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THE AFTERSHOCK SEQUENCE OF THE UDAYPUR (NEPAL) EARTHQUAKE OF AUGUST 20, 1988.

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INTRODUCTION

On 20th August 1988, a major earthquake of 6.6 magnitude (M_s USGS) occured in the foot-hill of the Central Himalaya of Nepal near the town of Gaighat. The historic seismicity of this region is not well known and since 1900 only seven events are reported by the International Seismological Centre (ISC). For the same period the western Nepal is shaken up by 214 earthquakes (M_S max = 7.5). The Indian Himalayan Plate Boundary presents a mean to large superficial seismicity where thrust faultings are predominent. The recent earthquake occured very near to the reported epicentre of Bihar-Nepal Great Earthquake of 1934 (ISC : M_S = 8.3). However, the location of this main event has been a subject of many discussions with respect to the reported variations of intensity within the territory of Nepal and northern India. A location northward in the Lower Himalaya is possible (Pandey and Molnar, 1988). The 20th August 1988 Earthquake is, therefore, the first great event happened in this area (Fig. 1).

MACROSEISMIC EFFECTS

Located in the Udaypur District of Nepal, the main shock devastated several regions of eastern and central Nepal and parts of northern India. Casualties due to this earthquake have been reported by USGS : they have estimated 721 people as killed and hundreds injured in the eastern Nepal including the Kathmandu Valley. Damages have been reported in the Gangtok area of Sikkim and in the Darjeilling area of India. It was felt in large parts of northern India from Delhi to the Burma border and in many parts of Bangladesh, (EDR n 8-88, Part 2 of 2, P. 206).

Preliminary result of intensity mapping is shown in Fig. 2. The map is compiled after the results of joint investigations by Nepalese and U.S. scientists within the territory of Nepal except the north-eastern parts of the country.

Preliminary assignement of maximum intensity is VIII MM (Modified-Mercalli) corresponding to important damages on buildings. Isoseismal of VIII extends roughly east west for about 100 km parallel to the Indian-Himalaya Suture. Its width is about 8 km in the west and about 15 km in the east. The zone of liquefaction is extended to different intensity zones and occupies mainly the gangatic alluvial plain, immediately southward of the maximum isoseismal zone of VIII. In the central part, the

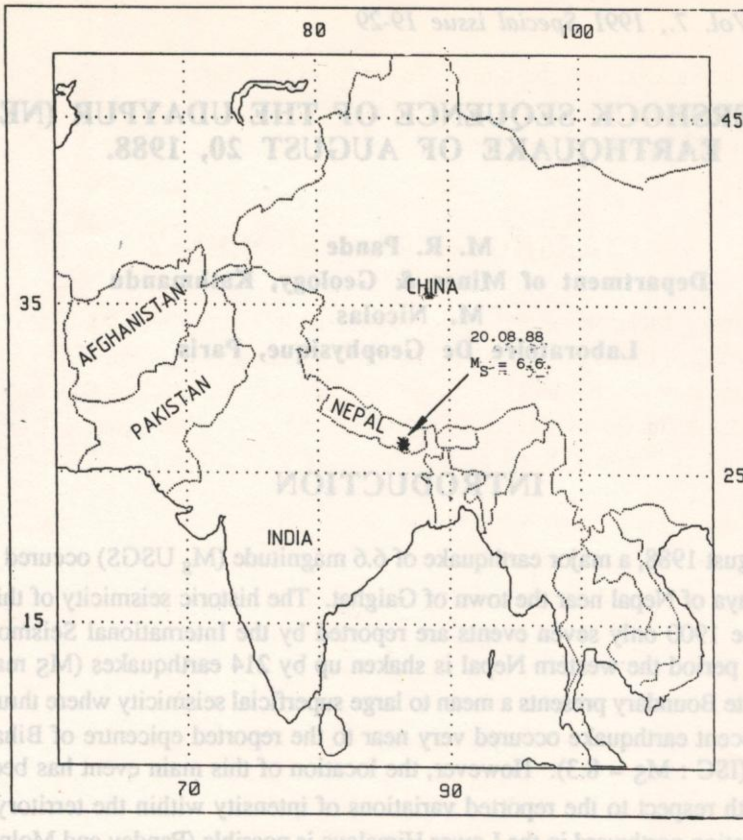

FIGURE 1 : Situation of the mainshock (20.08.88 - M_b = 6.4, M_S = 6.6)

