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Fatehjang (Pakistan) Earthquake of February 17, 1993: source mechanism and intensity distribution

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Abstract

A shallow earthquake of magnitude (M_L) 5.3 occurred at a depth of 8.9 km in the Fatehjang area on February 17, 1993. It was followed by four aftershocks with magnitude (M_L) $\leq$ 3.8. The main shock was located in the foothills of Kala Chitta Range which is a part of the Hazara Thrust System. The composite fault plane solution of these events yielded predominantly strike- slip movement with orientation striking N46^{o}W and dipping 45^o NE. The maximum intensity in the epicentral area was V on the Modified Mercalli Intensity Scale near Mahura, trending in WNW direction. No loss of life or property was reported.

1. Introduction

On February 17, 1993 an earthquake was recorded by the seismic network of Micro Seismic Studies Programme (MSSP) at 21:05:08 hours (PST), with magnitude (ML) 5.3, in the foothills of Kala Chitta Range of Fatehjang area, District Rawalpindi. The earthquake was felt in several areas, including the twin cities of Rawalpindi and Islamabad. The epicenter of the earthquake was about 15 km west-northwest of Fatehjang and about 75 km west of Rawalpindi. The main shock, resulting from movement of a fault in the thrusted area, was followed by four aftershocks. An effort was made to obtain source mechanism solution and intensity distribution to identify the nature of fault movement associated with the events. The polarity data of few global stations was also added to improve solution for source mechanism. An intensity survey was carried out by a team of the Micro Seismic Studies Programme (MSSP) personnel soon after the occurrence of the event for this purpose.

2. Seismic observations

Fatehjang area is situated in the northern part of the Potwar Plateau, which belongs to the Himalayan Foreland having a number of active faults. It is in the north of the Soan syncline, up to the Margalla Hills of the Main Boundary Thrust (MBT), and in the East the area is terminated by the almost north-south trending left-lateral Jhelum wrench fault. The modern seismicity of this area reveals that it is concentrated mainly around the Hazara Thrust System, which is regarded as the extension of the MBT. A very few significant events have magnitude close to 5. The historical seismicity indicates that the region has been struck by some wrecking earthquakes. Taxila earthquake was one of the deadliest that razed each and everything. The historical seismicity of this area is shown in Fig. 1. The catalogue of instrumentally recorded seismic events was compiled by MSSP and includes also the locally recorded data since 1976. The modern seismicity of this region has been plotted in Fig. 2, alongwith the fault plane solutions of the earthquakes.

2.1. Main shock and aftershocks

The seismic data recorded by local seismic network operated by MSSP was used to locate the main shock. The hypocentral parameters were obtained by using computer programme "hypocenter" (Lienert and Havskov, 1995) of computer code SEISAN (Havskov and Ottemoller, 2001) and given in Table 1. The hypocentral parameters of the same earthquake as reported by US Geological Survey (USGS, 1993) are also given in Table 1 for comparison. The earthquake was located with diminutive errors and plotted with elliptical error ellipse in Fig. 3.

