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Seismological Trends in Indian Subcontinent

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Abstract

Earthquakes are the most perilous natural events that leave their imprint on geological, ecological as well as socio-economic aspects, as measured on the Richter scale. Earthquakes produce due to sudden release of energy from inside the earth's crust triggered by the tectonic activities and rock masses move in relation to one another. The movement and straining of rock masses against one another developing numerous fractures or slips. These structures are designated as geologic faults. The major fault lines are associated with tectonic plates of earth crust. At present, the movement of Indian plate continues at the rate of 3.7 centimeter per year in North East direction and putting enormous pressure on the Eurasian plate. The effect of plate-tectonic forces acting in this region is to compress the part of Asia including India. The tremendous amount of stress generated within the Earth's crust, and released periodically by earthquakes along the numerous faults that shape the topography of in Indian sub continents such as in the year 1819, 1881, 1897, 1905, 1934, 1941, 1950, 2001, 2004 and 2015 some of along the plate boundaries and some are not. World's most destructive earthquakes in the history are also related to these continuing tectonic processes when the Indian and Eurasian continent collides. The present paper as an attempt, to find out the seismological trends of major earthquakes (magnitude more than or equal to 7 on Richter scale) on the basis of the nature of movement of Indian plate and also to find out the faceable zones of earthquake occurrences in near future related to Indian subcontinent.

Keywords: Earthquake, Plate movement, Stress, Earthquake magnitude, Stress release.

Introduction

Earthquake is the time-worn natural phenomena, resultant as shaking of the ground caused by the quick release of storage energy and the movement within the earth crust is a passage of seismic waves through earth's rocks.

The energy have stored in sufficient quantity in the earth surface is important and its sudden release, can produce major movement on the earth's crust. This type of energy release is called tectonic earthquakes.

When the energy is released, it moves outward as seismic waves in all directions and it shakes the ground, sometimes it can cause damage above the ground. The earthquake's magnitude is measurement of the "size," or amplitude, of the seismic waves and recorded by seismographs. The magnitude scale of set up in 1935 by an American seismologist Charles F. Richter as logarithm to base 10 of the maximum seismic wave amplitude. The seismological magnitude recorded tells us about the strength and speed of the energy traveling from the epicenter.

On the basis of the location of origin with respects to the plates, earthquakes are grouped in two types, first are interplate and second intraplate. The earthquake occurs at the boundary between two tectonic plates is called interplate earthquake and this type of earthquake account for more than 90 percent of the total seismic energy released around the world[1]. World's major topographical features such as mountains, rift valleys, mid-oceanic ridges, and ocean trenches are cause of great interplate earthquakes.

The motion in subduction boundary is causing due to plates slipping and generated most powerful interplate thrust or mega thrust earthquakes. The interplate earthquakes result in an immediate stress drop along the fault plane or deep fracture[2], that followed by period of post seismic stress restoration. This restoration occurs quickly within the first few decades following the rupture, due to tectonic movements and viscous relaxation in the lower crust. This results in a transfer of stress to the upper crust followed by a period of steady stress increasing due to tectonic loading[3].

The intraplate earthquakes occur in the interior of a tectonic plate. These earthquakes are relatively rare. The intraplate earthquakes could inflict heavy damage and quite large in magnitude and intensities, because such areas are not accustomed to earthquake and civil structures are usually not seismically retrofitted. Gujarat earthquake in 2001, the 2004 Indian Ocean earthquakes, the 1811-1812 earthquakes in New Madrid, Missouri, the 1886 earthquake in Charleston and South Carolina[4] are most common examples of interplate earthquake that done huge losses. The small and large earthquakes do occur

in some defined regions well within the plates; however, such intraplate seismic events can be explained by tectonic mechanisms, other than plate boundary motions and their associated phenomena.

