MACROSEISMIC STUDIES OF FOUR RECENT INDIAN EARTHQUAKES

by

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SYNOPSIS

During last four years four medium size earthquakes occurred in India. These earthquakes were extensively studied through field damage survey and questionnaire programme. Brief description of these earthquakes with reference to various geoseismological and geotectonic conditions is presented below :

Koyna (Maharashtra) Earthquake of October 17, 1973 (1525 hrs GMT)

A moderate earthquake of Richter magnitude 5.2 with epicentre at Lat. 17°20' N; Long. 73°42' E about 10 km SSW of the Koyna dam on the river Koyna, Maharashtra, rocked Koynanagar and the surrounding area at 1525 hrs GMT on October 17, 1973. The earthquake generated an intensity of little over VI (MM) and the radius of felt area and the depth of focus were about 150 km (Fig.1) and 10 km respectively. No significant damage was caused to any of the structures in the epicentral area where most of the residencial houses were constructed with steel tubular frame work after the devastating Koyna earthquake of December 10, 1967. In spite of the frequent experience of tremors in the area since past one decade or so the present earthquake caused considerable panic amongst the inhabitants of the area. The shock was well recorded by seismographs in the Koyna seismograph net and regional seismological observatories of the India Meteorological Department. The foreshock and the aftershock laws (Fig.2) are of the forms a^{-t} and t^{-b} where 'a' and 'b' are constants and 't' is the time measured backward and forward respectively from main earthquake of October 17, 1973. The nature of the curves indicate broadly homogeneous underground structure (Mogi, 1963). Maximum horizontal ground acceleration recorded in the epicentral area was about 15% 'g'. Accelerograms recorded in the Koyna strong motion accelerograph net and corresponding velocity response spectra are presented in Fig.7 (Guha et al. 1974).

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Kinnaur (Himachal Pradesh) Earthquake of January 19, 1975 (0802 hrs GMT)

On January 19, 1975 Lahul-Spiti and Kinnaur districts of Himachal Pradesh experienced a medium earthquake of Richter magnitude 6.2 with epicentre at Lat. 32°30' N; Long. 78°24' E. Surface damages corresponding to field intensity of little over IX (MM) occurred in the epicentral area (Fig.3). A ground fissure of about 18 km length was formed which appeared to be a surface expression of the fault causing the earthquake. The shock was felt over an area of about 550 km radius and the depth of focus and magnitude computed from macroseismic data are 30 km and 6.5 respectively which compare favourably with those given by U.S.Geological Survey. Fig.4 shows the fore-shock and aftershock laws of the earthquake and the curves indicate extreme inhomogeneity in the underground structure. The earthquake triggered heavy landslides near Chango, Sumdo and Kaurik, and the debris formed a dam across the river Parachu. Field damage survey revealed local accentuation of intensity at least by one in MM scale which could be attributed to loose foundation consisting of glacial till. Death roll mounted to about 47 and several cattle were also killed as a result of landslides. National Highway No.22 was severely damaged as a result of landslides. Isoseismals are elliptical with their major axis roughly parallel to the axis of regional fold in the area trending NNW-SSE similar to Kangra 1905 (Middlemiss, 1910) and other earthquakes in the Himalayan area.

Shimoga (Karnataka) Earthquake of May 12, 1975 (1509 hrs GMT)

Shimoga town in Karnataka State and the surrounding areas were rocked by a medium size earthquake of Richter magnitude 5.0 at 1509 hrs GMT on May 12, 1975. Questionnaire programme was taken up immediately after the occurrence of the quake which was well responded by the State and Central Government offices and the public in general. From the data thus collected, the epicentre could be placed at Lat. 13°48' N; Long. 75°18' E about 30 km SW of the Shimoga Town. Maximum field intensity of V (MM) could be assigned to a very limited area (Fig.5). The shock was felt over an area of about 140 km radius. No loss of life or damages of significance to property were reported. Crescent shaped isoseismals with concave side facing NNE perhaps indicate influence of highly elastic Deccan Trap effusives which are covering extensive areas in the Western and Central parts of Indian Peninsula. Depth of focus computed from emperical formulae works out to about 35 km. This earthquake is interesting as there are no past records of any other significant seismic activity in the area.

