J. Ind. Geophys. Union (May 2016)
v.20, no.3, pp: 316-324

Global Seismic Temporal Pattern and Enhanced Seismicity Since 2000

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ABSTRACT

Temporal pattern of global seismicity indicates temporal clustering of large earthquakes ($M_w \geq 8.2$) followed by relative quiescence (stress shadow). It is a characteristic seismic pattern along the plate boundaries. Clustering of the largest earthquakes during 1950s to 1960s followed by the extended period of low-moment release until 2003 and then again heightened moment release since 2004 has been observed, which represents a seismic temporal pattern of 50 years period. Similarly, the Alpine-Himalaya-Andaman-Sumatra (AHAS) belt and stable Indian Peninsular region have showed repeated temporal pattern of high and low seismicity. In the AHAS belt, seismicity was high during 1897 to 1916, low during 1917 to 1933, high again during 1934 to 1951, low again during 1952-1999 and since 2000 onwards seismicity has again enhanced. It has been observed that when there were no great earthquakes in Himalaya, the Peninsular India experienced, during that period, more number of $M \geq 6$ earthquakes.

Key words: Seismicity, Clustering, Quiescence, Temporal pattern.

INTRODUCTION

Earthquakes do not occur randomly in space and time; on this assumption, temporal and spatial seismicity patterns have been studied by various researchers (Benioff, 1951, 1954; Davies and Brune, 1971; Mogi, 1974, 1979; Evison, 1982; Kagan and Jackson, 1991; Pacheco and Sykes, 1992; Bufe, 1997; Bufe and Perkins, 2005), and have observed that the study of seismic pattern is very much essential to understand the phenomenon of great earthquake preparation. Many researchers including Evison (1982), Bowman et al., (1998) Jaume and Sykes (1999), Bufe and Perkins (2005) have reported the changes in seismicity over a wider region before the occurrence of a major event. Further, most of the space-time pattern seismic studies are mainly concentrated on seismic quiescence, accelerating seismic energy/moment release and migration of seismicity. The present study is also focused on the temporal pattern of energy release of globally recorded strong earthquakes of $M_w \geq 8.2$, and accelerated seismicity and seismic moment release before the occurrence of a great earthquake.

In the present study, we have considered the globally recorded large earthquakes since 1900 of $M_w \geq 8.2$, which contribute the maximum moment to the accelerating seismic moment, and it is observed that the $M_w \geq 8.2$ earthquakes are the most influencing to the rate of moment release, directly or indirectly. Also, it has been observed that worldwide rate of occurrence of smaller earthquakes ($M < 7$) does not change systematically over time (Pacheco and Sykes, 1992, Bufe and Perkins, 2005). Hence, our present study is based on the large earthquakes of $M_w \geq 8.2$ for global seismicity study. Moreover, we have observed that the great earthquakes of $M_w \geq 9.0$ are preceded by quiescence or relatively lower seismicity of $M_w \geq 8.2$ earthquakes. Hence, $M_w \geq 8.2$ earthquakes can be considered as precursor to great or mega earthquake, and it can be considered as partially reoccurrence temporal pattern of high and relatively low seismicity.

Globally, rate of release of seismic moment has seen a sudden rise after 2004 Sumatra earthquake (M_w 9.3, Tsai et al., 2005) that still continues, and which may be considered as a precursor to the next great earthquake, similar to 1960 Chile earthquake (M_w 9.5, Kanamori and Anderson, 1975). The 1952 Kamchatka earthquake can be considered as a precursor to the great 1960 Chile earthquake. Moreover, similar kind of seismic pattern has also been observed at regional and local scale. The Alpine-Himalaya-Andaman-Sumatra (AHAS) belt and stable Indian Peninsula has also observed alternative temporal pattern of relatively low and high seismicity for $M \geq 7.7$ and $M \geq 6.0$, respectively.

