SEISMIC HAZARD ESTIMATION IN NORTHEASTERN KUMAUN HIMALAYAS

AJAY PAUL and P.D. PANT
Department of Geology, Kumaun University, Nainital - 263 002

This paper presents the estimated peak ground accelerations (PGA) at some selected sites in the north-eastern Kumaun region of the Himalayas in India. The fidelity of calculating ground acceleration is demonstrated by waveform modelling of the observed accelerograms of the October 20,1991 Uttarkashi earthquake. Seismic hazard estimation becomes a useful exercise as some of the locations are proposed dam sites.

Introduction

To minimize disasters from earthquakes it is important to evaluate seismic hazard in a region. Most of the Kumaun region in the Himalayas lies in the zone V of the Seismic Zoning Map of India (IS; 1893-1984). GPS data acquired in Nepal and in central Himalaya appear to confirm the deformation going on in the Himalayas in India (Bilham et al. 1997). The deformations caused by the collision of Indian and Eurasian plates results in the build up of elastic strain energy. Earthquakes in India are caused by the release of this elastic strain energy (Bilham and Gaur, 2000). The Kumaun-Garhwal region of the Himalayas has not experienced any major earthquake in the last hundred years. Hence it can be said that the elastic strain energy build-up in this region is yet to be released. Also, the sites selected in the present study in northeast Kumaun region are either proposed dam sites or neotectonically active. Proper evaluation of seismic hazard helps in taking preventive measures such as proper designing of structures and consequently the loss of life and property could be minimized.

The observed ground motion records of the past earthquakes are helpful to develop theoretical formulations to synthesize accelerograms from expected earthquakes. In the present work, ground motion records of October 20, 1991 Uttarkashi earthquake (M_b = 6.5) have been used to develop reliable methods for generating synthetic ground accelerations. The PGA values have been calculated taking the source parameters of 29th March 1999 Chamoli earthquake (M_b=6.8) and Dharchula (29.85N, 80.35E) as the epicentral location (Fig. **1).**

Seismotectonic Set-up

The region forms the plate boundary between the colliding Indian and the Eurasian plates. The earthquakes of this region are caused by the strain generated by the convergence of Indian and Eurasian plates. India currently moves southward 8±1 cm/yr (Bilham et al. 1998). The study area lies in close vicinity of the boundary of the Greater and Lesser Himalaya zone. The Main Central Thrust (MCT) at the base of the crystalline zone (Gansser, 1964) dipping 30° to 45° northward is a zone of intense shearing. The MCT is believed to have developed since mid-Tertiary time and there are some geological indications of major recent movements along the MCT (Valdiya, 1980). From the study of seismicity, Ni and Barazangi (1984) suggested 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 (30°) shallow (10-15 km) plane, quite different from MCT, but possibly delineating the interface between the underthrusting Indian plate and overlying Himalayan mass. Analysis of microearthquake data shows thrust as well as strike-slip mechanism (Khattri, 1992a,b). The main tectonic features of the region are shown in Fig. 1.

Methodology for Synthesizing Ground Accelerations

Several quantitative models on the earthquake rupture processes have been developed with the ultimate goal of predicting strong ground motion for a given potential earthquake on the basis of understanding of basic physical laws governing fault mechanics (Khattri et al. 1995; Paul, 1997). The problem of synthesizing ground accelerations is difficult because of the sensitivity of high frequency waves to the details of fault plane irregularities and heterogeneous earth structures.

In the present work the earthquake source has been represented by a number of point source shear dislocations distributed over the fault plane buried in an elastic, homogeneous and isotropic half space. The method consists in integrating the far field contribution of Green's function for number of point sources at the observation point (Aki and Richards, 1980). A uniform elastic half space earth model has been assumed and all the receiving points have been placed on the surface of such a half space.