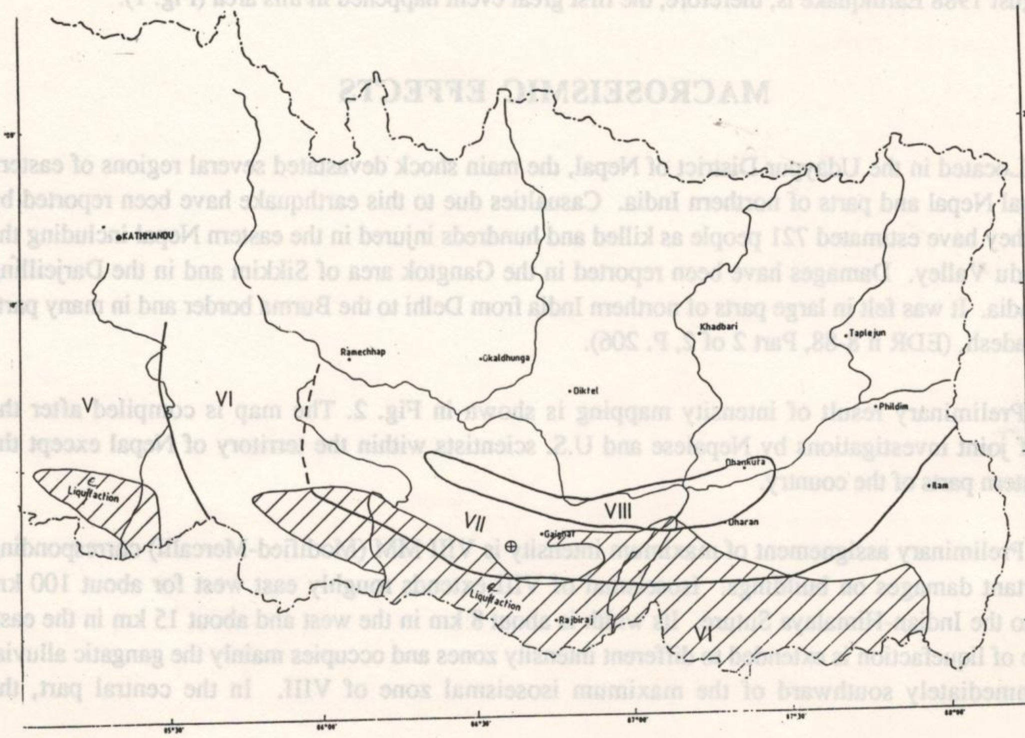

Fig. 2 : Isoseismal map

liquefaction zone makes a seep into the north. To the west of Gaighat the liquefaction zone extends parallel to the maximum isoseismal contour, while in the east, the northern limit of the liquefaction zone is diagonally located to the isoseismal contour.

AFTERSHOCK TIME SEQUENCE

The preliminary location of the 20th August 1988 event made by National Earthquake Information Service (NEIS) is 26.775 N, 86.609 E and 57 km deep using a set of 555 data. Body wave and surface wave magnitude are 6.4 and 6.6 respectively as recorded by the Department of Mines and Geology (DMG), Kathmandu, in collaboration with Laboratoire de Geophysique Appliqu*e, Universit* Pierre et Marie Curie, Paris (France). Records of the mainshock are saturated and no S phase arrival time data could be obtained. The precise location of the mainshock and of the largest aftershocks is not possible with the Nepalese data alone. Nevertheless, the result of the location of the first aftershocks recorded by the network has been found to be reasonably consistent with the NEIS result for the mainshock within a discrepancy of 10 km.