Assam Earthquake of July 8, 1975 (1205 hrs GMT)

Shillong and adjacent areas in Meghalaya, Mizoram, Tripura, Manipur, Nagaland and parts of West Bengal and Bangla Desh were strongly rocked by an earthquake of Richter magnitude 6.7 which was perhaps the severest shock in that area in the last decade. The shock was felt over an area of about 800 km

radius and maximum intensity of VII (MM) could be assigned to the epicentral area from the reports of damages available from Shillong, Gauhati, Hailakandi and Imphal where the shock was felt strongly (Fig.6). The shock was well recorded by the seismographs working in the country. Depth of focus computed from macroseismic and instrumental data works out to about 60 km. Incidentaly, the epicentral area is quite close to that of the great Assam earthquake of 1897 (Oldham, 1899) indicating activity along the same neighbouring thrust and fault zones.

ACKNOWLEDGEMENT

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BIBLIOGRAPHY

Mogi, K. (1963). Some discussions on aftershocks foreshocks and Earthquake Swarms - The Fracture of a Semi-infinite Body Caused by an Inner Stress Origin and its Relation to the Earthquake Phenomena (Third Paper), Bull. Earthquake Res. Inst., Univ. Tokyo, 41, 615 - 658.

Guha, S.K. et al. (1974). Koyna Earthquakes, a Comprehensive Report October 1963 to December 1973, Central Water and Power Research Station, Khadakwasla, Poona - 411 024 (India).

Middlemiss, C.S. (1910). The Kangra Earthquake of 4th April, 1905, Mem. Geol. Survey of India, 38, 1 - 409.

Oldham, R.D. (1899). Report on the Great Earthquake of 12th June, 1897, Mem. Geol. Survey of India, 29, 1 - 379.

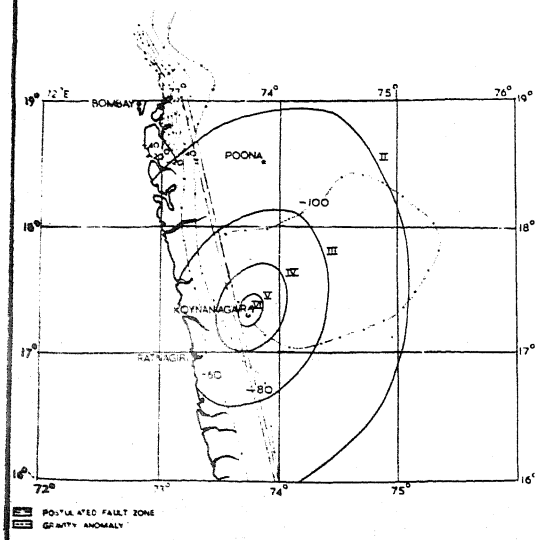


FIG 1 ISOSEISMAL MAP OF KOYNANAGAR EARTHQUAKE OF OCTOBER 17, 1973

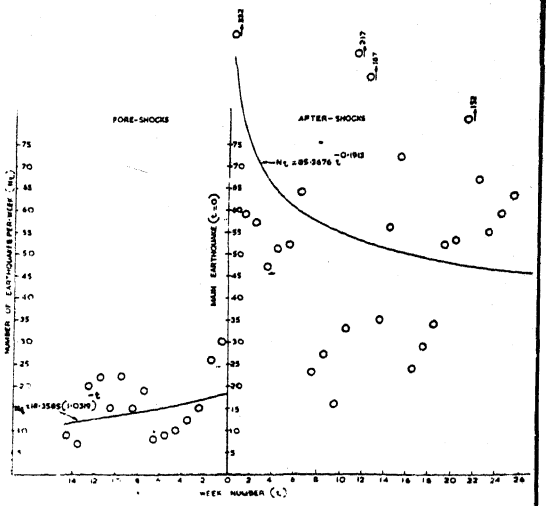
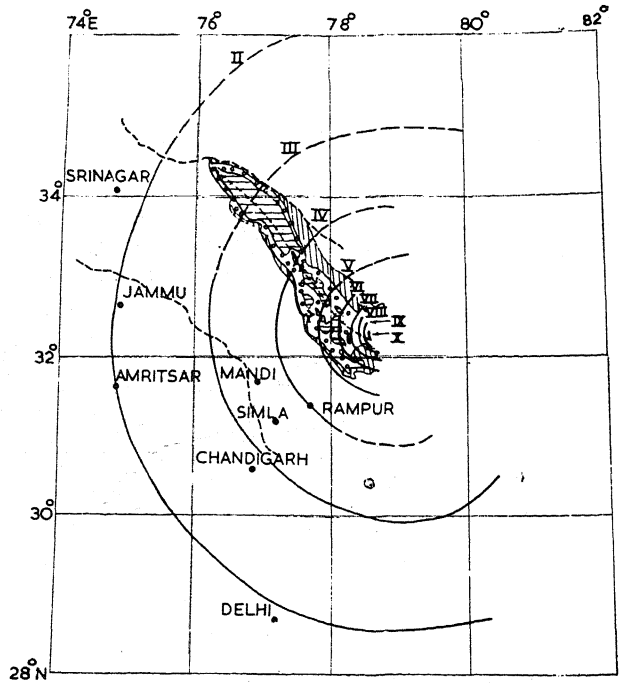