The displacement from far field observation points is given by,

$$U = f\ (M_o, R, f', v, r, t)$$

where, M is the seismic moment, R is the radiation pattern,

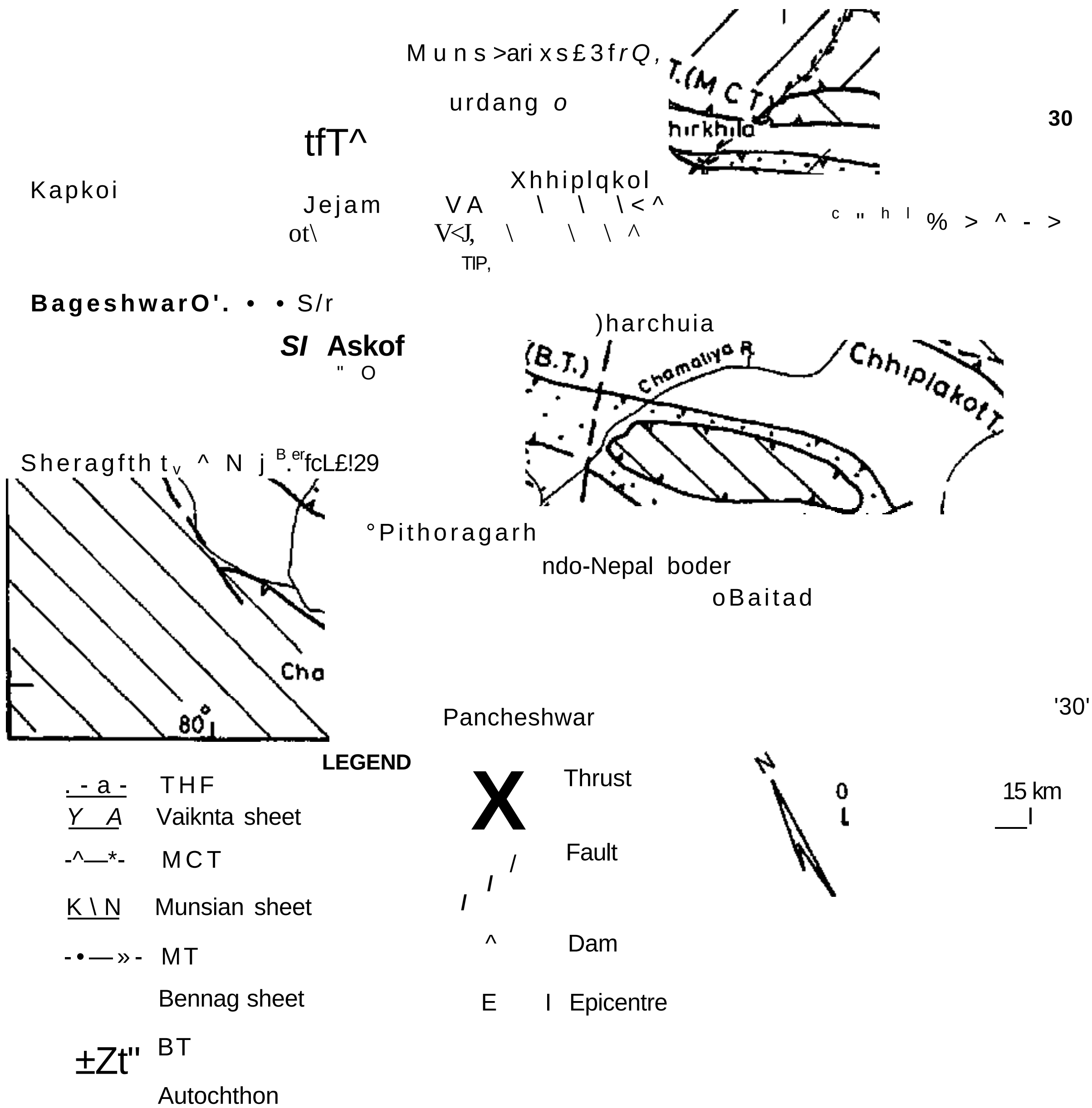

Fig.l. Tectonics, Selected Sites and Lithology of the area (modified after Valdiya, 1980)

f is the free surface effect, v is the velocity of body wave, r is the hypocentral distance and t is the delay time on the rupture front

This methodology has been used to generate synthetic accelerograms for Uttarkashi earthquake This earthquake was recorded on strong motion instruments at 13 sites (Chandrasekaran and Das, 1992) at distances from about 25 to 150 km) Synthetic accelerograms have been generated at seven recording stations and compared with the observed ones following the arrival of S waves Figure 2 shows the observed accelerogram superimposed over synthetic accelerogram (station Uttarkashi, duration of superimposed accelerogram 5 5 sec, observed accelerogram 2 6 sec - 8 10 sec, synthetic accelerogram 12 62 sec -18 12 sec) The time 0 0 sec for observed accelerogram is the onset time for the seismic wave to strike the station, while it is the time at which the seismic wave started from the rupture fault in the case of synthetic accelerogram

In the present work the PGA values have been calculated for some selected sites (Table 1) in the northeastern Kumaun region and adjoining Nepal in the event of an earthquake, taking Dharchula as the epicentre and the source

