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# MANGLA EARTHQUAKE OF MARCH 10, 2006: SOURCE PARAMETERS AND NATURE OF THE DERIVED FAULT

BY

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**Abstract:-** *On March 10, 2006, an earthquake of magnitude $M_L$ 5.0 occurred near Mangla Lake about 95 km south-east of Islamabad. The epicentral area was jolted by the earthquake. One person was killed, 22 injured in Mirpur District. Further, the earthquake was felt widely from Peshawar to Lahore. The well controlled fault plane solution was obtained on the basis of P-wave polarity data of seismic stations of the local seismic network including world wide seismic stations. The fault plane is oriented in NW and SE direction with strike, dip and rake 293°, 20° and 117° respectively which is in accordance with the local tectonics of the region. On the basis of Landsat Imagery, and seismotectonic analysis, a possibility of a thrust fault is also derived which passes near a small town Kalial where this earthquake occurred can be named as Kalial Thrust.*

## INTRODUCTION

A moderate earthquake of Local Magnitude 5.0 occurred in the morning of March 10, 2006 at 07:50 GMT. This earthquake shook the city of Mirpur and Mangla with intensity VII on MMI (Modified Mercalli Intensity) scale (Fig.1). Seismic intensity at Pindori,15 km almost west of the source near Mangla was VI. It was felt at Bhimbar, Kharian and Gujar Khan with intensity V. The earthquake was located at 33.10º N and 73.76º E at a focal depth of 10 km in the area of Azad Jammu and Kashmir near Mangla Lake in Mirpur District. It was followed by two aftershocks of Local Magnitude 4.0 and 3.0 respectively. The source lies in the area of Mangla Anticline near the town of Mangla. The populated city in the area is Mirpur. This city being on the hanging wall was most affected. One person was killed and 22 injured in the city. It was felt from Peshawar to Lahore. Fault plane solution of this earthquake was determined on the basis of P-wave polarity data by AZMTAK and PMAN (Suetsugu 1997).

## LOCATION PARAMETERS

Micro Seismic Studies Programme (MSSP), an establishment of Pakistan Atomic Energy Commission is operating a seismic network of 25 stations in Pakistan. To get the better coverage for the location of this earthquake, the data of a few nearby global stations was also used. Computer software SEISAN (Havskov, J. and Ottemoller L. 2001) gave the following hypocentral parameters with the Azimuthal coverage of 288°.

| | |
|---|---|
| Origin Time | 07:50:12.94 |
| Latitude | 33.10° ± 4.7km |
| Longitude | 73.76° ± 5.7km |
| Depth | 10km ± 4.3km |
| Magnitude, $M_L$ | 5.0, ($m_b$ = 4.9 as reported by USGS) |

The result of location was good showing reasonably small errors in longitude, latitude and depth as it is evident from the error ellipse (Fig.2).

## REGIONAL GEOLOGY

The study area where earthquake occurred is surrounded by the region of low hills composed of Siwalik group of rocks. Material accumulated in the Gangetic geosynclines, where the rate of subsidence kept pace with the rate of deposition until about 20000 feet of material was deposited. The axis of this geosyncline was more northerly than that of geosyncline in which the rivers of the Indus-Ganges plain are depositing their sediments today. The most recent uplifts folded the Siwalik deposits and, to a lesser degree, displaced these along thrust faults. This probably occurred in the middle of the Pliocene Epoch and may be continuing on a lesser scale today. The area is seismically unstable and destructive earthquakes occur from time to time. The great system of thrust faults has, in the past, been considered as a single fault known as the Main Boundary Thrust (MBT). One branch of this major fault, the Bhimbar thrust (Fig. 3), passes at the distance of about 30 km from Mangla Dam whereas on the other hand, eastern termination of Salt Range Thrust lies in the south of Mangla Dam at the distance of 15 km.

## SEISMOTECTONIC ANALYSIS

The earthquake was occurred due to the movement of the fault passing near the town of Kalial. The pre-earthquake satellite imagery and digital elevation model analysis show that the fault existed previously but was not properly investigated. However the surface trace of this fault was marked on map (Searle et. al. 1996)). The recorded instrumental seismic data did not indicate any significant seismic event generated by this fault in the last few decades.

The earthquake area is an active seismic zone where Jhelum Fault, Salt Range Thrust, Main Boundary Thrust (MBT) and Kashmir Thrust are some pronounced seismogenic sources (Kazmi and Jan 1997, Ali et. al. 2008). The analysis of recorded seismic data shows that the area is dominated by low to moderate frequent seismicity at shallow depths (<33 km) Fig. 4 and Fig.5. The significant earthquakes occurring in the surrounding region in the near past are the Pattan earthquake ($m_b$=6.0) of Dec. 28, 1974 (Wayne et. al. 1979), Astor Valley earthquake ($m_b$=6.2) of Nov. 1, 2002 (Mahmood et. al. 2002), Kaghan Valley earthquake ($M_L$=5.6) of Feb, 14, 2004 (Khan et. al. 2004) and Muzaffarabad earthquake ($M_L$=7.0) of Oct. 8, 2005 (Qaisar et. al. 2007).