FIG. 2 FORESHOCKS AND AFTERSHOCKS OF KOYNANAGAR EARTHQUAKE OF OCTOBER 17, 1973



TRIASSIC
JURASSIC
CARBONIFEROUS - PERMIAN
AXIS OF FOLD
FAULT

FIG 3 ISOSEISMAL MAP OF KINNAUR EARTHQUAKE OF JANUARY 19, 1975.

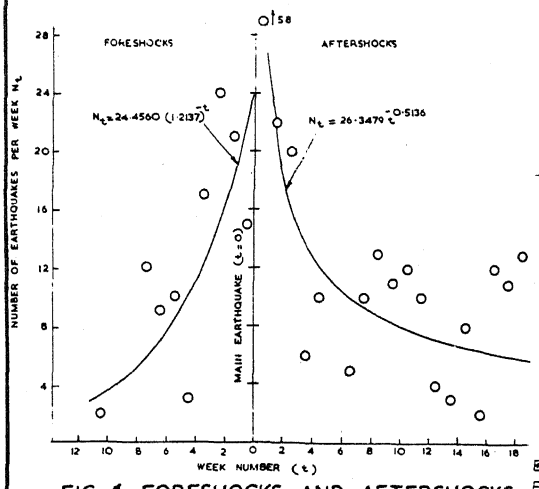


FIG. 4 FORESHOCKS AND AFTERSHOCKS OF KINNAUR EARTHQUAKE OF JANUARY 19, 1975

