sive) in a wild stock of *D. bipectinata*[10] which diminishes sexual activity of males[8]. In sepia mutant stock, 17 females and 10 males showing two outgrowths on dorsal side of thorax were found. Figure 1 shows the photograph of a sepia mutant with two outgrowths on the dorsal side of the thorax. A separate line of sepia mutants showing outgrowths on thorax could be established. It has been observed that there is individual variation in both sexes in expression of this character and generally outgrowths are larger in females than in males. In the stock of mutants showing outgrowths, a few flies are regularly found which do not possess outgrowths on their thorax. In the sepia mutant stock also, a few flies with outgrowths are regularly found.

To understand the mode of inheritance of this unique phenotypic change, four different crosses were made. All the crosses were made in food bottles by using wild type, sepia mutants with and without outgrowths on thorax (normal thorax). In each cross, a large number of F_1 flies were observed to score the number of flies with/without outgrowths on thorax. A random sample of 50 flies (females and males in equal number) from F_1 were transferred to a fresh food bottle to obtain the F_2 generation of each cross. F_2 flies were observed to score the different types of flies. Results of all four crosses are presented in Table 1. In reciprocal crosses (1 and 2) between sepia mutants with normal thorax and with outgrowths, both types of flies were found in F_1 and F_2 generations and the results of reciprocal crosses are more or less similar. The frequency of sepia mutants with outgrowths on thorax varies from 40 to 60% in F_1 and F_2 of these crosses. However, the results of reciprocal crosses between sepia mutants with outgrowths and wild type (red eye and normal thorax) flies are different from those of the crosses involving sepia mutants with normal thorax and with outgrowths on thorax. When wild type females were crossed with sepia mutant males with outgrowths, flies with outgrowths on thorax were absent in F_1. In the F_2 generation of this cross, red-eyed flies with outgrowths and without outgrowths as well as sepia mutants with outgrowths and without outgrowths were found but the frequency of flies with outgrowths was lower (23.58%) as compared to the crosses involving sepia mutants. In the opposite cross (sepia females with outgrowths × wild type males), seven females with very small outgrowths on thorax were found in the F_1 generation. In the F_2 generation, four types of flies were found and the frequency of flies with outgrowths on thorax was very low (16.75%). Thus the results of different crosses vary and development of outgrowths on thorax occurs in both wild type (red eye) and sepia mutants of *D. bipectinata*.

---

1. Singh, B. N and Das, A, *Biol. Zent. bl.*, 1991, **110**, 157–162.
2. Singh, B N. and Chatterjee, S., *Evol. Biol.*, 1991, **5**, 105–113.
3. Singh, B. N. and Chatterjee, S, *Genome*, 1991, **34**, 849–852.
4. Singh, B N and Pandey, M, *Indian J. Exp. Biol*, 1991, **29**, 926–929
5. Naseerulla, M. K. and Hegde, S. N., *Indian J. Exp Biol*, 1993, **31**, 215–218
6. Singh, B. N. and Sisodia, S, *Biol. Zent. bl.*, 1995, **114**, 95–101.
7. Banerjee, R. and Singh, B N., *Proc. Zool Soc. Calcutta*, 1995, **47**, 125–133.
8. Sisodia, S. and Singh, B. N., Third *Drosophila* Meeting, Mysore, Abstract, 1995, p. 37.
9. Sisodia, S. and Singh, B N., *Zoological Studies*, 1995, **35**, in press
10. Singh, B N., Sisodia, S. and Banerjee, R., *Dros. Inf. Serv.*, 1995, in press.

ACKNOWLEDGEMENTS. Financial support from the UGC, New Delhi, in the form of research project to BNS, a JRF to RB and from BHU in the form of research scholarship to SS is gratefully acknowledged. We also thank Dr A. K. Sundaran for his help in photography.

Received 19 July 1995, accepted 29 September 1995

A new empirical relation for strong seismic ground motion for the Himalayan region

Ashutosh Aman, Umesh K. Singh and Ramesh P. Singh

Department of Civil Engineering, Indian Institute of Technology, Kanpur 208 016, India

Strong ground motion data from five earthquakes that occurred along the Himalayan range have been taken to study the attenuation characteristics of horizontal peak acceleration and velocity. Using these data, we have found empirical relations for horizontal acceleration and velocity. These empirical relations for peak horizontal ground acceleration and velocity give good fit with the observed strong ground motion in the Uttarkashi earthquake of 20 October 1991. The attenuation relations found in the present study will be useful in estimating the peak horizontal ground acceleration and velocity of future earthquakes and will also be useful in designing earthquake-resistant structures in the Himalayan region.

EARTHQUAKE-resistant design of structures require estimate of the expected ground motions at the earthquake-prone sites. In order to develop ability to reasonably assess the expected ground motion due to future earthquake, it is essential to study the characteristics of strong ground motion recorded in the past earthquakes. Prediction of peak ground acceleration and velocity is useful to obtain an estimate of the outer envelope of the ground motion spectrum[1]. Peak ground motions are important in earthquake safety analysis and in the evalua-

Table 1. Earthquakes considered in the present work

Earthquake	Date of occurrence	Magnitude (M_B)
Dharamsala	26 April 1986	5.7
Meghalaya	10 September 1986	5.7
Burma–India	14 May 1987	5.7
Tripura–Assam	6 February 1988	5.8
Gauhati	6 August 1988	7.2

