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Spatial and Temporal Variation of Seismic activity in Western Nepal

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Abstract

The central Himalaya, including Nepal and its adjoining region, is a seismically active region, and is seismically catagorized in to three zones. One of this zone is the western region of Nepal. This study examine the spatial and temporal variation of seismicity in Western Nepal, provides how the activity was changing during the period 1964-2008. Using earthquake data from NEIC and ISC catalogs, a comprehensive data set is prepared for the study period. This analysis focus on the spatial, temporal, and depth-wise distribution of earthquakes in the region. The clustering pattern of the shallow and intermediate events extending beyond 70 km focal depth in the western part of the central himalayan thrusts signify a high crustal thickness.

Keywords: Earthquake patterns, Central Himalaya, Seismic activity, Spatial variation, Temporal variation

Introduction

The sudden and temporary vibration which is set up on the surface of earth is known as earthquake. It is due to the fracture of a weak zone inside the Earth's crust. From the source, energy is propagated out by the seismic waves, during earthquake. Inside the earth's surface, the point where seismic waves originated, is known as the focus. On the surface of the earth, the point directly above the focus is called the epicenter [1].

In the Himalayan part of region, seismic activity is reflected, by earthquake frequency of varying magnitudes since the historical past [2-4]. In this region, the cause of earthquakes is due to the high stress build-up resulting from the convergence of Indian and Eurasian plates. A comprehensive earthquake catalogue which covers broad range of magnitude and is necessary to understand the features of seismic activity. In Nepal there is lack of such types of database for historical earthquakes. Located in one of the most seismically active regions, Nepal has considerable seismic risk [10].

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The Himalayas are believed to have formed due to the collision between the Indian and Eurasian tectonic plates [5, 6]. As the region has highly seismic risk, future earthquakes may result in great loss of life and property [7,9]. Understanding seismic activity is therefore crucial for assessing the current status of geodynamic phenomena in the region and this study can be of high interest.

Earthquake data

In this study, Western Nepal and its nearby region ($80.0^{o}E \leq$ Longitude $\leq 82.5^{o}E$; $26.0^{o}N \leq$ Latitude $\leq 31.0^{o}E$) for the period 1964-2008 is assumed for detail investigation on spatial and temporal approaches of seismicity by using updated seismicity database from NEIC and ISC catalogs.

Table 1: Yearly list of all earthquakes occurred in the time 1964 to 2008 which is occurred in Nepal in Central Himalayan arc. Number of events without magnitude, the maximum magnitude of the earthquake at that particular year and its focal depth are also tabulated [8,].

Year	Total number of events	Events without magnitude	Maximum magnitude (M_{max})	Focal depth of M_{max}
1964	9	1	6.2	50 km
1965	5	0	6.1	23
1966	16	1	6	0
1967	4	0	5.2	42
1968	3	0	5.1	27
1969	3	0	5.2	63
1970	3	0	5.4	44
1971	4	0	5.4	16
1972	5	0	5.3	33
1973	3	0	5.2	33
1974	7	0	5.7	33
1975	10	0	5.4	33
1976	4	0	5.2	33
1977	5	2	5	23
1978	9	1	5.2	33
1979	5	0	5.9	33
1980	28	0	6.2	33
1981	4	0	5.1	33
1982	7	0	5.1	33
1983	4	0	4.8	33
1985	12	0	4.9	33
1986	10	2	5.4	54.6
1987	11	2	5.6	47.5

1988	71	46	6.6	57.4
1989	10	5	5	34
1990	24	10	5.5	79
1991	13	5	5.6	29.4
1992	8	1	5.2	56.3
1993	18	0	5.8	12.2
1994	10	0	5	29.2
1995	37	5	4.9	61.1
1996	82	5	5.7	33
1997	44	15	5.6	33
1998	81	11	5.9	33
1999	15	1	5.2	40.2
2000	21	6	4.8	33
2001	30	8	5.5	33
2002	66	19	5.6	33
2003	51	24	5.1	12.2
2004	57	17	6.2	13
2005	68	1	6.3	11
2006	30	1	5.3	30
2007	26	4	5	35
2008	191	26	6.7	12

The final database contains number of earthquakes 1141. This data contains 524, 109 and 20 number of events having range of magnitude 4.1- 4.9, 5.0 - 5.4, 5.5 - 5.9 respectively, whereas the rests 216 events have no magnitude. Therefore, total number of events (665) occurred in the region with cutoff magnitude m_b= 4.1 in the period 1964-2008.

