himalaya. According to Molnar (1983) the

Table1: Hypocentral parameters and magnitude of local earthquake events recorded by DTSN in Kumaun Himalaya.

Sl. No.	Date	Origin Time (U.T.C.) Hr. Min. Sec.	Lat. (°N)	Long. (°E)	Mag. (M_L)	RMS
1	14/05/1999	08 31 04.14	30.29	79.32	3.2	0.12
2	02/06/1999	08 53 18.54	30.26	79.37	4.1	0.18
3	05/06/1999	16 38 18.45	30.02	79.96	1.0	0.29
4	07/06/1999	23 34 30.82	29.37	80.99	1.2	0.11
5	09/06/1999	18 38 17.84	29.19	81.41	0.5	0.16
6	12/06/1999	17 09 00.37	29.34	79.88	2.3	0.20
7	12/06/1999	22 03 25.91	29.51	79.47	1.4	0.60
8	13/06/1999	21 24 05.15	30.23	79.23	3.3	0.21
9	14/06/1999	19 26 12.25	30.31	79.32	1.2	0.36
10	14/06/1999	21 49 13.98	31.11	79.12	0.6	0.87
11	27/07/1999	12 35 05.78	30.33	79.33	3.1	0.32
12	28/07/1999	18 37 10.75	30.37	79.41	2.0	0.56
13	28/07/1999	22 33 50.15	29.99	80.02	1.3	0.25
14	30/07/1999	23 06 32.08	29.61	80.65	3.0	0.58
15	31/07/1999	21 47 17.12	29.68	80.14	1.2	2.28
16	06/08/1999	22 50 01.36	30.60	79.21	1.6	0.89
17	08/08/1999	21 48 19.44	29.74	79.78	1.2	0.21
18	08/08/1999	22 05 19.24	29.74	79.78	1.7	0.32
19	09/08/1999	22 53 22.36	30.50	79.30	2.0	0.40
20	09/08/1999	23 31 18.46	30.02	79.65	1.5	0.85
21	09/08/1999	23 37 23.11	29.95	80.02	1.6	0.34
22	10/08/1999	02 22 40.71	29.74	80.17	1.9	0.28
23	10/08/1999	15 24 31.16	30.30	79.31	1.7	0.20
24	14/08/1999	22 33 36.39	30.24	80.00	1.7	0.97
25	14/08/1999	22 36 28.41	29.97	79.75	1.3	0.58
26	24/08/1999	17 04 35.89	30.35	79.52	2.2	0.26
27	24/08/1999	21 51 18.21	30.41	79.90	2.2	0.58
28	26/08/1999	06 04 36.09	29.52	80.96	2.3	0.52
29	28/08/1999	02 41 12.61	30.39	79.78	2.4	0.60
30	12/09/1999	09 00 41.01	29.73	79.51	3.4	1.65
31	15/09/1999	17 31 34.25	30.19	79.57	0.5	0.68
32	22/09/1999	00 56 25.24	30.95	79.04	2.4	0.76
33	22/09/1999	16 50 18.71	29.88	79.79	3.1	1.87
34	22/09/1999	17 43 59.56	29.75	79.68	1.8	0.85