Some 155 aftershocks have been recorded by the seismic network of DMG within 39 days after the mainshock. Histogram of number of events per day is shown in Fig. 3. This sequence corresponds to the type I in Mogi classification (no foreshock and quick decrease of the activity), and this could be interpreted by the response at an uniform stressfield. Similar result has been obtained for other seismic sequences of Lower Himalaya e.g. 29th July 1980 (Bouvier, 1981).

Duration magnitude is estimated by the following formula:

$$M_D = 3.45 + 1.41 \text{ Log } t$$

With t = duration of signal in minutes.

This law is well correlated with mb (USGS) for regional earthquakes and epicentral distances longer than 200 km. For local events ($\Delta < 200$ km) the available formula is :

$$M_D = 3.45 + 1.41 \log t + 0.8 \sin [4.5 (t - 20)].$$

Frequency magnitude relation of the aftershocks is shown in figure 4. The lope of the regression (0.79) is almost the same as the reported b value for normal sequence and suggests a fast strain release.

LOCATION OF AFTERSHOCKS

About forty events with magnitude ranging from 2.5 to 3.8 Reichter are chosen for this study. Signals for larger events are saturated and therefore, cannot be used to provide arrival time data of S local phases. The signals are zoomed on the screen and precise arrival time (0.05 sec) of P and S waves are determined after adequate filtering. In view of the wide aximuthal gap (around 300 degree) of the network

