J. Ind. Geophys. Union (July 2012)
Vol.16, No.3, pp. 87-96

Pre- and post-seismic activities along the Myanmar-Andaman-Sumatra Subduction Margin: insights for tectonic segmentation

Prosanta Kumar Khan*, Anand Mohan and Suparna Chowdhury
Department of Applied Geophysics, Indian School of Mines, Dhanbad, Jharkhand, India
*Corresponding author. Email: pkkhan_india@yahoo.com

ABSTRACT
Spatial variation of the occurrences of large and great earthquakes along the subduction margin can be linked with various plate tectonics parameters viz. converging plate velocity vector, plate obliquity, age of the subducting plate, depth of plate flexing and inter-plate coupling. Present study addresses many of these parameters for understanding the seismotectonic status along the eastern subduction margin (i.e., Mayanmer-Andaman-Sumatra) of India analyzing earthquake dataset with magnitude $m_b \geqslant 4.5$ taken from the Harvard Centroid Moment Tensor (CMT) catalogue for the period starting from January 01, 1976 to December 09, 2009. The dataset was divided into two categories: pre- and post-events based on the occurrence of 26 December 2004 off Sumatra mega-event (Mw = 9.3). The study area between Myanmar and Sumatra was divided into 12 sectors based on plate obliquity.

Analysis shows that area near Sumatra record highest seismicity concentration, and area past the north Andaman has least concentration, preceding the 2004 mega-event, and further increases marginally towards north. Instead, following the mega-event, concentration though decreases towards north, phenomenally reduces past the sector 7 (near the central part of the arc). The seismic moment energy release decreases more than two orders of magnitude past the sector 7 towards north during post-seismic deformation phase. It is, thus, may be inferred that stress energy was mainly confined between Sumatra and Andaman after the 2004 event. These observations are clearly accounted for tectonic subdivision of the margin into northern and southern near transition zone around the central part of the arc. It was also appreciated in the literature that the transition zone apparently countered spreading motion of the Andaman Sea in the back-arc area. It was furthermore reported that the 2004 off Sumatra mega-event rupture did not move further towards north past the North Andaman area. It is thus, may be proposed that the two arcs along this subduction margin are tectonically playing differently behind the generation of moderate earthquakes along this margin.

INTRODUCTION

The Myanmar-Sumatra subduction margin, concern of the present study, extends over 3000 km with a lateral dimension of ~200 km (Fig. 1a). It appears to be a transitional domain between the zones of frontal subduction of the Indo-Australian plate beneath the northeast Himalaya in the north and the Java arc in its south, and is characterized by widely varying subduction character all along this margin (Le Dain et al., 1984; Maung, 1987; McCaffrey et al., 2000; Dasgupta et al., 2003). The 26 December 2004 off Sumatra earthquake was the first giant earthquake (moment magnitude $M_w > 9.0$) to have occurred since the advent of modern space-based geodesy and broadband seismology at the south of this transition domain, and has provided an unprecedented opportunity to understand the features viz. rupture evolution, tsunami generation, geoid changes, co- and post-seismic deformation, changes in the rotation and oblateness of the Earth, etc. (Ammon et al., 2005; Ishii et al., 2005; Lay et al., 2005; Kreemer et al., 2006; Subarya et al., 2006; Khan, 2007). The rupture propagation character from the source region was resolved effectively (Ishii et al., 2005; Kruger and Ohrnberger, 2005; Lay et al., 2005), and the rupture processes and tsunami generation have been understood in terms of along-trench change in plate geometry as well as plate driving forces (Khan, 2007, 2010). Source dynamics/kinematics was explained,

