The relationship between the body wave and the local magnitudes for Himalayan earthquakes

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Summary. — Body wave (M_B) and local magnitude (M_L) were determined for earthquakes occurring within the epicentral range of 2 to 10° from New Delhi during the years 1965-1974. The following relationships between them were found to hold good.

$M_L = (0.95 \pm 1.4) + (0.81 \pm 0.06)\ M_B \qquad (\Delta = 2° \text{ to } 5°)$

$M_L = (1.26 \pm 0.76) + (0.76 \pm 0.02)\ M_B \qquad (\Delta = 5° \text{ to } 10°)$

$M_L = (1.00 \pm 0.57) + (0.80 \pm 0.01)\ M_B \qquad (\Delta = 2° \text{ to } 10°)$

The regional variation of ($M_{CGS} - M_B$) has been discussed in terms of the focal mechanism and other parameters. It has been found that ($M_{CGS} - M_B$) is positive near India-Nepal and Tibet border while elsewhere it is generally negative.

Riassunto. — Le magnitudo M_B ed M_L sono state determinate per quei terremoti avvenuti durante gli anni 1965-1974, entro un'area epicentrale compresa tra 2° e 10° da Nuova Delhi.

Le relazioni che legano M_B ad M_L sono risultate valide e sono le seguenti:

$M_L = (0.95 \pm 1.4) + (0.81 \pm 0.06)\ M_B \qquad (\Delta = 2° \text{ to } 5°)$

$M_L = (1.26 \pm 0.76) + (0.76 \pm 0.02)\ M_B \qquad (\Delta = 5° \text{ to } 10°)$

$M_L = (1.00 \pm 0.57) + (0.80 \pm 0.01)\ M_B \qquad (\Delta = 2° \text{ to } 10°)$

È stata discussa la variazione regionale ($M_{CGS} - M_B$) basandosi sul meccanismo focale ed altri parametri.

La differenza suddetta ha valore positivo al confine fra India – Nepal e Tibet, mentre altrove risulta generalmente negativa.

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Introduction

The magnitude scales derived from body waves and surface waves have been widely accepted after the installation of world wide seismograph system. However while using them for earthquakes occurring within the epicentral distance of ten degrees, several difficulties are encountered. In particular, surface waves of 20 $\pm$ 2 seconds period are rarely developed within this epicentral range to allow a computation of M_S (surface wave magnitude). On the other hand, the use of the body wave magnitude, M_B has been recommended for epicentral distances larger than 5 degrees. The determination of M_B is difficult when the initial motion within a few cycles of the onset of *P*–waves is disturbed due to the complexities of the crustal structure as generally observed for the Himalayan earthquakes. Also, M_b cannot be calculated for strong earthquakes, which render the record white.

For earthquakes occurring within 600 km, the local magnitude, M_L first derived by Richter for southern California based on the records of standard Wood Anderson Seismographs is generally used. Since however the magnification of the torsion seismometer is quite low, many earthquakes occurring in the Himalayan region are not recorded by them. Thus, the only alternative is to use M_B for such smaller events inspite of its limitations within 5 degrees.

The object of this paper is to study the relationship between M_B and M_L for the epicentral distance range of 2 to 10 degrees so that the effects of using M_B for $\Delta \leqslant 5$ and $M_L \geqslant 5.5$ may be brought out. In addition, the regional variation of the C.G.S. magnitude *M*, M_{CGS} versus M_B and M_L has also been attempted in the light of the dominant focal mechanism in different regions.

Data and Analysis

For this study, the records of all the earthquakes with foci within the crust which occurred within the epicentral distance of 2 to 10 degrees from New Delhi were examined for the years 1965 to 1974. A total of 150 earthquakes were selected out of which M_B and M_L both could be determined for 52 earthquakes only. Although the focal depth determination were available only upto 1973 from the Bulletin of the International Seismological Centre, we have included those earth-

Table 1

Earthquake magnitudes, M_B and M_L (1965-1974)

$\Delta = 2^o$ to 5^o: depth upto 60 km.

