Seismicity in Jammu and Kashmir Region with Special Reference to Kishtwar

Sandeep Sharma[*], Arjun Kumar[**], Vandana Ghangas[**]

[*]Chenab Valley Power Projects Jammu-180006
[**]Indian Institute of Technology, Roorkee-247667

Abstract- The present study involves study of more than 60 earthquake events that took place in the state of Jammu and Kashmir from which it was illustrated that most of the earthquakes were taken place in between and around the main boundary thrust and Main Central Thrust. Further it was seen that a Northwest and Southeast trending pattern will developed almost parallel to the Main Boundary Thrust and Main Central Thrust which indicates that further study is required in the concerned area to trace the faults and thrusts in this region. The epicentre of these earthquakes lies in between 32^0N-37^0N, and 72^0E-80^0E and the Richter scale magnitude of these Earthquake lies in between 2 to 6. The depth of these earthquakes varies from 5km to 100km. The former observations indicate that the entire region is tectonically active and continuous build up stress along these thrusts and faults has been released from time to time. It was further seemed that majority of earthquakes take place around Kupwara, district of Srinagar and Kishtwar and Doda district of Jammu.

Index Terms- Seismicity, Main Boundary Thrust, Main Central Thrust, Epicentre.

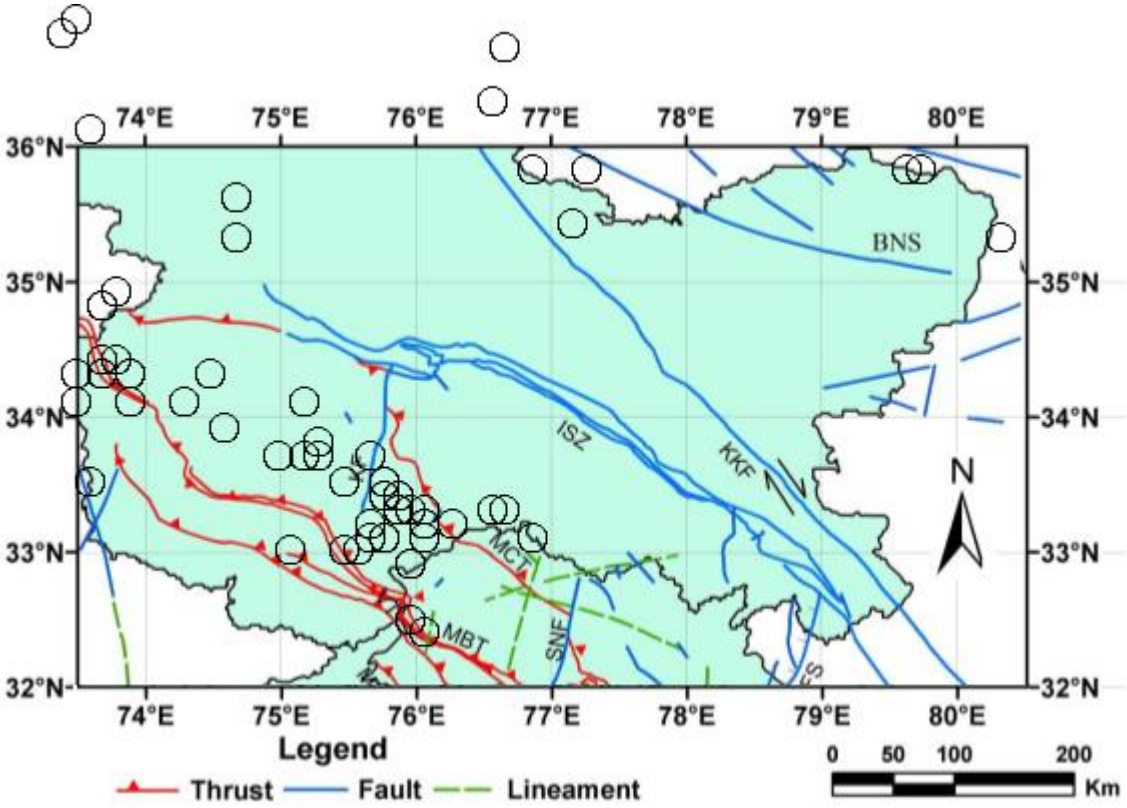
I. INTRODUCTION

The Himalaya originated due to continental collision between the Indian and the Eurasian plates that took place during the Late Cretaceous to Early Eocene times (Searle *et al.*, 1987, Le Fort, 1989, Searle, 1991, Thakur, 1992). This orogenic process continues even in present times, as is indicated by significant small and moderate earthquakes and neotectonic movements along several thrusts and faults in the region (*Valdiya 1998, 2001*). The active tectonics along faults provides direct evidence of continued tectonic movements. The Indian and Asian continental plates collided some 50 Million years ago (*Le Fort*, 1975) resulting in lithosphere deformation and modification of the seismotectonic setup of the region. The Himalayan zone is divided into three seismic gaps – Kashmir gap, Central gap and Assam gap. The Jammu and Kashmir, Himachal Pradesh and Uttrakhand falls under Kashmir gap which is the highest earthquake prone seismic zone.

Among the most notable are the Northwest Kashmir earthquake of 2005 (Mw 7.6); 2002 (Mw 6.4), Pattan earthquake of 1974 (Mw 7.4), Kangra earthquake of 1905 (Mw 7.8), 1885 Magnitude 7.5, 1842 Magnitude 7.5 Kashmir valley earthquake, 1505 Magnitude 7.6 earthquake of Kashmir, 1555 magnitude more than 8 , etc. According to the seismic zonation map, the region under study falls in seismic zones IV and V. A recent seismic hazard analysis of Northwest Himalayan region has categorized Jammu region under high hazard zone (*Mahajan* et al., 2007). The entire study area is flanked by a number of faults and thrusts some of them being considered very active (e. g., Main Boundary Thrust (MBT) and Murree thrust). Most of the earthquakes are generated by the fault movements (Bolt 1999) and in Jammu and Kashmir region there are parallel faults trending north west to south east.