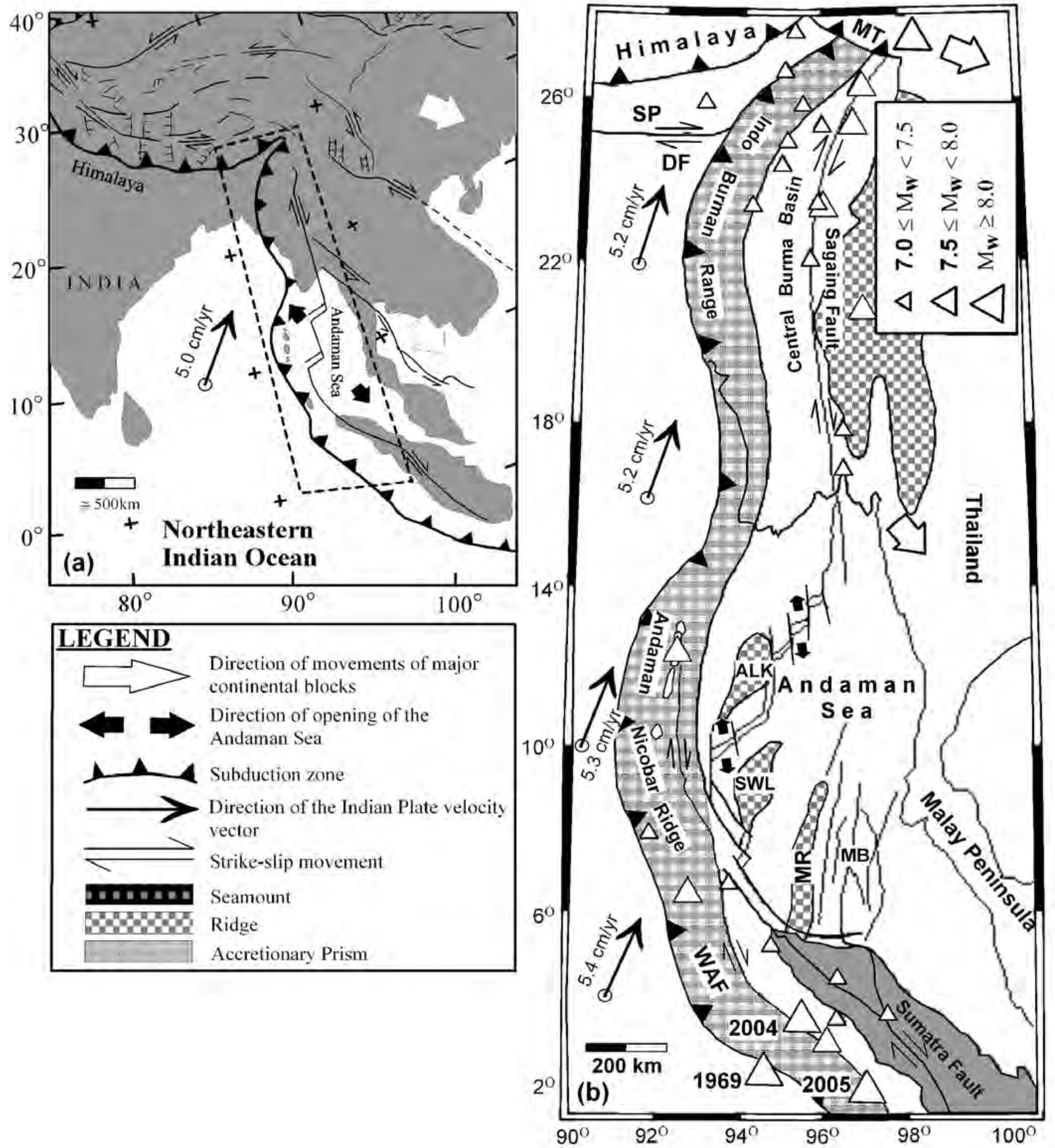

Figure 1. Map on the right showing various physiographic and tectonic features around the Myanmar-Andaman-Sumatra subduction margin (after Curray, 2005). The dashed block on the left map (after Tapponnier et al., 1982) represents the study area. Left bottom solid arrow indicates Indian plate velocity vector and right top open arrow is for major block motion with respect to Siberia since the Miocene. Open triangles represent the significant historical earthquakes of three different magnitudes. Note the preferential incidences of mega-events near Sumatra. Also note the absence of any great historical earthquake in the central part of the arc.

and the associated estimated parameters did not support the interplate hypothesis for subduction zone mega-shocks. Aftershock distribution following this 2004 earthquake though was studied under local scale, never been attempted on regional perspective. Historic database for the occurrences of great earthquake events over last 200 years reveal their preferential confinement in the northern and southern parts of Myanmar-Andaman-Sumatra tectonic belt (e.g., 1950 Assam, M_W = ~8.8; 2004 Sumatra; 2005 Sumatra, M_W = 8.6) (Fig. 1b). In contrast, no great earthquakes have occurred towards its central part and the gap in seismicity (Khan et al., 2010) was explained in terms of margin tectonic variation from south to north between Sumatra and Myanmar. In the present study, we have addressed issues like the spreading of aftershocks along the entire Myanmar-Andaman-Sumatra margin, relationship between pre- and post-seismicity distribution, and possible tectonic controls on their distribution.

It was suggested that the processes underpinning the earthquake activities along subduction margins are normally understood in terms of dip and age of subducting plate, plate obliquity, subduction rate, etc. (Khan and Chakraborty, 2005, 2009 and references therein). Many researchers have interpreted the earthquake rupture propagation and the along-strike variation in seismic activity in terms of several plate tectonic parameters i.e. plate converging velocity, age of the subducting plate, dip of the Benioff zones, nature of crust of the upper plate, etc. (Ben-Menahem et al., 1974; Jarrard, 1986; Newcomb and McCann, 1987; McCaffrey et al., 2000; Dasgupta et al., 2003; Khan, 2005, 2007). The variation in the penetration-depth of seismic activity and inconsistency in the lateral dimension of the seismic-contours along the Myanmar-Andaman-Sumatra margin are also being explained in terms of similar tectonic parameters (Dasgupta et al., 2003). In the present study, a qualitative assessment of along-strike unusual stress accumulation under pre- and post-seismic deformation is also attempted.

