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550.341 (541.1)

Estimation of earthquake magnitudes from signal duration for the Shillong observatory

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ABSTRACT. A relation $Ms = 0.53 + 1.07 \log \tau + 0.0019 \triangle$, has been derived for estimating surface wave magnitudes (Ms) of local events from signal duration τ in sec for the Central Seismological Observatory (CSO), Shillong. Magnitudes can be estimated using this relation within the limits of $\pm$ 0.27 units. This relation has been obtained using the data of about 100 well recorded earthquakes from the seismograms of the Shillong observatory.

1. Introduction

The original method proposed for estimating the local magnitude of earthquakes (Richter 1935) and later extended for teleseismic events (Gutenberg and Richter 1956) involves the measurement of maximum trace amplitudes and corresponding periods of the seismic waves on the seismogram. Karnik *et al.* (1962) developed an equation for estimating surface wave magnitude (Ms) from the maximum trace amplitudes and corresponding periods of surface waves. These days, sensitive instruments are deployed to monitor local seismicity throughout the world. Very often, it becomes difficult to measure the maximum trace amplitudes due to fainting of trace or clipping off of amplitudes. This is responsible, for magnitudes being not reported for many earthquakes.

In recent years, signal duration (τ) is being used for estimating eqarthquake magnitudes (Solov'ev 1965, Lee *et al.* 1972, Real and Teng 1973). Rao and Gupta (1979) and Gupta *et al.* (1980) developed relations for estimating surface wave magnitudes using signal duration for the seismological observatory at Hyderabad (HYB) operated by the National Geophysical Research Institute (NGRI) and the Koyna network seismic stations operated by the Central Water & Power Research Station (CW&PRS) respectively. Since this relation depends mostly on instrumental constants and geology of the site of seismological network/observatory, it is desirable to calibrate all seismic stations.

2. Data and methodology

The India Meteorological Department has been operating a seismological observatory at Shillong (SHL) located at 25.57° N, and 91.88° E. This became a part of the World Wide Network of Seismological Stations (WWNSS) of United States Geological Survey (USGS) in 1963. The surrounding area is seismically very active. Frontal Himalayan Thrust in the north; Himalayan syntaxial bend in northeast; Dauki fault, as well as the epicentre of the 1897 earthquake of magnitude 8.7 in the south and many more faults in the western side are all seismically very potential (Fig. 1).

The SHL is equipped with the three component short period Benioff seismometers and recording is done photographically. As this observatory is a part of WWNSS, calibration of the instruments is in accordance with WWNSS specifications. Magnification of the short-period seismometers is 200 K at 1 Hz. The surface wave magnitude is estimated using the relation (Karnik *et al.* 1962) :

$$Ms = \log A_H/T_H + 1.66 \log \triangle + 3.3 \qquad (1)$$

where, $A_H = (A_N^2 + A_E^2)^{1/2}$

$T_H = (T_N + T_E) / 2$

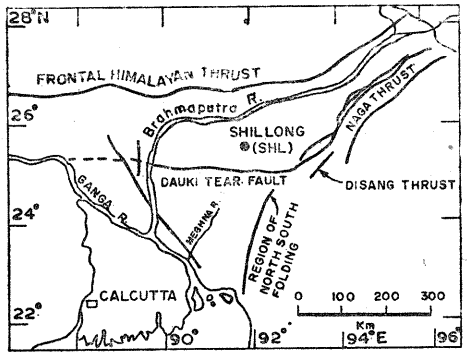

Fig. 1. Location of Shillong (SHL) Observatory and faults around it (Redrawn from Mathur and Sykes 1964)

A_N and A_E being maximum ground motion in microns in N-S and E-W directions and T_N and T_E are corresponding periods in sec. $\triangle$ is the epicentral distance in degrees. Signal duration, τ, has been defined by many authors elsewhere (Lee *et al.* 1972, Rao and Gupta 1979, Gupta *et al.* 1980) . Keeping in view of the high magnification (200 K) and background noise level of SHL, signal duration is defined as the duration in seconds from the onset of first phase to the time till the signal apmlitude continues to be 3 mm (peak to peak) on the short-period vertical component seismogram.

The data for about 100 events was taken from the seismograms of the SHL observatory. We have inspected a number of seismograms and only such seismograms were selected where the period and amplitudes of the local earthquakes could be read without any ambiguity. There is a possibility of S_g and L_g phases getting mixed up. Proper care was taken to ensure that our readings belong to one phase only. The surface wave magnitudes of these earthquakes are calculated using the relation (1). Their corresponding signal durations are noted in accordance with the above definition. In the present study, the magnitude range covered is 1.6 to 4.0 and the epicentral distance ranges from about 10 to 450 km.

