Technical Note

Would it Have Been Possible to Predict October 08, 2005 Kashmir Earthquake? Possibility of Another Earthquake in Himalayas

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ABSTRACT

Earthquake predictability has been the topic of debate within the seismological community. The interest in the topic is understandable, since it stems both from our present inability to predict earthquakes and from the potentially great value that prediction could have for society. Our difficulty in predicting earthquakes is partly due to the inherent characteristics of earthquakes and partly to an incomplete understanding of the earthquake process. Recent investigations have shown that any forecast for an individual earthquake is a test of the validity of a model casual link between some kind of precursor(s) and the focal parameters of a forthcoming earthquake. Recent seismological studies have indicated that in most cases the earthquake recurrence interval and the size of the preceding event are positively correlated. The Kashmir earthquake (also known as the Northern Pakistan earthquake or South Asia earthquake), of M_w 7.5 having a focal depth of 26 km below the surface was a major seismological disturbance that occurred at 08:50:38 Pakistan Standard Time (03:50:38 UTC, 09:20:38 India Standard Time) on October 8, 2005 with an epicenter (34°29′35″N and 73°37′44″E) about 19 km neartheast of Mujaffarabad in the Pakistan–administered region of the disputed territory of Kashmir. Its foci lie in a well defined seismogenic source HPH–3 (Fig. 1) with estimated expected earthquake of M7.5 and occurrence probability almost equal to 1.0, evidencing that the forecast is valid.

Keywords: Earthquake prediction evaluation, seismic hazard assessment, earthquake magnitude, epicentre.

1. FORECAST IN HIMALAYAN REGION

Kashmir lies in the area where the Eurasian and Indian tectonic plates are colliding. Out of this collision, the Himalayas began uplifting 50 million years ago, and continue to rise by about 5 mm/year. This geological activity is the cause of the earthquakes in the area. The October 8, 2005 earthquake caused widespread destruction in northern Pakistan, as well as damage in Afghanistan and northern India. The worst hit areas were Pakistan–administered Kashmir, Pakistan's North–West frontier Provinces (NWFP), and western and southern parts of the Kashmir valley in the Indian–administered Kashmir. It also affected some parts of the Pakistani province of Punjab and the city of Karachi experienced a minor aftershock of magnitude 4.6.

Consideration of the temporal and spatial patterns of earthquake occurrence is an important aspect of earthquake hazard assessment and has drawn much attention. To estimate the long–term probabilities for the generation of strong earthquakes on single faults, the time predictable model seems to be more plausible (Papazachos, 1989; Papazachos and Papaioannou, 1993; Papazachos et al., 1997).

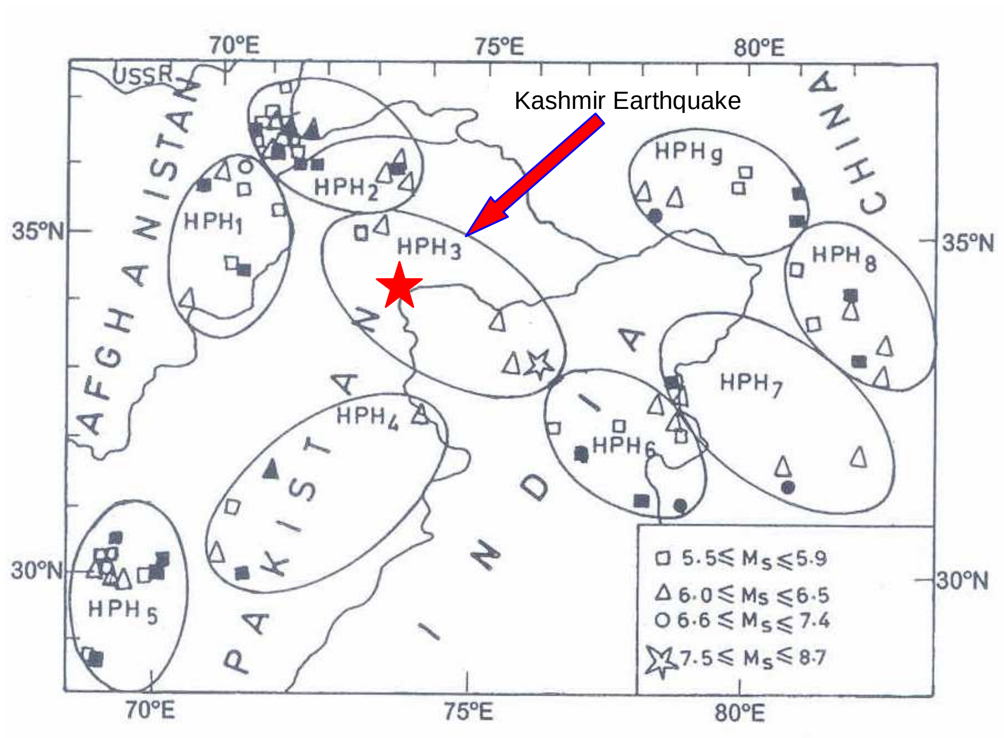

Fig.1 - Earthquake epicenters with $M_s \geq 5.5$ for the period 1905–1999. The Nine seismogenic sources are demarcated by elliptical boundaries. Filled symbols denote foreshocks/aftershocks (Shanker and Papadimitriou, 2004)

The inter–arrival times of the strong shallow main shocks in nine seismogenic sources in the Hindukush–Pamir–Himalayan region have been determined (*Shanker and Papadimitriou, 2001; Shanker and Papadimitriou, 2004*). The rupture zones of the largest earthquake occurring in each seismogenic source delineate segmentation of the area as shown in (Fig. 1).