Table 1. Location Parameters and Peak Accelerations at the Selected Sites

SI No	Name of Station	Location		Peak Acceleration (erri/sec/sec)		
		Lat N	Long E	NS	EW	VER
1	Begeshwar (b)	29 80	79 80	-5 20	-190	1 15
2	Bajang (a)	29 53	80 95	12 59	2 89	0 59
3	Baitadi (b)	29 51	80 45	56	-304	-1 9
4	Batuwakot (a)	29 80	80 44	1316	60 43	49 70
5	Baram (a)	29 86	80 35	37 52	5 29	12 75
6	Bennag (b)	29 95	80 06	65	43	12 8
7	Chamgad (c)	29 43	80 15	3 04	2 09	-14 09
8	Chhiplakot (a)	29 96	80 31	-60	-30	30
9	Chipaltara (c)	29 80	80 37	57 06	23 09	32 41
10	Chhirkhila (c)	29 97	80 57	30 34	39 07	17 67
11	Dhamigaon (a)	29 94	80 27	23 44	10 17	1 24
12	Dharchula (a)	29 80	80 50	174 9	31 55	-34 14
13	Jaulgibi (a)	29 75	80 37	50 16	28 53	39 74
14	Kapkot (a)	29 95	79 90	19 28	5 32	1 21
15	Madkot (a)	30 03	80 17	14 40	8 14	3 50
16	Munsian (b)	30 10	80 37	99	19	07
17	Pancheshwar (c)	29 47	80 25	2 28	5 04	-22 19
18	Pithoragarh (b)	29 58	80 25	4 35	4 43	17 63
19	Sera (a)	29 82	80 32	27 34	6 23	-32 87
20	Seraghat (b)	29 72	79 90	2 06	0 52	-9 16
21	Sirdang (a)	30 00	80 56	20	-34	10 5
22	Tawaghat (b)	30 04	80 33	65 86	23 31	-26 70
23	Tejam (a)	29 80	80 14	261	1 97	-13 46
24	Tyem (a)	30 04	80 34	23 05	23 39	7 59

(a- active fault, b - settlement., c - proposed dam)

parameters (Table 2) of Chamoli earthquake (which happens to be the most recent earthquake in the Kumaun-Garhwal region having magnitude M_L >5).

Observations **and** Results

The peak ground accelerations for each of the three components (north, south and vertical) at each location are given in Table 1. The actual ground motion is influenced by a number of factors. Some of them which have been incorporated in the present study for evaluating ground accelerations are: source geometry, process of rupture propagation and characteristics of the medium between the source and the recording stations. Effect of near surface unconsolidated sediments, scattering and diffraction, geological inhomogeneities and faults, frequency dependent absorption and topographic effects which are likely to influence recorded ground motion in Himalayan terrain have not been taken into account. Thus, the results of the present study are of a primary nature. The synthetic waveforms display primarily the effect of source and rupture propagation.

Figure 3 shows the contours of peak ground accelerations prepared for all the twenty four stations chosen in the northeastern Kumaun. The PGA values vary from 0.51 to 98 cm/sec/sec. The PGA values (in cm/sec/sec) at the proposed dam sites are 14.09 (Chamgad), 57.06 (Chipaltara) 39.07 (Chhirkhila) and 22.19 (Pancheshwar). The PGA values from the observed accelerograms for Uttarkashi earthquake vary from 11.04 cm/sec/sec at Kausani to 303.99 cm/sec/sec at Uttarkashi.

Table 2. Source Parameters of Chamoh Earthquake

SI No	Parameter	Value
1	Length	15 km
2	Downward extension	5 km
3	Strike	282°
4	Dip	9°
5	Slip amount	100 cm
6	Slip Angle	97°
7	Focal Depth	12 km
8	Rupture Type	Circular
9	Magnitude (M_b)	65