The earth crust is made up of seven primary and eight secondary tectonic plates, with dozens of tertiary micro plates. The large plates move very slowly, owing to convection currents within the mantle. Due to different velocity of plates they often directly collide or move laterally along each other and creating a tectonic environment and generated frequent earthquakes. Relatively few earthquakes occur in intraplate environments; occur along the faultsplane near the plate margins.

The Indian plate is located at north eastern hemisphere. It is bounded by 4 major tectonic plates. The Eurasian plate in the north, the Australian plate in the south east, the African plate in the south west and the Arabian plate in the west. The Indian plate is moving northward relative to the Eurasian plate and collided with it, a convergent boundary is formed and the opposite side, the Indo-African boundary is divergent. The western Indo-Arabian boundary is lateral relative to each other giving rise to a transform boundary the eastern part of Indian subcontinent (Australia) is moving northward at the rate of 5.6 cm per year while the western part (India) is moving only at the rate of 3.7 cm per year due to the obstruction of the Himalayas. This differential movement has resulted in the compression of the former plate near its center of Sumatra and the division into the Indian and Australian Plates[5].

Many geoscientists have carried out geological and tectonic studies in the Himalaya and adjoining regions, to understand the earthquake in Indian plate and published their important findings by Wadia, D.N.[6], Valdiya K.S.[7-9], Dewey J.F. et. al.[10], Verma R.K.[11] and many more. Many studies have described several characteristic features and case studies of major earthquakes such as Rao Ramalingeswar et. al.[12], Biswas S.K.[13], Talwani and Rajendran[14], Kayal et. al[15], Johnston et. al.[16], Rajendran C.P.[17], Kayal J.R.[18], Kayal et al[19], Gangopadhyay A. et. al.[20], Yadav R.B.S. et.al.[21] and many more. Besides the scientist community the government and nongovernmental research institutes and organizations are also continuously doing their studies to understand the seismological trends, their characteristics and implications.

Earthquakes have varied effects, including change in topography, geologic structure, damage of man-made structures and impact on ecosystem and economic loss. Most of effects occur on earth surface, but, since most of earthquakes are actually located under the ocean bottom, severe effects are often observed along the margins of oceans in terms of tsunamis.

The prediction of earthquakes is not possible till date. The main objective of this paper is to decipher the next probable major active seismological areas in India on the basis of nature and occurrences of the past earthquakes and movement of Indian and adjoining plates.

Synthesis of Data

The many governmental and research institutes are conducting seismological studies and established earthquake observatories at various parts of country. In modern technologies the satellite are also used for study the seismological events. For the present study, the data collected for major earthquakes from Indian Meteorological department, Govt. of India, official internet web sites and other sources. The Major earthquakes occur only at or near the plate boundaries and originated only due to stress buildup by plate movements. Due to releasing of stress or adjustment of plates, major earthquakes (more than or equal to 7) occurred. The Table-1shows the list of major earthquakes and table-2shows the location wise major earthquakes and their magnitude in Indian subcontinents.

Discussions

The major earthquakes generated due to the movement of plates or stress released along the plate boundaries. As the Indian plate moves towards NE direction at a speed of 3.7cm per year. But by mean of collision of Indian plate into the Eurasian Plate, huge stress buildup at northern part of the Indian subcontinent. The different part of the Indian subcontinent has felt different stress and for adjustment/release of this stress, plate moves time to time and major earthquakes are generated.

The most of major earthquakes generated in Eastern (NE and SE) part of the Indian plate. It generally shows that when an earthquake hits Eastern part than Western part also gets an earthquake for balancing the plate. For example: In year 1819, earthquake hits with magnitude 8 in western part of Indian subcontinent, means movement in western part of plate and after 50 years another major earthquake hits in NE direction with 7.5 magnitude in the year 1881 and another earthquake hits SE part with 7.9 magnitude, for the balancing of Indian plate, while the NW part moves/adjusted in the year 1885 with a magnitude of 7.

