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ON ESTIMATION OF LOCAL MAGNITUDE (M_L) OF THE DHARAMSHALA EARTHQUAKE OF 1986 USING STRONG MOTION ARRAY DATA

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ABSTRACT

In this paper we make use of digital strong motion accelerograms recorded for Dharamshala earthquake of April 26,1986 to estimate its M_L. Digital acceleration data from six stations around the epicentre in the Dharamshala region are inputs for generation of synthetic Wood-Anderson seismograms using the fourth order Runge-Kutta method. An estimation of local magnitude (M_L) is made from the synthetic W-A seismograms. An average value of $M_L = 5.5$ is in good agreement with the previously reported value of 5.40.

INTRODUCTION

The area affected by the Dharamshala eartnquake of April 26,1986 lies in the main seismotectonic belt of the Himalaya (Kumar and Mahajan,1990) (Fig.1). Within this centuary this area has sufferd a number of significant earthquakes, such as the great Kangra earthquake of 1905, moderate earthquakes of 5th November,1968 and 14th June,1978 as well as the earthquake under discussion here. The Dharamshala earthquake of 1986 occurred in the epicentral tract of the great 1905 Kangra earthquake. Thus the region has been identified as one of great seismic risk and placed in Zone V on the seismic zoning map of India (Fig.1).

Three major rivers, namely, Ravi, Beas and Satluj flow through the region. A number of hydroelectric projects are located on these rivers and many other engineering projects are coming up in the area. Much other developmental activity is also underway there. Seismic risk mitigation measures should be undertaken in the region if developmental work has to go on uninterruptedly. Among these measures, earthquake resistant design of structures is desirable. For this purpose knowledge of probable strong ground motion at sites in the the region is necessary.

Local magnitude (M_L) is determined using waves in the period range of 0.2 to 3 secs. The natural periods of vibration of the fundamental modes of important civil engineering structures (e.g. a dam or a high rise building) also lie within these limits frequently. Hence M_L is a parameter directly related to strong ground motion and its determination can be very useful for designing earthquake resistant structures in the region. Here we estimate M_L of Dharamshala earthquake using strong ground motion data. Using this estimate, the Dharamshala earthquake strong motion records can be accurately scaled for estimation of strong ground motion during earthquakes of other magnitudes which may be anticipated in future in that region.

Although the entire Himalayan domain is seismically active and worthy of detailed investigations, two strong motion arrays have been installed so far in NE India and Kangra regions. While the first strong ground motion record was produced in India for the Koyna earthquake of 1967, in the Himalayan region, the Dharamshala earthquake of 1986 yielded the first strong ground motion recordings.

As the strong ground motion recording took place within a short distance of the epicentre , the M_L determined in this way should be subject to effects of distance and medium inhomogeneities minimally. Therefore this M_L estimate should be more reliable to that obtained with a standard Wood-Anderson seismograph at a larger epicentral distance. Moreover, strong motion records obtained with digital accelerographs have the advantage that data processing can commence directly.

DETERMINATION OF M_L USING STRONG MOTION DATA

The concept of local magnitude (M_L) was given by Richter (1935). Its determination is based upon Wood-Anderson seismograph records. The instrument has a natural period 0.8 secs, damping 80% of critical and static magnification of 2800. Standard Wood- Anderson seismograph normally works only at short epicentral distances. But for earthquakes having $M_L \geq 4.5$ and epicentral distances ≤ 25 km. this instrument is not reliable because it is driven off scale (Jennings and Kanamori, 1983).So, for large earthquakes at short epicentral distances it is logical to use strong motion array data to determine local magnitudes by first computing synthetic (Housner et al, 1964) Wood-Anderson seismograms.

Kanamori and Jennings (1978) used strong motion records to calculate local magnitude. They applied the time domain convolution method to generate the synthetic seismograms. Uhrhammer and Collins (1990) and Uhrhammer and Bolt (1991) used frequency domain convolution to compute the local magnitude. If, as in the present case, strong motion accelerogram is in digital form, then theoretical standard Wood-Anderson impulse response (given by Bullen.,1953,page 142) can not be used as such. We need digital simulation of analog impulse response for digital convoluton with digital strong motion acceleration data (accelerogram)in order to get synthetic W-A seismogram. This problem of convolution has been avoided here by using the fourth order Runge-Kutta method (Scarborough, 1930) to integrate the Wood-Anderson seismograph equation directly.

