Large and Great Earthquakes in the Stable Continental Region of India: Seismotectonic Perspective

J. R. Kayal*, Jadavpur University, Kolkata-700032, India; email: jr.kayal@gmail.com

Figure 1: Seismic zoning map of India

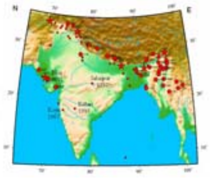


Figure 2: Large and great earthquakes in Indian subcontinent (Kayal, 2008)

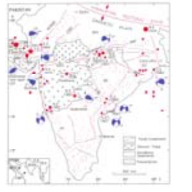


Figure 3: Seismotectonic domains in Peninsular India and significant earthquakes with fault-plane solutions (Kayal, 2000).

Figure 4: National network showing permanent observatories (Source: IMD website)

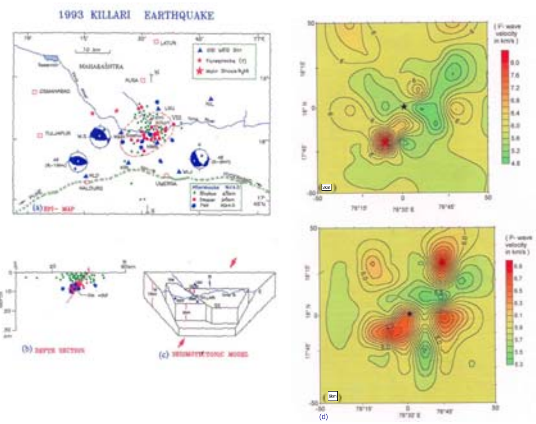


Figure 5: (a) Isoseismal VII and the 1993 Killari earthquake sequence.(b) Seismic cross section.(c) Seismotectonic model. (d) Seismic tomography of the earthquake source area (Kayal and Mukhopadhyay, 2002)

1. Introduction

Seismic zoning map, recent earthquakes, seismotectonic map, and national seismic network of India are shown in Figs1-4. Stable Continental Region (SCR) earthquakes (M_w>6.0),though occur less frequently, may cause severe damages and loss of lives. There had been three SCR events M_w 6.0 - 7.7, in Indian peninsular shield during the last two decades, sequentially the 1993 Killari earthquake and 1997 Jabalpur earthquake in central India and the 2001 Bhuj earthquake in western India. A NNE-SSW regional tectonic stress is dominant in shield area due to collision tectonics of the Indian and Eurasian plates at the Himalayan arc to the north and continent-continent atypical subduction tectonics at the Burmese arc to the east. Aftershock investigations gave us a better understanding of seismotectonics of these SCR events .

The 1897 great Shillong earthquake (M_s 8.7) has been examined with recent digital broad band seismic data. These data shed a new light on seismotectonics of this great earthquake in the plateau region , which is a part of the Indian shield.

2. The 1993 Killari Earthquake (m_b 6.3)

The September 30, 1993 Killari earthquake (m_b 6.3) occured in the Deccan province of central India; the maximum intensity VIII was estimated (Fig. 5a). The Killari earthquake and its 150 well located aftershocks were confined to a shallow depth (0-15 km) (Fig. 5b), a common type of SCR seismicity. The main shock occurred by reverse faulting at a depth of 6 km; the deeper aftershocks (6-15 km.) also occurred by reverse faulting. The shallower aftershocks,(0-<6 km), on the other hand, occurred by right-lateral strike-slip faulting (Kayal, 2000). The Killari earthquake sequence is explained by a fault interaction model (Fig. 5c). Seismic tomography study revealed a detailed structure of the source area; The main shock occurred at the contact zone of a high velocity and low velocity zones at the fault end (Fig. 5d) (Kayal and Mukhopadhyay, 2002).

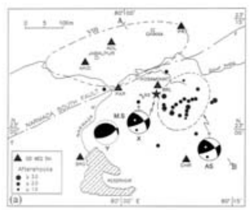
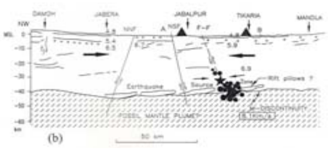


Figure 6: (a) Isoseismal VIII, and the 1997 Jabalpur earthquake sequence



(b) Seismic cross section and the tectonic model. (Kayal, 2000).

3. The 1997 Jabalpur Earthquake (m_b 6.0)

The May 22, 1997 Jabalpur earthquake (m_b 6.0), maximum intensity VIII, occurred at the base of the Narmada Rift Basin, within the SCR, at a depth of 35 km by reverse faulting with a left-lateral strike-slip motion (Fig.6a). Only about 25 aftershocks were recorded that occurred at a depth 35-40 km in the lower crust (Fig. 6b).A composite fault-plane solution of the aftershocks also reveals the reverse faulting with left lateral strike-slip motion. The south dipping Narmada South Fault, the southern margin fault of Narmada Rift Basin, was activated by reverse faulting (Kayal, 2000).Seismic tomography study of the source area could not be done due to meagre aftershock data.

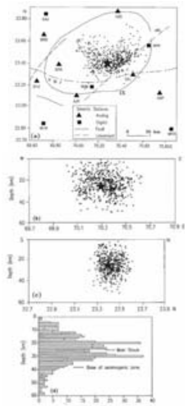


Figure 7 (a) Isoseismal VII and the aftershock sequence,2001 Bhuj earthquake (Kayal et al., 2002a). (b & c) Seismic sections and (d) bimodal seismicity (Kayal et al., 2002b).