REGIONAL TECTONIC FRAMEWORK

Internal deformation and crowding of a number of oceanic and continental sub-plates at the leading edge of indenting Indian subcontinent framed the complex Cenozoic tectonics of Southeast Asia (Fitch, 1972; Mitchell, 1981; Tapponnier et al., 1986; Hall, 1996, 2002). Subduction is considered to have started along the western Sunda arc following the break-up of Gondwanaland in the early Cretaceous (Scotese et al., 1988). Deformation of Eocene-Oligocene-Miocene-Pliocene sediments on the Andaman Islands, accretion of Cretaceous-Eocene sediments, arc volcanic activity in the Miocene-Pliocene, and the occurrence of young volcanoes in the Andaman and Nicobar islands suggest that subduction-related processes in the Myanmar-Java Trench were operative either continuously or intermittently from the Cretaceous onwards (Pal et al., 2003; Chakraborty and Khan, 2009). Myanmar-Andaman-Sumatra subduction margin, concern of the present study, belongs to a transitional domain delimited by the zones of frontal subduction of the Indian plate beneath the Himalayas and the Australian plate beneath the Java arc (Gansser, 1981; Curray, 2005). Along-strike tectonic characterization of the Sunda plate margin reveals i) increase in the converging plate obliquity exceeding critical limit ($20^0 \pm 5^0$, McCaffrey, 1992) between 2 and 4°N latitudes (Khan and Chakraborty, 2005), and ii) youngest age for the subducting oceanic crust (~47 Ma) in the northwest Sumatra region (~67 and ~120 Ma ages around the north Andaman and northern Myanmar regions) (Müller et al., 1997). The convergence obliquity between the Indian and Asian plates is primarily being accommodated by several on-land strike-slip fault systems (e.g., Sagaing Fault, Semangko Fault, West Andaman Fault, Kabaw Fault, etc.) (cf. Mitchel and McKerrow, 1975; Diament et al., 1992) developed all along the margin. It is also appreciated (Replumaz and Tapponnier, 2003; Khan, 2005; Khan and Chakraborty, 2005) that the widely varying plate-dip-angle, subduction rate and plate convergence obliquity forced the opening of several basins (e.g., Mergui-Sumatra, Andaman, Central Myanmar Basins, etc.) on the overriding Asian plate between Myanmar and Sumatra over different tectonic episodes.

From north to south the tectono-geomorphic belt is represented by the Myanmar orogen at the north and runs southward to Andaman and Nicobar Islands and further south to the Mentawai islands, southwest Sumatra. Myanmar and India were juxtaposed since the end of Eocene times (Mitchell, 1985); the arc and forearc development of the Andaman and Nicobar Islands can have parallels with the southern part of subduction complex, i.e. Sumatra and Java. The dextral displacement along the Sagaing fault and spreading of the Andaman Sea accelerated the separation of the Myanmar plate from northwest Sumatra in the middle Miocene (Maung, 1987; Hall, 2002). Sumatra, forming the southwestern margin of Sundaland, is constituted of fragments of continental plates and magmatic arcs that were derived from the Gondwana during the late Paleozoic and Mesozoic (Metcalfe, 1996; Barber and Crow, 2003). The Myanmar orogen is subdivided into Eastern Highland (Shan Plateau), the Central Lowland and the Indo-Myanmar Ranges on an east-west transect (Mitchel and McKerrow, 1975; Bertrand and Rangin, 2003). The north-south running Sagaing fault separates the Shan plateau from the Central Trough; the Kabaw fault delimits the Central Lowland from the Indo-Myanmar Range. Besides, the north-South running right-lateral fault systems, the other salient features include i) andesitic volcanism between Eastern and Western Troughs of Central Lowland, and ii) ~ 400 km westward offsetting of the Irawaddy River from its former, the Chindwin River (Maung, 1987). A number of N-S-trending dismembered ophiolite slices of Cretaceous age, occurring at different structural levels with Eocene trench-slope sediments, were uplifted and emplaced by a series of E-dipping thrusts (Pal et al., 2003). Frontal accretion eventually led to a gradual increase in the slope of the wedge and ultimately to extension during late Eocene-Oligocene times (Pal et al., 2003; Chakraborty and Khan, 2009). Subsequently, E–W normal and N–S strike-slip faults resulted in the development of a forearc basin with deposition of Oligocene and Mio-Pliocene sediments (Metapelites and metabasics of green schist to amphibolite grade in a melange zone of ophiolites).

DATA, METHODOLOGY AND RESULTS

The earthquake data (m_b 4.5) were taken from Harvard Centroid Moment Tensor (CMT) catalogue for the period between January 01, 1976 and December 09, 2009. The whole dataset has been divided into two groups viz. pre- and post-events with respect to the occurrence of 26 December 2004 off Sumatra mega-event. The study area is divided into 12 sectors (S1-S12) based on the plate obliquity and trends of major tectonic elements. A relative comparison of seismic activities between sectors along the Myanmar-Andaman-Sumatra margin has been assessed (Table 1, Figs, 1 & 2). Furthermore, the moment energy release per unit arc length per year between segments along this margin has also been compared.

Figure 2 illustrates the distribution of moderate magnitude earthquakes along the Myanmar-

Table 1. Sector specific arc-parameters and the pre- and post-seismicity concentrations along the Myanmar-Andaman-Sumatra subduction margin.

Sector	Arc Length (km)	Plate Obliquity (deg.)	No. of Historical Event	No. of Pre-Event	No. of Post-Event
Sector 1	386	131	4	9	1
Sector 2	333	93	9	39	5
Sector 3	319	75	6	31	5
Sector 4	206	58	1	9	3
Sector 5	359	62	2	11	3
Sector 6	306	85	0	8	3
Sector 7	326	105	1	15	24
Sector 8	286	75	2	16	13
Sector 9	326	55	0	35	82
Sector 10	566	50	3	80	153
Sector 11	426	40	4	67	122
Sector 12	433	18	5	41	71