35	22/09/1999	22 27 30.68	29.94	80.06	1.7	2.45
36	22/09/1999	23 58 23.49	29.94	80.04	2.0	2.40
37	23/09/1999	03 49 12.41	29.90	79.97	2.8	2.27
38	23/09/1999	04 53 51.84	30.07	79.65	1.4	0.58
39	23/09/1999	21 45 59.71	29.51	80.64	2.1	1.80
40	15/10/1999	14 46 10.81	29.59	79.78	0.5	0.57
41	01/12/1999	13 57 10.16	29.71	79.79	3.4	0.70
42	04/12/1999	17 43 38.34	30.45	79.68	1.9	1.02
43	07/12/1999	00 32 00.60	29.84	79.49	2.8	1.11
44	07/12/1999	12 59 25.40	29.94	79.85	3.5	0.14
45	08/12/1999	20 24 15.89	29.95	79.41	3.7	0.17
46	09/12/1999	02 59 42.72	29.74	79.79	1.9	1.25
47	10/12/1999	14 43 14.74	30.16	79.32	1.6	1.82
48	10/12/1999	20 55 25.52	30.01	80.33	1.9	0.43
49	10/12/1999	21 18 27.17	29.72	80.16	2.0	0.96
50	10/12/1999	21 27 25.03	29.97	79.98	1.7	0.68
51	13/12/1999	01 55 33.48	29.96	79.18	1.7	1.75
52	13/12/1999	07 41 09.50	29.97	79.91	1.6	0.63
53	13/12/1999	12 45 20.14	30.37	79.35	1.0	0.58
54	13/12/1999	18 37 11.70	29.68	80.38	2.6	0.65
55	13/12/1999	22 49 13.27	29.43	79.80	2.0	0.71
56	15/12/1999	20 57 57.92	29.84	79.37	1.8	0.23
57	16/12/1999	15 50 00.65	29.83	79.50	1.8	0.61
58	16/12/1999	22 03 26.36	29.91	79.47	1.5	0.63
59	18/12/1999	05 25 06.87	29.88	79.72	1.7	0.27
60	18/12/1999	14 41 16.37	29.92	79.13	1.5	1.49
61	19/12/1999	13 34 55.37	29.84	79.38	1.0	1.10
62	19/12/1999	18 46 15.01	29.85	79.91	0.8	1.51
63	22/12/1999	19 54 15.24	29.91	79.13	0.8	0.17
64	23/12/1999	16 40 27.91	30.52	79.61	3.3	0.12
65	24/12/1999	23 15 24.28	30.11	79.61	1.6	1.42
66	25/12/1999	18 39 05.18	29.88	79.52	2.3	0.40
67	26/12/1999	10 31 12.79	29.89	79.78	1.4	0.50
68	30/12/1999	00 08 06.51	29.95	79.76	1.5	1.67
69	30/12/1999	16 36 29.98	29.70	80.71	0.6	0.49
70	30/12/1999	17 18 30.56	30.50	79.46	1.9	1.00
71	31/12/1999	00 37 02.32	29.71	79.96	1.3	0.64
72	01/01/2000	18 37 48.40	29.75	80.77	3.5	0.83
73	01/01/2000	18 54 25.88	29.81	80.15	2.7	0.54
74	01/01/2000	20 44 37.12	29.80	80.22	1.2	0.44
75	03/01/2000	22 25 21.04	29.76	80.07	1.9	0.48
76	05/01/2000	13 45 53.29	29.36	80.99	3.3	0.30
77	05/01/2000	22 34 06.36	30.03	79.89	1.4	0.99
78	06/01/2000	04 28 38.21	29.54	80.03	2.1	0.31
79	09/01/2000	06 42 35.99	29.92	79.46	1.8	0.96
80	09/01/2000	12 40 52.26	29.52	79.92	1.4	0.24
81	09/01/2000	18 46 18.52	30.08	79.94	1.2	1.42
82	10/01/2000	17 43 08.68	30.01	79.43	2.1	1.69
83	10/01/2000	21 35 14.97	30.48	79.45	2.5	1.00
84	12/01/2000	01 56 07.38	29.82	79.45	1.4	0.90
85	14/01/2000	19 44 22.89	29.75	79.12	1.0	0.90
86	17/01/2000	17 15 12.11	29.68	80.50	2.2	2.18