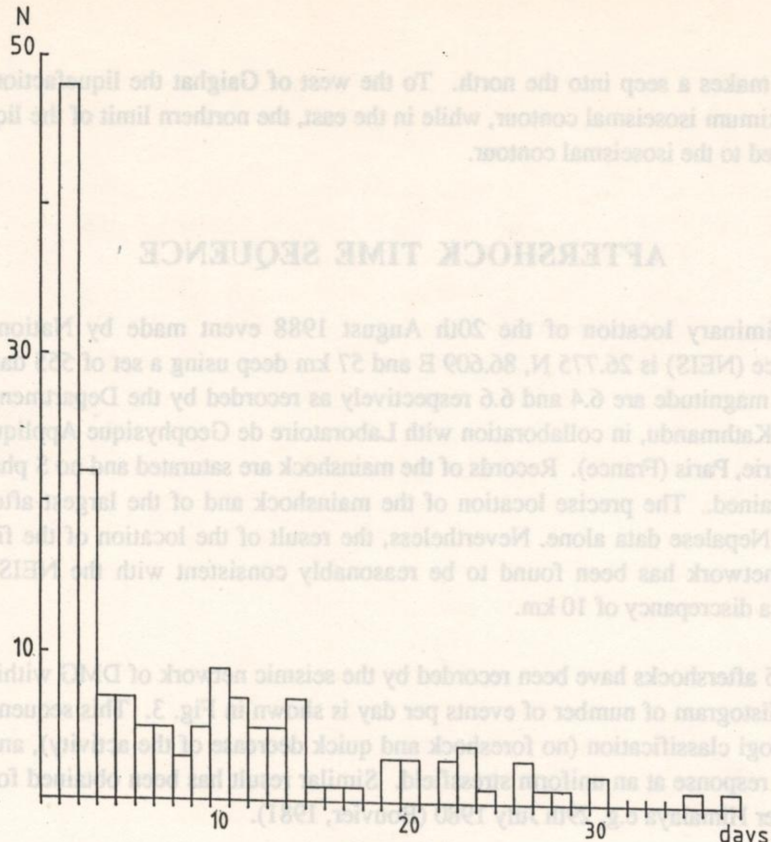

Figure 3

Number of aftershocks versus time

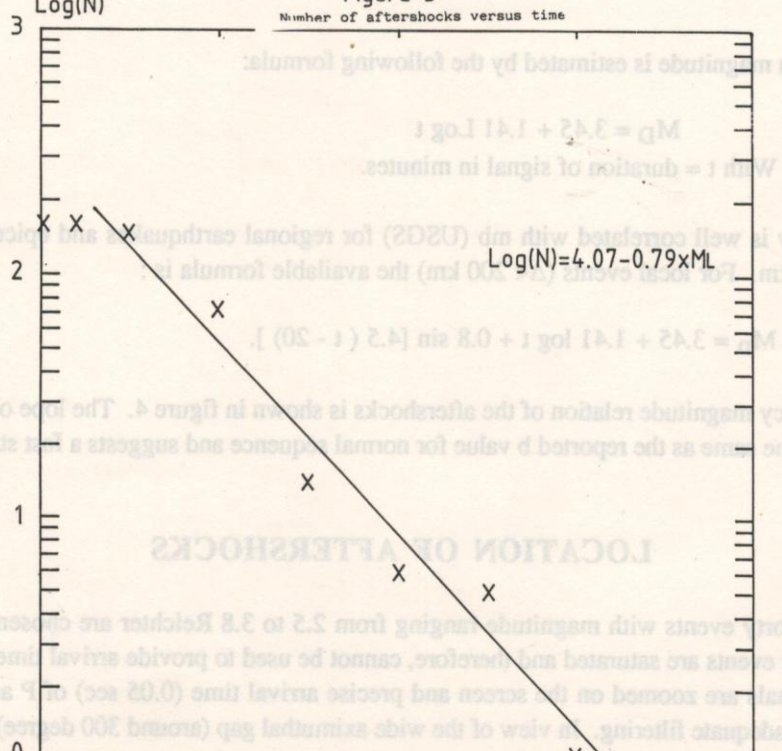

Figure 4

coverage with respect to the location of the events, S phase arrivals are considered to be crucial for the location of the events. The result of the location is shown in figure 7 with the geological context.

The limitations of the phase arrival data and the small aperture of the network do not allow a consistant depth determination. As a rule two minima of RMS are observed in all determinations. The first is confined to the depth of the interface of first or second layer (-23 km), and the second leads to depth in the range of 45-55 km immediately over the Moho. These two minima differ by insignificant values so that depth allocation based upon RMS variation does not seem to be significant. The relative departure in plan corresponding to the two depth ranges given by RMS minima is found to be less than 10 km. This departure is insufficient to make a choice between the two depths.

The located aftershocks are scattered around the NEIS location of the mainshock within a radiums 10-15 km (Fig. 7). However there seems to be a tendency of WNW-ESE trend in the location of the swarm. This lineation runs for nearly 45 km and pass close to Gaighat. Keeping in view of the geometry of the network and uncertainity of the epicentre location which may be of the order of 10 km, correlation to any geological structure may not be relevant at this stage.

The waveforms recorded for the events exhibit various characters as illustrated in Fig. 9 - 13. Polarity of first arrival as well as nodal plane characteristics of P and S waves amplitude suggest different combinations, probably related to different fault-plane solutions. Lg wave is not observed in any station as a rule. This lag is generally interpreted by a discontinuity of continental crust between the epicentre and the stations, or by a focus location within the lower crust or the upper mantle.

DISCUSSION AND CONCLUSION

Some arguments, though not very obvious, may be done regarding the correlation of aftershock location and the isoseismal of maximum intensity. The maximum intensity isoseismal seems to have a WNW orientation in western part while it is trending ENE in the area east of Gaighat (Fig. 2). The western WNW trending VIII MM zone correlates with feebly expressed lineament of aftershock discussed above (Fig. 7);. this trend is parallel to the dominent strike of the Main Boundary Fault (MBF) and the geological contacts in this area.

The preliminary fault-plane solution for the main shock (Fig. 14) obtained with about sixty first motions shows a N 135 degree thrust faulting with dextral strike-slip component very coherent with the main tectonic direction (EDR n degree 88-8, Part 2 of 2, p. 206). The N 182 degree P axis is in good accordance with the stressfield induced by the Indian Eurasia convergence (Das and Filson, 1975).

The mainshock seems similar to former the great earthquake in the region except for the depth (57 km) which is rather unusual. According to the actual models (e.g. Tapponier and Molnar, 1977), the detachment lies less than 20 km below the country. For example, the 1934 Bihar-Nepal Earthquake is located with a focal depth of 20 km correlated with the Main Boundary Thrust (MBT) (Singh and Gupta, 1980).