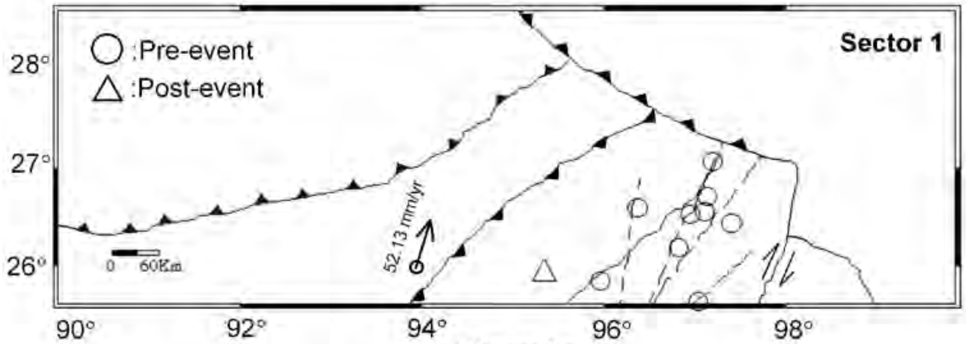

Figure 2a

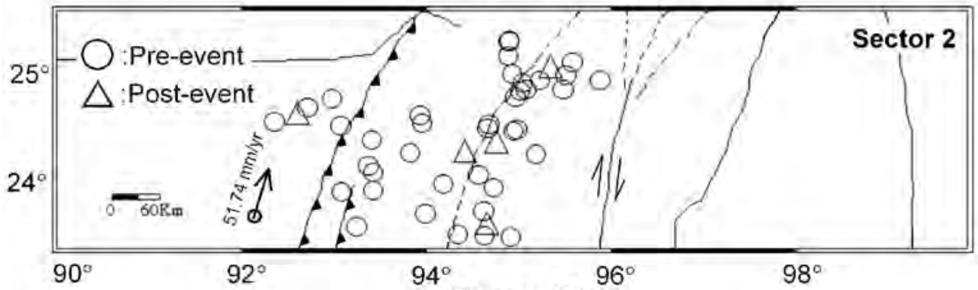

Figure 2b

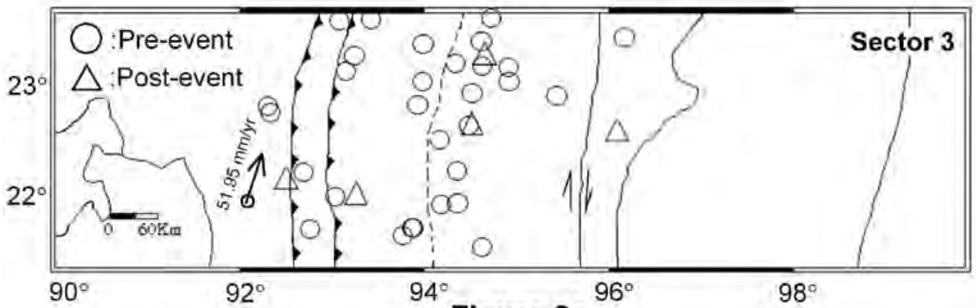

Figure 2c

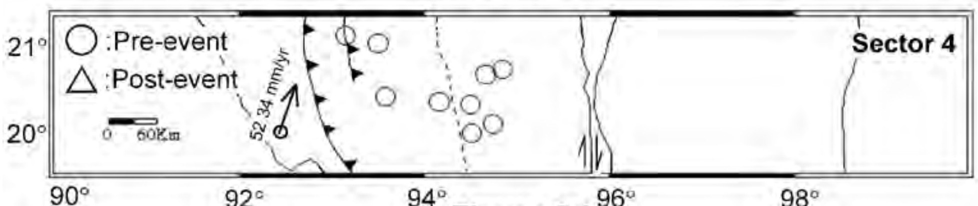

Figure 2d

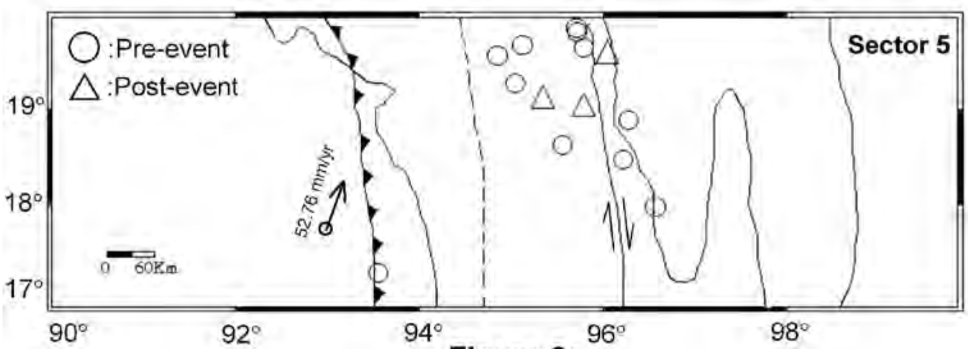

Figure 2e

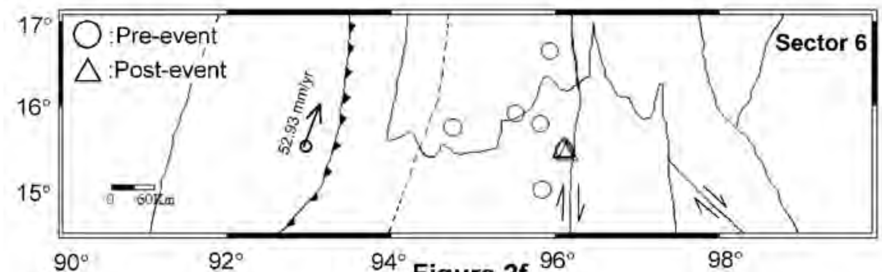

Figure 2f

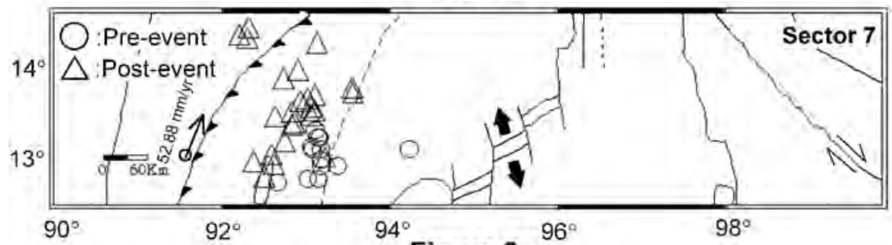

Figure 2g

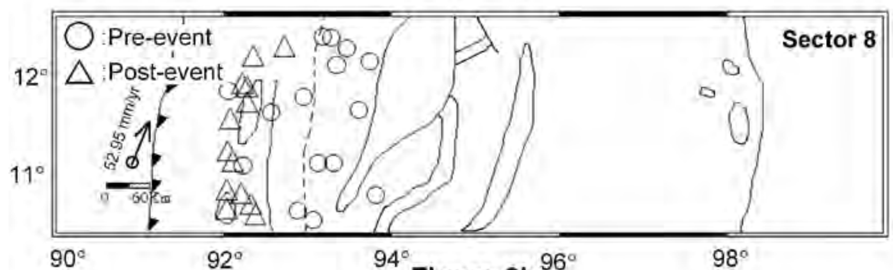

Figure 2h

Figure 2i

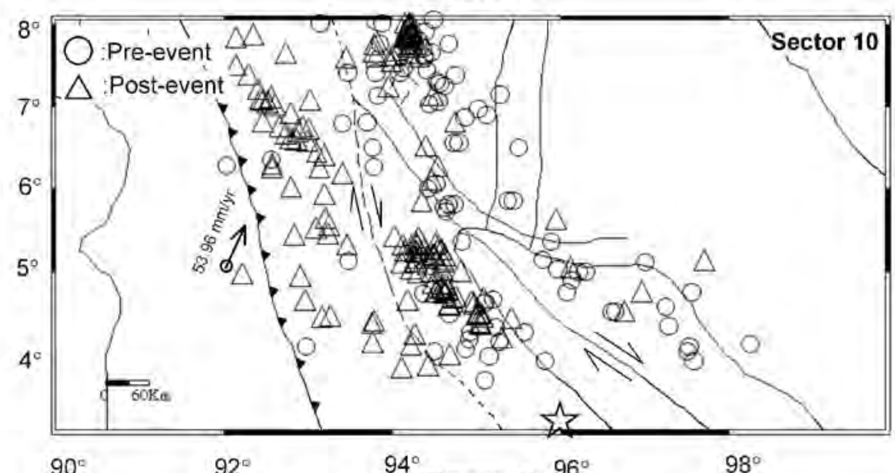

Figure 2j

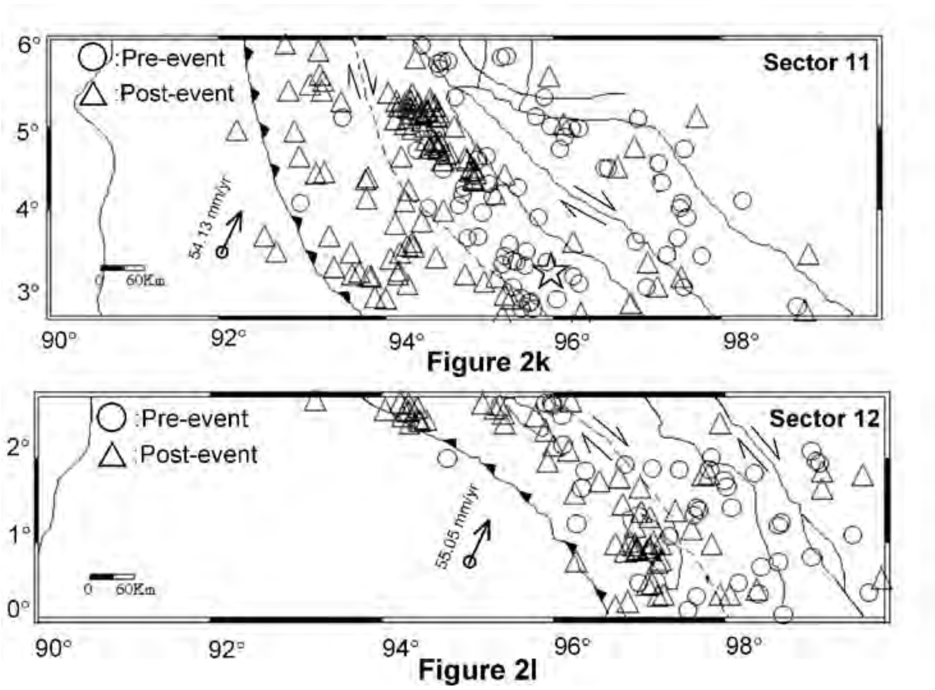

Figure 2. Maps (a-l) showing the distribution of seismicity in different sectors (S1-S12) along the margin.

Sumatra subduction margin. It is observed that the concentrations of pre- and post-seismic activities in different sectors are not of similar character, with respect to the locations of different tectonic elements. In sectors 1-5 (Fig. 2a-e), no specific trend of distribution is observed, and however, in sectors 7-12 (Figs. g-l), the pre-seismic activities are more dominant in areas away from the trench-axis and the post-seismicity is likely shifted towards the trench areas. Before the incidence of 2004 off Sumatra mega-event, the maximum seismicity concentration was noted in sectors 10 and 11 (i.e., 80 and 67, Table 1), and the similar trend with relatively phenomenal change observed for post-seismic events (i.e., 153 and 122, Table 1) in those sectors. Relatively lower level of seismic activities with nearly similar order of jump is noted in sectors 9 and 12 both towards south and north. Further towards north in sectors 7 and 8, although the seismicity has decreased sharply, a minimum is noted in sector 6 (i.e., 8 events) and becomes maximum in sector 2 (i.e., 39 events) under pre-seismic regime (Table 1), and more surprisingly, the activities have not increased under post-seismic dynamic stress condition (cf. Khan, 2007) beyond sector 6 towards north.