S. No	Date	Origin Time h m s	Latitude °N	Longitude °E	Depth in km	Mag. CGS	Δ in degrees	M_B (Delhi)	M_L (Delhi)
1	21.2.1965	03 35 25	32.4	76.9	33	4.5	4	4.8	4.2
2	1.6. »	07 52 26.1	28.5	83.2	20	5.2	4.9	5.4	4.8
3	27.6.1966	10 41 08.6	29.7	80.9	37	6.1	3.2	4.9	5.8
4	28.6. »	15 43 37	29.4	81.1	33	5.4	3.2	4.4	4.7
5	29.6. »	00 42 08.6	29.8	81	12	4.9	3.1	4.2	4.6
6	16.12. »	22 12 09.2	29.7	81	7	5.4	3.0	5.3	5.7
7	18.12. »	22 42 38.3	29.6	81	16	5.0	3.1	4.6	4.2
8	21.12. »	22 10 58.8	29.4	81	21	5.4	3.1	5.3	5.0
9	20.2.1967	15 18 39.9	33.7	75.3	24	5.7	4.7	5.6	5.3
10	20.9. »	20 25 05.6	32.6	76.1	58	4.1	4.1	5.3	4.3
11	5.1.1968	06 42 44.7	30.4	79.1	7	5.4	2.8	4.3	5.2
12	3.3.1969	06 20 31.8	30.2	79.9	18	5.3	3.0	4.7	5.2
13	5.3.1970	18 34 22.5	32.4	76.5	33	4.9	3.3	5.0	4.4
14	30.1.1971	20 15 35	30.5	79.1	56	4.6	3.9	4.2	5.1
15	3.5. »	00 33 25.5	30.8	84.5	16	5.4	3.1	5.0	4.5
16	6.9. »	00 33 25.9	33.2	69.9	26	4.9	4.5	5.4	5.2
17	24.2.1974	21 32 10	30.7	78	33	4.3	3.1	4.7	4.8
18	2.3. »	04 53 15.6	30.8	86.3	33	5.3	3.1	4.8	4.2

quakes occurring during 1974 for which reliable estimates of depths were available from Indian Seismological network. The data for the earthquakes is given in Table 1.

The body wave magnitudes, M_B were determined by using the Gutenberg Richter's relation, namely

$$M_B = \log 10 \left(\frac{A_{max}}{KT} \right) + Q \qquad [1]$$

Where A_{max} is one half of the through to peak trace amplitude in microns, K is the peak magnification in thousands at the period to be read from the instrumental response characteristics of WWSSN Benioff system, T the period of the waves within (1 ± 0.3) records of the onset of P and Q is the depth distance factor. It may be mentioned that the values of Q have been tabulated from 2 degree onwards.

The local magnitude, M_L was determined from the two horizontal component torsion seismometers aligned in north-south and east-west directions. Since the magnification of these instruments has been set at 1000 at Delhi Seismological Observatory, the average of the maximum double amplitudes measured in both the components (after allowing for the trace thickness and reducing to ground amplitude in microns) has been used to compute M_L. The plot of M_B and M_L is shown in fig. 1 where details will be discussed later.

Results and Discussion

From the definition of M_B and M_L one may note that there is a very narrow range of epicentral distance around 5 degrees where both the magnitude scales are theoretically valid. A search for such earthquakes gave us meagre data (fig. 2). However in order to examine the effects of using M_B for $\Delta \leqslant 5$ and $M_L \geqslant 5.5$, two separate plots of M_B and M_L were made (fig. 1). The following relations have been found to hold good by least squares methods:

$$M_L = (0.95 \pm 1.4) + (0.81 \pm 0.06)\, M_B \qquad (\Delta = 2^\circ \text{ to } 5^\circ) \qquad [2]$$

$$M_L = (1.26 \pm 0.76) + (0.76 \pm 0.02)\, M_B \qquad (\Delta = 5^\circ \text{ to } 10^\circ) \qquad [3]$$

$$M_L = (1.0 \pm 0.57) + (0.80 \pm 0.01)\, M_B \qquad (\Delta = 2^\circ \text{ to } 10^\circ) \qquad [4]$$