II. REGIONAL SETTING

The map of Jammu and Kashmir earthquake epicentres (Figure 1) shows earthquakes from January 2006 to August 2013 with magnitudes of 2.0 and more on the Richter scale (Table 1). Events of magnitude 4.0 or more are capable of causing damage to buildings. Jammu and Kashmir lies within a broad NW-SE trending belt of epicentres. The largest events recorded in this zone were of Richter magnitude 7.6, the epicentre of which was in North Kashmir. Small earthquakes occur at a continuous rate in this region as a result of which the entire region is marked as very high damage risk zone V (MSK IX or more) and high damage risk zone IV (MSK-VIII).



MCT	Main Central Thrust	KKF	Karakoram Fault
MBT	Main Boundary Thrust	KFS	Kauric Fault System
KF	Kishtwar Fault	ISZ	Indus Suture Zone
BNS	Bangong-Nujiang Suture	SNF	Sunder Nagar Fault

Figure 1 Map showing earthquakes occurred in Jammu and Kashmir region from January2006 to August 2013 (Figure modified after Patil, 2012).

III. SEISMOTECTONIC SETUP OF THE REGION

Four major lithotectonic-physiographic belts of Himalaya have distinct tectonic, architecture, lithostratigraphic and evolution history, and episode of magmatism and metamorphism. The southern range of outer Himalaya (Siwalik belt) exhibits rugged youthful topography composed of molasses sediments. This belt is separated in the north from the Lesser Himalaya by Main Boundary Thrust (MBT) and from the plains to the south by Himalayan Frontal Fault (HFF). The lesser Himalayan domain is separated from the Great Himalaya by Main Central Thrust (MCT). To the north of Great Himalaya, stretches a vast sedimentary realm of Tethys Himalaya. The evolutionary model of Himalaya (Le Fort, 1975) reveals that Main Boundary Thrust (MBT) represents a younger tectonic activity as compared to Main Central Thrust (MCT), and is more active currently. However, both Main Boundary Thrust (MBT) and Main Central Thrust (MCT) have been considered as the contemporaneous features in the steady-state model of Seeber and Armbruster (1981) and these merge with each other at depth with a common detachment surface. The majority of earthquakes in NW Himalaya are concentrated in the zone between Main Boundary Thrust (MBT) and Main Central Thrust (MCT) of shallow focal depth and great Himalayan earthquake originate at the surface of detachment, which represents the upper surface of the under thrusting Indian plate with apparent northward dip of about 15^0 (Ni and Barazangi, 1984). Many of these faults, e.g. Murree Thrust have produced (and are capable of producing) earthquakes of magnitude 8.0 or greater, which have been responsible for the initiation of neotectonic movements in the past.