The following relations have been determined:

$$\log T_t = 0.19\,M_{min} + 0.52\,M_p + 0.29\log m_o - 10.63 \quad (1)$$

$$M_f = 1.31 M_{min} - 0.60\,M_p - 0.72\log m_o + 21.01 \quad (2)$$

Where, T_t is the inter-event time, measured in years; M_{min} the magnitude of the smallest main shock considered; M_p the magnitude of preceding main shock, M_f the magnitude of the following main shock and m_o the moment rate in each source per year.

The estimation of conditional probabilities and the magnitude of the expected event for the occurrence of the next large ($M_s \geq 6.0$) shallow main shocks during the next 10 years were based on the time and magnitude predictable model for the Hindukush–Pamir– Himalayan region expressed by the above both relations.

Table 1 - Expected magnitude, M_f and the corresponding probabilities, P_{20}, for the occurrence of large ($M_{min} \geq 5.5$) shallow main shocks during period 2000–2020 in the considered region

Seismogenic source	Source Name	$M_f \pm 0.36$	P_{20} (log–normal)
1	HPH_1	7.4	0.68
2	HPH_2	7.5	0.42
3	HPH_3	7.5	1.00
4	HPH_4	6.9	1.00
5	HPH_5	8.6	0.00
6	HPH_6	8.4	0.10
7	HPH_7	7.1	0.99
8	HPH_8	7.7	1.00
9	HPH_9	8.5	0.04

Out of nine seismogenic sources (Table 1) the HPH–3**,** HPH–4, HPH–7 and HPH–8 showed certain hazard in the near future. This will allow for making decisions that are adequate to the hazard data and reduce the seismic risk for the considered region.

The entire exercise shows that time predictable model seems to be more realistic tool for the Hindukush–Pamir–Himalayan region (*Shanker, 2004)* and can be employed for long–range earthquake prediction when better quality seismological datasets covering a wide range of magnitudes are available. Although there are some uncertainties involved in the methodology followed in the present study, the occurrence of Kashmir earthquake of 8th October, 2005 in the delineated zone and expected magnitude evidencing that the forecast is valid. If whole delineated zone has been targeted for continuous monitoring through large number of seismological network, then it would have been possible to forecast the time of impending earthquake (8th October, 2005) too.

Based on GPS measurement Bilham and Wallace, (2005) reported that Great Himalayas and Uttaranchal state in India is under threat of mega earthquake equivalent to 8.4-8.6 magnitude. However, estimates of Shanker et al. (2006 b), based on previous success analogy, indicate future earthquake in the Himalayas would be below 7.0

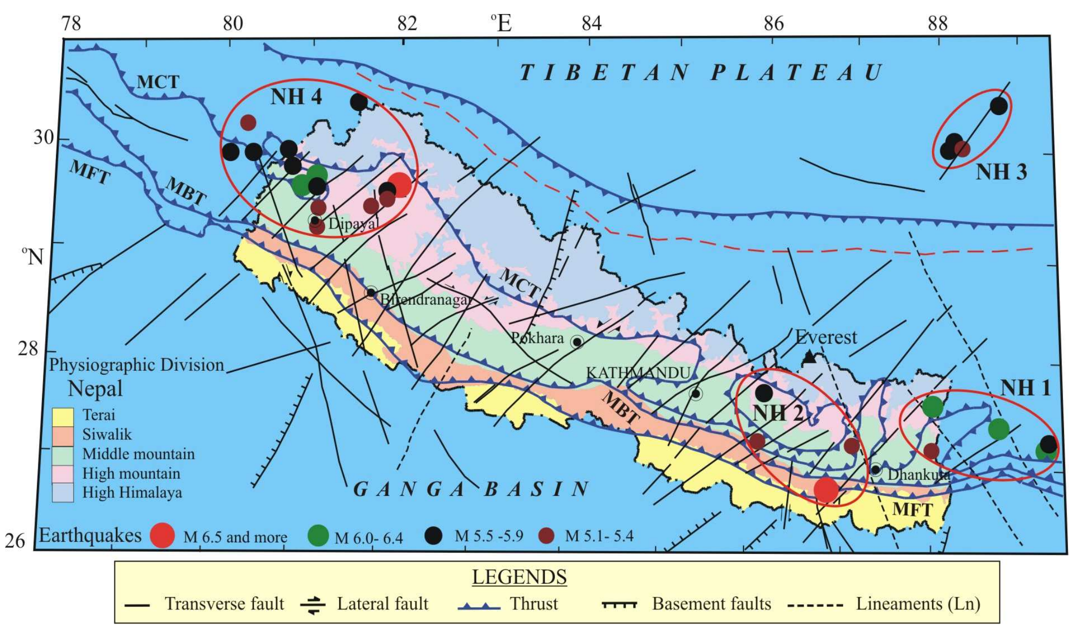

Fig. 2 – Delineated potential seismogenic sources in Himalayas

magnitude compared to the estimated magnitude by Bilham and his collaborator. The two delineated probable seismogenic sources in Nepal Himalayas (NH_2) and NH_4 show probability of occurrence of future earthquake magnitude 6.9 and 6.4 (Shanker et al., 2006 a), respectively, in the next 30 years (2006-2035). The Zone NH_4 falls between the seismic gap of 1934 Bihar-Nepal and 1905 Kangra earthquakes (Fig. 2).

The notions that slow tectonic deformation might precede significant earthquakes, and be detectable by seismic instrumentation. This still remains, in our opinion, the most likely form of an earthquake preparation phase. Progress, however, has been slow in evaluating this model and more generally in understanding the deformational context of earthquake occurrence. It is the knowledge of this deformational environment that we believe will fill a major gap in our understanding of earthquake generation process. In the broadest sense, plate tectonic theory has provided us with the underlying cause of most earthquakes, as due to the relative motion of plates along their boundaries.

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