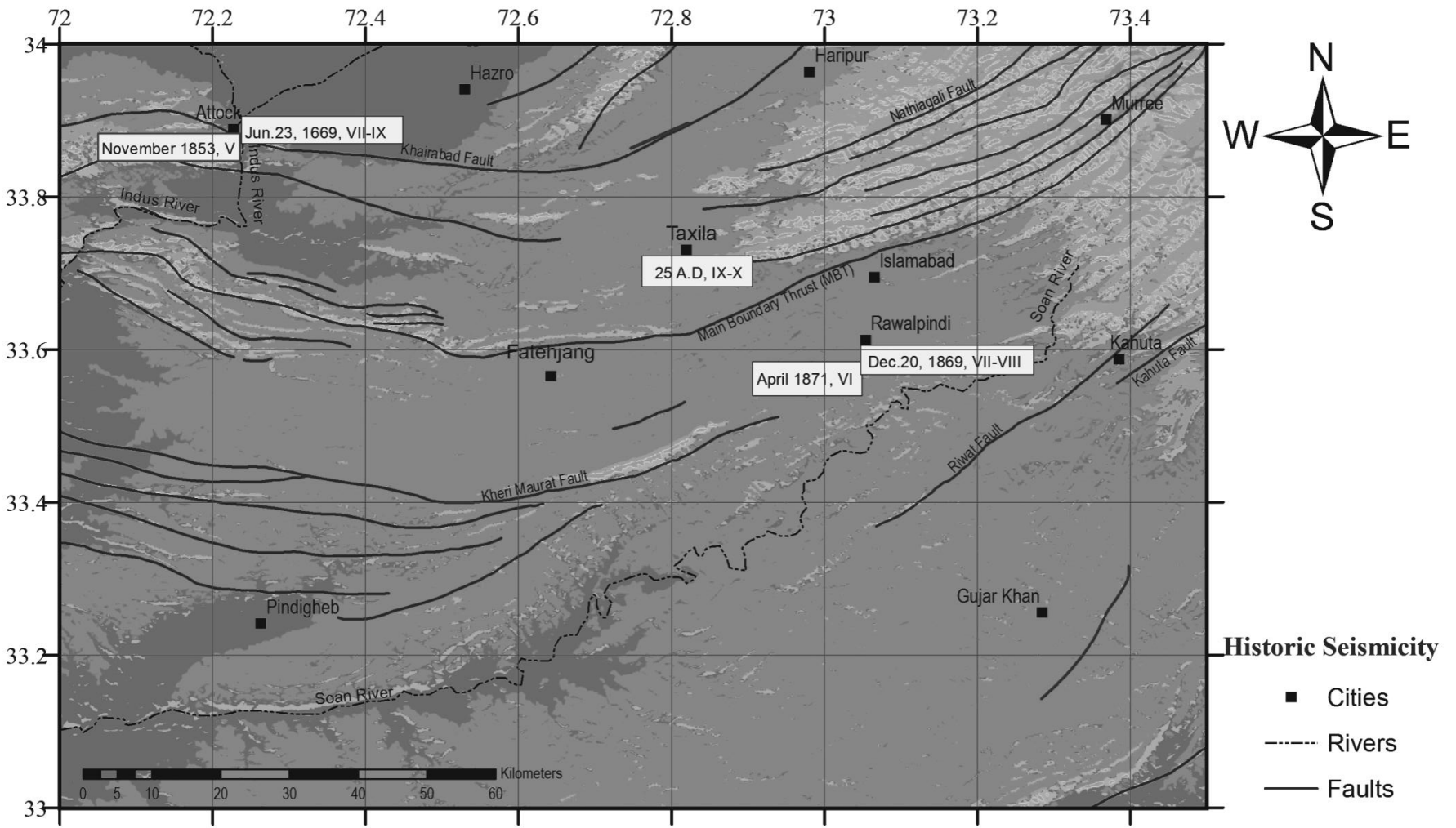


Fig. 1. Historical seismicity of Fatehjang and its surrounding area.