The seismotectonic investigation has been carried out by many workers (Seeber and Armbruster 1981; Ni and Barazangi 1984; Thakur and Kumar 2002; Kayal 2007; Bollinger et al., 2007). To understand the ongoing pattern of Himalaya, Seeber and Armbruster (1981) proposed a steady state tectonic model while Ni and Barazangi (1984) formulated an evolutionary model. These models have highlighted the seismogenic discontinuities as Main Boundary Thrust (MBT), Main Central Thrust (MCT), a plane of detachment (Main Boundary Thrust (MBT) and Main Central Thrust (MCT) coincide with this plane at depth) and the basement thrust. Most of the seismicity of the

region lies between Main boundary Thrust (MBT) and Main Central Thrust (MCT) as shown in the map. The seismicity data has been taken from the IMD seismic network in India through IMD website and Department of Earthquake Engineering, Indian Institute of Technology Roorkee website www.pesmos.in (Kumar et al. 2012).

Table 1. List of Significant Earthquakes in J&K State*

S.No.	UTC Time	Hr:mm:ss	Latitude	Longitude	Depth (Km)	Magnitude
1	20060111	05:48:40	34.4N	73.7E	33.0	5.0
2	20060201	13:52:33	34.4N	73.8E	33.0	5.0
3	20060202	21:49:00	34.8N	73.7E	33.0	5.1
4	20060211	05:32:49	34.9N	73.8E	96.0	5.0
5	20060310	07:50:10	33.5N	73.6E	33.0	5.2
6	20060320	17:40:54	34.3N	73.9E	35.0	5.5
7	20060422	08:31:14	34.3N	73.7E	33.0	3.7
8	20060426	00:41:42	32.9N	76.0E	33.0	4.7
9	20060522	08:31:14	34.3N	73.7E	33.0	3.7
10	20060526	00:41:42	32.9N	76.0E	33.0	4.7
11	20070224	09:06:14	33.5N	75.8E	8.8	3.3
12	20070801	04:53:40	33.9N	74.6E	39.1	3.1
13	20071004	05:14:15	32.5N	76.0E	10.0	3.8
14	20071026	06:49:59	35.8N	76.9E	8.5	5.1
15	20071211	15:56:37	35.4N	77.2E	35.0	5.3
16	20080225	07:25:01	34.1N	74.3E	33.0	3.9
17	20080301	08:36:07	35.6N	74.7E	20.0	4.1
18	20080311	16:44:06	33.3N	76.1E	33.0	3.5
19	20080316	05:44:44	33.7N	75.3E	100.0	3.5
20	20080510	06:35:52	33.3N	76.7E	96.0	3.8
21	20080914	22:11:30	32.4N	76.1E	10.0	3.4
22	20090126	07:25:20	33.7N	75.2E	10.0	2.1
23	20090208	14:33:17	34.3N	73.5E	08.0	4.0
24	20090220	03:48:48	34.3N	73.9E	10.0	5.5
25	20090519	19:29:46	33.2N	76.1E	10.0	4.9
26	20090612	04:03:15	35.8N	77.3E	60.0	5.3
27	20100314	19:09:01	35.3N	74.7E	10.0	4.9
28	20100323	09:59:55	33.8N	75.3E	10.0	3.9
29	20100911	03:10:38	33.7N	75.7E	13.0	4.6
30	20101107	03:40:21	34.1N	73.9E	35.0	4.2
31	20110209	04:36:38	36.1N	73.6E	15.0	5.0
32	20110323	05:55:53	36.3N	76.6E	57.0	5.2
33	20110428	09:53:07	33.3N	76.6E	10.0	3.8
34	20110728	18:42:34	33.3N	76.0E	21.0	4.4
35	20110823	01:23:00	33.1N	76.9E	40.0	4.8
36	20110924	15:21:35	34.1N	75.2E	42.0	4.3
37	20110927	11:02:59	36.7N	76.7E	84.0	4.9
38	20120104	16:31:24	33.7N	75.0E	10.0	4.0
39	20120220	13:59:24	35.8N	79.7E	10.0	4.9
40	20120220	14:18:05	35.8N	79.8E	10.0	5.0
41	20120312	06:06:44	36.8N	73.4E	33.0	5.8
42	20120509	18:05:58	34.3N	74.5E	08.0	3.4
43	20120603	23:19:04	35.3N	80.4E	10.0	3.1
44	20120726	05:31:36	33.2N	76.3E	05.0	3.8
45	20120813	20:32:59	34.8N	73.7E	30.0	5.2
46	20121011	23:54:27	34.1N	73.5E	10.0	4.5