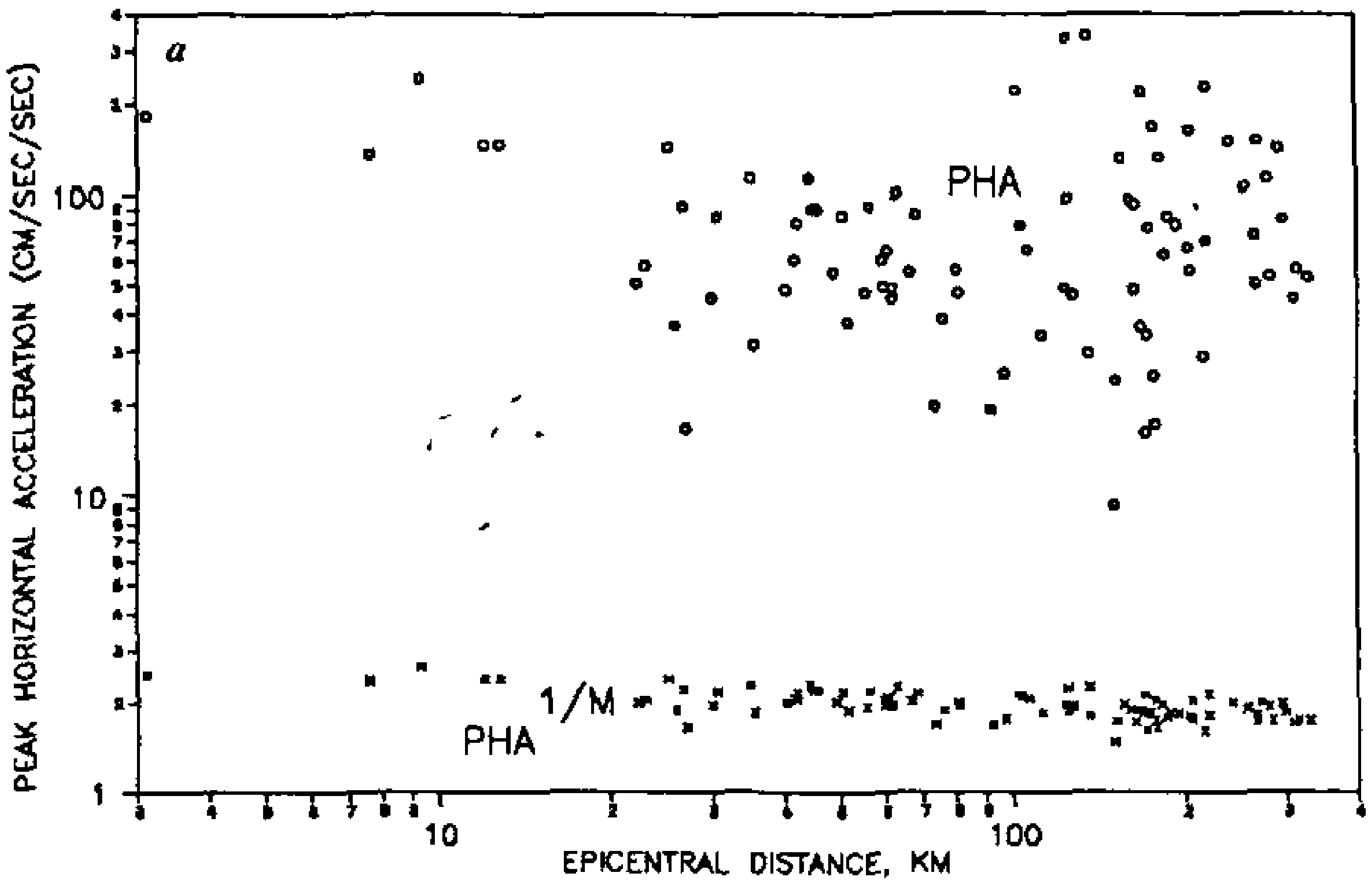

Figure 1 *a*. Observed peak horizontal acceleration (PHA) and its raised power ($PHA^{1/M}$)