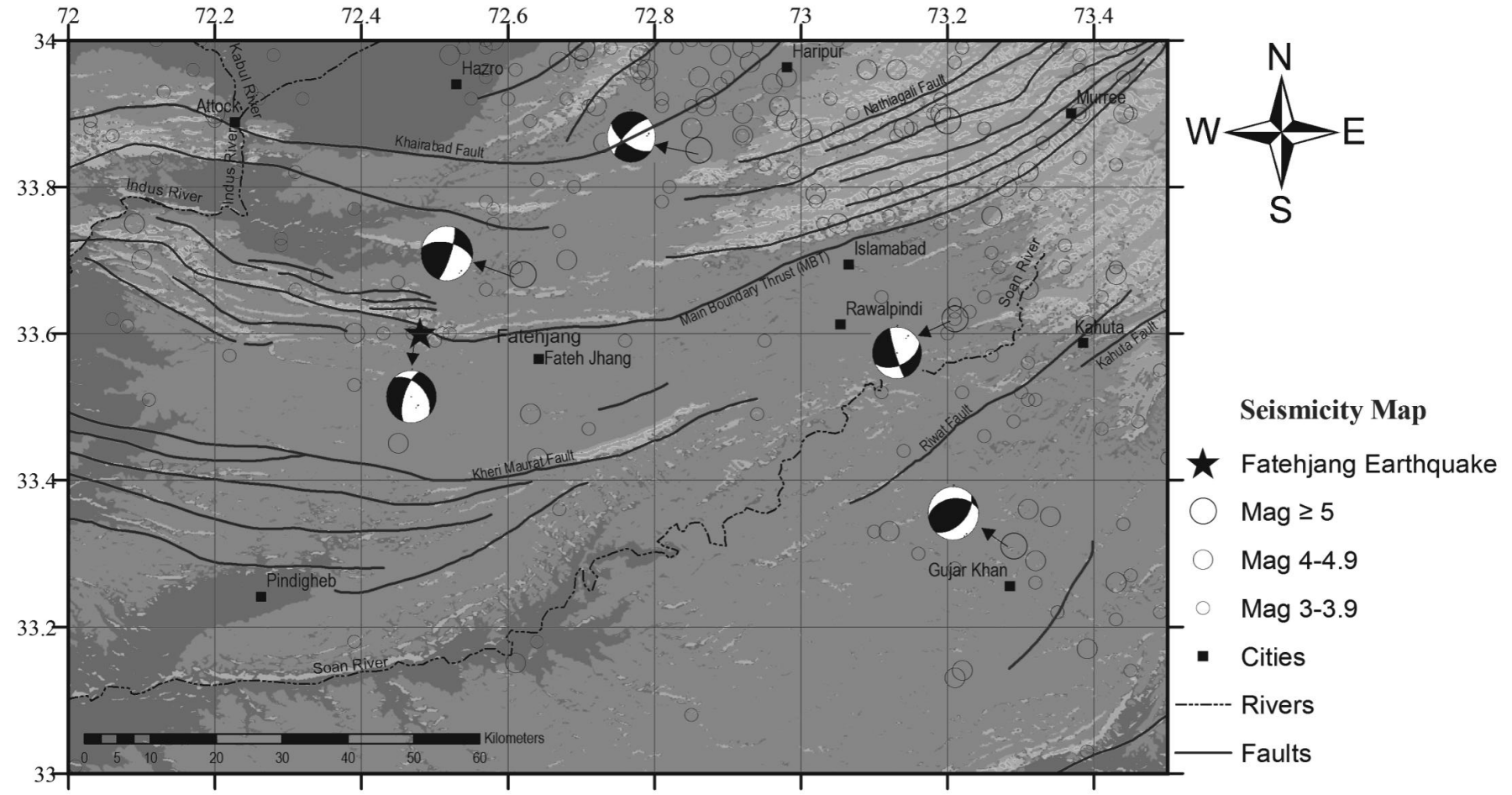
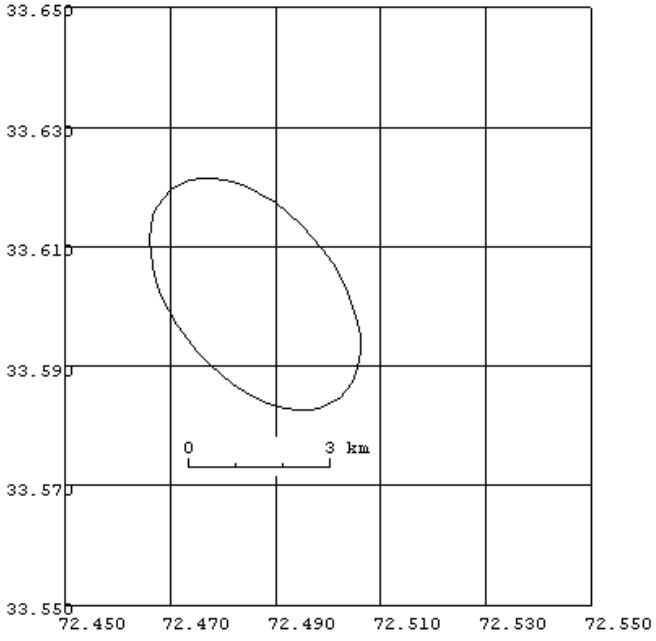


Fig. 2. Modern seismicity of the Fatehjang and its surrounding area till Dec. 2008.



Latitude	Longitude	Depth
33.60°N±2.3km	72.48°E±2.1km	8.9±2.4km

Fig. 3. Elliptical error ellipse exhibiting errors in the hypocenter.

Table 1. Comparison of hypocentral parameters.

Hypocentral parameters	**MSSP**	**USGS**
Date	17-02-1993	17-02-1993
Origin Time	16:06:08.0	16:06:05.2
Latitude	33.60°N	33.56°N
Longitude	72.48°E	72.59°E
Depth	8.9 km	12 km
Magnitude	$M_L = 5.3$	$m_b = 4.8$, M_s 4.5

Four aftershocks were recorded within three hours of the commencement of the main shock. Among them, the aftershock of magnitude 3.8 that originated at midnight was the bigger one. It was also felt in the epicentral region by some persons who were not sleeping.