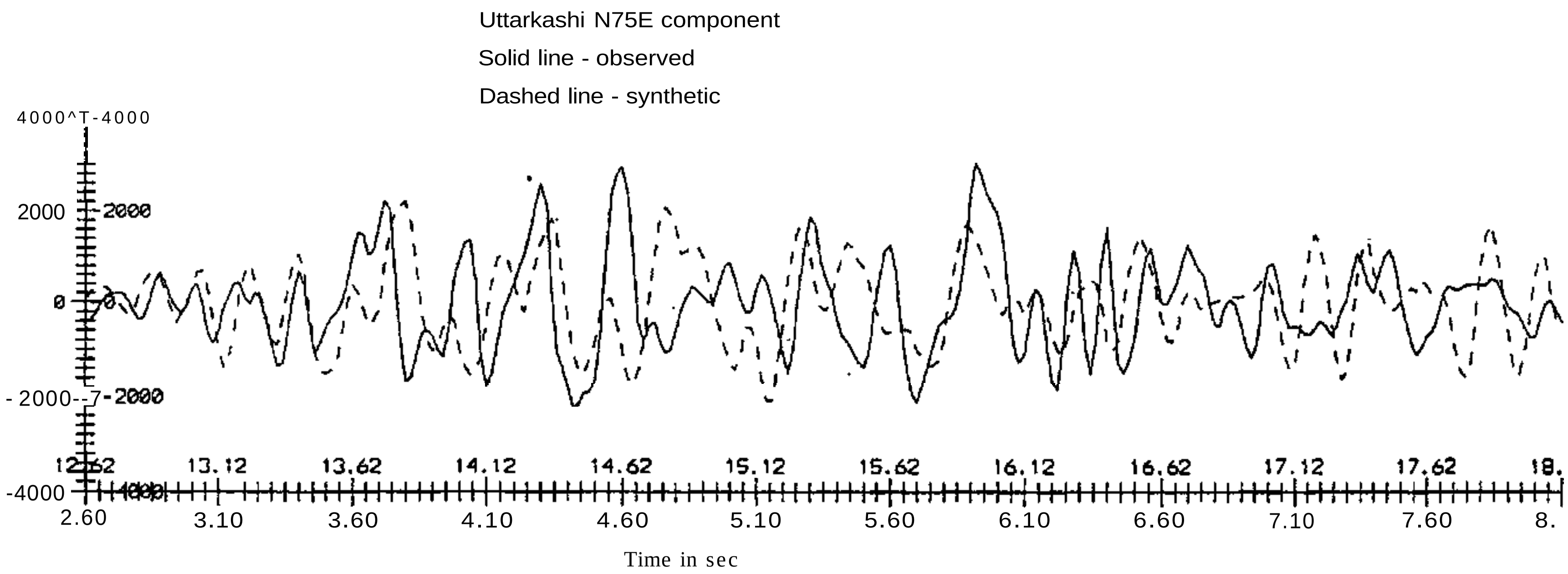

Fig.2. Synthetic accelerogram superimposed over the observed ones for the N75E component at Uttarkashi.