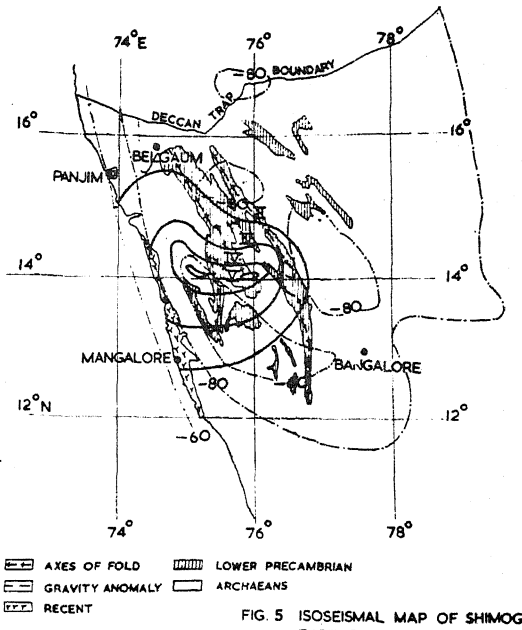


FIG. 5 ISOSEISMAL MAP OF SHIMOGA EARTHQUAKE OF MAY 12, 1975

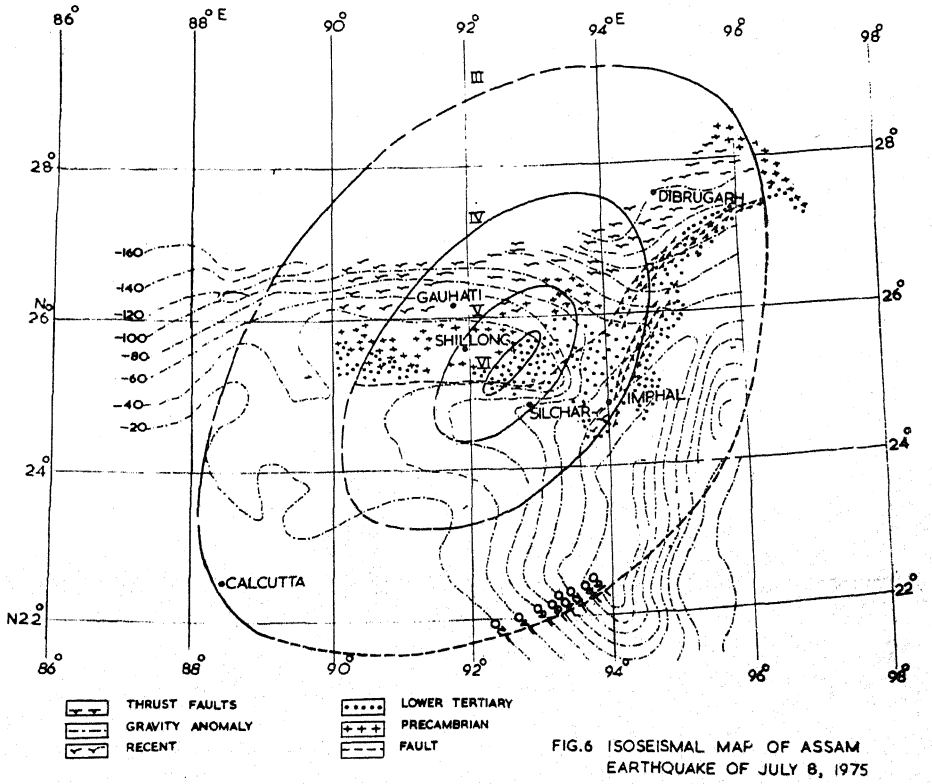
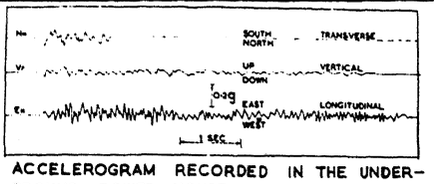
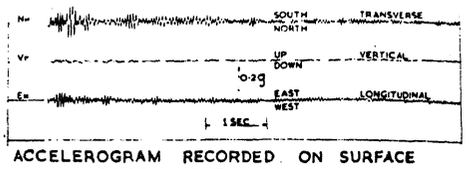


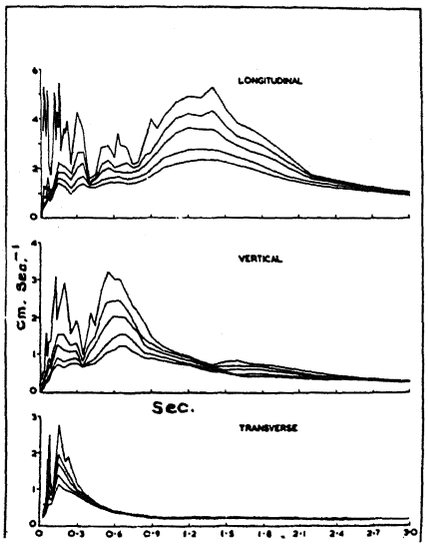
FIG.6 ISOSEISMAL MAP OF ASSAM EARTHQUAKE OF JULY 8, 1975