Again the NE part hits an earthquake with a magnitude of 8.7 in the year 1897 and for adjustment in NW part hits an earthquake in the year 1905 with a magnitude of 8. In the year 1918, 1930 and 1934 earthquakes occurred in the NE and Central Himalayan region with the magnitudes of 7.6, 7.1 and 8.3 respectively and for adjustment of this stress again western part felt the earthquake in the year 1935 with an intensity of 7.7 magnitudes.

Again in the year 1941, 1943 and 1950 stress released in Eastern part of the Indian subcontinent with an intensity of 8.1, 7.2 and 8.5 magnitude and adjustment earthquake happened in the year 1956 in western part of the Indian subcontinent with intensity of magnitude 7.

After a gap of 45 years (as earlier happened in 1819 and 1869, 50 year of rest period), the western part of India again activated in 2001 with an intensity of 7.7 magnitude and for balancing it Sumatra Orogeny felt historical earthquake in the year 2004 with a magnitude of 9.3 in the far SE direction and again stress released in NW direction in the year 2005 with an intensity of 7.6 magnitude earthquake, again the SE part felt earthquake in the year 2009 magnitude of 7.7 intensity and now in the year 2015 Central Himalaya felt earthquake after 80 years (Figure- 1 and Figure- 2).

Table- 1
List of Major Earthquake in Indian subcontinents[22,23]

Date	Location	Latitude	Longitude	Magnitude
June 28, 2015	Assam	26.5°N	90.1°E	5.6
May 12, 2015	Northern India, Nepal	27.794°N	85.974°E	7.3
April 25, 2015	Nepal	28.147°N	84.708°E	7.8
March 21, 2014	Andmanand Nicobar Island	7.6°N	94.4°E	6.7
April 25, 2012	Andmanand Nicobar Island	9.9°N	94.0°E	6.2
March 5, 2012	Delhi	28.6°N	77.4°E	5.2
September 18, 2011	Gangtok Sikkim	27.723°N	88.064°E	6.9
August 10, 2009	Andmanand Nicobar Island	14.1°N	92.8°E	7.7
October 8, 2005	Kashmir, Pakistan	34.49° N	73.15° E	7.6
December 26, 2004	West Coast Northern Sumatra	3.34°N	96.13°E	9.3
January 26, 2001	Bhuj, Gujrat	23.40°N	70.28°E	7.7
March 29, 1999	Chamoli, Uttarakhand	30.41°N	79.42°E	6.8
May 22, 1997	Jabalpur, Madhya Pradesh	23.08°N	80.06°E	6
September 30, 1993	Latur, Maharastra	18.07°N	76.62°E	6.3
October 20, 1991	Uttarkashi	30.75°N	78.86°E	6.6
August 21, 1988	Bihar-Nepal Bourder	26.72°N	86.63°E	6.4
August 6, 1988	Manipur-Myanmar border	25.13°N	95.15°E	6.6
January 19, 1975	Kinnur, Himachal Pradesh	32.38°N	78.49°E	6.2
December 10, 1967	Koyna, Maharastra	17.37°N	73.75°E	6.5
July 21, 1956	Anjar, Gujrat	23.3°N	70°E	7
August 15, 1950	Arunachal Pradesh-China Bourder	28.5°N	96.7°E	8.5
October 23, 1943	Assam	26.8°N	94°E	7.2
June 26, 1941	Andmanand Nicobar Island	12.4°N	92.5°E	8.1
May 31, 1935	Baluchistan	28.87°N	66.38°E	7.7
January 15, 1934	Nepal- Bihar Bourder	26.6°N	86.8°E	8.3
July 2, 1930	Dhubri, Assam	25.8°N	90.2°E	7.1
July 8, 1918	Srimangal, Assam	24.5°N	91°E	7.6
April 4, 1905	Kangra, Himachal Pradesh	32.3°N	76.3°E	8
June 12, 1897	Shilong	26°N	91°E	8.7
May 30, 1885	Sopor, J and K	34.1°N	74.6°E	7
Dec 31, 1881	Andmanand Nicobar Island	8.52°N	92.43°E	7.9
Jan 10, 1869	Cachar, Assam	25°N	93°E	7.5
June 16, 1819	Kutch, Gujarat	23.6°N	68.6°E	8