The Landsat ETM imagery, SRTM Digital Elevation Model (DEM), GPS, GIS and remote sensing alongwith source parameters were utilized in spatial analysis to understand and mark surface features of the earthquake causative fault. The focal mechanism solution as determined predominantly thrust, striking northwest and dipping northeast, with a slight

strike slip component (Fig. 6) coincides well with the slip nature of the fault and also supported by surface evidences marked through spatial analysis of the area. As the fault passes near the town of Kalial, the fault may be named as Kalial_thrust fault. The epicentral location was also supported by the intensity survey as maximum intensity was found near Kalial, District Mirpur. The seismic data of the main shock and aftershocks indicated that tectonic movements concentrated on part of Kalial Thrust at shallow depths. The projected surface trace length of the Kalial Thrust is estimated to be about 23 km.

## FAULT PLANE SOLUTION

Fault plane solution of the earthquake on the basis of P-wave polarity data was obtained. The solution was derived using computer codes AZMTAK (Suetsugu, 1997) to calculate the azimuth and take off angle for the seismic stations used in the solution and PMAN (Suetsugu, 1997) to draw the nodal planes on the focal sphere as shown in Fig. 6. The earthquake followed by the two significant aftershocks having Local Magnitude 4.0 and 3.0 respectively. The clear P-wave polarity data of local network along with the seven global seismic stations for the main shock were sufficient to draw the nodal planes, but the aftershock's P-wave polarity data played an additional role in controlling the fault planes. Out of 43 data points used in the composite fault plane solution, 38 were consistent and only 5 remained inconsistent. Thus we got a well-controlled composite fault plane solution of the earthquake. The East-West oriented fault plane dipping towards north gave strike 293°, dip 20° and rake 117°. The fault plane solution clearly shows that the nature of the source is low angle thrusting. The Centroid Moment Tensor (CMT) solution given by the Havard university is in agreement with the solution obtained in this study.

## INTENSITY DISTRIBUTION

A team of MSSP scientists and engineers made the intensity survey of the area affected by the earthquake to understand the mechanism of earthquake and its impacts on civil structure. The survey was based on the effects on land, houses and other buildings through the observations of the people living in the affected area and geology of the area through published maps. The maximum intensity VII on MMI scale occurred near the Mangla in Mirpur district where one person was killed and 22 were injured. The intensity decreased sharply in north south direction as is evident from the contour elongated in the WNW-ESE direction (Fig. 1).

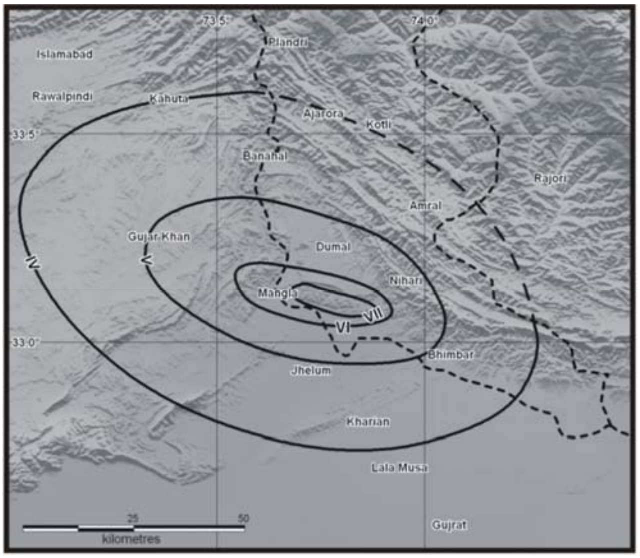



**Fig. 1.** .Isoseismals of the Mangla Earthquake of March 10, 2006

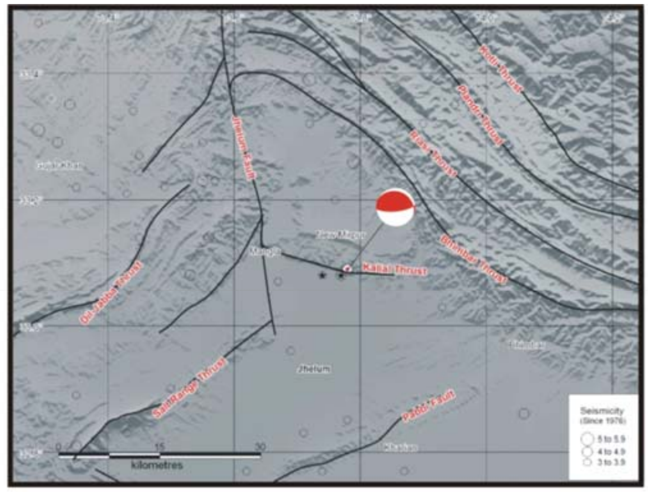



**Fig. 3** Seismicity of Mangla region since 1976 in the light of local tectonics
(Dot shows main shock and stars aftershocks of Mangla earthquake)

