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DETERMINATION OF EARTHQUAKE MAGNITUDE FROM TOTAL SIGNAL DURATION FOR TEHRI-GARHWAL AND KOYNA REGIONS, INDIA

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INTRODUCTION

Microearthquake recording was carried out at Chiplun (about 30 km from Koyna) and at Barethi (Tehri-Garhwal region) using high-gain high-frequency portable microearthquake systems (Sprengnether MEQ—800). This paper describes in detail a method used for the determination of magnitude of a large number of local earthquakes recorded at the above sites. The conventional approach of using amplitude data to determine Richter magnitude involves several difficulties as discussed in the following paragraphs.

Richter (1958) and Eaton (1970) have discussed a number of problems in estimating the local magnitude by the standard method for earthquakes recorded by instruments other than the Wood-Anderson seismograph. In the recording of microearthquake high-gain high-frequency systems are used. The use of amplitude measurements on microearthquake records for determining magnitude is faced with several difficulties such as (a) the instrumental response characteristics of the Wood-Anderson seismograph and the high-gain high-frequency system are very different (b) most of the microearthquake recording seismographs are vertical component instruments where as Wood-Anderson seismogram records only horizontal ground motion, (c) significantly different response at different stations may be observed due to large vatiations in the attenuation of seismic waves in the crust, (d) it is generally difficult to resolve local earthquakes into their component waves unlike teleseismic events. Eaton (1970) observed that the waves that are largest in any given range of distance vary from region to region, depending upon the details of the crustal structure, (e) saturation of amplitudes is commonly observed for moderate size earthquakes recorded by high-gain systems hence in such cases the amplitude data can not be used for assigning the magnitude.

In the present survey, recordings from Wood-Anderson seismograph allowed the determination of Richter magnitude of a number of local events. In view of the uncertain nature of using the amplitude data as discussed above, magnitudes were determined using a method developed by Tsumura (1967). This method consists of establishing a relationship between the total signal duration (coda length) and conventionally defined magnitude. Such relationship for the Tehri-Garhwal and Koyna regions are presented here.

DEFINITION OF CODA LENGTH AND ITS RELATION TO MAGNITUDE

The total signal duration of an earthquake has been defined as the duration of both the body and surface waves. The difference in the definition given by various authors (Lee et al. 1972, Real, 1973) is mainly dependent of the manner in which the end of the seismogram is chosen. Bisztricany (1958) defined coda length as the duration of surface waves only, whereas Lee (1972) in order to overcome the problem of overlapping

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the coda length with noise found it convenient to define coda length of an earthquake as the time interval between the onset of the first arrival to the point where signal falls below a certain pre-assigned minimum amplitude threshold. Real (1973) defines the coda length as the time interval between the onset of first arrival and the point at which earthquake signal falls and remains below the background noise level. For small earthquakes recorded at distant stations with small amplitudes, the method of pre-assigning an arbitary cutof amplitude may not be feasible, on the other hand, it is more practical to read the entre duration. Another advantage of defining the end of the record with respect to the background noise makes the duration somewhat independent of the instrumental gain since increasing the gain would amplify both the signal and the background noise. In the present study the coda lengths have been defined after Real.

The factors influencing the coda length have not been well established. Some of the variables that might influence coda length are (a) local site geology, (b) attenuation due to lateral inhomogeneties of crustal rocks and (c) radiation pattern of seismic energy. Crosson (1972) and Tsumura (1967) found coda lengths independent of distance from the hypocentre. The observed independence of coda length with respect to distance provides another simplification in application of the technique. Real (1973) has shown that there is little azimuthal dependency of signal duration. This might be expected because the total duration of the surface waves which, because of their long periods are attenuated more slowly and are less affected by local irregularities.

We adopt an equaiion of the form (Tsumura 1967)

$$M_L = a + b \log T$$

where T is the total signal duration in seconds, a and b are constants, for the determination of magnitude. Magnitudes were calculated independently from the Wood-Anderson records in the usual manner (Richter 1958). Because of uncertainties in the depth of focus of the earthquakes, hypocentral distance rather than epicentral distances were used for calculation of magnitudes. The authors are aware of the fact that the distance corrections used are for the California region, but it has been reported that for short, distances the distance correction does not vary significantly for various regions (Sbar et al. 1972).

DATA ANALYSIS AND ITS REDUCTION

Tables 1 and 2 give the coda lengths and Richter magnitudes (M) for Tehri-Garhwal and Koyna regions respectively. Only those events have been included here for which the Wood Anderson records were available. This limited the selection of the data considerably. The events studied for Tehri-Garhwal region at Barethi recording station varied in range from 130 to 180 km. with more events close to 140 km. While distances for Chiplun station for Koyna region varied from 28 to 40 km with more events close to 32 km. The coda lengths were read by a single person to minimise personnel errors. The highest magnitude (M_L) used in this study is 4.9 and the lower limit of magnitude as could be obtained from Wood-Anderson record is 2.0.