Figure 3 illustrates the annual seismic moment energy release per unit arc-length in different sectors along the margin. In the release pattern, a seismic transition in sector 6 is identified. The transition divides the entire subduction margin into two clear tectonic domains, namely, south and north. Under post-seismic status (i.e., dynamic stress regime) of this part of Sunda subduction margin, a sharp change of average seismic moment energy release (more than two-orders), is noted between north and south domains, (cf. Fig. 2), while a relatively very small change in average energy release (less than one-order) is noted under pre-seismic status between the domains.

DISCUSSION AND CONCLUSIONS

Stress energy release in the form of moderate to great earthquake incidences along subduction margins are usually correlated with age and speed of the descending plate (Uyeda and Kanamori, 1979; Ruff and Kanamori, 1980). Later studies based on more reliable dataset revealed these correlations to be less compelling (Pacheco et al., 1993) or possibly related to nonmechanical factors (McCaffrey, 1997). The major seismic energy bursts near Sumatra and Car-Nicobar with a minimum energy release near Great Nicobar (Ishii et al., 2005) do not corroborate with these relationships. Several other plausible

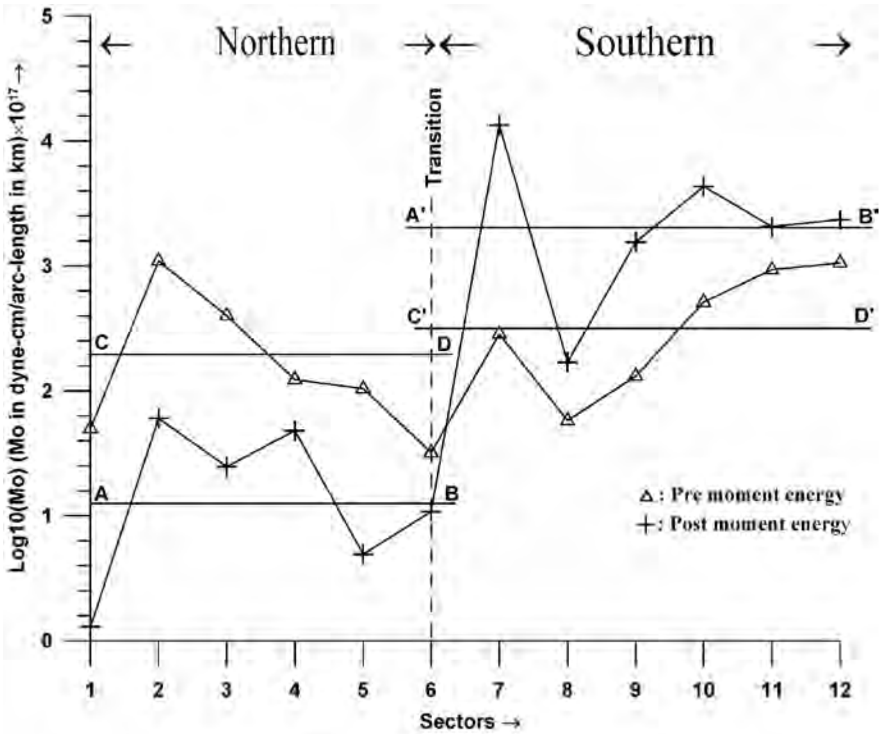

Figure 3. Plot showing the sector-specific distribution of annual seismic moment energy per unit length of the arc. AB and A′B′ and CD and C′D′ are average levels of seismic moment energies released under post- and pre-seismic stress regimes. Note the sharp change (AB to A′B′) in average energy from northern to southern part of the arc under post-seismic stress regime.

mechanical explanations were suggested (Ruff, 1989; McCaffrey, 1993; Scholz and Campos, 1995; Ruff and Tichelaar, 1996), but all have significant exceptions when compared to the actual earthquake history. Recent studies of Khan and Chakraborty (2009) and Khan (2010) clearly reveal the bearing of plate geometry, plate rheology and plate driving forces on the incidence of 2004 off Sumatra mega-event. Khan (2007) also showed the preferential release of seismic energy compatible with plate obliquity and plate deformation variations for the region between Sumatra and Car-Nicobar. In other studies of Khan (2005), Khan and Chakraborty (2005) and Khan et al. (2010), the depth of flexing of the descending Indian oceanic lithospheres and the depth of continuity of earthquake activities in different sectors from Sumatra to Myanmar were identified and correlated with the plate obliquities and subduction rates of the slab. It is thus imperative to state that the change in orientation of the strike of trench, relative plate convergence and the geometry of the descending lithosphere must have a definite role on the release of seismic energy in the form of moderate to great earthquakes along this margin.