87	17/01/2000	19 15 54.01	30.41	79.49	2.5	1.61
88	20/01/2000	18 29 29.03	29.68	79.87	1.8	0.12
89	21/01/2000	15 17 39.83	30.70	79.24	2.0	1.25
90	21/01/2000	23 20 58.89	29.70	79.66	1.1	1.17
91	18/04/2000	00 30 19.38	30.98	78.53	2.8	1.79
92	25/04/2000	21 40 19.38	30.98	78.82	2.4	3.60
93	04/05/2000	02 40 06.86	30.06	79.87	4.2	0.06
94	04/05/2000	04 30 01.47	29.46	78.12	3.4	0.91
95	04/05/2000	16 09 35.02	31.04	78.92	3.1	0.08
96	08/05/2000	21 16 10.26	30.19	77.47	3.0	2.26
97	01/06/2000	06 38 24.58	29.80	79.22	4.5	1.98
98	21/06/2000	16 11 18.74	30.56	79.48	3.5	1.48
99	12/072000	03 17 22.38	29.73	78.37	3.2	2.49
100	12/07/2000	22 24 48.58	30.23	79.08	3.0	0.94
101	10/08/2000	18 59 05.25	30.29	78.85	2.7	2.42
102	16/08/2000	13 29 37.28	30.33	78.84	3.1	1.43
103	13/09/2000	21 08 30.69	30.36	79.41	2.5	0.35
104	22/09/2000	18 29 29.38	29.70	78.93	2.9	0.52
105	29/09/2000	23 11 30.49	29.56	77.99	2.7	0.40
106	16/11/2000	07 53 52.37	29.94	79.19	3.7	0.98
107	25/01/2001	02 52 30.53	30.02	79.63	1.2	0.81
108	02/04/2001	17 40 17.34	30.16	79.61	1.4	0.00
109	03/04/2001	01 00 53.51	29.75	79.58	0.5	0.09
110	03/04/2001	06 01 45.73	29.78	79.42	0.5	0.04
111	03/04/2001	20 31 08.38	29.75	79.58	1.4	3.21
112	04/04/2001	21 41 50.08	29.90	79.81	0.5	0.01
113	05/04/2001	18 16 42.37	29.87	79.91	0.7	0.00
114	07/04/2001	01 57 06.69	29.75	79.77	1.0	8.18
115	07/04/2001	16 29 27.33	29.75	79.58	2.4	9.16
116	08/04/2001	16 41 51.84	30.59	79.13	2.3	1.08
117	10/04/2001	11 30 58.06	29.75	79.58	1.4	5.06
118	10/04/2001	22 11 19.12	29.62	80.05	2.3	2.92
119	10/04/2001	22 40 32.26	29.75	79.58	1.5	2.59
120	11/04/2001	18 04 01.91	29.92	79.76	1.6	0.65
121	11/04/2001	18 24 52.65	29.45	80.37	1.8	0.38
122	12/04/2001	18 43 30.07	29.97	79.71	1.7	0.23
123	12/04/2001	22 12 55.68	29.94	79.77	2.3	0.64
124	13/04/2001	13 44 59.29	29.35	80.36	1.0	0.26
125	14/04/2001	10 56 34.12	29.75	79.58	2.9	9.33
126	14/04/2001	23 36 40.73	29.93	79.86	1.5	0.01
127	16/04/2001	05 24 18.19	29.75	80.02	1.8	0.78
128	18/04/2001	13 34 01.75	30.27	79.01	0.8	0.65
129	19/04/2001	21 55 54.26	29.75	79.99	1.1	1.07
130	22/04/2001	06 00 14.42	29.84	79.69	1.2	0.01
131	22/04/2001	10 10 43.95	29.33	79.65	1.3	0.09
132	26/04/2001	03 32 15.91	29.75	79.58	1.6	3.61
133	01/05/2001	00 16 04.97	29.91	79.76	0.6	0.30
134	02/05/2001	22 39 13.91	29.62	79.70	1.9	4.35
135	05/05/2001	17 43 02.16	30.13	79.58	2.0	0.10
136	05/05/2001	18 31 07.21	29.75	79.58	1.6	4.96
137	07/05/2001	18 23 55.82	29.72	80.12	1.6	0.19
138	07/05/2001	22 01 20.54	29.90	79.58	2.2	5.30