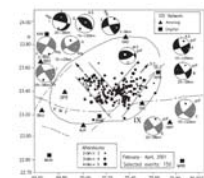


Figure: 8 Fault plane solutions of the aftershock sequence (Kayal et al., 2002a)

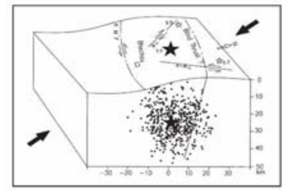


Figure 9: Seismotectonic model (Kayal et al., 2002a).

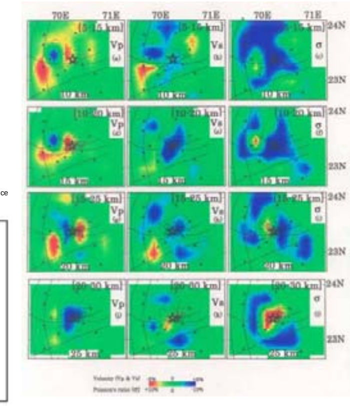


Figure 10: Seismic tomography of the 2001 Bhuj earthquake source area (Kayal et al., 2000 b).

(a)

4. The 2001 Bhuj Earthquake(M_w 7.7)

The most recent devastating Bhuj Earthquake (Mw 7.7) of January 26, 2001 is one of the rarest and largest events that occurred in SCR in the world (Figs 7-10).The maximum intensity reached X (MSK scale). This is the second largest event in the western margin of peninsular India continental region, after the 1819 Kutch earthquake of M_w7.8 (Fig. 2).The 2001 Bhuj earthquake is another example of deeper paleo - rift zone earthquake that occurred at a depth of 25 km in the Kutch Rift basin. The fault plane solutions of the main shock and the aftershocks show complicated seismogenic structures (Fig. 8). The observations suggest a fault interaction model, which illustrates that the main shock originated at the base of the paleo - rift by reverse faulting, the rupture propagated along NE as well as along NW. The aftershocks occurred by left-lateral strike-slip motion along the NE trending fault, ,compatible with the main shock solution, and by pure reverse to right-lateral strike-slip motion along the NW trending conjugate fault; these solutions are not compatible with the main shock solution (Kayal et al.,2002a). Seismic tomography study revealed high V_p, low V_s and high V_p/V_s in the source area, which indicate that the source area is a fluid filled fractured rock-matrix that triggered the main shock (Fig 10)(Kayal et al., 2002b).

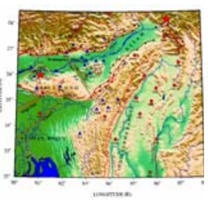


Fig 11(a): Topographic map with tectonic features of NE India region

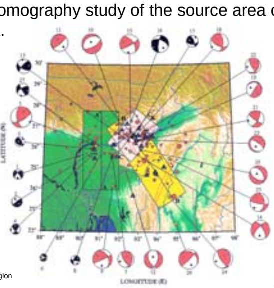


Fig 11(b): Digital seismic data with fault plane solutions

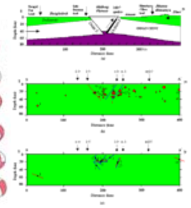


Fig: 12 (a) Pop-up tectonic model of the Shillong Plateau (Bilham and England, 2001), (b) Depth section of the events, (c) Inferred fault-plane solutions plotted at depth (Kayal et al., 2006)

5. The 1897 Shillong Earthquake (M_s 8.0)

The northeast region of India is seismically most active falling in zone V in seismic zoning map of India (Fig. 1). The region has experienced two great earthquakes (M_s>8.0) and about 20 large earthquakes (M_s > 7.0) since 1897 (Fig. 11a). The 1950 great Assam earthquake (M_s 8.7) in the eastern syntaxis zone is well studied (Tandon, 1954), and it is believed to be a strike-slip faulting earthquake (Holt et al., 1991). The great Shillong earthquake (revised M_s 8.0) was well studied by Oldham (1899), and was believed to be Himalayan thrust earthquake (Seeber et al., 1981). Bilham and England (2001) based on geodetic and GPS data argued that the 1897 earthquake was caused by the Oldham fault by pop-up tectonics of the Shillong plateau (Fig. 12a).

Recent broadband seismic data in the Shillong plateau in northeast India have shed more light on seismotectonics of the 1897 great earthquake (Fig. 11b). The plateau earthquakes are generated by pop-up tectonics between two boundary faults, the Dauki fault to the south and the Brahmaputra fault to the north (Kayal et al., 2006) (Fig. 12b & c). .This great earthquake, is now argued to be a shield intra-plate earthquake generated by *pop-up* tectonics of the Shillong plateau in the northeastern part of the Indian shield.

6. Conclusion

The 1993 Killari earthquake (mb 6.3), a typical shallow (< 10 km) SCR event, is explained by a fault interaction model; the main shock source area is imaged as a HVZ and LVZ contact zone at the fault end; no surface fault is mapped in the Deccan trap cover area (Fig. 3).

The 1997 Jabalpur earthquake (mb 6.0) is a deeper (35 km) rift basin earthquake, activated by reverse faulting by the deep rooted southern boundary fault, the Narmada South Fault (NSF) (Fig. 6).

The 2001 Bhuj earthquake (Mw 7.7) is also a rift basin deeper (25 km) earthquake, activated by reverse faulting; a fault interaction model is suggested to explain the fault plane solutions of the main shock and aftershocks, which is supported by seismic tomography images (Figs 7-10).

The 1897 great earthquake in the Shillong plateau is argued to be a shield earthquake caused by pop-up tectonics of the plateau (Fig. 12) ; it is not a Himalayan thrust earthquake .

References

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*CSIR Emeritus Scientist