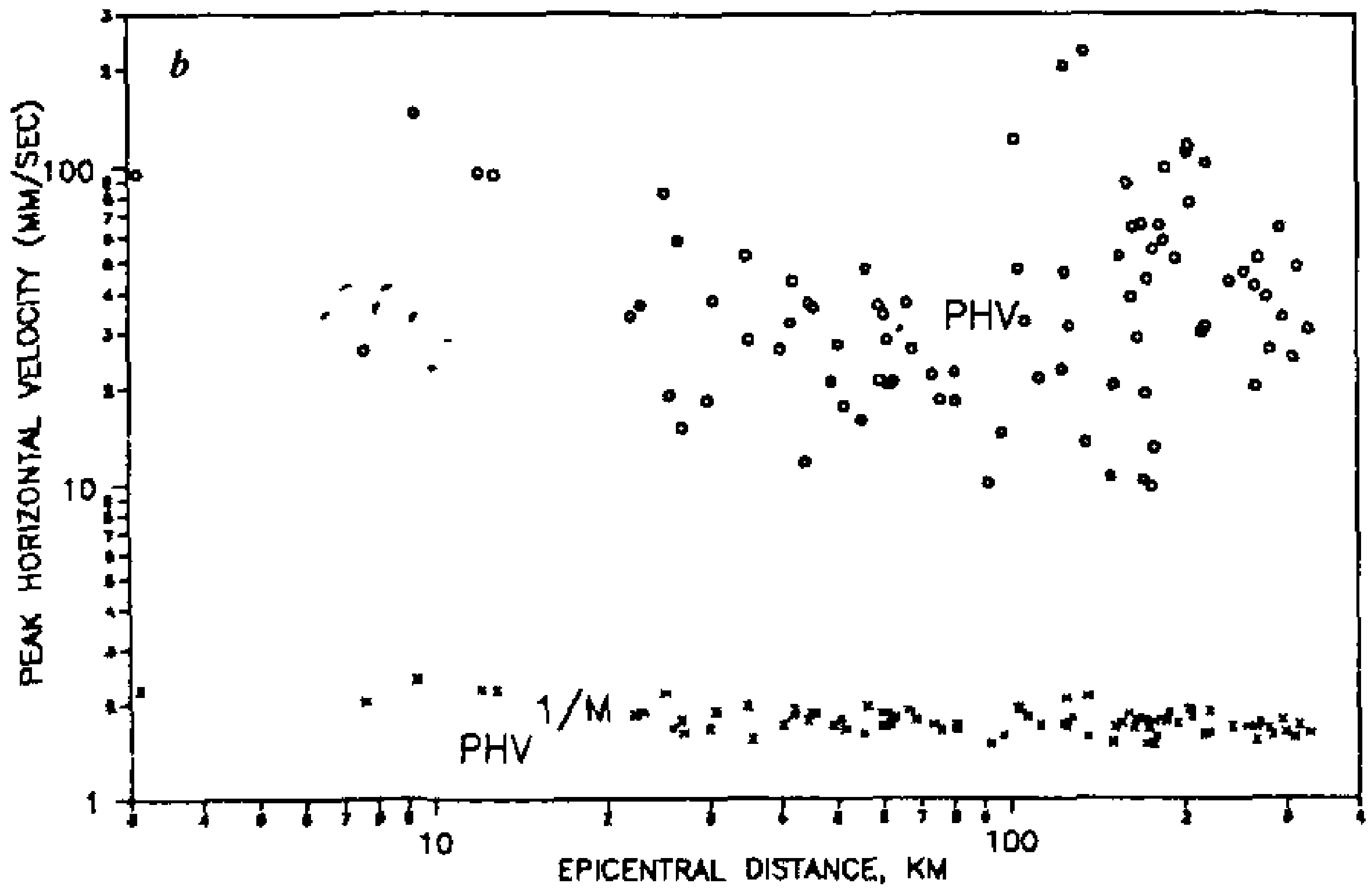

Figure 1 *b*. Observed peak horizontal velocity (PHV) and its raised power ($PHV^{1/M}$).

tion of earthquake design parameters. In order to predict peak ground motion data, the knowledge of attenuation relations of strong seismic ground motion of different regions is important. Such relations have been developed for USA[2-9], Canada[10], Japan[11] and Europe[12,13]. Such data are useful to seismologists and earthquake engineers to characterize strong ground motion and to prepare new regional seismic zoning map of different regions. In the past, most of the workers have widely used the following empirical relations given by Kanai[14]

$$\log_{10}(\mathrm{AGM}) = b_1 + b_2\,M - b_3 \log_{10} R,$$

where AGM refers to the amplitude of ground motion parameter (acceleration or velocity) under consideration, M is earthquake magnitude, R is epicentral distance, and b_1, b_2 and b_3 are coefficients which are dependent on numerous parameters, including geology of the region.

The strong ground motion data for Indian region were almost nonexistent before 1986 and therefore no estimate for either ground motion parameters or these three coefficients was made for Indian region. After 1986, however, a number of strong motion records are available from earthquakes in the Himalayan region. In the present work, strong ground motion data[15] from five earthquakes recorded along the Himalayan region during the period 1986–91 have been examined. The details of these earthquakes are given in Table 1. The strong ground motion data have been used to determine empirical relation to predict peak horizontal acceleration and velocity for future earthquakes along the Himalayan region. Figure 1 *a* and *b* shows peak horizontal acceleration and velocity respectively, from five earthquakes that occurred along the Himalayan region (Table 1). The observed peak horizontal acceleration and velocity have been raised to power $1/M$, where M is the magnitude of the earthquake (Figure 1). Figure 1 *a* and *b* shows variations of $a^{1/M}$ and $v^{1/M}$ with epicentral distance, R, which shows almost a linear trend. From these data, we have found the following empirical relations which fit well with the observed peak horizontal acceleration (a) and velocity (v):

$$\log(a^{1/M}) = 0.433 - 0.073 \log(R) \pm 0.037P, \qquad (1)$$

$$\log(v^{1/M}) = 0.351 - 0.053 \log(R) \pm 0.036P, \qquad (2)$$

where $P = 0$ for 50th percentile and $P = 1$ for 84th percentile, and ± sign shows the upper and lower limits of the peak horizontal acceleration and velocity.

Variation of peak horizontal acceleration and velocity in Figures 2 *a–e* and 3 *a–e* is shown respectively, with epicentral distance R for all the five earthquakes that occurred along the Himalayan region. It is clear from these figures that the peak horizontal acceleration and velocity decrease with epicentral distances at different rates for different earthquakes. The amplitude of the observed peak horizontal acceleration and velocity shows variation with the epicentral distance. These variations are due to the difference in the magnitude of the individual earthquakes. The qualitative nature of the variation with the epicentral distance in all these earthquakes is almost similar. The data are very much scattered. The error bars show the 84th percentile values of the peak horizontal acceleration and velocity given for individual earthquakes (Figures 2 *a–e* and 3 *a–e*).