139	08/05/2001	15 06 29.79	29.92	79 76	1.9	0.22
140	11/05/2001	01 00 06.80	29.75	79.58	1.5	8.81
141	11/05/2001	10 44 25.65	29.75	79.58	2.0	9.84
142	07/07/2001	09 58 29.25	29.75	79.58	1.7	3.87
143	07/07/2001	16 47 16.36	29.78	80.11	0.1	0.18
144	12/07/2001	17 41 24.31	29.78	80.01	0.6	0.12
145	15/07/2001	00 58 28.80	29.88	79.83	1.1	0.01
146	23/07/2001	21 45 58.12	29.75	79.98	1.1	0.40
147	06/08/2001	04 12 42.68	29.75	79.58	2.1	3.91
148	15/08/2001	06 51 31.80	30.10	79.58	2.7	0.37
149	13/09/2001	20 11 20.39	29.70	80.40	3.6	0.26
150	12/12/2001	22 18 45.97	29.94	79.74	0.3	0.05
151	15/12/2001	02 58 07.37	29.59	79.85	1.3	0.19
152	15/12/2001	00 38 49.67	29.75	79.95	1.9	1.20
153	16/12/2001	23 09 29.21	29.75	79.58	0.9	0.96
154	18/12/2001	29 38 13.20	29.75	79.49	1.0	3.58
155	22/12/2001	01 43 42.83	29.82	79.93	1.3	0.14
156	25/12/2001	12 05 52.25	29.82	79.82	0.5	0.38
157	26/12/2001	01 29 05.37	29.75	79.98	2.2	0.85
158	26/12/2001	10 18 10.64	29.75	79.93	2.1	0.88
159	29/12/2001	13 17 23.50	29.75	79.79	1.5	0.37
160	29/12/2001	17 06 18.24	29.75	79.94	0.2	0.62

overriding Himalaya on the more steeply dipping Indian plate will be uplifted the most, which also corroborates with the rapid morphogenic uplift of the Higher Himalaya (Gansser, 1982).

The formidable height and rugged topography of terrain, in general, is a consequence of the continued convergence (58 ± 4 mm/year) of the Indian and Eurasian plates. The region as such is under very strong compressive strain. Evidences of neotectonics and reactivation of faults and thrusts is noticed throughout the sector (Valdiya, 2001). The strain build-up is released intermittently by earthquakes of moderate intensities. The present paper aims at presenting the data recorded between May 1999 and December 2001 in this crucial sector of Himalayan arc.

DIGITAL TELEMETERED SEISMIC NETWORK IN KUMAUN HIMALAYA

A Digital Telmetered Seismic Network comprising four remote stations and one central recording station (CRS) has been installed in the Kumaun region of the Himalayas to monitor the local and regional seismic activity. The recording stations are located between Main Boundary Thrust (MBT) and Main Central Thrust (MCT) as shown in fig.1.Each of the recording stations has one three component seismometer, additionally one accelerometer is

Table 2: a and b values computed for the seismic moment-magnitude Log (Mo) = a + bM$_L$ relationship for different areas by various workers

S. no.	Reference	Region	a	b
1	Present study	Kumaun Himalaya	10.71 ± 0.14	0.689 ± .061
2	Sharma and Wason(1984)	Garhwal Himalaya	18.18 ± .021	0.89 ± 0.043
3	Wyss and Brune (1968)	San Andreas	17.0	1.4
4	Thatcher and Hanks (1973)	South California	16.0	1.5
5	Johnson and McEvilly (1974)	California	17.6 ± 0.28	1.16 ± 0.06
6	Oncescu (1983)	Romania	18.0 ± (0.5)	1.1 ± 0.1