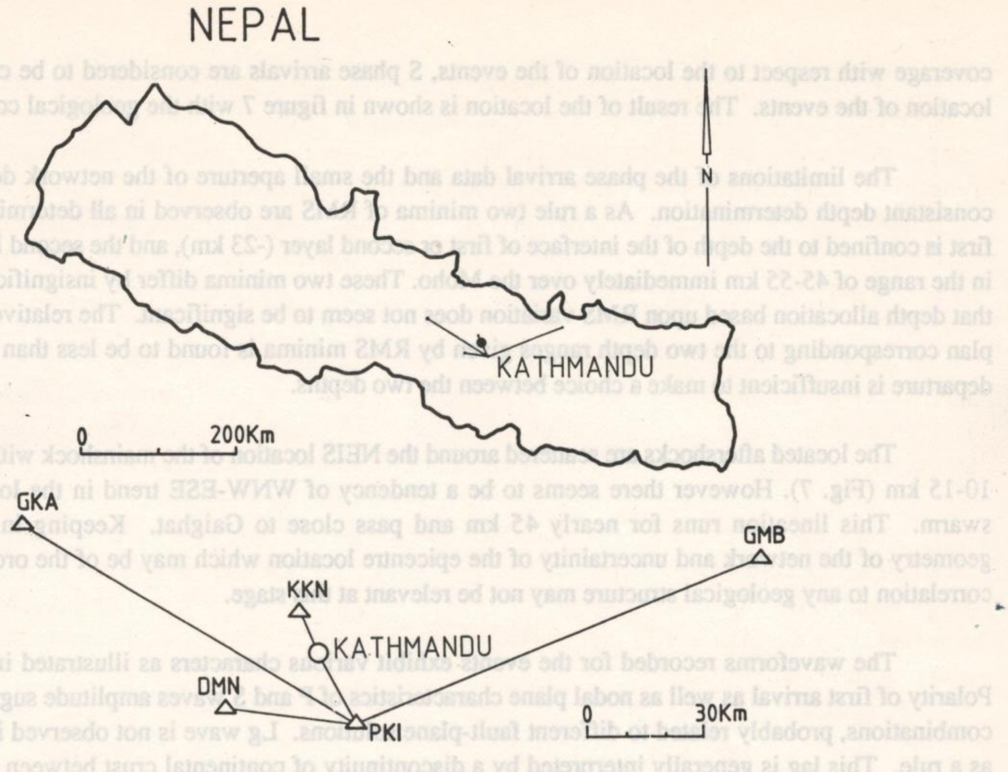

Fig. 5 : Nepalese seismic network

EGEND

Mid - Miocene - Pleistocene

SIWALIK GROUP

- Sw — Undifferentiated Siwalik rocks
- Us — Upper Siwalik
- Ms — Middle Siwalik
- Ls — Lower Siwalik

Upper pre-Cambrian - Late Paleozoic
Permo Carboniferous

MIDLAND GROUP

- Mdl — Undifferentiated Midland metasediments
- Ul — Ulleri Formation - Schist and augen gneisses

Pre-Cambrian

KATHMANDU GROUP

- Ktm — Undifferentiated metamorphic rocks, schists, quartzites, crystaline limestones
- + + + — Granites
- Hm — Undifferentiated metamorphic rocks, kyanite, gneisses Schists, two m.

Compiled after Geological map of Eastern and Central Nepal.
1/250,000 scale, Department of Mines & Geology, Kathmandu 1984

A preliminary seismotectonic intrepretation is possible with all the local data obtained here. The mainshock is perhaps located on an overthrust fault parallel to the MBT (WNW-ESE) corresponding to a simple shear zone, on a crustal scale proposed to explain the original of flattish cleavages in many orogens (Mattauer, 1975). The thrust faulting of the North Indian Plate Boundary over the Indian Craton corresponds to the beginning of a new thrust sheet southward of Himalaya. Other thrust or normal faulting located in the north Indian Shield (Tandon and Srivastava, 1975; Chandra, 1978) can be explained by this model.