The highest seismicity concentration near the Sumatra region appears to be correlated with the shallowest depth of flexing of the descending lithosphere (~25 km depth) and minimum plate obliquity (~18°) between Myanmar and Sumatra (Khan and Chakraborty, 2005). The nucleation with ~ 15 m slip initiated from a depth of ~ 25 km in the descending lithosphere in Sumatra area triggered ~ 30 m high Tsunami. The second energy burst with ~5 m slip was accompanied with the zone of deeper level of flexing near Car-Nicobar area, and towards further north the rupture died out rapidly. The dying out or stopping of rupture near North Andaman may be correlated with the northeastward veering of Andaman Sea Ridge (ASR) and the uplifting of oceanic crust in post-middle Miocene time in the form of Alcock and Sewell seamounts, and possibly controlled the plate curvature changes past the North Andaman. It is thus may be proposed that the double arc (Maung, 1987) is clearly divided by a tectonic transition zone at the central part and that is not allowing the stress transfer between south and north.

The sudden drop in concentration of seismicity and depth of continuity of earthquake events for both pre- and post-seismic deformation, and the sharp change of average seismic moment energy release from south to north segment under post-seismic deformation near the central part of the arc clearly support this observation.

ACKNOWLEDGEMENTS

First author is thankful to the Director, Indian School of Mines, Dhanbad for providing the infrastructure facilities. This work has been supported by the grant of the Ministry of Earth Sciences, Govt. of India, New Delhi.

REFERENCES

Ammon, C.J., Chen, Ji, Thio., H.-K., Robinson, D., Ni, S., Hjorleifsdottir, V., Kanamori, H., Lay, T., Das, S., Helmberger, D., Ichinore, G., Polet, J. and Wald, D., 2005. Rupture process of the 2004 Sumatra-Andaman earthquake. Science, 308, 1133-1139.

Barber, A.J., and Crow, M.J., 2003. An evaluation of plate tectonic models for the development of Sumatra. Gond. Res., 6, 1-28.

Bertrand, G., and Rangin, C., 2003. Tectonics of the western margin of the Shan plateau (central Myanmar): implication for the India-Indochina oblique convergence since the Oligocene. Jour. Asian Earth Sci., 21, 1139-1157.

Ben Menahem, A., Aboodi, E., and Schild, R., 1974. The source of great Assam earthquake an interplate wedge motion. Phys. Earth Planet. Int., 9, 265−289.

Chakraborty, P.P., and Khan, P. K., 2009. Cenozoic geodynamic evolution of the Andaman-Sumatra subduction margin: a current understanding. Island Arc, 18, 184-200, doi: 10.1111/j.1440-1738.2008.00641.x.

Curray, J.R., 2005. Tectonics and history of the Andaman Sea region. Jour. Asian Earth Sci., 25, 187-232.

Diament, M., Harjono, H., Karta, K., Deplus, C., Dahrin, D., Zen Jr., M.T., Gerard, M., Lassal, O., Martin, A., and Malod, J.A., 1992. Mentawai fault zone off Sumatra: A new key to the geodynamics of western Indonesia. Geol., 20, 259-262.

Dasgupta, S., Mukhopadhyay, M., Bhattacharya, A., and Jana, T.K., 2003.The geometry of the Burma-Andaman subducting lithosphere. Jour. Seismol., 7, 155-174.

Fitch, T.J., 1972. Plate convergence, transcurrent faults and internal deformation adjacent to southeast Asia and western Pacific. Jour. Geophys. Res., 77, 4432-4460.

Gansser, A., 1981. "The geodynamic history of the Himalaya", In: H. K. Gupta and F. Delany (Eds.), Zagros, Hindukush, Himalaya, Geodynamic evolution. Geodynamic Series., 3, 111-121.

Hall, R., 1996. Reconstruction Cenozoic SE Asia. In: R. Hall and D.J. Blundell (Eds.). Tectonic evolution of SE Asia, Geol. Soc. Special Pub., No. 106, pp. 153-184.

Hall, R., 2002. Cenozoic geological and plate tectonic evolution of SE Asia and the SW Pacific: computer-based reconstructions and animations. Jour. Asian Earth Sci., 20, 353-434.

Ishii, M., Shearer, P.M., Houston, H., and Vidale, J.E., 2005. Extent, duration and speed of the 2004 Sumatra-Andaman earthquake imaged by the Hi-Net array. Nature, 435, 933-936.

Jarrard, R.D., 1986. Terrane motion by strike-slip faulting of forearc slivers. Geol., 14, 780-783.

Khan, P., and Chakraborty, P.P., 2005. Two-phase opening of Andaman Sea: a new seismotectonics insight. Earth Planet. Sci. Lett., 229, 259-271.

Khan, P. K., 2005. Variation in dip-angle of the Indian plate subducting beneath the Burma plate and its tectonic implications. Jour. Geos., 9, 227-234.

Khan, P. K., 2007. Lithospheric deformation under pre- and post-seismic stress fields along the Nicobar-Sumatra subduction margin during 2004 Sumatra mega-event and its tectonic implications, Gond. Res., 12, 468-475.

Khan, P.K., and Chakraborty, P.P., 2009. Plate geometry, plate rheology, and their relation to shallow-focus mega-thrust seismicity with special reference to 26 December 2004 Sumatra event. Jour. Asian Earth Sci., 34, 480-491.

Khan, P. K., 2010. Role of unbalanced slab resistive force in the 2004 off Sumatra mega-earthquake (M_w > 9.0) event. Int. Jour. Earth Sci. (Geol Rundsch), 100, 1749–1758, DOI 10.1007/s00531-010-0576-4.

Khan, P.K., Mukherjee, G., and Chakraborty, P.P., 2010. Seismotectonic overview of the Burma-Andaman-Sumatra subduction margin preceding the 2004 off Sumatra mega-event. Jour. Geol. Soc. India., Memoir No. 75, 81-95.