Using equations (1) and (2), we have computed peak horizontal acceleration and velocity for each individual

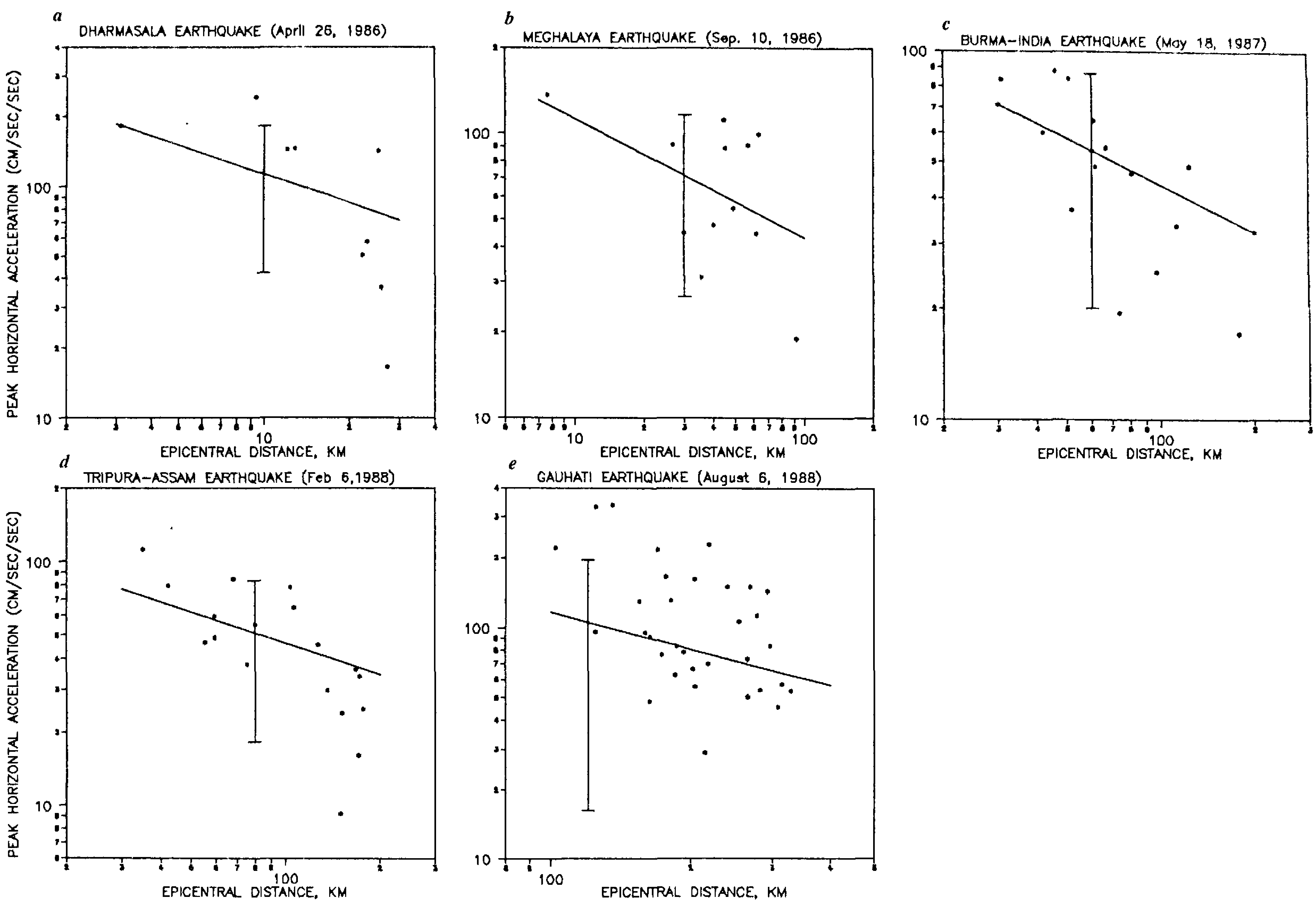

Figure 2 *a–e*. Observed peak horizontal acceleration, the solid line shows calculated acceleration from the empirical relation developed in the present work.