A NE trending geological fault is occurring in the vicinity of the mainshock running for approximately 12 km (fig. 6) distance. The fault displaces the upper Siwalik rock as well as the MBF. The sense of movement of this fault is dextral in the SW part. The diversity of the first motion of aftershocks is perhaps correlated with these structures, reactivated by the mainshock.

Since few years, we know that the Continental Plate convergence induced deformation and seismicity backward to the active chains (in northern Europe and central Asia for example) with predominant strike slip motion. The recent swarms of Indo-Nepal and of Armenia (1988, 7 December, M = 6.9) show the existence of great deformations in Intra-Plate domains forwarding the active chains with predominent thrust faulting.

ACKNOWLEDGEMENT

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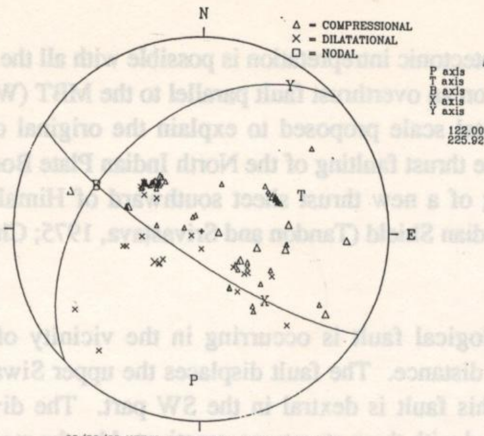

08/20/88 NEPAL-INDIA BORDER REGION 6.4mb

FIGURE 14 - FAULT PLANE SOLUTION OF THE MAIN SHOCK (SCHMIDT PROJECTION)