Table-2
List of locational aspects of major earthquake's magnitude in Indian subcontinents

Magnitude > =7		**Magnitude 6 to 7**		**Magnitude 5 to 6**	
Year	**Area**	**Year**	**Area**	**Year**	**Area**
1819	W	1967	C INDIA	2012	NW
1869	NE	1975	NW	2015	NE
1881	SE	1988	CH		
1885	NW	1991	NW		
1897	NE	1993	C INDIA		
1905	NW	1997	C INDIA		
1918	NE	1999	NW		
1930	NE	2011	CH		
1934	CH	2012	SE		
1935	W	2014	SE		
1941	SE				
1943	NE				
1950	NE			Symbol: W = West part NW = North West N = North CH = Central Himalaya NE = North East SE = South East	
1956	W				
2001	W				
2004	SE				
2005	NW				
2009	SE				
2015	CH				

We have to concentrate on the present plate movements for the analysis of current earthquake trends. The Indian plate felt major earthquake once again after 45 years, in the year 2001 with magnitude of 7.7 in western part of Indian plate. After that NW part moved in year 2005 with a magnitude of 7.6 and in the year 2015, Central Himalaya (Nepal) felt/adjust with a magnitude of 7.8 and 7.3. The Central Himalaya felt this earthquake after 81 years (last reported in the years 1934).

The Indian Plate made up of Indian, Eurasian and Australian subcontinents. Each subcontinent is moving in different velocity in NE direction 3.7 cm/yr and 5.6 cm/year respectively. But the Himalayas are impending the western half of it. The result is an area of compression in the centre of the plate, which may be cracking under the strain. In year 2004, major earthquake (intensity 9.3) happened which was far away from the Indian plate boundary.

Seismologist suggested that April 2012 earthquakes hint the tectonic breakup of Indian and Australian Plate[5]. Due to start of breaking up of the Indian plate both Indian and Australian subcontinent plates are feeling less obstruction to move and probably of earthquake along this breaking plane is high.