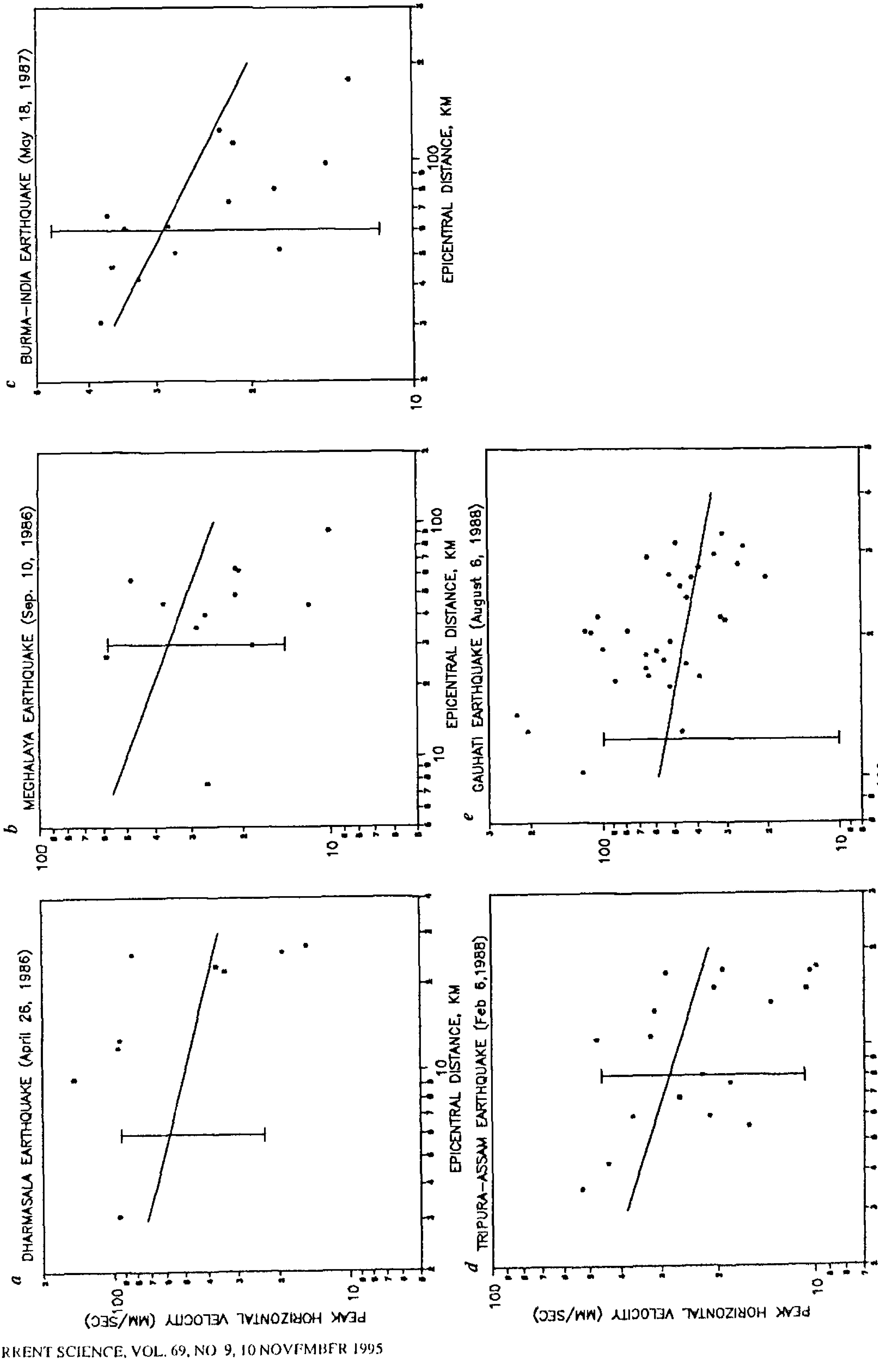

Figure 3*a–e*. Observed peak horizontal velocity, the solid line shows calculated acceleration from the empirical relation developed in the present work