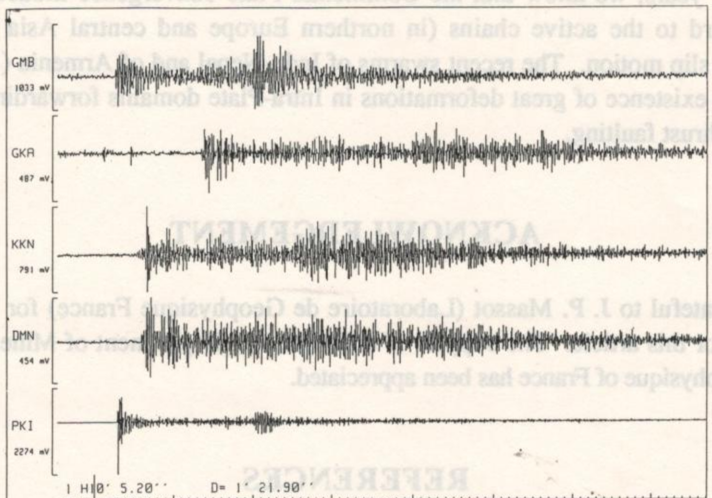

Figure 12 - Aftershock Mb : 3.8

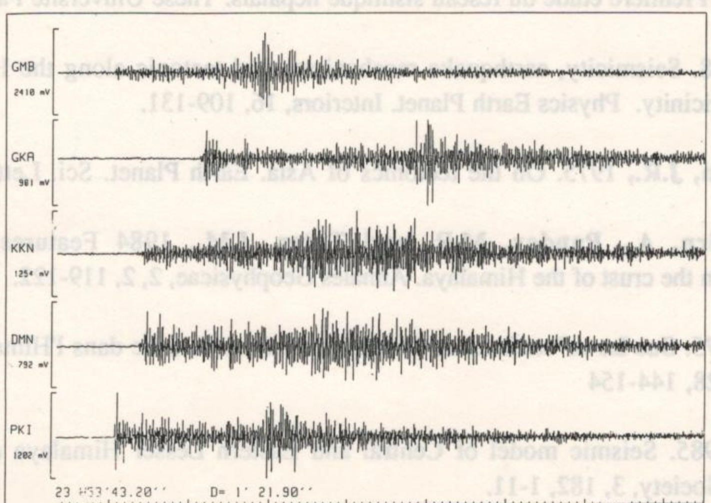

Figure 13 - Aftershock Mb : 3.5

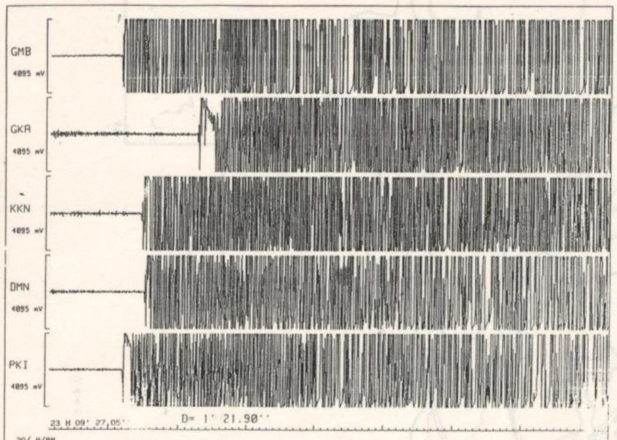

Figure. 8 = Records of main shock Mb : 6.4

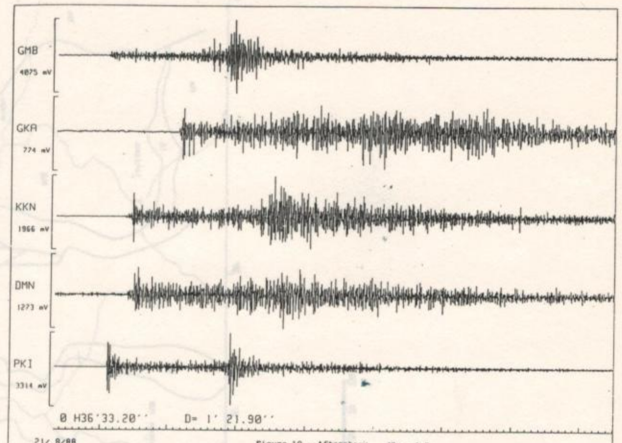

Figure 10 - Aftershock Mb : 4.0