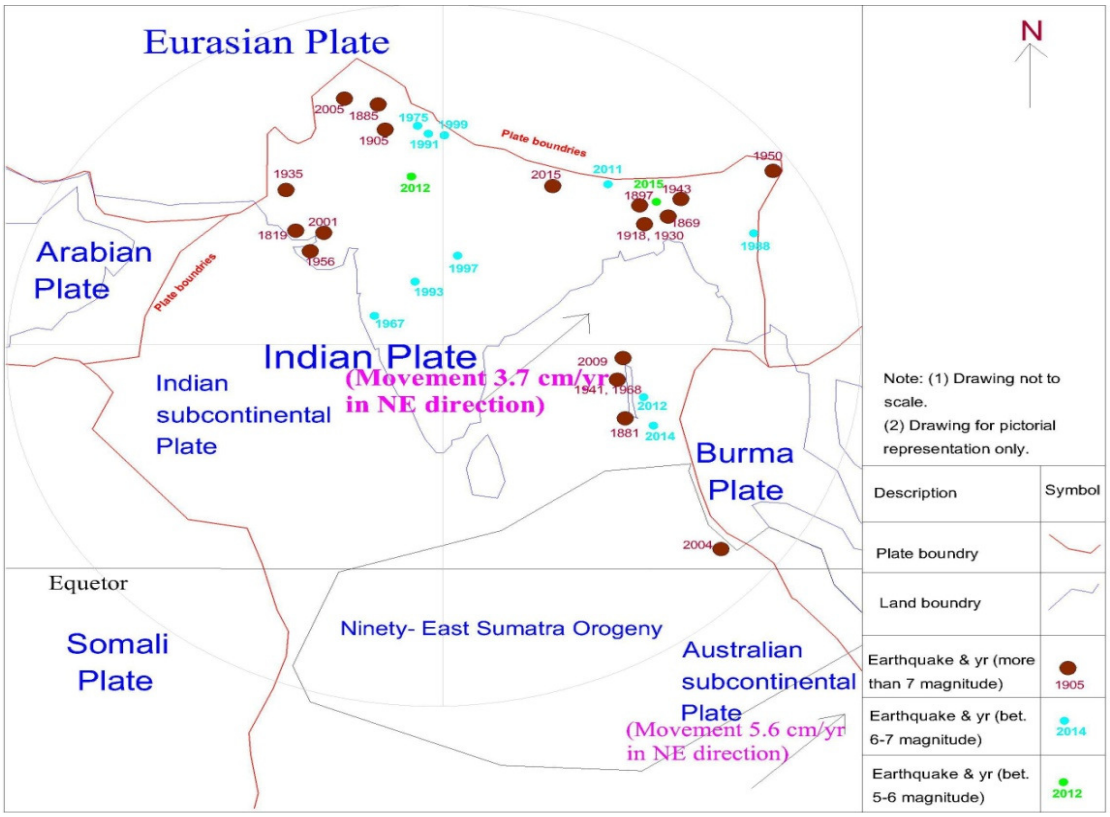

Figure-1
Indian Plate and major earthquakes[24]

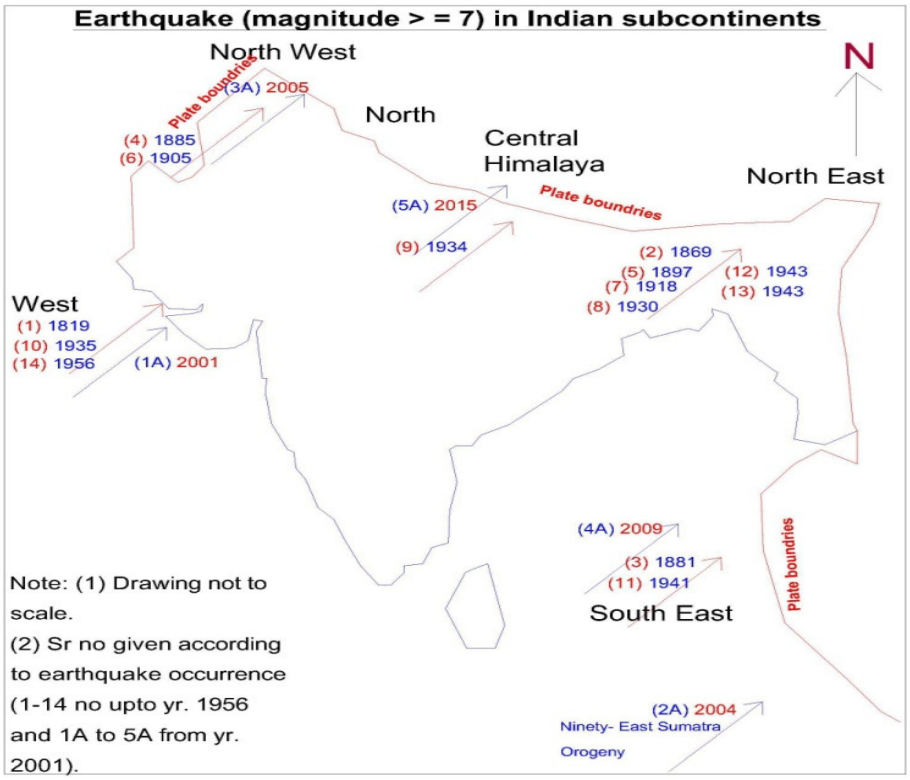

Figure-2
Earthquake (magnitude >=7) in Indian Subcontinent[24]