DATA

The epicentral data of Dharamshala earthquake of April 26,1986, revised by Indian Meteorological Department, New Delhi, using seismographic and strong motion array data are (Chandrasekaran, 1988 and Srivastava, 1989) :

Epicentre	Lat. 32.193^0 N Long. 76.290^0 E
Magnitude (M_L)	5.40
Focal depth	10 km (appx)
Origin time	07 35 17 GMT

We have analysed twelve strong motion digital accelerograms of this earthquake published by Chandrasekaran (1988). The records were obtained at six stations of the strong motion array located around the Dharamshala region. The station locations are shown in Fig.2.

DATA ANALYSIS

Fig. 3 shows a sample accelerogram and the corresponding synthetic Wood-Anderson seismogram, obtained using the fourth order Runge-Kutta method. From such synthetic seismograms we obtained maximum trace amplitudes (in mm) and then calculated the local magnitude (M_L) using the formula given by Richter (1958) :

$$M_L = \log_{10}X - \log_{10}X'(\Delta)$$

where X is maximum synthetic W-A trace amplitude

$-\log_{10}X'(\Delta)$ is the correction factor corresponding to the epicentral distance Δ (Richter, 1958,page 342). The epicentral distance is calculated using Bullen's (1953) formula :

$$\Delta^2 = (\theta - \theta')^2 + (\phi - \phi')^2 \sin^2 [(\theta+\theta')/2]$$

where, (θ,ϕ) : coordinates of epicentre
(θ',ϕ') : coordinates of recording station
θ : co-latitude
ϕ : east longitude

RESULT

Table 1 gives synthetic peak ground displacements and corresponding estimates of local magnitude at six stations used in this study. The results are also displayed in Fig.2. The range of M_L estimates is 5.41-5.69. Thus an average value of M_L=5.53, rounded to 5.5, is obtained using strong motion array data. The value reported by IMD is 5.4.

Importance of this analysis and result is that this method could be used for recent large earthquakes, such as, the Assam earthquake of August 7,1988, and the Bihar-Nepal earthquake of August 21,1988, for which digital strong motion accelerograms are available.It could also be used in future for other large earthquakes picked up using digital strong motion arrays.

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TABLE 1

Local magnitude M_L for Dharamshala earthquake estimated from strong motion array data

Station	Station Code	Seismograph Component (in degree)	Epi. Dist. Δ (km)	Dist. correction for M_L $(-\log_{10}X')$	Max. Syn. W-A tra. amplitude X (mm)	M_L	Mean M_L for each station
Dharamshala	DHAR	N76W	3.54	1.4	9906.928	5.39	
		N14E	3.54	1.4	19287.52	5.68	5.53
Shahpur	SHAH	N75E	10.38	1.5	10223.47	5.51	
		N15W	10.38	1.5	24057.20	5.88	5.69
Kangra	KANG	N43W	10.58	1.5	8334.811	5.42	
		N47E	10.58	1.5	18161.84	5.76	5.59
Nagrota	NAG	S85W	13.55	1.55	13685.84	5.69	
Bagwan	BAG	N5W	13.55	1.55	3834.301	5.13	5.41
Baroh	BARO	N25W	21.60	1.75	5503.353	5.49	
		N65E	21.60	1.75	4848.861	5.44	5.46
Sihunta	SIHU	N25W	22.81	1.8	4500.372	5.45	
		N65E	22.81	1.8	5886.350	5.57	5.51

M_L Average =5.53

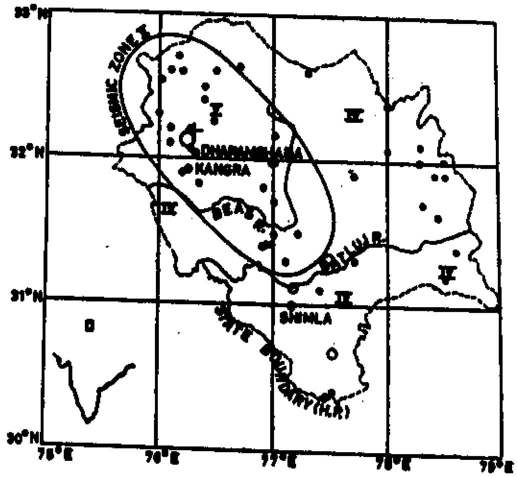

Fig.1 Seismicity of Himachal Pradesh in the NW Himalaya. Available data on moderate earthquakes is plotted along with the epicentres of 1905 (big circle) and 1986 earthquake (+). Information from seismic zoning map of India attached to ISI Code 1893-1975 is shown through Roman numerals (seismicity information after Arya, 1986).