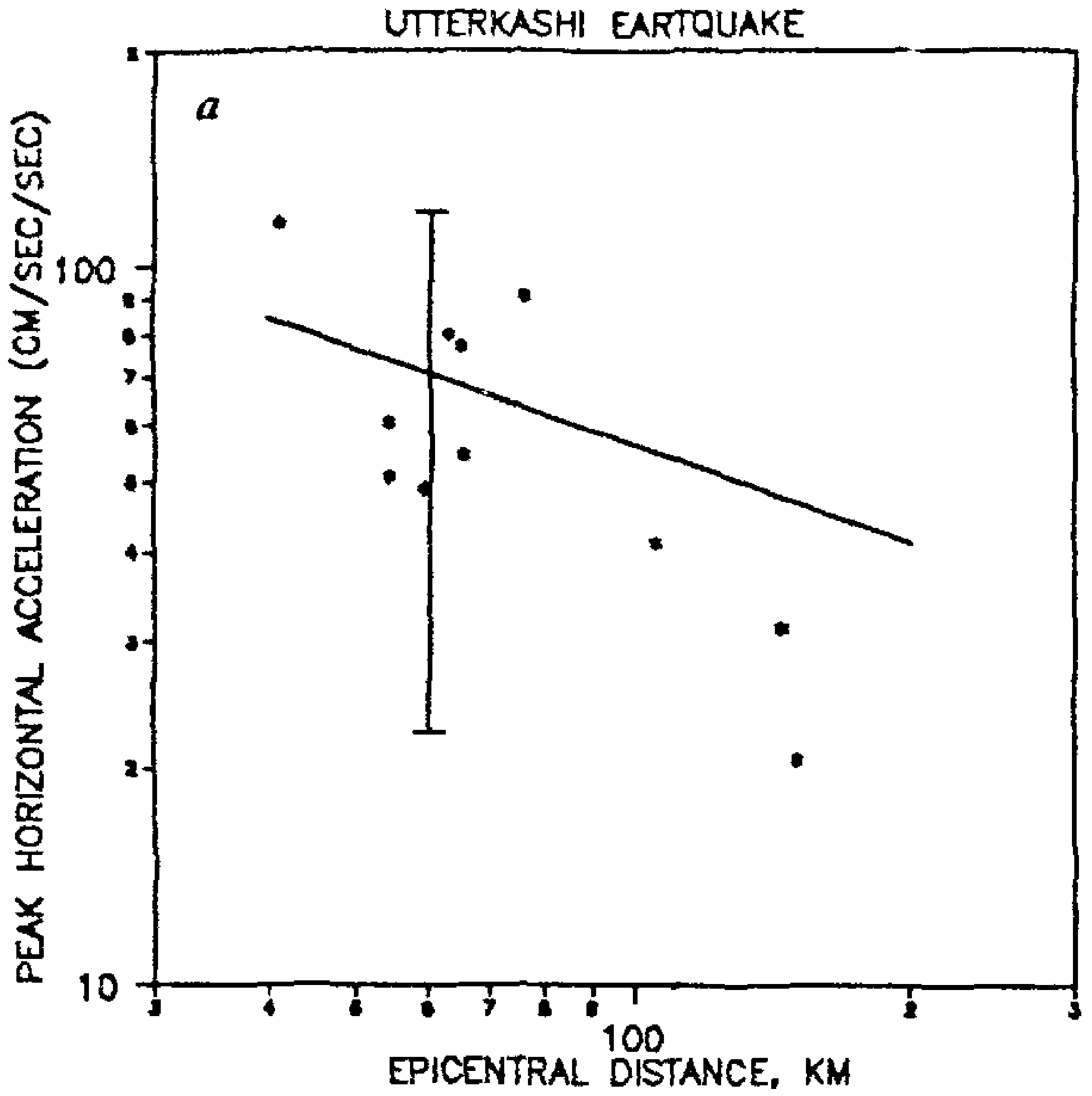

Figure 4 *a*. Observed peak acceleration in the Uttarkashi earthquake of 20 October 1991, the solid line shows theoretical predicted peak horizontal acceleration.

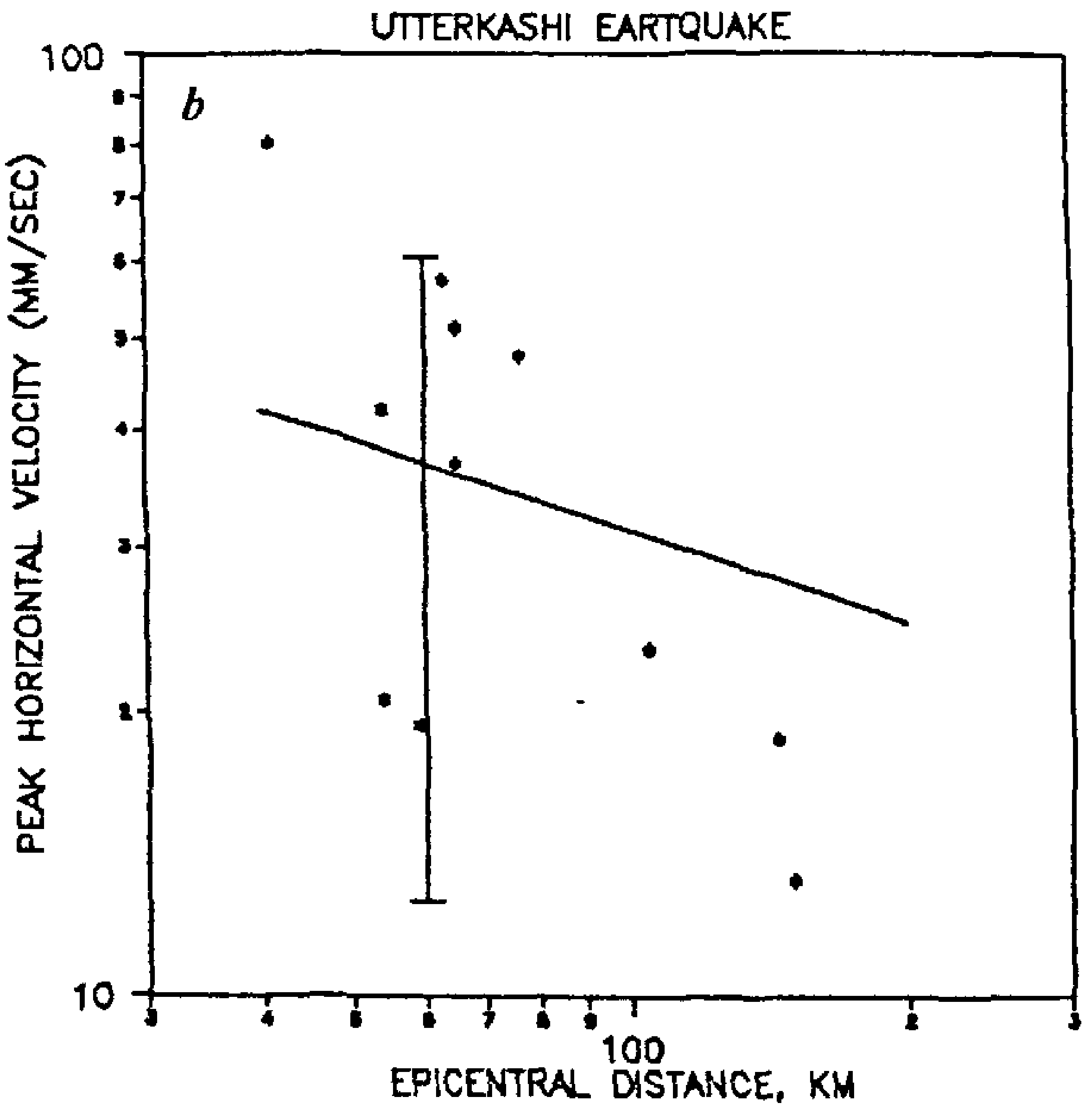

Figure 4 *b*. Observed peak velocity in the Uttarkashi earthquake of 20 October 1991, the solid line shows theoretical predicted peak horizontal velocity.