2.2. Source mechanism

A composite fault plane solution was carried out by combining the polarity data of the main shock with that of the two aftershocks having maximum numbers of clear onset of first motions on the seismograms. To increase the Azimuthal coverage of seismic stations, polarity data of a few global seismic stations was also added, which resulted in a much better fault plane solution. The aftershocks used in this solution occurred respectively, at 19:05 hours (Feb. 19, 1993) and 20:56 hours (March 10, 1993). The solution was obtained by using programme FOCMEC (Snoke et. al., 1984) of SEISAN computer code and plotted in Fig. 4. The solution depict two nodal planes striking N20^{o}E and N46^{o}W, respectively with the corresponding dips of 66^o NW and 45^o NE. The movement on both the nodal planes corresponds predominantly to strike-slip faulting with the direction of movement right-lateral on the plane striking NW and left-lateral on the one striking NE.

As the nature of tectonic structures in this region is generally thrusting, a possible explanation of this anomaly in the fault plane solution of the event may be found by carefully studying the

orientation of the Kala Chitta Range and the tectonics of the area where the EW- trending Seri Syncline with no surface trace of fault is present (Jaswal et al., 1997). A marked offset lateral to the East-West orientation of the Kala Chitta Range is observed just near east of the village Mahura where this earthquake was located. Here the Kala Chitta Range abruptly turns northwest and after a few kilometers again takes its original course i.e., East-West. This offset suggests a differential movement due to northward active tectonic forces in the region. As seen in the Fig. 1, the epicenter of the event lies almost in the middle of the offset blocks of the Kala Chitta Range. The strike-slip movement along the offset probably caused the earthquake. The relative north-westward movement of the western block along the offset suggests the plane striking northwest as the most probable fault plane.

3. Field observations

Seismological investigating team of the MSSP personnel carried out the field survey of the epicentral region.

3.1. Field investigation

The epicenter was about 5 km east-southeast of the village Mahura in the foothills of Kala Chitta Range. The epicentral area consists of a rough and rugged terrain making the slopes of Kala Chitta Range and a small valley south of the Mahura village. Mahura is situated about 13 km from the Fatehjang-Kohat road and makes the northern end of the valley where an abrupt rise in the slope is observed. Outcrops of the youngest rocks are seen here and there in the valley. The houses in Mahura and other localities around Mahura are generally built of stones using mud mortar, whereas the use of cement was also observed in some cases. The buildings are generally poor both in material and design. No damage of any kind was reported except some cases of fallen crockery.

3.2. Intensity distribution

The earthquake was felt by all, including those who were sleeping, in the village of Mahura and the surrounding localities and the people rushed out of the houses. Creaking of wooden doors and beams in roofs was generally reported, whereas some persons reported a mild roaring sound preceding the tremors. A person in the village of Mahura clearly described the roaring sound like that of tractor/truck being tried to start unsuccessfully.