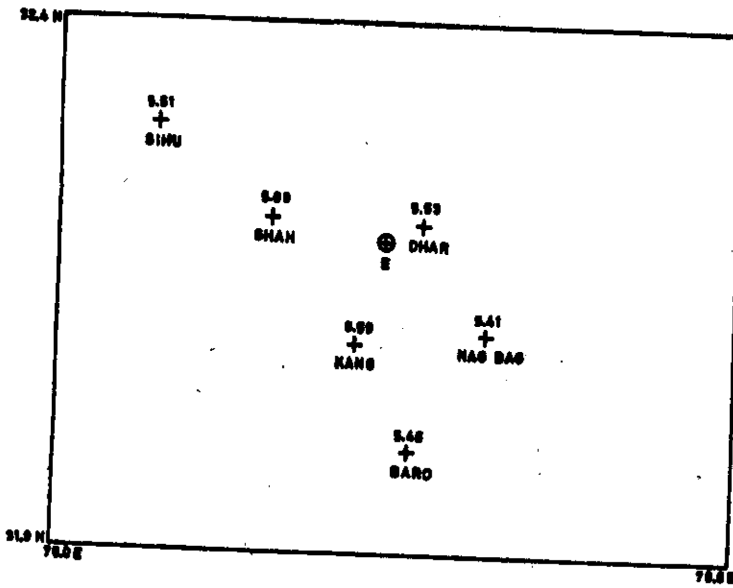

Fig.2 Station locations and M_L estimates around Dharamshala region. Station codes are taken from Table 1. E represents the epicentre of the Dharamshala earthquake of 1986.

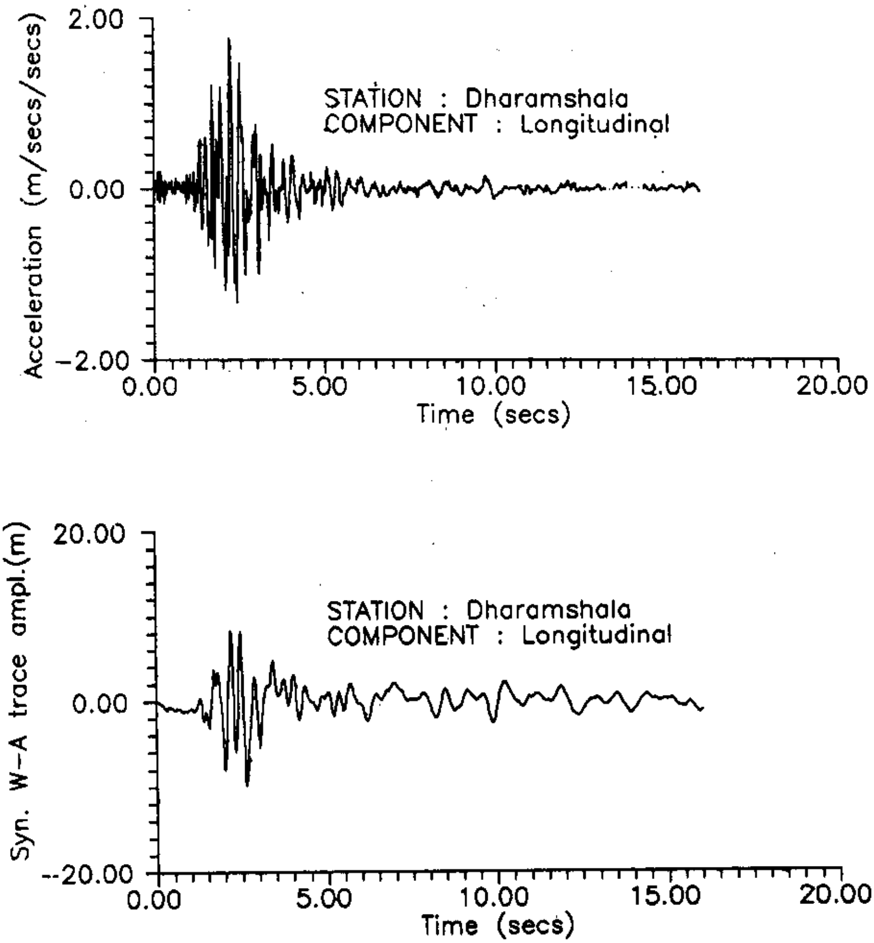

Fig.3 A Sample accelerogram and synthetic Wood-Anderson seismogram using the fourth order Runge Kutta method.