The relationship between M_B and M_L has been deducted earlier [2] as

$$M_B = 1.7 + 0.8\, M_L - 0.01\, M_L^2$$

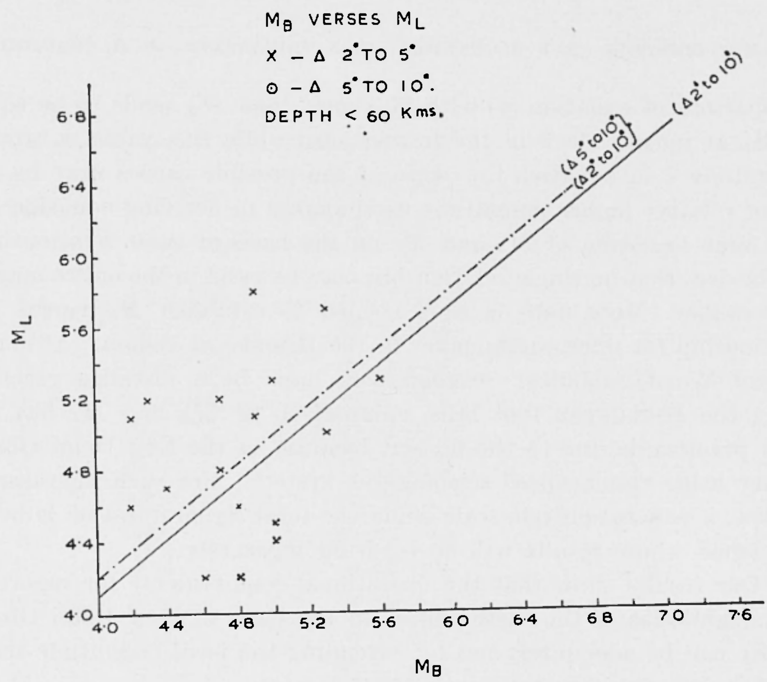

Fig. 1 – The relationship between M_B and M_L for earthquakes in Himalayas and neighbourhood.

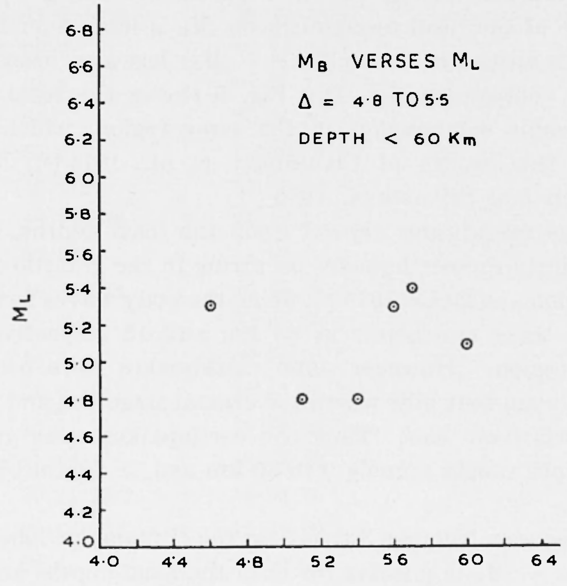

FIG. 2

Fig. 2 – The variation of M_B and M_L within the epicentral distance of 4.8 to 5.5°.

Comparison of equation [4] with [5] shows that M_B tends to be equal to M_L at magnitude 5 in the former case while this value is around magnitude 7 in equation [5]. One of the possible causes may be the use of relative higher magnitude earthquakes in deriving equation [5]. The large variation of M_B and M_L on the basis of these relationships emphasizes that no single relationship may be valid in the entire magnitude ranges. More data is thus needed to establish M_B versus M_L relationship for microearthquakes in the Himalayan region. Although several Wood Anderson Seismometers have been installed recently along the Himalayan foot hills, comparison of M_B and M_L has not been practicable due to the distant location of the New Delhi Observatory using standardised seismograph system. For such microearthquakes, a new magnitude scale using the total signal duration is being developed whose results will be reported separately.