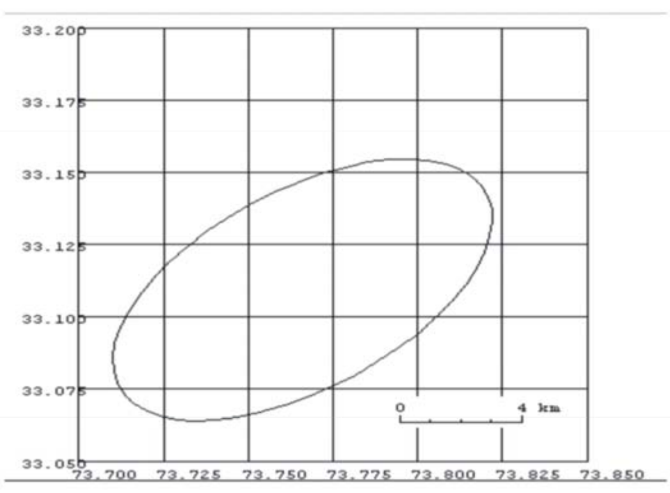



**Fig. 2.** Error ellipse showing the hypocentral parameters

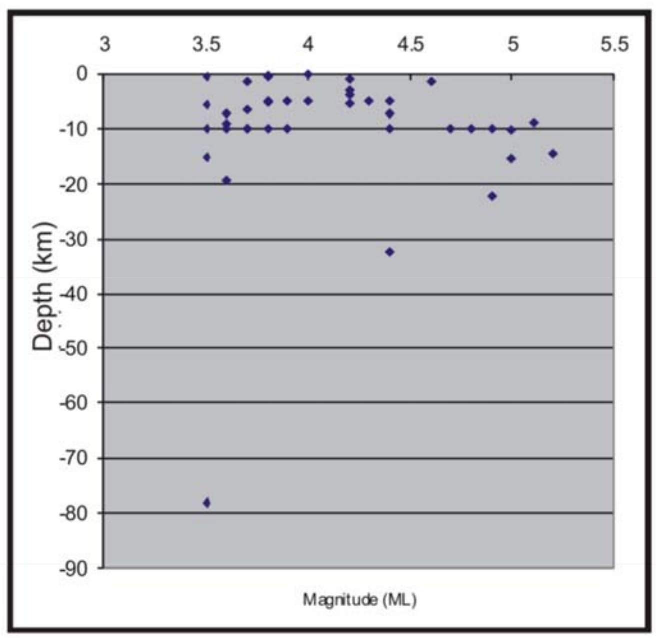
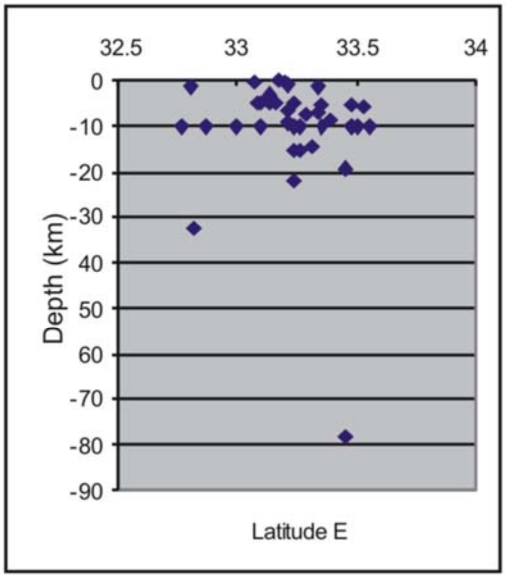