A plot of coda length versus magnitude is shown in Figs. 1 and 2 for the Tehri Garhwal and Koyna region respectively. A least square fit to the data resulted in the following equations,

$$M_L = 3.25 \text{ Log } T - 4.3 \qquad \text{for Tehri-Garhwal region}$$

$$M_L = 2.73 \text{ Log } T - 3.9 \qquad \text{for Koyna region}$$

TABLE 1 : DATA USED TO CORRELATE WOOD-ANDERSON MAGNITUDE WITH CODA-LENGTH OSBERVED DURING MICROEARTHQUAKE RECORDING AT BARETHI STATION, TEHRI-GARHWAL REGION.

Date 1975	*Time (IST)* *HR*	*MN*	*SEC*	*(S–P)* *SEC*	*Wood Anderson Magnitude*	*Coda Length* *SEC*
Jan 20	19	37	—	16.5	3.8	342
20	21	47	30.8	18.0	3.8	340
21	23	26	41.5	17.5	3.4	250
22	15	08	38.03	17·5	4.2	400
22	18	43	29.7	17.0	3.9	342
22	23	00	54.43	17.5	4·7	515
23	21	17	14.5	17.5	3.6	290
27	10	12	34.04	18.0	4.8	598
29	21	19	53.39	16.3	4.9	640
31	19	34	41.02	23.0	4.3	450

TABLE 2: DATA USED TO CORRELATE WOOD-ANDERSON MAGNITUDE WITH CODA-LENGTH OBSERVED DURING MICROEARTHQUAKE RECORDING AT CHIPLUN STATION, KOYNA REGION.

Date 1974	*Time (IST)* *HR*	*MN*	*SEC*	*(S–P)* *SEC*	*Wood Anderson Magnitude*	*Coda Length* *SEC*
Feb 1	17	07	28.2	4.0	2.0	150
2	11	51	22.0	4.0	2.1	160
7	21	41	26.3	3.5	2.2	170
9	03	50	09.0	4.0	2.3	195
10	05	42	16.0	3.5	2.4	202
11	00	52	20.0	4.0	2.68	232
15	03	39	16.8	4.0	2.7	240
16	04	05	—	4.0	2.9	300
17	01	42	28.0	4.0	2.72	260
17	19	36	14.0	5.0	3.8	700

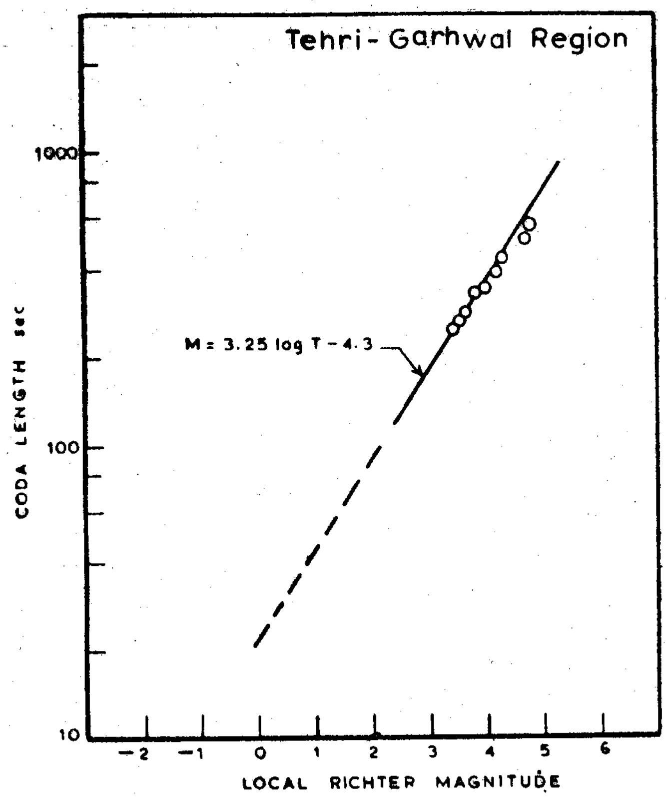

Fig. 1. Coda length versus magnitude plot for the Tehri-Garhwal region.