Earthquake data and Catalogue Preparation

Pacheco and Sykes (1992) have provided the high quality homogeneous seismic-moment catalogue for large magnitude ($M \geq 7.0$) and shallow depth ($z \leq 70$ km) earthquakes for the period 1900-1989. Hence, in the present study Pacheco–Sykes catalogue of $M_w \geq 8.2$ earthquakes has been considered for the period 1900 -1989, and from 1989 onwards Global Centroid Moment Tensor (GCMT) catalogue (Dziewonski et al., 1981, 2001; Ekstörm et al., 2012). In the present study, for 1960 Chile earthquake we have considered the Kanamori and Anderson (1975) estimated seismic moment (M_o) of 2000

Table 1. Extended Pacheco-Sykes catalog of earthquakes $M_w \geq 8.2$, 1900 - 2014. Pacheco-Sykes catalog from 1900-1989, and from 1989 onwards using GCMT catalog.

EQ Nos.	Date	Origin Time	Lat (°)	Long (°)	Depth (km)	$Mo \times 10^{20}$ (Nm)	M_w	Location
	YYYY-MM-DD	Hr:Mn						
1	1905-07-09	09:40	49.0	99.0	35	55.0	8.5	Mangolia
2	1905-07-23	02:46	49.0	97.0	35	50.0	8.4	Mangolia
3	1906-01-31	15:36	01.0	-81.3	33	80.0	8.6	Colombia-Ecuador
4	1906-08-17	00:40	-33.0	-72.0	33	66.0	8.5	Chile
5	1917-06-26	05:49	-15.5	-173.0	33	70.0	8.5	Tonga Islands
6	1918-08-15	12:18	05.7	123.5	33	25.0	8.2	Philippines
7	1918-09-07	17:16	45.5	151.5	33	22.0	8.2	Kurile Islands
8	1919-04-30	07:17	-19.0	-172.5	33	27.1	8.3	Tonga Islands
9	1920-12-16	12:05	36.6	105.4	33	30.0	8.3	Kansu, China
10	1922-11-11	04:32	-28.5	-70.0	33	140.0	8.7	Chile
11	1923-02-03	16:01	54.0	161.0	33	70.0	8.5	Kamchatka
12	1924-06-26	01:37	-55.0	158.4	33	30.2	8.3	Macquarie Ridge
13	1933-03-02	17:30	39.3	144.5	30	43.0	8.4	Japan
14	1938-02-01	19:04	-05.5	131.5	40	52.0	8.4	Banda Sea
15	1943-04-06	00:00	-31.0	-71.3	20	25.0	8.2	Chile
16	1950-08-15	14:09	28.7	96.6	30	95.0	8.6	Assam
17	1952-11-04	16:58	52.8	159.5	33	350.0	9.0	Kamchatka
18	1957-03-09	14:22	51.6	-175.4	33	100.0	8.6	Aleutian Islands
19	1958-11-06	22:58	44.4	148.5	32	44.0	8.4	Kuril Islands
20	1960-05-21	10:02	-37.2	-73.0	33	20.0	8.2	Chile
21	1960-05-22	19:11	-38.2	-73.5	32	2000.0	**9.5**[*]	Chile
22	1963-10-13	05:17	44.9	149.6	40	75.0	8.6	Kuril Islands
23	1964-03-28	03:36	61.1	-147.6	30	750.0	9.2	Alaska
24	1965-01-24	00:11	-02.4	126.0	23	24.0	8.2	Banda Sea
25	1965-02-04	05:01	51.3	178.6	35	140.0	8.7	Aleutian Islands
26	1966-10-17	21:41	-10.9	-78.8	21	20.0	8.2	Peru
27	1968-05-16	00:48	40.9	143.4	35	28.0	8.3	Tokachi-oki, Japan
28	1969-08-11	21:27	43.6	147.2	30	22.0	8.2	Kurile Islands
29	1977-08-19	06:08	-11.1	118.5	23	24.0	8.2	Indonesia
30	1979-12-12	07:59	01.6	-79.4	24	29.0	8.3	Colombia-Ecuador
31	1989-05-23	10:54	-52.3	160.6	50	24.0	8.2	Macquarie Ridge
32	1994-10-04	13:23	43.6	147.6	68	30.0	8.3	Kuril Islands
33	1996-02-17	06:00	-0.7	136.6	15	24.0	8.2	Irian, Indonesia
34	2001-06-23	20:34	-17.3	-72.7	30	47.0	8.4	Peru
35	2003-09-25	19:50	41.8	143.9	27	30.5	8.3	Hokkaido, Japan
36	2004-12-26	05:08	03.3	96.0	30	1200.0	**9.3**[**]	Sumatra
37	2005-03-28	16:09	2.1	97.1	30	105.0	8.6	Sumatra
38	2006-11-15	11:14	46.6	153.3	10	35.1	8.3	Kuril Islands
39	2007-09-12	11:10	-04.4	101.4	34	67.1	8.5	Sumatra
40	2010-02-27	06:34	-36.1	-72.9	22	186.0	8.8	Chile
41	2011-03-11	05:46	38.3	142.4	29	531.0	9.1	Honshu, Japan
42	2012-04-11	08:39	02.2	92.8	40	89.6	8.6	Sumatra
43	2012-04-11	10:43	0.8	92.3	53.7	25.3	8.2	Sumatra
44	2013-05-24	05:45	54.6	153.8	**611.4**[#]	39.5	8.3	Sea of Okhotsk
45	2014-04-01	23:47	-19.6	-70.8	20.1	23.5	**8.2**[$]	Chile