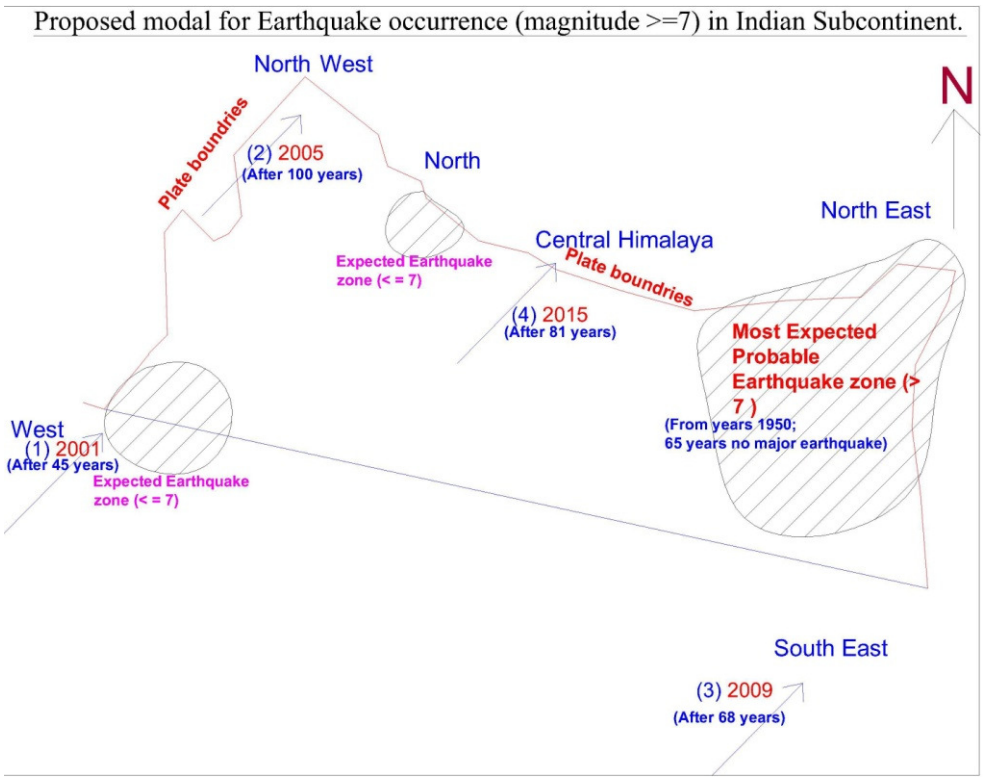

Figure-3
Proposed modal for Earthquake occurrence (magnitude >=7) in Indian Subcontinent

Conclusion

If we draw plate boundary from the western part to eastern part of India, Indian plate looks like a 'Bow' (Figure- 3) where stress had released in western, NW and Central Himalayan part. Due to these recent earthquake and stress generated naturally by mean of movement of the Indian plate, the NE part of Indian plate is getting highly compressed and may be released this stress in coming years and intensity of that probable earthquake would be more than equal to 7 magnitude. Further, it seems that some stress also developed in Northern part (adjoining area of Himachal Pradesh, Uttarakhand and western part of the Indian plate and this stress may be release in the coming years with an intensity less than or equal to7 magnitude.

Due to breaking up of the Indian plate, probability of a major earthquake along this breaking plane may not be ignored and that may be creating Tsunami also.

References

1. Bolt Bruce (2005). Earthquakes: 2006 Centennial Update – The 1906 Big One. Fifth ed., W. H. Freeman and Company.

2. Kato Naoyuki (2009). A possible explanation for difference in stress drop between intraplate and interplate earthquakes, *Geophysical Research Letters,* 36 (23).

3. LiQingson, Liu M., Qie Z, Eric S (2007). Stress evolution and seismicity in the central-eastern United States: Insights from geodynamic modeling. *Continental Intraplate Earthquakes: Science, Hazard, and Policy Issues.* 425, 153.