47	**20121109**	**05:49:34**	**36.9N**	**73.5E**	**10.0**	**4.3**
48	**20130430**	**09:41:52**	**33.1N**	**76.1E**	**10**	**4.1**
49	**20130501**	**06:57:12**	**33.1N**	**75.8E**	**15**	**5.8**
50	**20130501**	**08:42:43**	**33.1N**	**75.8E**	**10**	**3.7**
51	**20130501**	**09:19:49**	**33.1N**	**75.7E**	**10**	**4.6**
52	**20130503**	**01:38:15**	**33.4N**	**75.8E**	**5**	**3.7**
53	**20130505**	**04:39:38**	**33.0N**	**75.6E**	**12**	**3.5**
54	**20130514**	**19:58:24**	**33.2N**	**76.1E**	**10**	**4.4**
55	**20130514**	**20:00:07**	**33.4N**	**75.8E**	**10**	**4.8**
56	**20130514**	**21:01:42**	**33.3N**	**75.9E**	**10**	**3.8**
57	**20130515**	**12:05:41**	**33.3N**	**75.9E**	**15**	**3.8**
58	**20130711**	**19:39:49**	**33.2N**	**75.7E**	**10**	**3.9**
59	**20130722**	**09:07:19**	**33.0N**	**75.5E**	**10**	**3.7**
60	**20130730**	**18:09:13**	**33.0N**	**75.1E**	**5**	**3.8**
61	**20130802**	**02:32:50**	**33.5N**	**75.5E**	**28**	**5.4**
62	**20130802**	**21:37:40**	**33.4N**	**75.9E**	**20**	**5.2**
63	**20130802**	**22:42:05**	**33.4N**	**75.9E**	**10**	**3.7**
64	**20130803**	**09:31:04**	**33.5N**	**75.8E**	**10**	**3.3**
65	**20130805**	**13:57:47**	**33.3N**	**75.9E**	**27**	**4.4**
66	**20130814**	**07:37:34**	**33.4N**	**76.0E**	**15**	**3.3**
66	**20130818**	**23:53:27**	**33.3N**	**76.0E**	**18**	**4.6**

*Source IMD Earthquake website

IV. CONCLUSIONS

Based on the observed seismicity in Jammu and Kashmir region from January 2006 to August 2013, the following conclusions have been derived:

1. A review of the historical as well as recent earthquake activity in northern India indicates that different parts of the region are characterized by a moderate to very high level of seismic activity. It is observed that large and damaging earthquakes have occurred in the region. During the past few years many earthquakes of magnitude greater than 5 occurred. The Jammu and Kashmir has been a region of major seismic activity. Some of the largest earthquakes in India have occurred in this zone.
2. Several seismic zones have been tentatively identified on the seismicity map. Many of these are associated with known geological structures and fault zones. Others are related to unmapped subsurface structures.
3. Location of most of the earthquake epicentres lies north of Main Central Thrust and Main Boundary Thrust which shows that the movement is continued in this region and the build-up of stress was continuously reduced/released. From catalogue it is seen that most of the earthquakes occurs in Kupwara and Kishtwar district of Jammu and Kashmir which is looking more seismically prone areas. The earthquakes was continuously strike Kishtwar and Doda district of Jammu and Kashmir w.e.f. 31-04-2013 to 18-08-2013 around SNF (Sunder Nagar Fault) circumscribing Kishtwar window and it appears like that the earthquake in kisthwar is result of Sunder Nagar Fault which is getting active.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge Seismology Division, Ministry of Earth Sciences, Govt. of India Indian Metrological Department website, Prof. G.M. Bhat, Dr. Kamal, Raghvir Singh, and Rahul Verma.

REFERENCES

[1] Searle, M.P., Windley, B.F., Coward, M.P., Cooper, D.J.W., Rex, A. J., Rex, D., Tingdong, L., Xuchang, X., Jan, M.Q., Thakur, V.C. and Kumar, S., The closing of Tethys and the Tectonics of the Himalaya. Geol. Soc. Amer. Bull. 1987, 98, 678-701.