[*] EQ no. 21 (1960 Chile earthquake) M_w is consider after Kanamori and Anderson (1975), and Bufe and Perkins (2005).

[**] EQ no. 36 (2004 Sumatra earthquake) M_w is consider after Tsai et al., (2005), and Stein and Okal (2007).

[#] EQ no. 44 (2013 Sea of Okhotsk) is a deep earthquake.

[$] EQ no. 45 (2014 Chile earthquake) Hypocentral parameters, Moment magnitude (M_w) and Seismic Moment (M_o) are considered from USGS report.

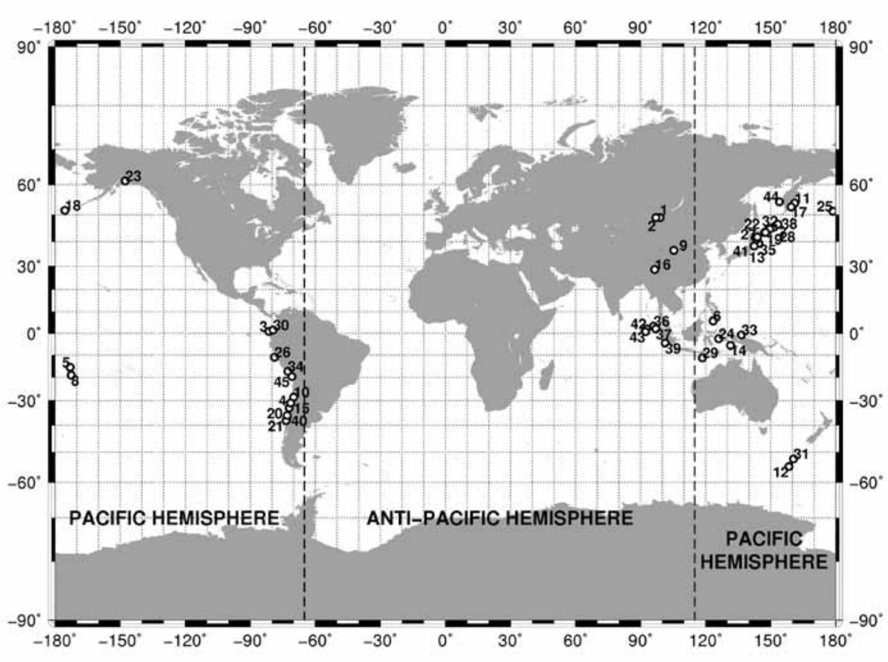

Figure 1. Global distribution of $M_w \geq 8.2$ earthquakes as a function of latitude and longitude by using catalogue provided in Table 1. The great earthquakes are represented here by earthquake (EQ) numbers provided in Table1.