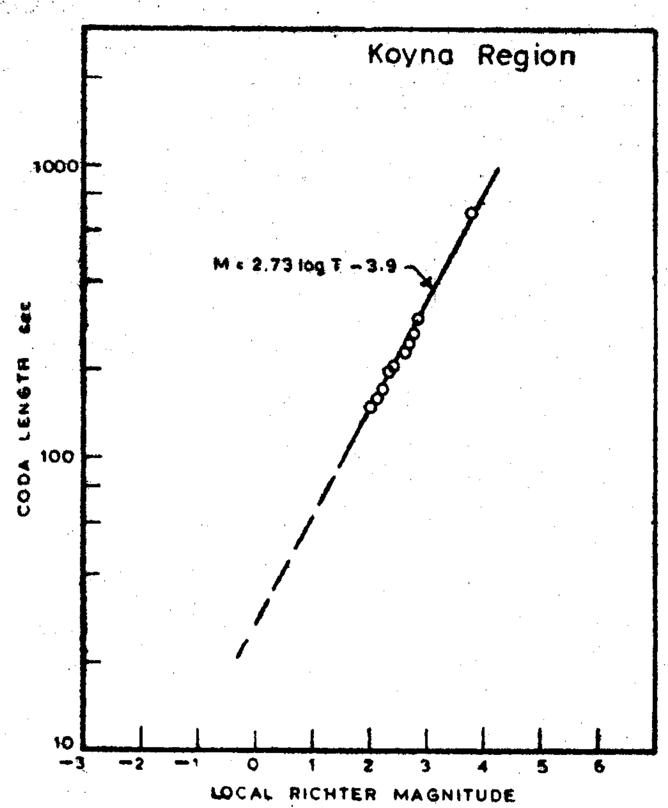

Fig. 2. Coda length versus magnitude plot for the Koyna region.

Use of these relations to calculate the magnitude of the microearthquakes recorded at the two regions will enable in assigning local magnitudes to large number of microearthquakes in much simpler and improved manner.

DISCUSSION

Empirical relations based on the total signal duration of an earthquake can be successfully used to determine local Richter magnitudes of microearthquakes. Such relations were obtained for Tehri-Garhwal and Koyna regions.

The limited data in the present study did not permit inclusion of a term relating the dependence of coda length to the epicentral distance. Tsumura (1967) introduced the distance term, giving a relationship of the form

$$M_L = a_0 + a_1 \text{ Log } T + a_2 \Delta$$

where Δ is the epicentral distance.

However, the value of the constant a_2 is so small (about 0.001) that for near distances, a_2 term can be neglected without appreciably affecting the magnitude values. This is further shown by Real (1973) and Crosson (1972) who found coda lengths independent of hypocentral distance. The small dependence of coda length on distance was also observed when a network of three stations recorded a large number of microearthquakes in Tehri-Garhwal region. Fig. 3 shows the plot of coda length versus (S—P) time for a number of earthquakes. Each of the earthquake recorded at three different stations is shown by three points in the figure. The earthquakes are well distributed around the net work and for various distances the variation in coda length observed at all the three stations is very small. The dependency of the short period body wave maximum amplitudes on azimuthal and crustal variations are larger relative to the coda lengths. Due to this, the uncertainty of local magnitudes computed from total signal duration is much lower than that computed by standard method. A requirement of the method involves the necessity of having a Wood—Anderson instrument nearby.

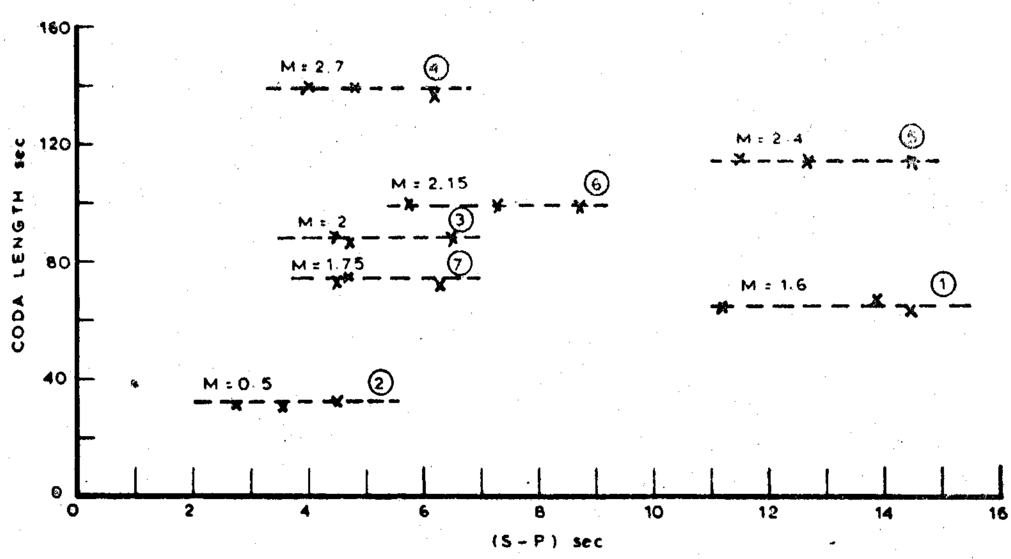

Fig. 3. Coda length versus (S-P) plot for seven earthquakes of different magnitudes. Each Earthquake was recorded at three stations (X).

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