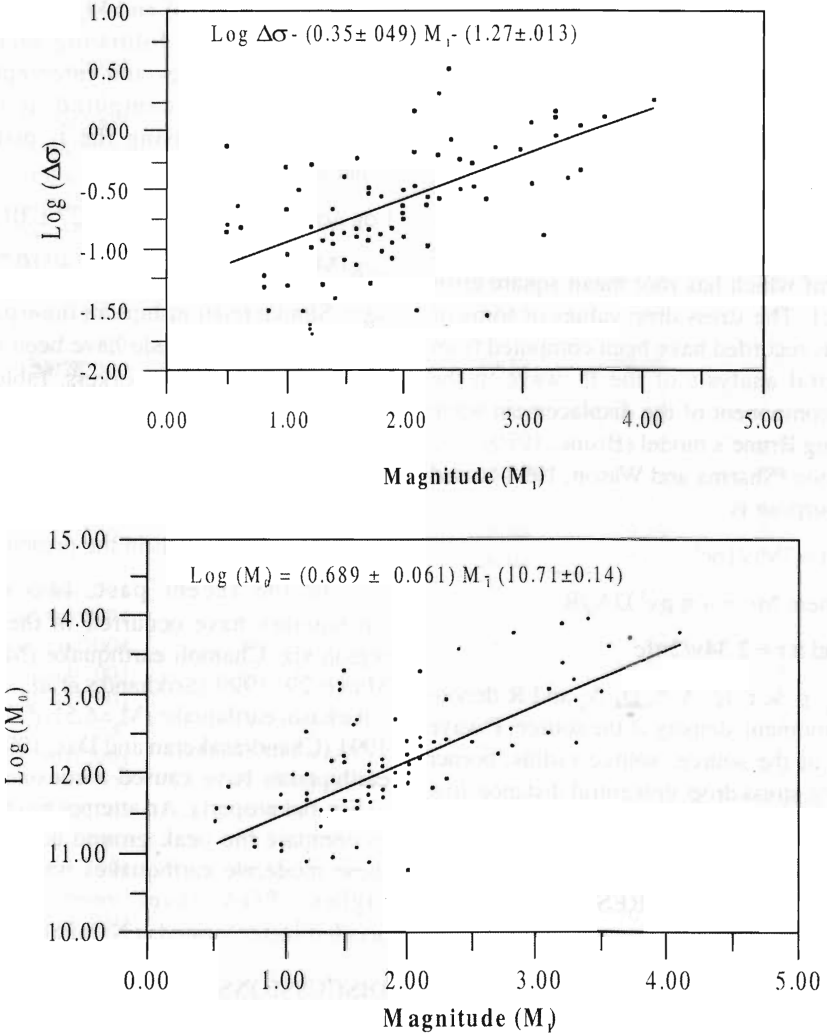

Fig. 2. (upper) Empirical relationship computed using the digital data for log (Δσ) Vs M_L, (lower) Empirical relationship computed using the digital data for log (Mo) Vs M_L

co-located at the CRS. The network is duplex type with two-way communication links. The seismometer response (data) is digitised at 100 samples per second by a 24-bit digitizer that permits 131 db dynamic ranges. The acquisition software (NAQS 32 Plus) checks the incoming data packets at CRS and re-requests all those data from remote site that is found to be erroneous/corrupted when received at the CRS. The data samples using a digitally compensated crystal oscillator and GPS time code receiver, allows a time accuracy of ±5 micro-seconds. The data is received and recorded in continuous mode.

DATA ANALYSIS

The data on earthquake events acquired from May 1999 to December 2001 have been analyzed for computing the hypocentral parameters (Table 1). The parameters have been determined using Hypo 71 programme developed by Lee and Lahr (1975). Figure 1 shows the locations of only those events the solution of which has root mean square error (RMS) <1. The stress drop values of some of the events recorded have been computed from the spectral analysis of the P- wave in the vertical component of the displacement wave form using Brune's model (Brune, 1970). The formulation (Sharma and Wason, 1994) used for the purpose is

$$\Delta \sigma = 7Mo/16r^3$$

Where $Mo = 4\,\pi\, pv^3\, DA_0/R$

And $\pi r = 2.34v/2\pi fc$

M_o, p, v, r, fc, $\Delta\sigma$, D, A_o and R denote seismic moment, density at the source, P wave velocity at the source, source radius, corner frequency, stress drop, epicentral distance, low frequency spectral level of P-wave and radiation pattern respectively.