[2] Le Fort, P., Himalayas: The collided range, present knowledge of the continental arc. Amer. J. Sci., Rogers, 1975, 275, 1-14.

[3] Valdiya, K.S., Reactivation of terrane-defining boundary thrusts in central sector of the Himalaya implications. J. Curr. Sci., 2001, 81, 1418-31.

[4] Bolt, B.A., 1999. "Earthquake", 4thEdn. W.H. freeman, San Francisco.

[5] Bollinger, L., Perrier, F., Avouac, J.P., Sapkota, S., Gautam, U. and Tiwari, D.R., 2007. Seasonal Modulation of Seismicity in the Himalaya of Nepal. Geophysics. Res. Lett. 34. doi:10.1029/2006GL029192

[6] EERI, 2006. The Kashmir Earthquake of October 8, 2005. Impacts in Pakistan. Special Earthquake Report.

[7] Hussain, A., Yeats, R. S., MonaLisa, 2009. Geological and tectonic setting of the 08 October 2005 Kashmir Earthquake. Journal of Seismology, v.13, pp. 315-325.

[8] Hussain, A. and Yeats, R. S., 2006. The Balakot-Bagh Fault that Triggered the October 8, Earthquake and Other Active Faults in the Himalayan Foreland Region, Pakistan. Extended Abstracts, International Conferences on 8th October 2005 Earthquake in Pakistan: It's Implications and Hazard Mitigation, 18-19 January2006, Islamabad.

[9] Kayal, J. R., 2007. Recent Large Earthquakes in India: Seismotectonic Perspective, IAGR Memoir, v.10, 189p.

[10] Kumar, A., Mittal, H., Sachdeva, R. and Kumar, A., 2012. Indian strong motion instrumentation network. Seismological Research Letters, 83(1), 59-66.

[11] Le Fort, P., 1975. Himalayas: The collided range, present knowledge of the continental arc. Amer. J. Sci., Rogers, v. 275, pp1-14.

[12] Mahajan, A. K., Thakur, V. C. and Chauhan, Mukesh, 2007. Probabilistic Seismic Hazard Map of NW Himalayan and in adjoining area India, Communicated for Permission to be sent to Natural Hazard Journal.

[13] Ni, J. and Barazangi, M., 1984. Seismotectonics of the Himalayan Collision Zone: Geometry of Under Thrusting Indian Plate beneath the Himalaya, J. Geophys. Res. v. 89, pp1147-1163.

[14] Patil, S. L. (2012). Probabilistic Seismic Hazard Assessment of Himachal Pradesh. A dissertation (M. Tech) submitted to Indian Institute of Technology Roorkee.

[15] Searle, M. P., Windley, B. F., Coward, M. P., Cooper, D. J. W., Rex, A. J., Rex, D., Tingdong, L., Xuchang, X., Jan, M. Q., Thakur, V.C. and Kumar, S., 1987. The closing of Tethys and the Tectonics of the Himalaya: Geol. Soc. Amer. Bull. v. 98, pp678-701.

[16] Seeber, L. and Armbruster, J. G., 1981. Great Detachment Earthquakes along the Himalayan Arc and Long Forecasting in Earthquake Prediction-An International Review, v. 4, 259p, Am. Geophysics Union., Maurice Ewing Ser. Washington.

[17] Thakur, V. C. and Kumar, S., 2002. Seismotectonics of the Chamoli Earthquake of March 29, 1999 and Earthquake Hazard Assessment of Garhwal – Kumaon Region, NW Himalaya, Himalayan Geology, 23 (1-2), 113p.

[18] Valdiya, K. S., 1998. Dynamic Himalaya Hyderabad. Universities press, 178p.

[19] Valdiya, K.S., 2001. Reactivation of Terrane-Defining boundary Thrusts in central sector of the Himalaya implications. Journal Current Sciences Vol. 81, pp1418-31.

AUTHORS

First Author – Sandeep Sharma (Geologist) Chenab Valley Power Projects, Jammu (Ex-JRF in Seismology Project of DST, Ministry of Earth Sciences) in Department of Geology University of Jammu.
Second Author – Dr. Arjun Kumar, (Fellow A) Department of Earthquake Engineering Indian Institute of Technology, Roorkee.
Third Author – Vandana Ghangas, Indian Institute of Technology, Roorkee.

Correspondence Author – Sandeep Sharma, sandeepseismologyjammu@gmail.com