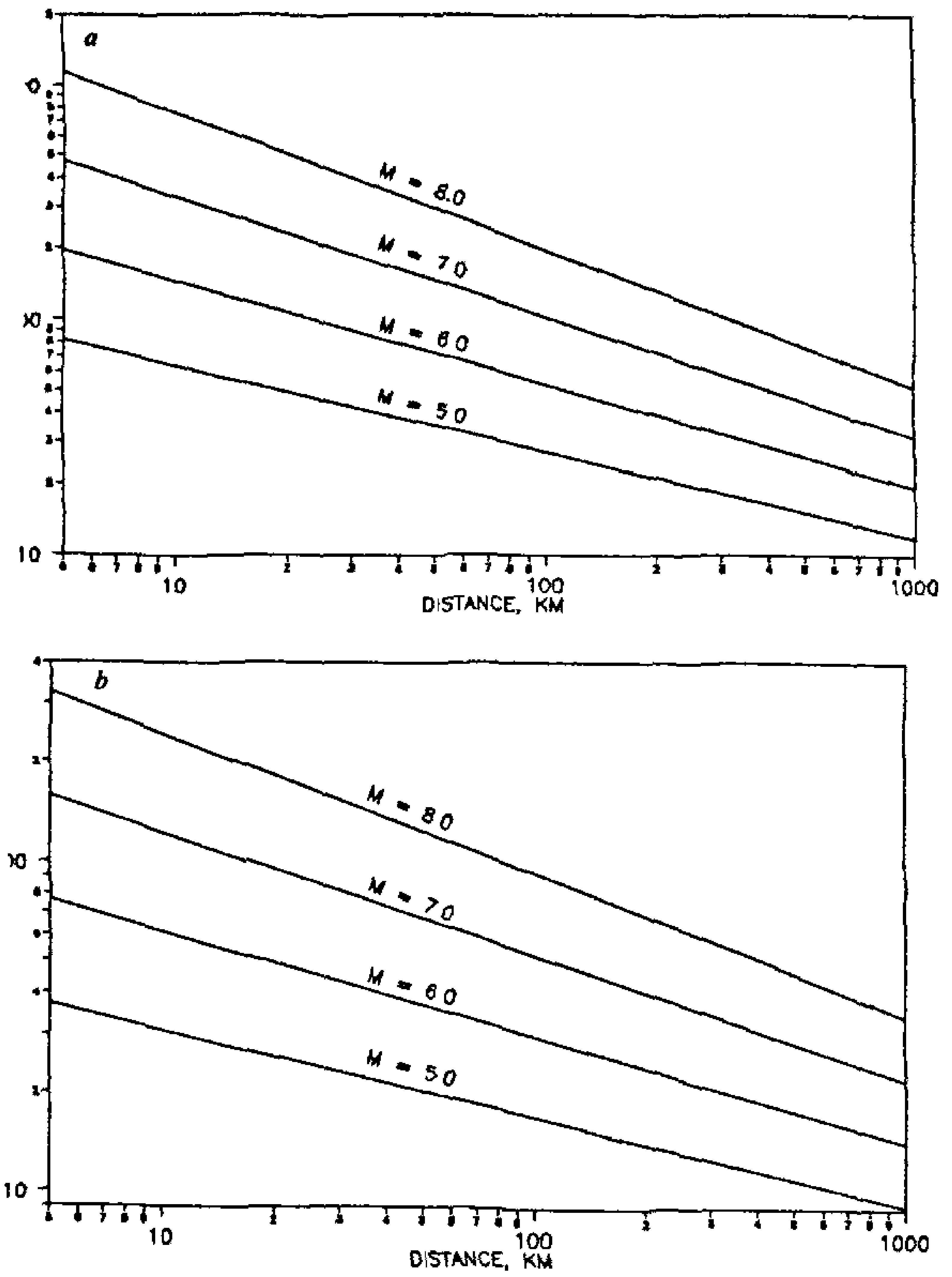

Figure 5 *a* and *b* Predicted peak horizontal acceleration (*a*) and velocity (*b*) for earthquakes having various magnitudes.

earthquake which is depicted by the solid line in Figures 2 *a–e* and 3 *a–e*. It is evident that our empirical relations can explain the observed data quite nicely.

The validation of the above empirical relations has been carried out with the observed strong ground motion data[16] in the Uttarkashi earthquake of 20 October 1991 (magnitude 6.1). The observed peak horizontal acceleration and velocity of the Uttarkashi earthquake with epicentral distances are shown respectively in Figure 4 *a* and *b*. The solid curve is the predicted acceleration and velocity which is found to be in agreement with the observed strong ground motion.

Following the attenuation relations developed in the present work, we have evaluated the expected peak horizontal acceleration and velocity for earthquakes of varying magnitudes ($M = 5$, 6, 7 and 8) in the Himalayan region (Figure 5 *a* and *b*). It has been found that the maximum peak horizontal acceleration of about 1.12 *g* (Figure 5 *a*) may be observed in the vicinity of 5 km from the epicentre, which can produce peak horizontal velocity of about 320 mm/s (Figure 5 *b*) in any future earthquake in the Himalayan region.

In conclusion, we have found new empirical relation for peak horizontal acceleration and velocity. These attenuation relations will be extremely useful in estimating strong ground motion parameters for future earthquakes in the Himalayan region. The present relations show the estimate of peak horizontal acceleration and velocity up to 1000 km from the epicentre of the earthquakes. Such relations are also needed for other major geological regions of India, e.g. Indo-gangetic basin and Peninsular regions, which can only be developed after having huge data base of the strong ground motion data from future earthquakes in these regions. Such relations will provide a useful guideline to the professional engineers while planning for major structures in the Himalayan region.