$\times 10^{20}$ Nm and $M_w = 9.5$. Cifuentes and Silver (1989) and Pacheco and Sykes (1992) estimate of $M_w = 9.6$ and $M_o = 3200 \times 10^{20}$ Nm were not considered. Also, for the 2004 Sumatra earthquake, Tsai et al., (2005) and Stein and Okal (2007) estimated values, $M_w = 9.3$ and $M_o = 1200 \times 10^{20}$ Nm were used in the present study. Further, seismic moment provided in the Pacheco and Sykes (1992) catalogue is converted into M_w using Hanks and Kanamori (1979) relation, $M_w = (\log(M_o) - 9.05)/1.5$ (M_o is in Nm) for global seismicity analysis. The spatial distribution of the globally recorded larger events ($Mw \geq 8.2$) that dominate the history of the moment release and used in the present study are represented in Figure 1 and tabulated in Table 1. Further the earthquakes ($M \geq 7.7$) distribution for the AHAS belt provided by the Hamada (1981) and Gupta (1992) has been updated using USGS catalogue as listed in Table 2.

Clustering, Quiescence, and Migration

To understand earthquakes occurrence as non-random, non-linear and coherent system, we have used the catalogue of large earthquakes at global and regional scale. The globally recorded $M_w \geq 8.2$ earthquakes catalogue is further studied to observe the temporal and spatial pattern. The alternative temporal pattern of enhanced seismic activity and quiescence has been observed for $M_w \geq 8.2$ earthquakes as shown in Figure 2a by decadal plot of earthquake records. Also the moment release by great earthquakes per decade is represented in Figure 2b and cumulative accumulation of seismic moment of $M_w \geq 8.2$ earthquakes in Figure 2c. The high moment release is noticed during 1950s to 1960s followed by extended period of low moment release until 1999 and again heightened moment release has been observed since 2000 as shown in Figures 2b and 2c. The period of 1950 to 1999 represents one complete seismic pattern of clustering and quiescence of great earthquakes. Further, on analysing the recent records of $M_w \geq 8.2$ earthquakes, it has been observed that the 34% of the total seismic moment since 1900 has been released during the decades of 2000s and 2010s (2010 decade includes data up to 2015). Hence the recent accelerated seismic moment can be compared with 1950-1960 accelerated seismic moment release as shown in Figure 2a. The rate of seismic moment release was accelerated after the 1952 Kamchatka earthquake (M_w 9.0) and continued till the occurrence of 20th century greatest 1960 Chile earthquake (M_w 9.5). However, no great earthquake of $M_w \geq 9.0$ was observed before the 1952 Kamchatka earthquake. Hence, 1952-1962 decade represents clustering of great earthquakes ($M_w \geq 9.0$), and includes 1952 Kamchatka, 1960 Chile and 1962 Alaska earthquakes. Similar observation of clustering of large earthquakes before the occurrence of great earthquake and quiescence (stress shadow) has been reported by Bufe and Perkins (2005). They have reported the seismic pattern of clustering and quiescence by using Monte-Carlo simulation technique to determine probabilities of random occurrence. Monte-Carlo simulations of random occurrence provided the probability of temporal clustering

Table 2. Earthquakes of Mw ≥ 7.7 in Alpine-Himalaya-Andaman-Sumatra belt during 1991 - 2014 using USGS catalog.