Our results show that the operational requirements for reporting the magnitudes of the earthquakes on the basis of New Delhi Observatory can be adequately net by extending the local magnitude scale, M_L upto the epicentral distance of 10 degrees.

The C.G.S. magnitude is the average of the body wave magnitudes reported by the standardized stations all over the world and thus takes into consideration the effects of the source mechanism. The difference of $M_{CGS} - M_B$ thus brings out the regional effects (fig. 3). Although the influence of the focal mechanism on M_L is less understood mainly because of its restricted use, ($M_{CGS} - M_L$) has also been plotted for the scale of comparison (fig. 4). Fig. 5 shows the focal mechanism solution of some earthquakes in the same region, which have been taken from the results of Chaudhury et al., 1974 [2], Nowroozi [4], 1972, Tandon and Srivastava, 1975 [7].

Since the magnitudes depend upon the focal depths, it was desirable to separate the earthquakes occurring in the granitic and basaltic layers. Tandon and Dube, 1973 [6], using the body waves have found the thickness of these two layers as 38 km and 13 respectively, for the Himalayan region. However some earthquakes have occurred close to the Himalayan foot hills where the crustal structure and the granitic layers are relatively less. Thus the earthquakes were grouped into two focal depth ranges namely 0 to 30 km and $\geqslant$ 30 km but restricted to the crust.

It may be seen from fig. 3 that near the Himalayan Tibet and Nepal border, $M_{CGS} - M_B$ is positive for both the focal depths and elsewhere it is generally negative. Although the nature of the faulting (fig. 5)

TABLE 2

Earthquake magnitudes

Δ = 5° to 10°: depth upto 60 km.

S. No	Date	Origin Time h m s	Latitude °N	Longitude °E	Depth in km	Mag. CGS	Δ in degrees	M_B (Delhi)	M_L (Delhi)
1	12.1.1965	13 32 24	27.6	88	23	6.1	9.4	6.6	6.2
2	29.1. »	20.06 02.4	35.6	73.6	41	5.7	10.0	5.7	5.6
3	17.6. »	20 14 48.6	32	87.8	15	5.4	9.7	5.7	5.7
4	11.1.1966	09 12 59.3	34	72	36	5.4	9.1	5.7	5.6
5	24.1. »	07 23 07.6	29.9	69.7	26	5.8	6.7	6.2	6.5
6	24.1. »	15 32 48.1	29.9	69.8	14	5.3	6.4	5.3	5.4
7	02.2. »	09 20 07.5	33.9	73	37	5.3	8.3	5.7	5.7
8	09.2. »	08 22 17.9	29.8	69.8	16	5.2	8.7	5.8	5.9
9	13.2. »	19 09 47.4	29.8	69.7	9	5.1	8.7	5.8	6.3
10	17.2. »	18 26 17.7	29.9	69.8	40	4.4	8.7	6.5	5.6
11	04.3. »	06 01 05	30.0	70.0	33	4.4	8.4	5.8	6.0
12	06.4. »	01 51 51.8	35	73	54	5.1	9.3	6.4	6.1
13	01.8. »	19 09 55.1	29.9	68.8	33	5.8	7.3	6.3	5.9
14	02.8. »	05 41 37.4	30	68.8	32	5.2	7.5	5.9	5.5
15	02.2.1967	07 37 54.9	39.7	75.5	39	5.3	10.7	6.0	5.0
16	30.5. »	18 56 28.7	31.7	30.1	44	4.6	6.4	5.0	4.9
17	11.2.1968	20 38 29.4	34.2	78.6	44	5.1	5.5	5.1	4.8
18	03.3. »	09 31 20.2	34.7	72.3	43	5.2	7.1	5.4	5.3
19	04.4. »	01 44 26.4	24.6	66	33	5.0	10.3	5.6	5.7
20	26.7. »	20 48 07.2	32.07	70.07	50	4.8	7.2	5.0	4.9
21	26.6. »	00 46 13.8	37.7	69.9	16	5.2	10.0	6.1	6.0
22	18.11. »	05 05 04.3	33.1	71.1	41	5.3	6.8	5.6	5.1
23	22.1.1969	19 42 21.8	32.2	70	23	4.7	7.1	5.8	5.2
24	03.3. »	14 03 00.5	31	71.8	35	4.5	5.5	4.6	5.3
25	10.4.1970	10 23 58.2	25.3	66.7	33	5.1	9.7	6.3	5.5
26	12.5. »	22 07 39.4	27.5	67.5	7	4.7	8.5	4.7	5.2
27	14.8. »	00 36 34.5	31.2	74.3	44	5.2	5.2	5.7	5.4
28	08.1.1971	23 52 16.3	29.1	69.1	19	5.2	7.1	5.7	5.8
29	24.3. »	13 39 46.3	30.3	67.8	18	4.9	8.0	5.4	5.0
30	21.12. »	09 54 40	35.7	73.4	15	5.7	10.0	6.2	6 1
31	06.11.1972	10 56 14	26.8	88.4	59	4.4	9.8	5.6	5.7
32	20.1.1973	12 34 20	29.3	68.6	19	5.3	7.1	5.9	5.6
33	24.2. »	21 57 04	26.7	66.3	48	4.2	9.2	6.0	5.2
34	09.2.1974	04 07 37.7	28.7	69.4	33	4.9	8.5	5.4	4.8
35	07.4. »	16 07 43.8	32.0	69.7	44	4.8	9.6	4.8	5.3
36	03.8. »	04 08 13.9	35.4	71.7	20	5.0	10.3	6.0	5.4