OBSERVATIONS AND RESULTS

Figure 1 shows the locations of about one hundred sixty events recorded by the network. The magnitude (M_L) of the events lies between 0.5 and 4.2 and the stress drop ($\Delta\sigma$) values range between 0.01 bar to 9.4 bars. The $\Delta\sigma$ values for most of the earthquakes is less than one bar. The straight line fit has been obtained by least square regression analysis to determine useful empirical relationship between log($\Delta\sigma$) and M_L and log(Mo) and M_L (fig. 2a and 2b respectively). The following relationship emerges with slopes and intercepts of the straight line fits computed at the 90% confidence level using the t- distribution (Chatfield, 1989).

$$\text{Log}\,\Delta\sigma = (0.35 \pm .049)\,M_L - (1.27 \pm .013)$$

$$\text{Log}\,(Mo) = (0.689 \pm 0.061)\,M_L + (10.71 \pm 0.14)$$

Similar relationships for these parameters in relation to magnitude have been found for other regions by other workers. Table 2 shows a list of relationships obtained between magnitude and seismic moment for some other regions in comparison with the Kumaun Himalayan region for which the relationships have been worked out in the present study.

In the recent past, two moderate earthquakes have occurred in the Garhwal region viz. Chamoli earthquake (M_b= 6.6) of March 29, 1999 (Srikhande *et al.,* 2001) and Uttarkashi earthquake (M_b=6.5) of October 20, 1991 (Chandrasakeran and Das, 1992). These earthquakes have caused a considerable loss to life and property. An attempt has been made to compare the peak ground acceleration of these moderate earthquakes with that of the highest PGA level recorded by the accelerometer located at Nainital. (Table 3)

DISCUSSIONS

The seismicity of the region as a whole does not necessarily indicate a particular locked portion. However, regions around and between MCT and NAT have more energy releasing sectors comparatively. The comparison between observed PGA value for Chamoli

Table 3: Comparison of the Peak Ground Accelerations.

Event	PGA (m/s/s)	Duration of devastative acceleration (secs)
Uttarkashi Earthquake 20/10/1991	3.12	10
Chamoli Earthquake 29/3/1999	3.5	5
Near Pithoragarh (recordedw by DTSN) 13/9/2001	.051x10e(-3)	20

earthquake of 29th March 1999 (3.5 m/s*s at N20E Gopeshwar), Uttarkashi earthquake of 20th October 1991 (3.129 m/s*s at N75E Uttarkashi) with the Pithoragarh earthquake of 13th September 2001 (.051x10e(-3) recorded at Nainital) indicates that at present the region near MBT is experiencing low acceleration levels. Low values of stress drop events can be explained by partial stress drop models (Brune, 1970) and low effective stress models (Brune, *et al.,* 1986). The low values can also be explained in terms of lithological set up of the region. Perhaps the crust of the region may not be able to sustain higher stresses.

It is significant to note that the region lying between Main Central Thrust (MCT) and Main Boundary Thrust (MBT) is neotectonically active (Valdiya, 1976; Valdiya and Pant, 1986; Pant *et al.,* 1992; Valdiya, 1999; Kotlia *et al.,* 2000; Valdiya, 2001). The shallow seismicity of the Kumaun Himalaya has been ascribed to the strike-slip movements along some of the transverse faults registering mainly dextral displacement (Valdiya, 1976; Kayal, 1996) and also along east-west trending thrusts and faults. The seismicity pattern as recorded in the present network, indicates that the region lying between North Almora Thrust and Main Central Thrust is seismotectonically active. The region has witnessed movements along many thrusts in the Quaternary times. The reactivation of thrust/faults caused impoundment of the river course and deposition of lacustrine mud in these palaeolakes. The radiocarbon dates of the lacustrine mud suggest that these lakes (Wadda, Kosi, Bhimtal, Naukuchiatal, Dulam etc.) were formed around 36 Ka and vanished around 10-2 Ka due to reactivations of NAT and its subsidiary thrusts (Valdiya *et al.,* 1996; Valdiya, 1999; Kotlia, *et al.,* 2000; Valdiya, 2001). It may be concluded that the North Almora Thrust and Main Central Thrust and subsidiary thrusts in Kumaun Himalaya are more active than the other thrusts and that the strain accumulated due to continuing convergence is being released intermittently.

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