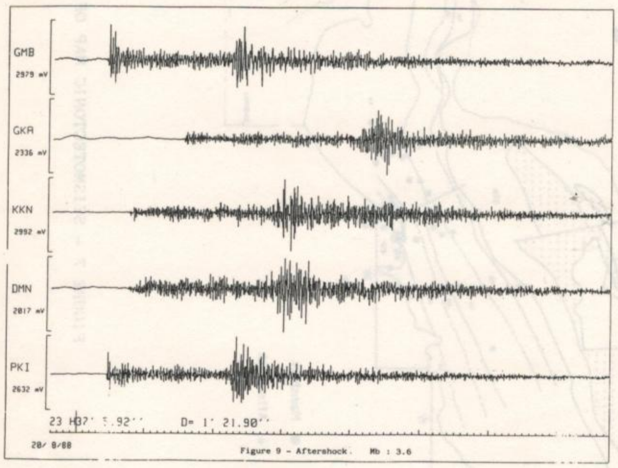

Figure 9 - Aftershock. Mb : 3.6

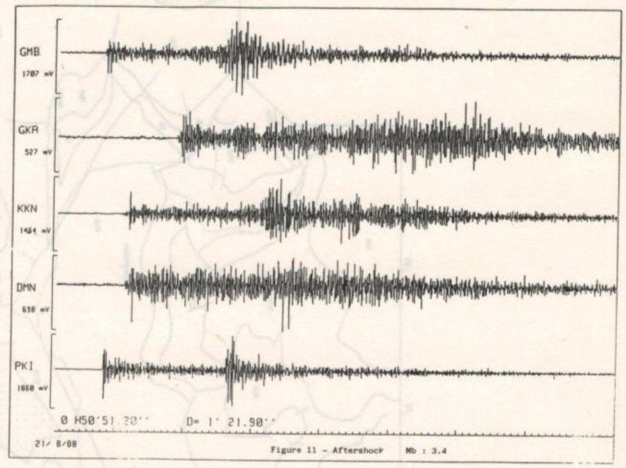

Figure 11 - Aftershock Mb : 3.4

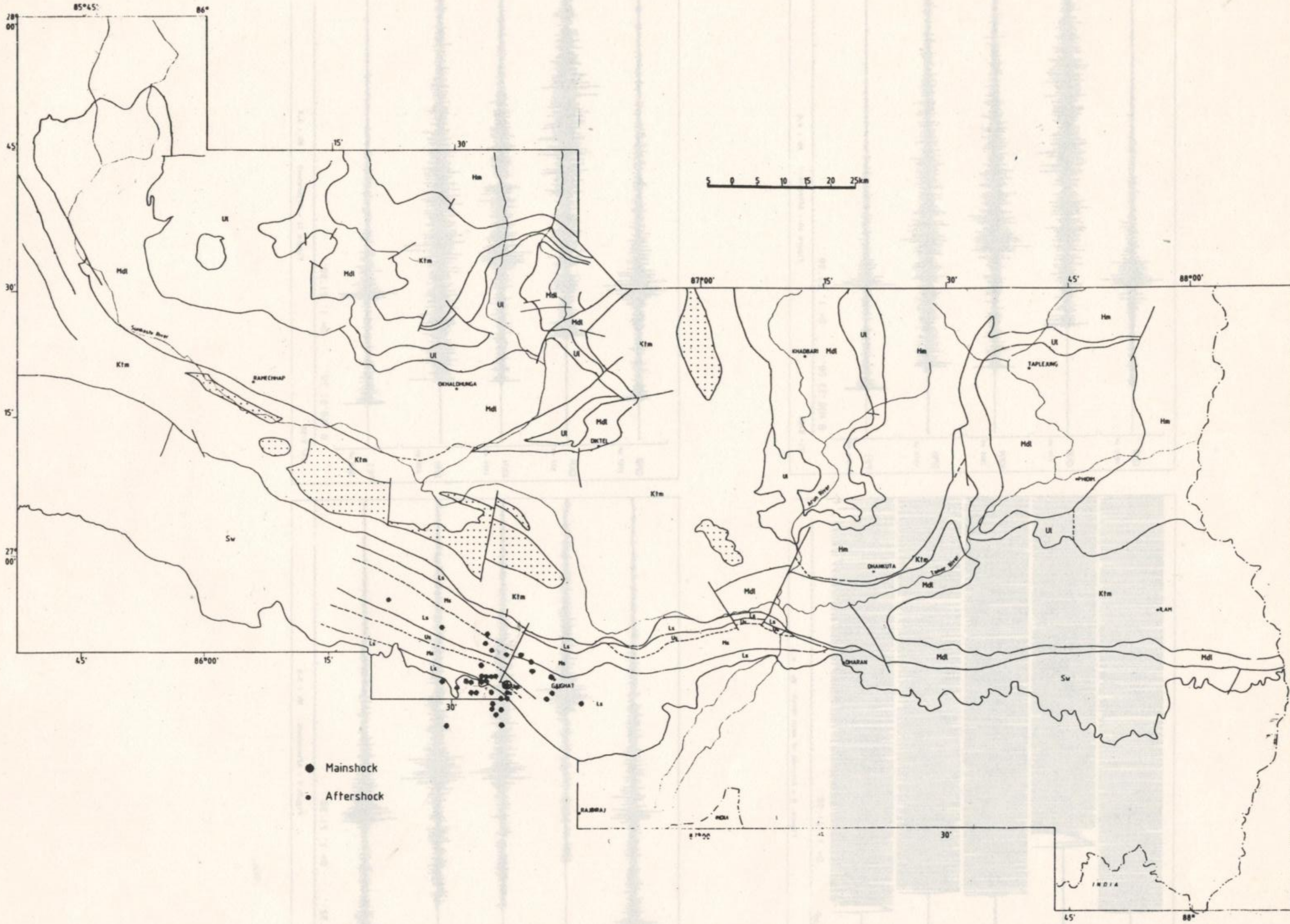

FIGURE 7 - SEISMOTECTONIC MAP OF THE CONCERNED AREA

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