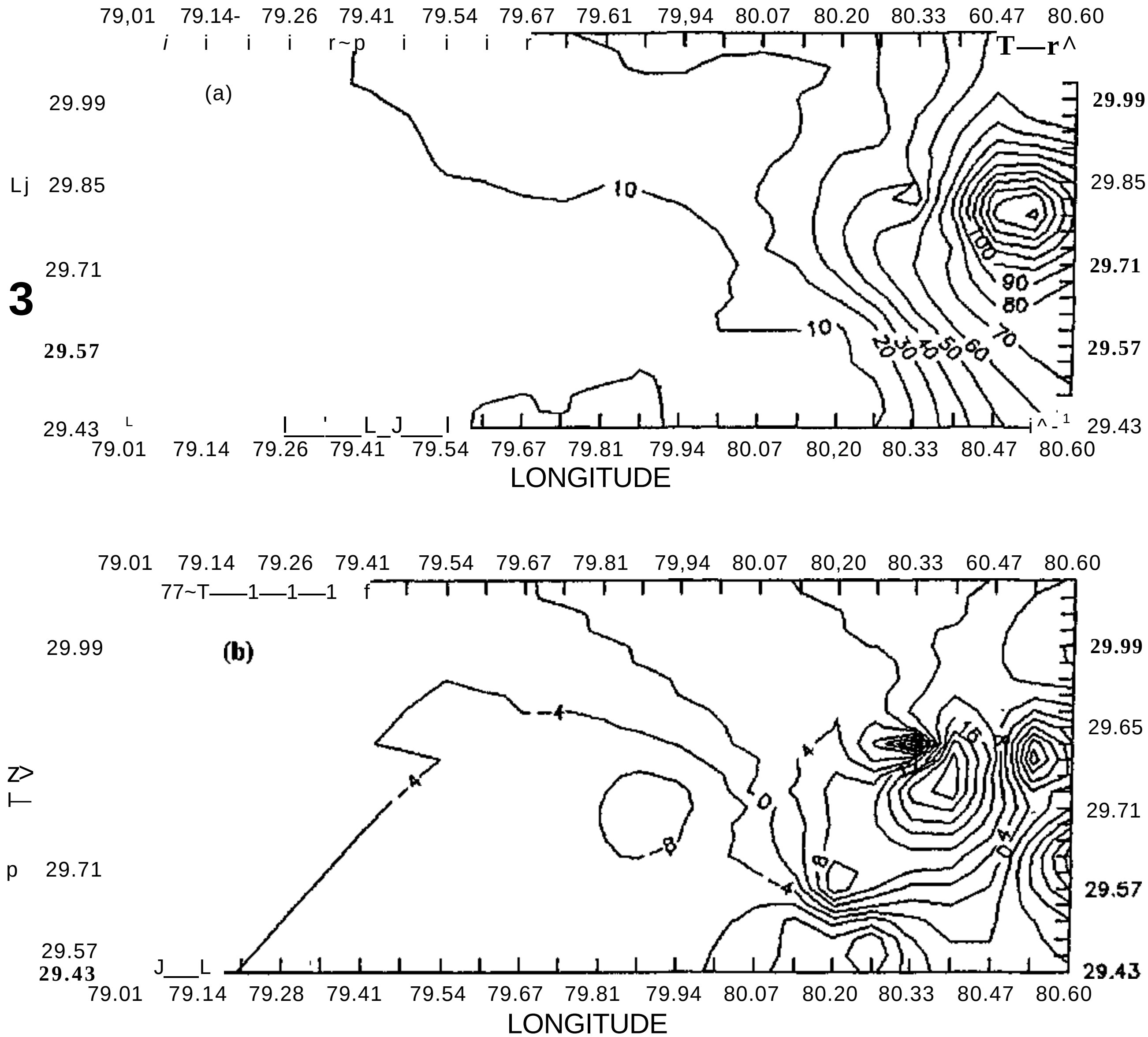

Fig.3. Isoacceleration contours (a) Resultant Horizontal; (b) Vertical accelerations.

The results described above give an approximate idea of the severe ground shaking, which the areas in north-eastern Kumaun, may suffer in the event of an earthquake analogous to Chamoli earthquake and Dharchula as its epicentre. The findings though based on the basis of simplified theory and subject to many assumptions still indicate that the source characteristics play a predominant role at a place near the source when the medium effects are not so pronounced. The peak accelerations likely to be experienced are essentially somewhat on the higher side.

References

AKI, K. and RICHARDS, P.G. (1980) Quantitative Seismology, Theory and Methods, v. 1 and 2, W.H. Freeman and Company, San Francisco.

BILHAM, R., LARSON K., FREYMUELLER, J. and PROJECT IDYLHIM MEMBERS, (1997) GPS Measurements of Present Day Convergence Across the Nepal Himalaya. Nature, v.386, pp.61-64.

BILHAM, R., FREDRICK B., BENDICK, R. and GAUR, V.K. (1998) Geodetic Constraints on the Translation and Deformation of India: Implications for Future Great Himalayan Earthquakes.

Current Science, v 74, No 3, pp 213-229

BILHAM.R andGAUR, VK (2000) Geodetic Contnbutions to the Study of Seismotectonics in India Current Science, v 79, no 9, pp 1259-1269

CHANDRASEKARAN, A R and DAS, J D (1992) Analysis of Strong Motion Accelerograms of Uttarkashi Earthquake of October 20,1991, Paper No 315, Bull Indian Soc Earthquake Tech , v 29, No 1, March, pp 35-55

GANSSER, A (1964) Geology of the Himalaya Interscience Publishers, London, 289p

KHATTRI, K N (1992a) Local Seismic Investigations in the Garhwal Kumaon Himalaya, Mem Geol Soc India, no 23, pp 45-66

KHATTRI, K N (1992b) Seismological Investigations in Northeastern Region of India Mem Geol Soc India, no 23, pp 275-302

KHATTRI, K N , Yu, G , ANDERSON, J G , BRUNE, J N and ZFNG, Y (1995) Strong Ground Motion from the Uttarkashi, Himalaya, India, Earthquake Comparison and observations with synthetics using the composite source model, BSSA, v 85, No 1.pp 31-50

Ni,J andBARAZANGi, M (1984) Seismotectonics of the Himalayan collision zone geometry of the underthrusting Indian plate beneath the Himalayas, Jour Geophys Res , v 89, pp 1147-1163

PAUL, A (1997) Source parameters of Uttarkashi Earthquake of October 19, 1991 by Waveform Modelling, PhD thesis submitted to the Dept of Earth Sciences, University of Roorkee, Roorkee

VALDIYA.KS (1980) Geology of Kumaun Lesser Himalaya Wadia Institute of Himalayan Geology, Dehra Dun, U P, 291p

(Received 10 May 2002, Revised form accepted 13 September 2002)