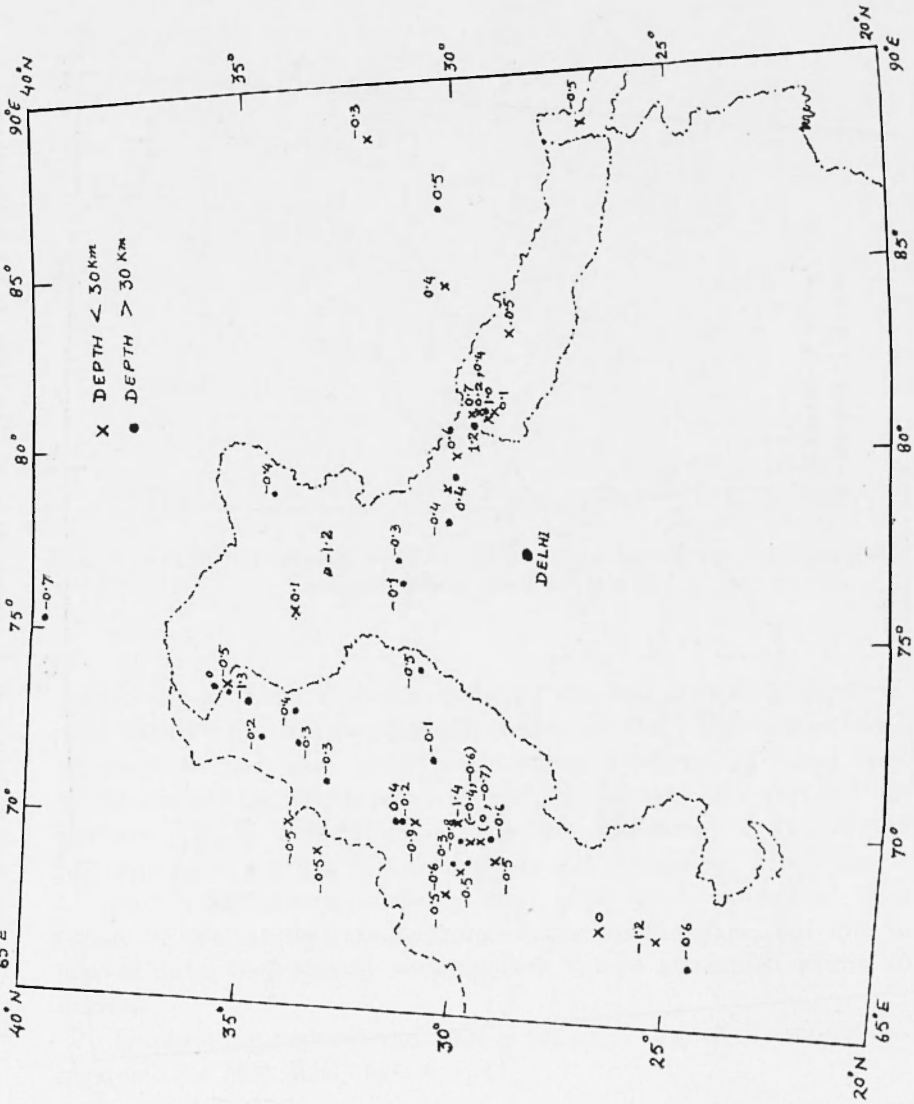

Fig. 3 – Regional variation of M_{CGS} — M_B over Himalaya and neighbourhood.