1. Newmark, N. M. and Hall, W. J., Proceedings of the Fourth World Conference on Earthquake Engineering, 1969, vol. 2, pp. 37–50.
2. Orphal, D. L. and Lahoud, J. A., *Bull. Seismol. Soc. Am.*, 1974, **64**, 1563–1574.
3. Trifunac, M. D. and Lee, V. W., *Soil Dyn. Earthq. Engg.*, 1992, **11**, 101–110.
4. Anderson, J. G., *Bull. Seismol. Soc. Am.*, 1978, **68**, 1147–1179.
5. Boore, D. M., *Bull. Seismol. Soc. Am.*, 1983, **73**, 1865–1894.
6. Campbell, K. W., *Bull. Seismol. Soc. Am.*, 1981, **71**, 2039–2070.
7. Campbell, K. W., *Bull. Seismol. Soc. Am.*, 1989, **79**, 1311–1346.
8. Joyner, W. B. and Boore, D. M., *Bull. Seismol. Soc. Am.*, 1981, **71**, 2011–2038.
9. Joyner, W. B. and Boore, D. M., *Geotech News*, 1991, **9**, 21–26.
10. Hasegawa, H. S., Basham, P. W. and Berry, M. J., *Bull. Seismol. Soc. Am.*, 1981, **71**, 1943–1962.
11. Fukushima, Y. and Tanaka, T., *Bull. Seismol. Soc. Am.*, 1990, **80**, 757–783.
12. Murphy, J. R. and O'Brien, L. J., *Bull. Seismol. Soc. Am.*, 1977, **67**, 877–915.
13. Ambraseys, N. N. and Bommer, J. J., *Earthq. Eng. Struct. Dyn.*, 1991, **20**, 1179–1202.
14. Kanai, K., *Bull. Earthquake Res. Inst.*, 1961, **39**, 85–95.
15. Chandrasekharan, A. R. and Das, J. D., *Indian Soc. Earthq. Technol.*, 1990, **27**, 1–66.
16. Chandrasekharan, A. R. and Das, J. D., *Indian Soc. Earthq. Technol.*, 1992, **29**, 35–55.

Received 10 May 1995, revised accepted 7 October 1995

Involvement of calcium in brassinolide and auxin-induced cell elongation

Anitha Naren, T. G. Prasad, V. R. Sashidhar and M. Udaya Kumar

Department of Crop Physiology, University of Agricultural Sciences, GKVK, Bangalore 560 065, India

Coleoptile segments incubated in brassinolide (BR) or auxin (IAA) along with calmodulin inhibitor, chlorpromazine (CPZ) or calcium chelating agent (EGTA) or calcium surface antagonist, lanthanum chloride (La^{+3}Cl$_3$) resulted in inhibition of BR and IAA-induced elongation growth of coleoptiles. Pretreatment of coleoptile segments for 4 h with EGTA or La^{+3}Cl$_3$ also inhibited both BR and IAA-induced growth. Coleoptile segments with enriched endogenous levels of free calcium showed more elongation in the presence of BR or IAA. However, BR and IAA were ineffective in inducing coleoptile growth in the presence of calcium inhibitors. Results indicated that BR and IAA act through calcium and or calmodulin protein in inducing elongation growth in coleoptile.

BRASSINOSTEROID, a novel plant growth-promoting steroidal lactone, was first isolated and identified from pollen grains of brassica (*Brassica napus*)[1]. Recently, the presence of this new class of plant hormones has been shown in a number of plant species. It has also been shown to be involved in growth responses in many test systems[2–5], especially inducing cell elongation and cell division[1,5–7]. In addition to acting independently, it is found to act synergistically with other growth hormones found in plants[3,8,9]. One such interaction widely reported is that between BR and auxin in inducing cell elongation[3,8,10]. Auxin-induced cell elongation has been shown earlier to be mediated through the release of Ca^{2+} from membrane vesicles, which on complexing with the calcium-modulated protein, calmodulin, results in the response. It is known that calmodulin modulates auxin-induced growth[11]. Though the involvement of calcium in auxin action has been recognized for many years[12], the nature of interaction between auxin and calcium is poorly understood. Auxin-induced elongation in pea epicotyl is blocked by treating the segments with calcium chelators (EGTA and CTC), calcium surface antagonist (Lanthanum) and calcium channel blocker, Verapamil. The existing evidence suggests that auxin causes calcium efflux. In recent years, Ca^{2+} has been regarded as a second messenger and in conjunction with the calcium-binding protein, calmodulin, has been reported to be involved in the regulation of a number of cell processes, both in animals and plants[13–17]. Because of the close mimicking of the action of auxin by BR, we hypothesize that the mechanism underlying BR-induced cell elongation could also be mediated through calcium. We test this hypothesis here by using surface calcium antagonist, calcium chelating agent and finally potent antagonists of calcium calmodulin protein.

Brasinolide (BR) chemical was obtained from Godrej Soaps Ltd, Bombay. Calmodulin antagonist – chlorpromazine (CPZ), calcium chelating agent – ethylene glycol-*bis*(aminoethyl)tetraacetic acid (EGTA) and calcium surface antagonist – lanthanum chloride (La^{+3}Cl$_3$) and indole-3-acetic acid (IAA) were from Sigma Co, USA.

The assay of cell elongation induced by BR and IAA was carried out using wheat coleoptiles. Wheat seeds