**Fig. 4.** Depth-Magnitude comparison of the seismicity of Mangla region since 1976



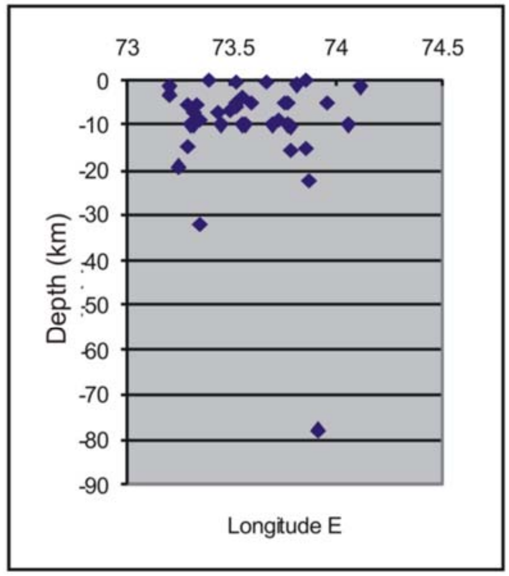




**Fig. 5.** Variation of Focal depth (km) with Latitude and Longitude

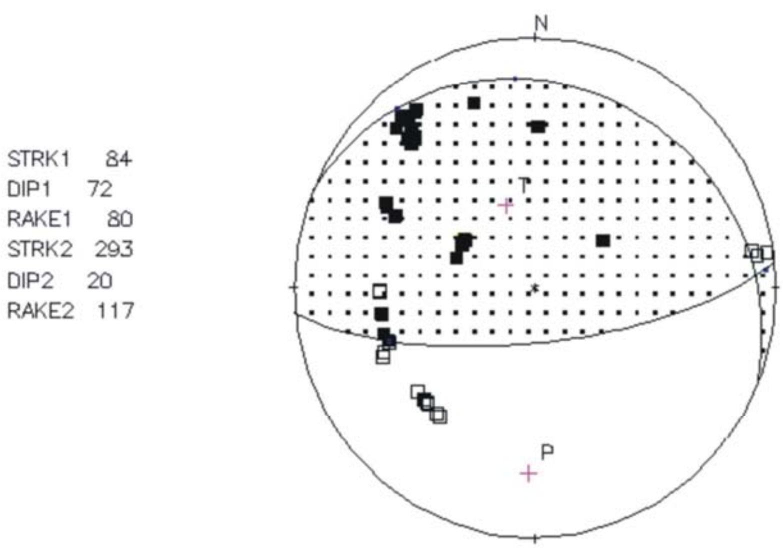



**Fig. 6.** Fault plane solution of Mangla earthquake

Following is the intensity felt in some well known places in the affected area.

**Mangla**

Mangla is a well known town in Mirpur district due to Mangla Lake almost 12 km west of the epicenter. That is why the earthquake was named as the Mangla Earthquake. The population of Mangla is more than 3000. The intensive shaking was felt indoor and outdoor. The moderate damage to mud-stone masonry structure and partial damage to concrete structure was seen. The observed intensity was estimated as VII on MMI scale.

**Mirpur**

It is a well populated city in the earthquake affected area having more than 371000 people living in it. It lies about 10 km NW of the epicenter of the main shock on the hanging wall of the fault plane. Being a populated city, each type of civil structure including very loose masonry structure exists in the city, therefore, it faced severe damage to loose structure and few cracks were seen in concrete structure. It was difficult to stand on the ground due to shaking. The overall observed intensity was same as felt at Mangla, that is VII on MMI scale.

**Gujar Khan**

It is a densely populated city situated about 48 km WNW of the earthquake epicenter. The population is more than 70,000.There is no damage to civil structure, but many people felt the earthquake even during the outdoor activities. The intensity was estimated between IV and V for Gujar Khan.

**Bhimber**

Bhimber is a small city, about 29 km ESE of the source with a population of 5500. All types of the civil structure were shook considerably but no damaged was seen in the city. The observed intensity was about IV to V on MMI scale in the city.

**Jhelum**

Jhelum is an old city which lies almost 18 km south of the epicenter having more than 30,000 populations. The Jhelum is nearer to the source than Gujar Khan and Bhimber, but the earthquake was felt just indoors and household goods like crockery clashes in some houses. It shows that intensity decreases very sharply in north south direction, and hence the observed intensity at Jhelum was IV on MMI scale.

The intensity in some other cities and towns had also been observed and is shown in Fig. 1.

## CONCLUSION

An attempt is made to determine the source parameters along with nature of causative fault where the earthquake occurred. The location parameters of the earthquake were found with 288$^o$ coverage of seismic stations. The errors found in latitude, longitude and depth were ± 4.7, ± 5.7 and ± 4.3 km respectively which shows very small uncertainty in location. This earthquake is followed by the two aftershocks along with the spread of seismicity (Fig. 3) which shows that there is a reasonable concentration of the earthquakes in the vicinity of the current event. A well controlled fault plane solution of the earthquake shows that the nature of the causative fault is low angle thrusting with a very small strike-slip component which is in accordance with the structural trend in the area. On the basis of the above facts and that the large earthquakes are always associated with some fault, indicating the presence of subsurface low angle thrust fault near the town of Kalial may be named as Kalial Thrust fault.

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