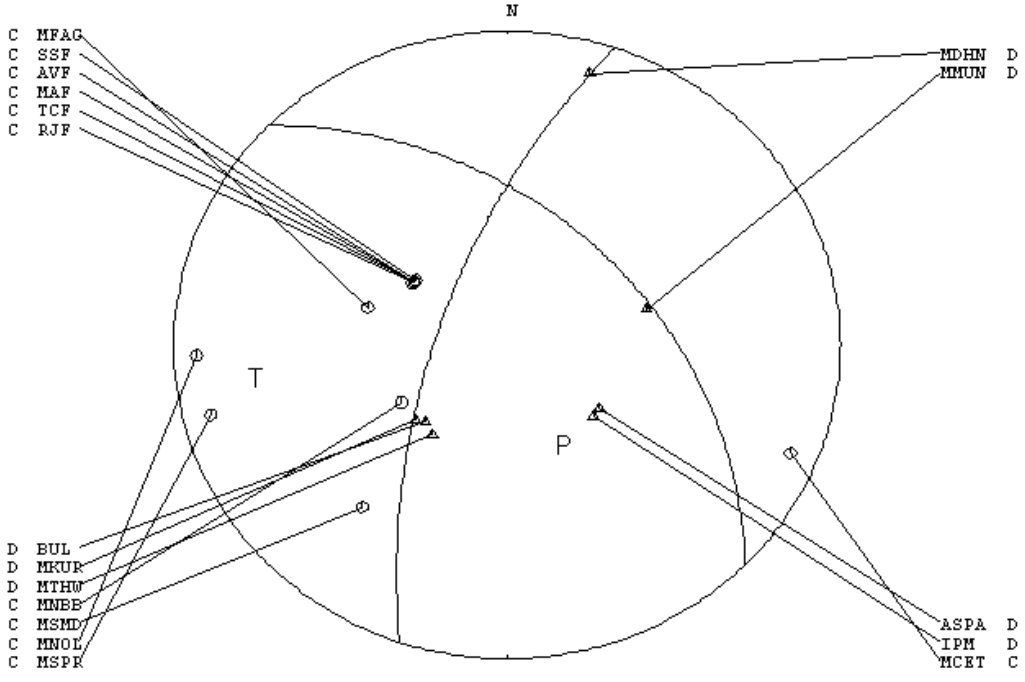


Fig. 4. Fault plane solution of Fatehjang earthquake of Feb. 17, 1993. "C" means compression and "D" dilatation.

People generally exaggerated about the duration of the tremors. One person, in the village of Gaggan, told that he noted exactly the duration as three seconds. A single jolt was generally felt whereas there were also some reports of two jolts. One person could also estimate correctly the direction of the jolt as North-South in the village of Mahura. A few persons, some of them were not even asked, reported the minute tremors of the aftershock of magnitude 3.8. The intensity in the epicentral area was estimated to be V on the Modified Mercalli Intensity (MMI) Scale (Bullen and Bolt, 1985).

Away from the area of maximum intensity up to the town of Fatehjang in the east, Basal in the west and Attock in the north, the tremors were felt by all those who were awake and some who were sleeping. Majority of the people felt two jolts whereas some reported a single jolt only. No roaring sound except that of the creaking of wooden beams in roofs was heard. No damage, not even a case of fallen crockery was reported. In the localities south of Fatehjang-Kohat road a marked decrease was observed in the intensity. Some of those who were walking at the time did not feel the tremors. The attitude of most of the people was casual when asked about the earthquake. About 20 km south along the Talagang road, minor tremors were felt in the surrounding localities. Most of the persons looked as if they were trying to remember when asked about the time of occurrence of the tremors. A man from Pindigheb told that neither he himself felt the tremors nor any body else mentioned any such thing. As said earlier, the tremors were widely felt in the twin cities of Rawalpindi and Islamabad which lie at about the same distance from the epicenter as Pindigheb. The observations made during the intensity survey were recapitulated in isoseismals map given in Fig. 5. and MMI values of the surveyed locations are given in Table 2.

Table 2. MMI values of Fatehjang Earthquake February 17, 1993 at some surveyed locations.

Locations	**Longitude ºE**	**Latitude ºN**	**Distance from the epicenter (km)**	**MMI**
Mahura	72.41	33.61	6	V
Choha Norpur	72.42	33.57	7	V
Gaggan	72.48	33.54	8	V
Jafar	72.51	33.55	8	V
Akhori	72.45	33.68	8	IV
Bahtiot	72.51	33.57	6	IV
Fatehjang	72.64	33.57	17	IV
Kot Bela	72.48	33.48	14	IV
Basal	72.25	33.55	21	IV
Jorian Bonni	72.30	33.59	16	IV
Chhoiwali Baihk	72.45	33.70	12	IV
Hatar	72.71	33.58	22	IV
Ismail	72.55	33.43	20	III
Dhok Dorian	72.43	33.42	21	III
Padhana	72.90	33.62	40	III
Adiala	72.98	33.47	50	III
Sang Kas	72.87	33.43	42	III
Pind Sultani	72.17	33.50	30	III
Dhok Tarbethi	72.45	33.73	18	III
Chor Pani	72.18	33.83	36	III
Kanwala	72.25	33.85	34	III
Pathargarh	72.67	33.78	27	III
Jabi Kas	72.75	33.75	30	III