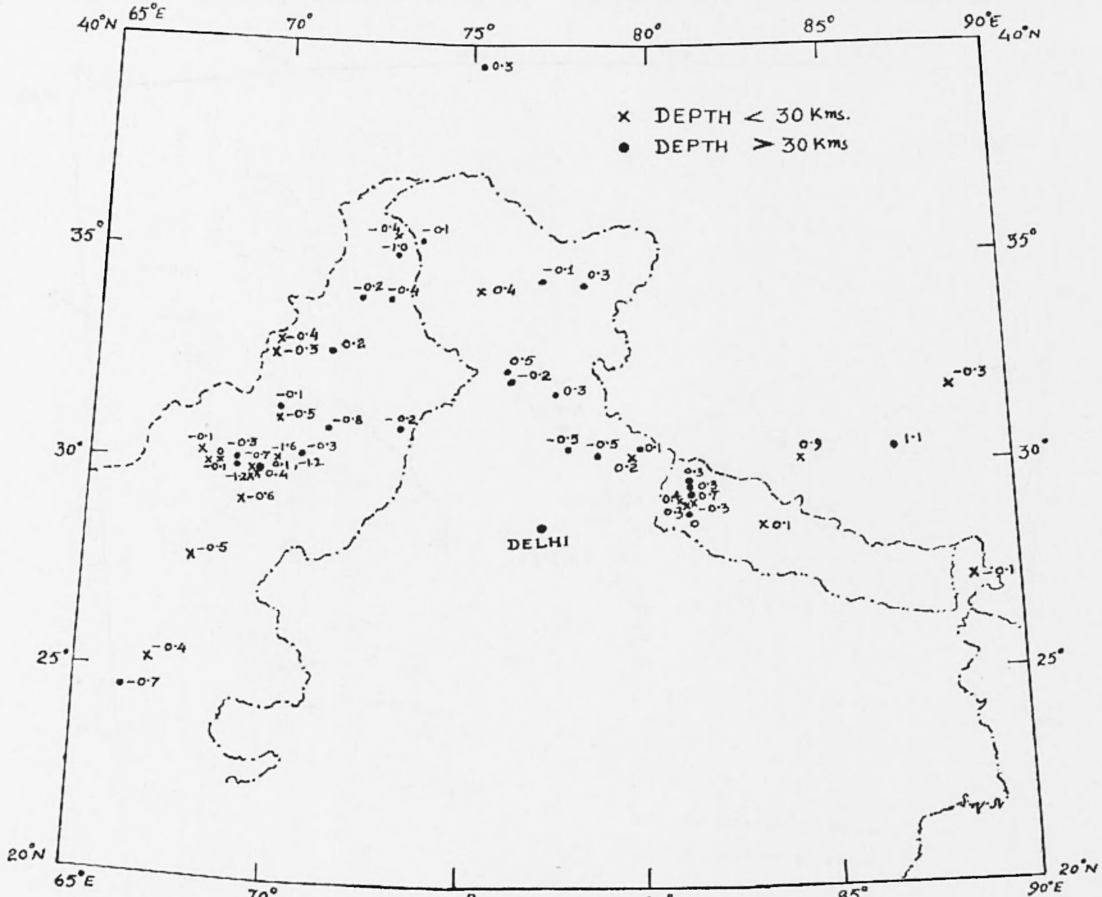

Fig. 4 – Regional variation of $M_{CGS} — M_L$ over Himalaya and neighbourhood.