Theory

The estimation of b-value is used for empirical relation between the magnitudes, and the frequency of earthquake occurrence, given by [3]

$$\text{Log } N = a - b\,M$$

In this relation *N* denotes number of the earthquakes of magnitude *M,* or greater than *M* per unit time, the constants a and b represents character of seismic activity.

By using seismic data during the period 1964-2008, the relationship for the Himalayan region of Nepal, as depicted in Fig. 1.

$$\text{Log N} = 7.29 - 1.05\ \text{M with } R^2 = 0.99.$$

The fitting of curve is best for the data having magnitude 4.1 and above, for the field study area, which represents the cut-off magnitude 4.1, and the estimated b – value is 1.05.

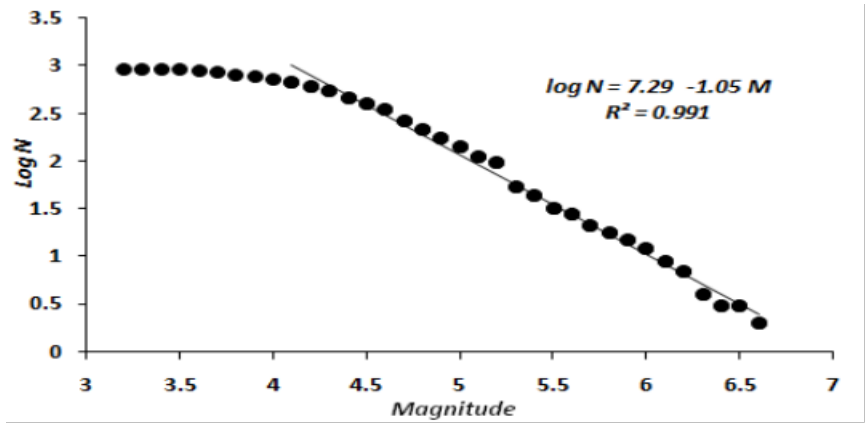

Figure 1: Estimation of b-value for the Central Himalayan region by using earthquake data from 1964-2008

The 665 events occurred in the region with cut-off magnitude m_b= 4.1 in the period 1964-2008. Rest events 476 lies in the catalog of incomplete part. In this study, the events $m_b \geq 4.1$ have been analyzed in the spatial pattern of seismicity.

Data Analysis

In detail, the seismic activity is studied, and this area is divided into three different parts which is based on the spatial distribution of events from 1964 - 2008. These three different parts are Regions A, B and C.

A is the Western Nepal (80.0°E ≤ Longitude ≤ 82.5°E; 26.0°N ≤ Latitude ≤ 31.0°E)

B is Central Nepal (82.5 °E ≤ Longitude ≤ 85.5°E; 26.0°N ≤ Latitude ≤ 31.0°E) and

C is Eastern Nepal (85.5°E ≤ Longitude ≤ 89.0°E; 26.0°N ≤ Latitude ≤ 31.0°E)

Seismic characters which is based on earthquakes frequency in three delineated regions for the events $m_b \geq 4.1$ is depicted in Table 2.

Table 2: Frequency of earthquakes occurred from 1964-2008 in three regions with respect to various magnitude.

Delineated Regions	Number of earthquakes			
	$m_b \geq 4.1$	$m_b \geq 5.0$	$m_b \geq 5.5$	$m_b \geq 6.0$
Central Himalaya	665	141	32	12
Region A	186	53	13	4
Region B	165	32	7	4
Region C	314	56	12	4

Western Nepal (i.e. region A) delineated by 80.0°E ≤ longitude ≤ 82.5°E; 26.0°N ≤ latitude ≤ 31.0°E. Since 1964 to 2008, there is occurance of 273 which include 68% (186 events) with $m_b \geq$ 4.1; 19% (53 events) with $m_b \geq 5$, 13 events with $m_b \geq 5.5$ and 4 events with $m_b \geq 6.0$.