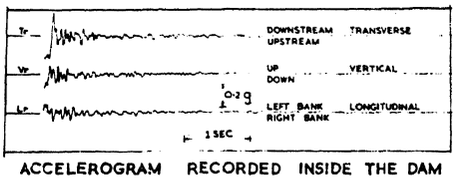


ACCELEROGRAM RECORDED IN THE UNDER-GROUND POWER HOUSE

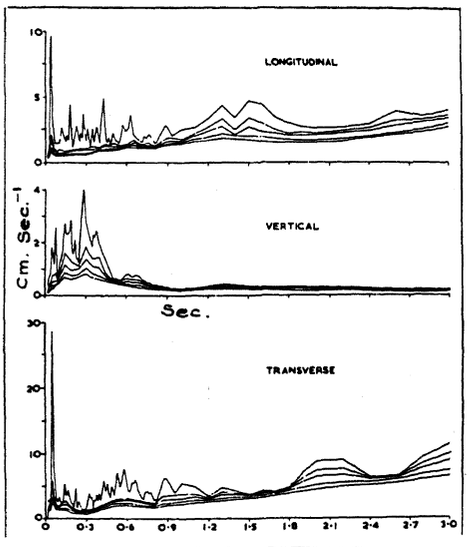


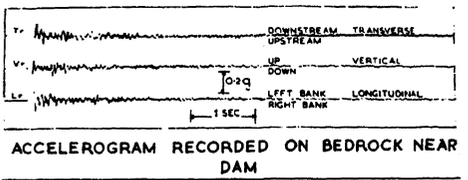
ACCELEROGRAM RECORDED ON SURFACE NEAR POWER HOUSE



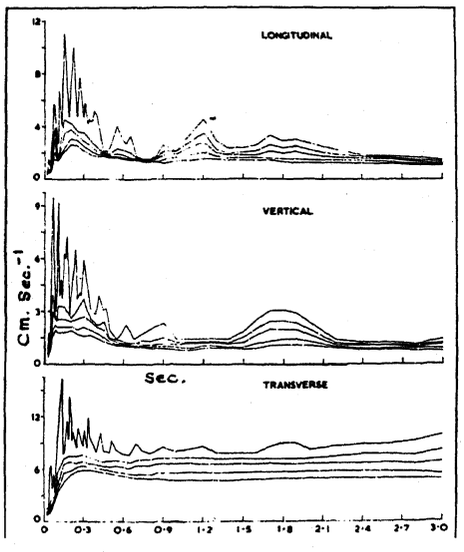


ACCELEROGRAM RECORDED INSIDE THE DAM





ACCELEROGRAM RECORDED ON BEDROCK NEAR DAM



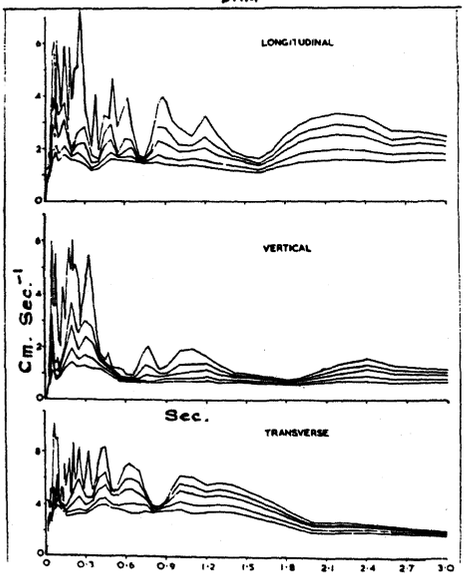


FIG. 7 ACCELEROGRAMS AND CORRESPONDING RESPONSE SPECTRA OF KOYNANAGAR EARTHQUAKE OF OCTOBER 17, 1973.

DISCUSSION

H.M. Chaudhury (India)

The authors have drawn isoseismals of the earthquakes, it appears, from answers to questionaire, and the epicentral regions have been inferred. As the earthquakes were strong enough to merit such a study, they were also well recorded by seismographs in the network of observatories in the India Meteorological Department. The epicentres determined from the instrumental data, differ very widely from the authors inferences in two cases as may be seen below:

	I.M.D.	USGS/MOS	AUTHORS
(1) May 12, 1975	15°N	14.9°N	13°.48'N
	76°E	75.5°E	75°.18'E
(2) July 8, 1975	22.0°N	21.2°N	Close to Shillong
	94.4°E	94.9°E	

The divergence is about 150 Km in one, and in the other as much as 350 Km. Field studies of earthquakes are known to give valuable data and are vital to the study of strong earthquakes. But such large divergence can not be explained easily. The authors may like to clarify.