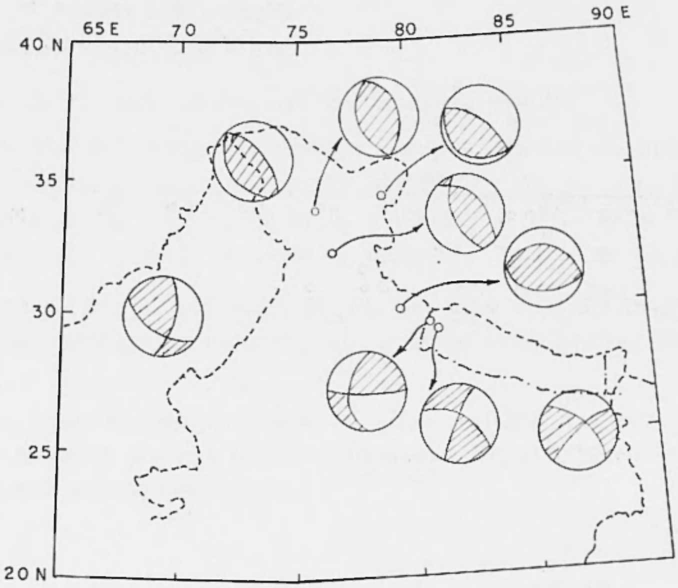

Fig. 5 – Focal mechanism solutions of some earthquakes in Himalaya and neighbourhood (see reference).

is generally of thrust type with different amounts of strike slip component in different regions, the orientation of the nodal planes with reference to the New Delhi Seismological Observatory could thus be responsible for this type of regional variations. The regional variation of (M_{CGS} — M_L) is comparatively less marked (fig. 4) although this also gives a positive residual near the Himalayan trijunction.

Padmanabhamurthy, 1969 ([5]), has found negative residual from (M_{CGS} — M_L) at New Delhi from shallow earthquakes, but due to lack of data, the regional variation was not be attempted within 10 degrees.

Ignoring the regional variation of (M_{CGS} — M_B) or M_L the following relations hold good (figs. 6 a, b).

$$(M_{CGS} - M_B) = (-2.2 + 0.3) + (0.38 + 0.02)\ M_{CGS} \quad [6]$$
$$(M_{CGS} - M_L) = (-2.3 + 0.3) + (0.45 + 0.02)\ M_{CGS} \quad [7]$$

Comparison of [6] with [7] shows that both the scales M_L or M_B can be used with almost same accuracy upto 10 degrees from New Delhi Observatory.