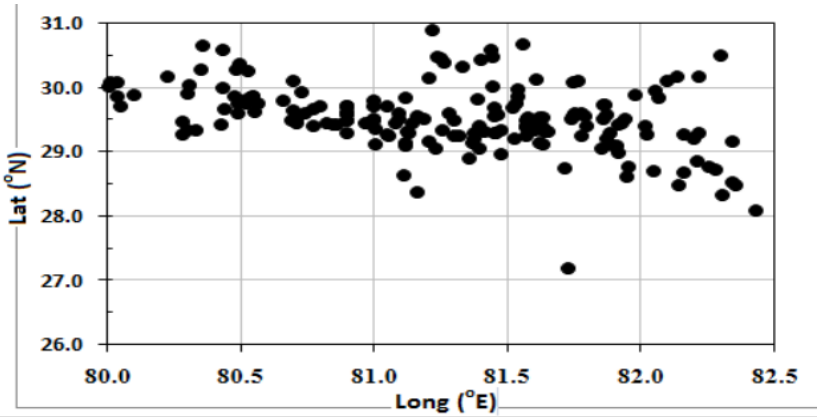

Figure 2: Spatial earthquake distribution in Western Nepal from 1964 to 2008 ($m_b \geq 4.1$).

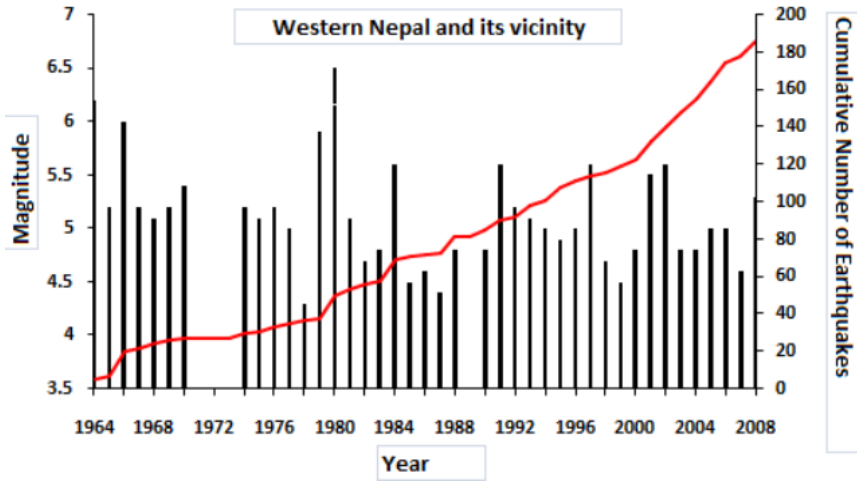

Figure 3: Temporal pattern of earthquakes in Western Nepal from 1964 to 2008 ($m_b \geq 4.1$).

The spatial and temporal distributions of all the earthquakes during this period for Western Nepal are shown in Figure 2 and Figure 3 respectively. The majority of events that are shallow and intermediate are located between the MCT and the MBT. Four earthquakes (m_b □ 6) have occurred during 1964 to 2008 in Western Nepal. In 1980 Bajhang earthquake caused several destructive effects. The corresponding statistical data of the occurrences of earthquake are furnished in Table 2. Seismic activity in Western part around 80° E, seems to be associated with the MCT. The area bounded by 29°-30° N, shows various clusters of events, that are related with the transverse faults.

Earthquakes with the temporal variation in the western region is given in Figure 3. A general, mild seismicity rate increase, in high and low pattern, whereas sharp increase rate, is evident till 2008 after the 1980 Bajhang earthquake. The fluctuation of seismicity in high and low pattern prior to 1973, followed by slow increasing pattern, till 1977 before the Bajhang earthquake. It has been observed that, there is no sudden jump, in cumulative number of earthquakes curve.

In order to investigate the general nature of the earthquake distribution pattern with depth in the Central Himalayan region, the existing data from 1963-2008 has been analyzed in the present study, even though the earthquake catalogues are associated with some obvious limitation in the depth estimation. However, Seeber et al. [6] determined, the focal depths accurately, of a few medium sized thrust earthquakes and indicated that, there is occurrence of earthquakes within a depth range from (10 - 20) km in the Himalayan thrust belt.