4. Hough Susan E., Leonardo S.B and Armbruster John G (2003). Intraplate Triggered Earthquakes: Observations and Interpretation. Bulletin of the Seismological Society of America. 101(3), 2212–2221.

5. Matthias Delescluse, Nicolas C.R., Rodolphe C., Luce Fleitout, Olga T. and Christophe V. (2012). Intra-oceanic seismicity off Sumatra boosted by the Banda-Aceh megathrust. *Nature,* 490, 240–244.

6. Wadia D. N. (1975). Geology of India. Tata Mcgraw Hill, New Delhi. 4th Edition, 508.

7. Valdiya K.S. (1976). Himalaya transverse faults and their parallesim with subsurface structures of North Indian planes. *Tectonophysics,* 32, 353-386.

8. Valdiya K.S. (1981). Tectonics of the crustal sector of the Himalaya, In Zagros, Hindu Kush, Himalaya, Geodynamic Evolution. Geodynamic Ser. Washington D. C., 3, 87-110.

9. Valdiya K.S. (1988). Tectonics and evolution of the central sector of the Himalaya, *Trans. R. Soc. London,* A326. 151-174.

10. Dewey J.F., Robert, Shackleton R.M., Chengfa C. and Yiyin S. (1988). The tectonic evolution of the Tibetan plateau. *Phil. Trans. Royal Soc. Londan,* A327, 379-413.

11. Verma R.K. (1991). Geodynamics of the Indian Peninsula and the Indian Plate Margin. Oxford and IBH Publication Co. Pvt Ltd., New Delhi.

12. Rao B Ramalingeswara and Rao P. Sitapathi (1984).Historical seismicity of Peninsular India, *Bulletin of the Seismological Society of America,*74(6), 2519-2533.

13. Biswas S.K. (1987). Regional tectonic framework, structure and evolution of the western marginal basin of India. Tectonophysics 135, 307-327.

14. Talwani P. and Rajendran P. (1991). Some seismological and geometric features of intraplate earthquakes. *Tectonophysics,* 186, 19-41.

15. Kayal J.R., De R., Das B. and Chowdhury S.N. (1996). Aftershock monitoring and focal mechanism studies. *Geological Survey of India Special Publication.* 37, 165-185.

16. Johnston A.C., Coppersmith K.J., Kanter L.R. and Cornell C.A. (1994). The Earthquakes of Stable Continental Regions: Assessment of Large Earthquake Potential. EPRI Repot TR-102261, CA: Electric Power Research Institute, 309.

17. Rajendran C.P. (2000). Using geological data for earthquake studies: A perspective from peninsular India, *Current Science,* 79, 1251-1258.

18. Kayal J.R. (2000). Seismotectonic study of the two recent SCR earthquakes in Central India, *Journal of the Geological Society of India*, 55, 123-138.

19. Kayal J.R., De R., Ram S,Srirama B.V.and Gaonkar S.G. (2002). Aftershock of the 26 January 2001 Bhuj earthquake in Western India and its seismotectonic implications. *Journal of the Geological Society of India,* 59, 395-417.

20. Gangopadhyay A and Talwani P (2003). Symptomatic features of Intraplate Earthquakes, *Seismological Research Letters.* 74 (6), 863-883.

21. Yadav R.B.S., Shanker D., Chopra S. and Singh A.P. (2010). An application of regional time and magnitude predictable model for long-term earthquake prediction in the vicinity of October 8, 2005 Kashmir Himalaya earthquake, *Journal of Natural Hazard,* 54(3), 985-1014.

22. List of Earthquake in Indian subcontinents. http://www. imd.gov.in/section/seismo/static/ signif.htm 19-09-2014.

23. List of Earthquake in Indian subcontinents. https://en.wikipedia.org/wiki/List_of_earthquakes _in_ India20-10-2015

24. Tectonic plates boundaries detailed. https:// commons.wikimedia.org/wiki/File:Tectonic_ plates_ boundaries_ detailed-en.svg#file. 09-2015.