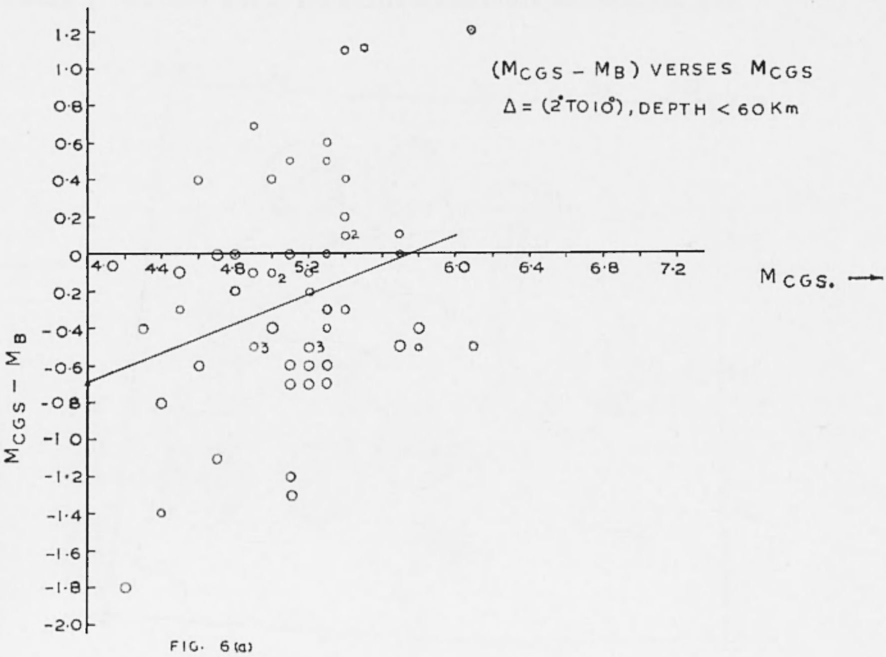

Fig. 6a – The relationship between (M_{CGS} — M_B) and M_{CGS}

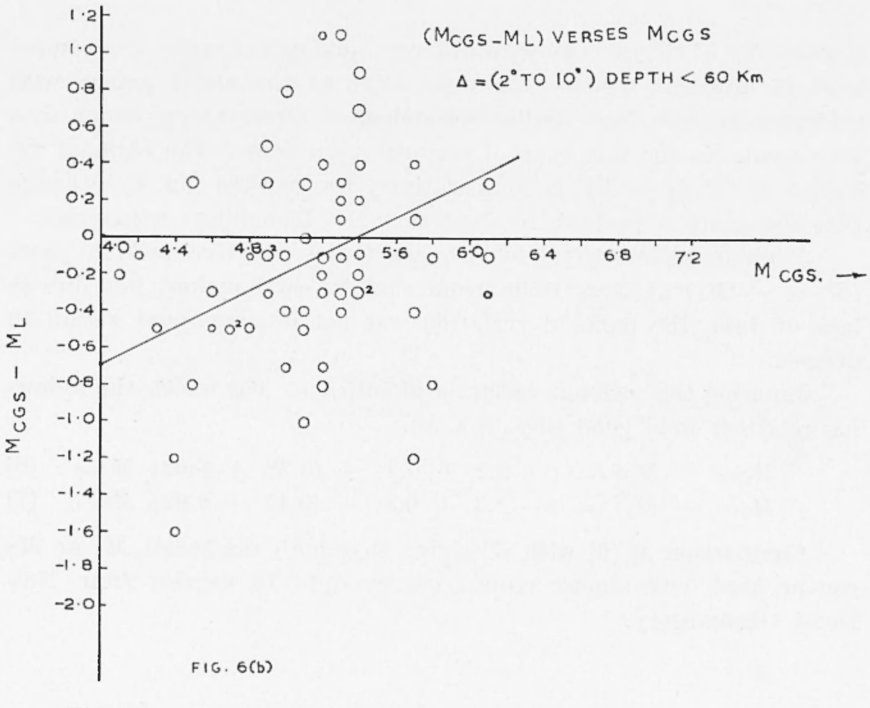

Fig. 6b – The relationship between (M_{CGS} — M_L) and M_{CGS}.

Conclusion

The above study brings out the following results:

1) – The following relationships between M_B and M_L hold good.

$$M_L = (0.95 \pm 1.4) + (0.81 \pm 0.06)\, M_B \quad (\Delta = 2^\circ \text{ to } 5^\circ)$$
$$M_L = (1.26 \pm 0.76) + (0.76 \pm 0.02)\, M_B \quad (\Delta = 5^\circ \text{ to } 10^\circ)$$
$$M_L = (1.0 \pm 0.57) + (0.80 \pm 0.01)\, M_B \quad (\Delta = 2^\circ \text{ to } 10^\circ)$$

The local magnitude scale, M_L can be used upto 10 degrees for the crustal earthquakes occurring in the Himalayan Krithar Sulaiman ranges.

2) – Some regional variation of (M_{CGS} — M_B) has been noted. (M_B — M_{CGS}) is positive for the Himalayan Nepal Tibet tri-junction and general negative elsewhere.

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