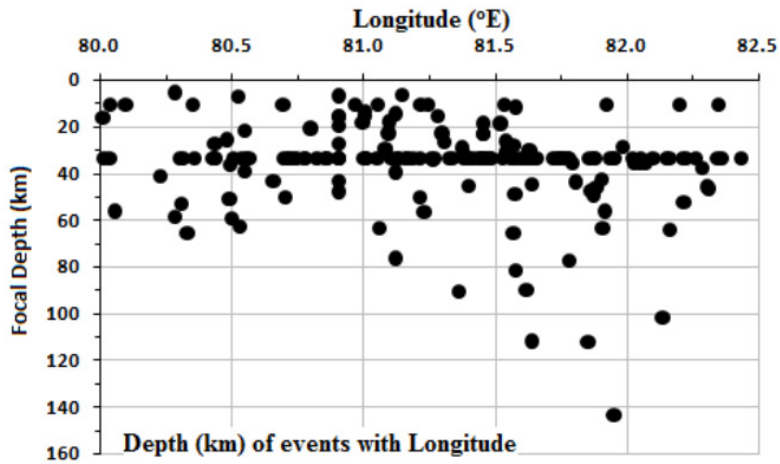

Figure 4: Focal depth (in km) of earthquakes with longitudes in Western Nepal from 1964 to 2008 ($m_b \geq 4.1$).

In the Western Nepal, few depth of intermediate events lie between the MBT and the MCT. The orientation of earthquakes extends in NW-SE direction. In a region (81°-82.5°E), medium size events are located up to 60 km focal depth, which signifies that, there is a large crustal thickness having highly brittle character of the rock strata. Figure 4 and Figure 5 show the variation of depth of focus with longitude and latitude respectively.

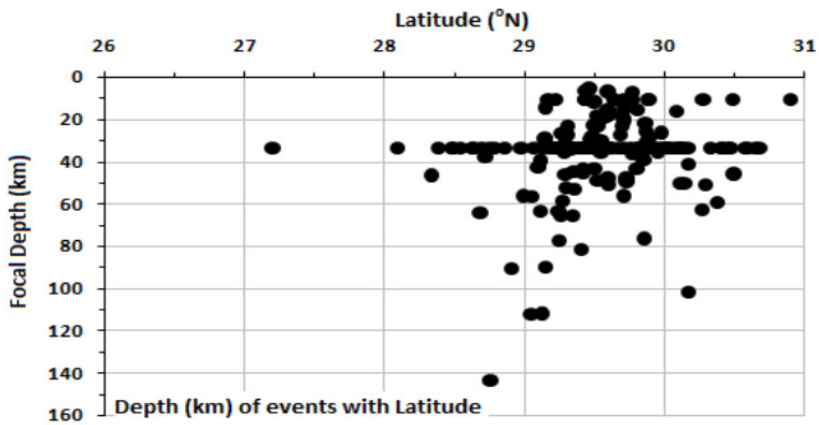

Figure 5: Focal depth (in km) of earthquakes with latitudes in Western Nepal from 1964 to 2008 ($m_b \geq 4.1$).

In Figure 5, approximately 95% of the total events are shallow (0-70 km) whereas about 22% events are found to occur, in the depth range of 40-80 km. There is uniform distribution of events up to depth 40 km, and deeper events are located between 81.5°E to 82°E. There is highly fractured zone which seems to lie between 29°N to 30°N where its activity goes downwards up to the depth about 80 km. Few intermediate events only occurred, which shows no any correlation between them.

Conclusions

Nepal and its adjoining region represent a seismically complex region that has been segmented into three regions. One of these is western Nepal region. In general, the seismicity rate exhibits a fluctuating high -and-low pattern,with a sharp increase observed until 2008, particularly after the 1980 Bajhang earthquake. In the region (81°-82.5°E), the location of medium-sized events are up to focal depths of 60 km. Approximately 95% of the total seismic events are shallow (0-70 km), while about 22% events occur within the depth range of 40-80 km. The highly fractured zone seems to lie between 29°N to 30°N and its activity goes downwards up to the depth about 80 km.

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