In the case of the Kinnaur Earthquake Foreshock after shock diagram (No. 4), it is seen that as many as 90 foreshocks in a 10 week period have been plotted. The source of this data may be given. India Meteorological Department is having a number of seismic stations about 170 to 250 Km from this earthquake source region. At one of the stations NURPUR (with instrument operating at 100 K magnification) at a distance of 2.3 degree which has given continuous data a total of only 24 events have been recorded with epicentral distance between 2.0 and 2.6. It is doubtful whether all these could be taken as foreshocks. Further the diagram shows that the weekly number of foreshocks about 8 weeks prior to the main event is of the same order as that 8 weeks after the event. This picture is not confirmed from instrumental data.

Author's Closure

Comments on querries raised by Mr. H.M. Chaudhury are:

Shimoga (Karnataka) Earthquake of May 12, 1975 (1509 hrs GMT)

Isoseismals of Shimoga (Karnataka) earthquake of May 12, 1975 (1509 hrs GMT) (page 1-50 of the preprints of Sixth World Conference on Earthquake Engineering) have been drawn from the information collected through an extensive questionnaire programme. Large number of questionnaires revealed that the maximum intensity was experienced in two areas in the vicinity of Lat. 14°N; Long 75°E and Lat. 14°N; Long 76°E which have been enclosed in isoseismal V (MM). Extensive field data thus collected indicate that only an intensity of II (MM) was experienced at Lat. 15°N; Long 76°E where epicentre from instrumental data has been placed.

Divergence between epicentre obtained from instrumental data and the same obtained from macroseismic data could perhaps be attributed to following factors:

i) Instrumental epicentre could be indicative of place of initiation of the seismic event where maximum intensity may not necessarily generate.

ii) Field intensity is assigned from the damage criterion and thus local geology, amongst other factors, plays a vital roll in deciding the extent of damages.

iii) It has also been observed in case of Koyna earthquakes that the epicentres fixed by various agencies from instrumental data did not agree with each other and also with areas where maximum intensities were experienced. Such observations may not be an exception and could be observed in many earthquakes.

Kinnaur (Himachal Pradesh) Earthquake of January 19,1975 (0802 hrs GMS)

Foreshock and aftershock sequence of Kinnaur Earthquake of January 19, 1975 (0802 hrs GMT) (page 1-50 of the preprints of Sixth World Conference on Earthquake Engineering) has been recorded at Sawalkot dam, Lat. 33°15'N; Long. 75°10'E, on the river Chenab in J & K State. Electromagnetic seismograph on which the sequence has been recorded has instrumental constants as under:

$$T_o = 0.5 \text{ sec}$$
$$T_g = 0.1 \text{ sec}$$
$$\text{System damping} = 30:1$$

System magnification = 10,000
Recording = Photographic at 60 mm/min

Mean epicentral distance of Kinnaur events computed from (S-P) interval recorded at Sawalkot works out to 300 km. Foreshocks and aftershocks have mainly been identified from the nature of wave patterns and also from the mean epicentral distance of Kinnaur events from Sawalkot as that was the main active source during the period of observation. In such estimates depending primarily on epicentral distances computed from one station a few events could be from other areas having similar epicentral distances. It has, however, been confirmed from the background activity at Sawalkot much earlier to the main event that the enhancement in the seismic activity during this period could only be from Kinnaur area.

Assam Earthquake of July 8, 1975 (1205 hrs GMT)

Isoseismals of Assam Earthquake of July 8,1975 (1205 hrs GMT) (page 1-50 of the preprints of Sixth World Conference on Earthquake Engineering) have been drawn from the information collected through a questionnaire programme and the highest intensity of VII (MM) has been inferred from the personal experiences of the reporters and the extent of damages described by them.

Consensus of reports indicate strong feeling of this shock at Shillong which would not be possible had the epicentre been as far away as Lat. 21.2°N; Long. 94.9°E placed by USCGS/MOS. Review of questionnaires in the light of USCGS/MOS epicentre makes authors feel that the epicentre could be somewhat to the east of the present location but definitely not as far away as has been placed by USCGS/MOS.

Here again the local geology appears to have played an important role in deciding the intensities and the extent of surface damages.