From the experience of previous workers and our own work, a relation of the type :

$$Ms = b_0 + b_1 \log \tau + b_2 \triangle \qquad (2)$$

has been adopted for estimating surface wave magnitudes using signal duration. Here, Ms is the surface wave magnitude, τ is the signal duration in seconds and $\triangle$ is the epicentral distance in km. b_0 is a seismometer dependent constant, and b_1 and b_2 are partial regression coefficients. They are determined using least square method by minimizing :

$$\sum_{i=1}^{n} E_i^2 \qquad (3)$$

where, $E_i = Ms_i - (b_0 + b_1 \log \tau_i + b_2 \triangle)$

to zero by partial differentiation of ΣE_i^2 with respect to b_0, b_1 and b_2 (Adam and Kennedy 1964). Thus three simultaneous equations are obtained. They are solved using Gaussian elimination method. PDP 11/40 computer is used for calculations. Through this procedure a relation :

$$Ms = 0.53 + 1.07 \log \tau + 0.0019 \triangle \qquad (4)$$

is obtained for SHL. Uncertainity in determining magnitudes using above relation is estimated by :

$$\sigma = [\sum_{i=1}^{n} (Ms - M\tau)_i^2 / (n-1)]^{1/2} \qquad (5)$$

and is found to be $\pm$ 0.27 units.

TABLE 1

The coefficients in the relation $Ms = b_0 + b_1 \log \tau + b_2 \triangle$ as obtained by different authors

Investigator	Calib. mag.	b_0	b_1	b_2	Uncertainity
Bisztriscany (1958)	M	—2.92	2.25	0.001	0.32
Tsumara (1967)	M	—2.53	2.85	0.0014	0.2-0.3
Lee *et al.* (1972)	M_L	—0.87	2.00	0.0035	0.22
Crosson (1972)	M_L	—2.46	2.82	—	0.21
Real and Teng (1973)	M_L	—1.01	1.89	0.0009	0.16
	M_L	1.03	0.43	0.0009	0.15
Rao and Gupta (1979)	M	—0.74	1.67	0.0009	0.28
Gupta *et al.* (1980)	M	—2.44	2.61	—	0.25
Present studies	M	0.53	1.07	0.0019	0.27

3. Discussion

Results of the earlier workers are summerised in Table 1. The coefficients in the Eqn. (2), obtained in the present study are compared with those of earlier workers. The variation, as explained earlier, is due to difference in instruments and geographic location.

Apart from instrumental response and geology of the site of observatory, the signal duration also depends on (*i*) depth of focus of the earthquake and (*ii*) the azimuth of the station from the epicentre. While evaluating the relation between

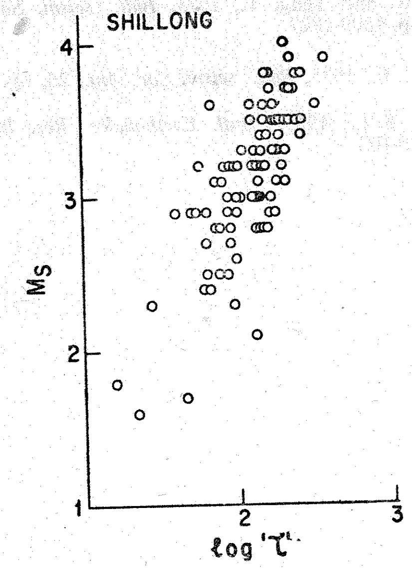

Fig. 2. Relation between *Ms* and log τ. *Ms* is the surface wave magnitude estimated from amplitudes and periods; τ is the signal duration in sec.

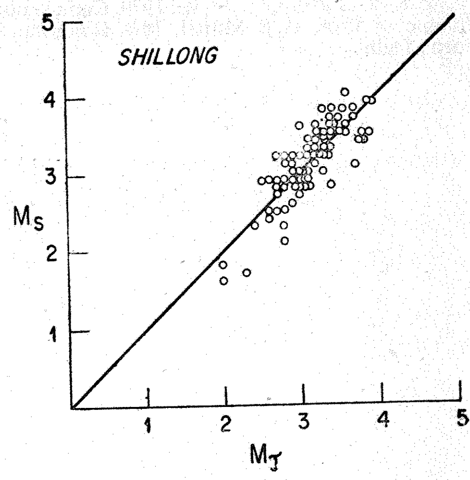

Fig. 3. Relation between *Ms* and M_τ. *Ms* and M_τ are the surface wave magnitudes estimated from amplitudes and signal duration respectively.

earthquake magnitude and signal duration, these two factors also must be taken into account. However, in the present study we did not take these two factors into account, because the depth of focus is not known for the events used in this study. However, from Fig. 2 it can be seen that though we have not taken into accout the azimuth, the relation between *Ms* and log τ is very linear. However, the linearity deviates slightly at 3.5 *Ms* approximately. This deviation could be due to shift in the corner frequency with the increase in earthquake size, which causes a corresponding decrease in the amplitude of the coda and hence relatively smaller duration (Hermann 1975). The tentative relation obtained for estimating earthquake magnitude from signal duration is very useful and from Fig. 3 it can be seen that the relation between *Ms* and M_τ is quite linear and stable.

4. Conclusion

Using the data from the seismograms of the SHL, the following empirical relation between surface wave magnitude (*Ms*) and signal duration (τ) for earthquakes occurring around SHL has been obtained :

$$Ms = 0.53 + 1.07 \log \tau + 0.0019 \triangle$$

Surface wave magnitudes (*Ms*) can be estimated using this relation within ± 0.27 units. Considering the fact that for many earthquakes magnitudes were not estimated earlier because the amplitudes and periods could not be read reliabily, the coda magnitude relation developed in the present paper shall be quite useful.

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