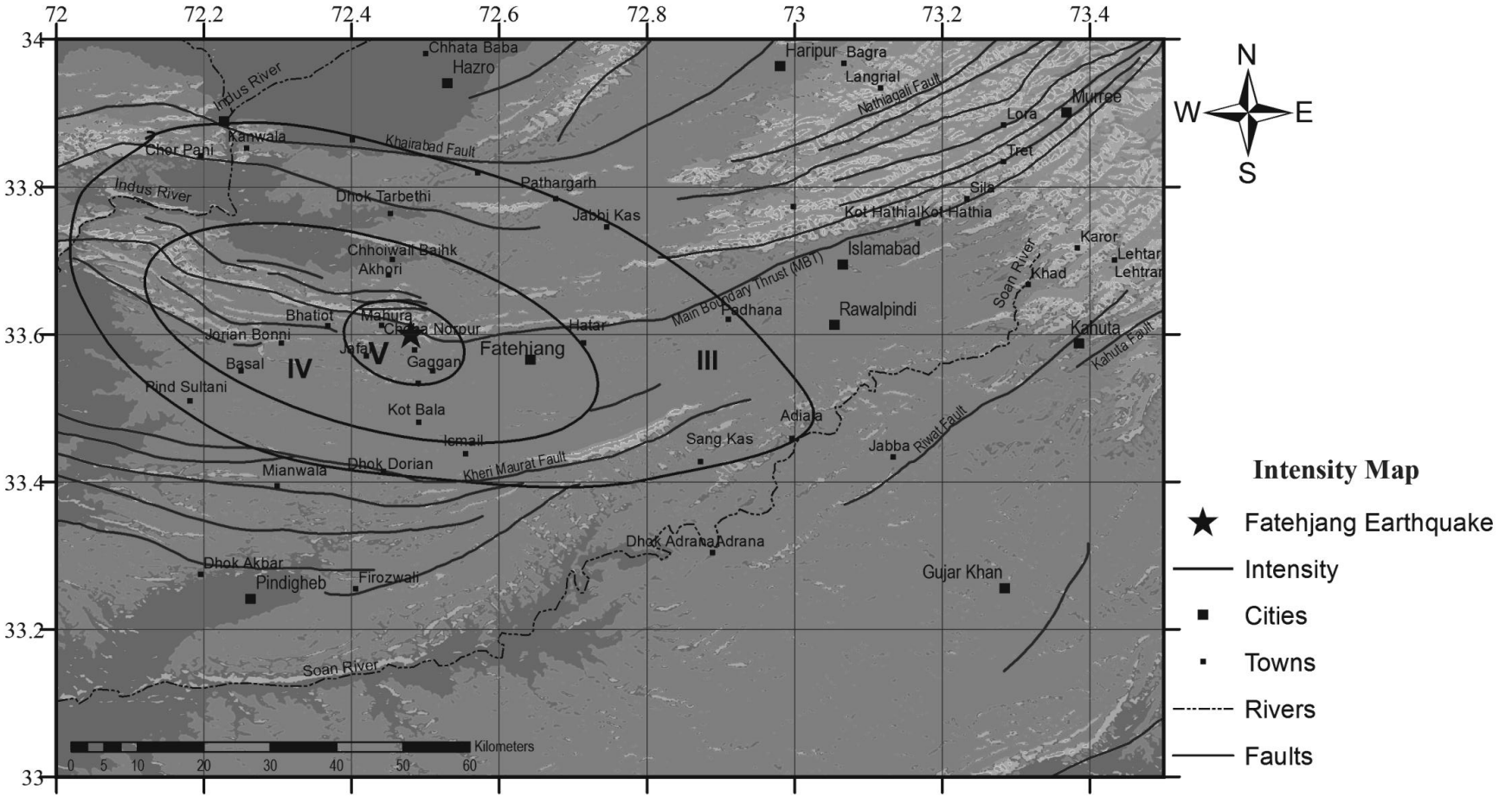


Fig. 5. Isoseismals map of the Fatehjang earthquake of Feb. 17, 1993.

4. Conclusions

The study of Fatehjang earthquake and its aftershocks shows that they lie in an area that contains a number of low to moderate earthquakes with only few earthquakes of magnitude greater than (M_L) 5. Focal mechanism solutions indicate right-lateral strike-slip along the fault planes of northwest-southeast orientations which corresponds to the general trend of local tectonics. Pivnik and Sercombe (1993) indicated that the Potwar Plateau is hybrid terrain consisting of thrust faults and a series of short lateral displacement with high vertical pressure ridges associated with offsets in the basement. This suggests that the inferred strike-slip fault may be a part of one such pressure ridge. The observations made during the intensity survey indicated that the isoseismal map and well-controlled fault plane solution of the event are in accordance with the structural trend in the area. Damage to buildings and other structures in general agreed with the intensity of shaking observed at various places.

Acknowledgement

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