Kreemer, C., Blewitt, G., Hammond, W.C., and Plag, H.-P., 2006. Global deformation from the great 2004 Sumatra-Andaman Earthquake observed by GPS: Implications for rupture process and global reference frame. Earth Planet Space, 58, 141-148.

Krüger, F., Ohrnberger, M., 2005. Tracking the rupture of the M_w = 9.3 Sumatra earthquake over 1,150 km at teleseismic distance. Nature, 435 , 937-939.

Lay, T., Kanamori, H., Ammon, C.J., Nettles, M., Ward, S.N., Aster, R.C., Beck, S.L., Bilek, S.L., Brudzinski, M.R., Butler, R., DeShon, H.R., Ekstrom, G., Satake, K., and Sipkin, S., 2005. The great Sumatra-Andaman earthquake of 26 December 2004. Science, 308, 1127-1133.

Le Dain, A.Y., Tapponnier, P., and Molnar, P., 1984. Active faulting and tectonics of Burma and surrounding regions. Jour. Geophys. Res., 89, 453−472.

McCaffrey, R., 1992. Oblique plate convergence, slip vectors, and forearc deformation, Jour. Geophys. Res., 97, 8905-8915.

McCaffrey, R., 1993. On the role of the upper plate in great subduction zone earthquakes. Jour. Geophys. Res., 98, 11953-11966.

McCaffrey, R., 1997. Influences of recurrence times and fault zone temperatures on the age rate dependence of subduction zone seismicity. Jour. Geophys. Res., 102, 22839-22854.

McCaffery, R., Zwick, P.C., Bock, Y., Prawirodirdjo, L., Genrich, J.F., Stevens, C.W., Puntodewo, S.O., and Subarya, C., 2000. Strain partitioning during oblique plate convergence in northern Sumatra: geodetic and seismologic constraints and numerical modeling. Jour. Geophys. Res., 105, 28363–28376.

Maung, H., 1987. Transcurrent movement in the Myanmar Andaman Sea region, Geol., 15, 911-912.

Metcalfe, I., 2006. Palaeozoic and Mesozoic tectonic evolution and palaeogeography of East Asian crustal fragments: the Korean Peninsula in context. Gond. Res., 9, 24 –46.

Mitchell, A.H.G., 1981. Phanerozoic plate boundaries in mainland SE Asia, the Himalayas and Tibet. Jour. Geol. Soc., 138, 109−122.

Mitchell, A.H.G., and McKerrow, W.S., 1975. Analogous evolution of the Burma orogen and the Scottish Caledonides. Bull. Geol. Soc. America., 86, 305"315.

Mitchell, A.H.G., 1985. Collision-related fore-arc and back-arc evolution of the northern Sunda arc. Tectonophysics, 116, 323-334.

Müller, R.D., Roest, W.R., Royer, J.Y., Gahagan, L.M. and Sclater, J.G., 1997. Digital isochrones of the world's ocean floor. Jour. Geophys. Res., 102, 3211–3214.

Newcomb, K.R., and McCann, W., 1987. Seismic history and seismotectonics of the Sunda arc. Jour. Geophys. Res., 92, 421-439.

Pacheco, J.F., Sykes, L.R., Scholz, C.H., 1993. Nature of seismic coupling along simple plate boundaries of the subduction type. Jour. Geophys. Res., 98, 14133-14159.

Pal, T., Chakraborty, P.P., Duttagupta, T., and Singh, C.D., 2003. Geodynamic evolution of the outer-arc-forearc belt in the Andaman Islands, the central part of the Burma-Java subduction complex. Geol. Mag., 140, 289-307.

Replumaz, A., and Tapponnier, P., 2003. Reconstruction of the deformed collision zone between Indian and Asia by backward motion of lithospheric blocks. Jour. Geophys. Res., 108, 2285, doi: 10.1029/2001JB000661.

Ruff, L., Kanamori, H., 1980. Seismicity and the subduction process. Phys. Earth Planet. Int., 23, 240-252.

Ruff, L.J., 1989. Do trench sediments affect great earthquake occaurances in subduction zones? Pure App. Geophys., 129, 263-282, doi: 10.1007/BF00874629.

Ruff, L.J., and Tichelaar, B.W., 1996. What controls the seismogenic plate interface at subduction zones?, in Bebout, G.E. et al., eds., Subduction Top to bottom. Am. Geophys. Union Geophys. Monog., 96, 105-111.

Scholz, C.H., and Campos, J., 1995. On the mechanism of seismic decoupling and back arc spreading at subduction zones. Jour. Geophys. Res., 100, 22103-22115.

Scotese, C.R., Gahagan, L.M., and Larson, R.L., 1988. Plate tectonic reconstructions of the Cretaceous and Cenozoic ocean basins. Tectonophysics, 155, 27-48.

Subarya, C., Mohamed, C., Prawirodirdjo, L., Avouac, J.-P., Bock, Y., Sieh, K., Meltzner, A.J., Natawidjaja, D.H. and McCaffrey, R., 2006. Plate-boundary deformation associated with the great Sumatra-Andaman earthquake. Nature, 440, 46-51.

Tapponnier, P., Peltzer, G., and Armijo, R., 1986. On the mechanics of the collision between India and Asia. In: M.P. Coward and A.C. Ries (Eds.). Collision Tectonics. Spec. Pub. Geol. Soc. London, 19, 115–157.

Uyeda, S. and Kanamori, H., 1979. Back-arc opening and the mode of subduction. Jour. Geophys. Res., 84, 1049-1061.