EQ Nos.	Date	Origin Time	Lat.(°)	Long.(°)	Depth (Km)	Mw	Location
	YYYY-MM-DD	Hr:Mn:Sec					
1	1992-12-12	05:29:26	-8.5	121.9	28	7.8	Indonesia
2	1994-06-02	18:17:34	-10.5	112.8	18	7.8	Java,Indonesia
3	1996-01-01	08:05:11	0.7	119.9	24	7.9	Minahassa Peninsula, Sulawesi
4	1998-11-29	14:10:32	-2.1	124.9	33	7.7	Ceram Sea
5	1999-09-20	17:47:18	23.8	121.0	33	7.7	Taiwan
6	2000-06-04	16:28:26	-4.7	102.1	33	7.9	Sumatra,Indonesia
7	2000-06-18	14:44:13	-13.8	97.5	10	7.9	South Indian Ocean
8	2001-01-26	03:16:41	23.4	70.2	16	7.7	Kachchh,Gujarat,India
9	2001-11-14	09:26:10	40.0	90.5	10	7.8	Qinghai,China
10	2004-12-26	00:58:53	3.3	96.0	30	9.3	Sumatra,Indonesia
11	2005-03-28	16:09:37	2.1	97.2	30	8.6	Sumatra,Indonesia
12	2006-07-17	08:19:27	-9.3	107.4	20	7.7	Java,Indonesia
13	2007-09-12	23:49:04	-2.6	100.8	35	7.9	Kepulauan Mentawai Region,Indonesia
14	2007-09-12	11:10:27	-4.4	101.4	34	8.5	Sumatra,Indonesia
15	2008-05-12	06:28:02	31.0	103.3	19	7.9	Sichuan,China
16	2010-04-06	22:15:02	2.4	97.5	31	7.8	Sumatra,Indonesia
17	2010-10-25	14:42:22	-3.5	100.1	20	7.8	Kepulauan Mentawai Region,Indonesia
18	2012-04-11	10:43:11	0.8	92.5	25	8.2	Sumatra,Indonesia
19	2012-04-11	08:38:37	2.3	93.1	20	8.6	Sumatra,Indonesia
20	2013-04-16	10:44:21	28.1	62.1	82	7.7	Iran -Pakistan Border Region
21	2013-09-24	11:29:47	26.9	65.5	15	7.7	Awaran, Pakistan
22	2015-04-25	06:11:25	28.2	84.7	8	7.8	Lamjung, Nepal

in a 12-yr period (1952–1964) of the three greatest ($M_w \geq 9.0$) earthquakes as 4%. Also they have provided 0.5% probability of quiescence of $M_w \geq 8.4$ earthquakes for a period of 36 yrs (after 1964), and this quiescence period is called as global stress shadow. Mogi (1969), Sykes and Jaume (1990), Bufe and Varnes (1993), Sobolev and Tyupkin (1999), and Bufe and Perkins (2005) have also reported the clustering of large earthquakes before the occurrence of great earthquakes. Moreover, Kagan and Jackson (1991) have also provided the statistical results on existence of large-scale temporal earthquake clustering and quiescence. The observed global moment release pattern (clustering of large earthquakes, with acceleration before and deceleration after the mainshock) suggests that Earth, over many decades, may also respond as a coherent, non random, nonlinear system of stress redistribution.

Further, we have also observed high and low seismic moment release alternatively in pacific and anti-pacific hemispheres as shown in Figure 3. In 1960's decade, Pacific hemisphere has only seen the seismic moment release through great earthquakes. While on the contrary, in 2000's decade anti-pacific hemisphere has seen the maximum moment release (see Figure 3). On comparing the seismic moment release in the pacific and anti-pacific hemispheres, we have observed that during 1950-1970, 97% of the seismic moment released in the pacific hemisphere, with a dominating 1960 Chile earthquake, which itself contributes 84% of the total moment released. Only 1950 Assam earthquake (M_w 8.6) contributed to the anti-pacific moment release. While since 2000 we have seen equal number of great earthquakes in both the hemispheres with 63% of moment release in anti-pacific hemisphere (see Figure 3). The 2004 Sumatra earthquake (Mw 9.3) itself contributes 51% of the total moment released during 2000-2015. This increase in global-moment release rate in both the Pacific and anti-Pacific hemispheres may be related to the recent changes in moment of inertia and shape of the earth (Cox and Chao, 2002). Dickey et al., (2002) attribute the observed increase to subpolar glacial melting and mass shifts in the oceans. Also, Bufe and Perkins (2005) urge for the concept that if global seismic cycle is valid, then the global cycle durations will be shorter than the recurrence times of most individual great earthquakes, because not all the global potential seismic moment or energy is released

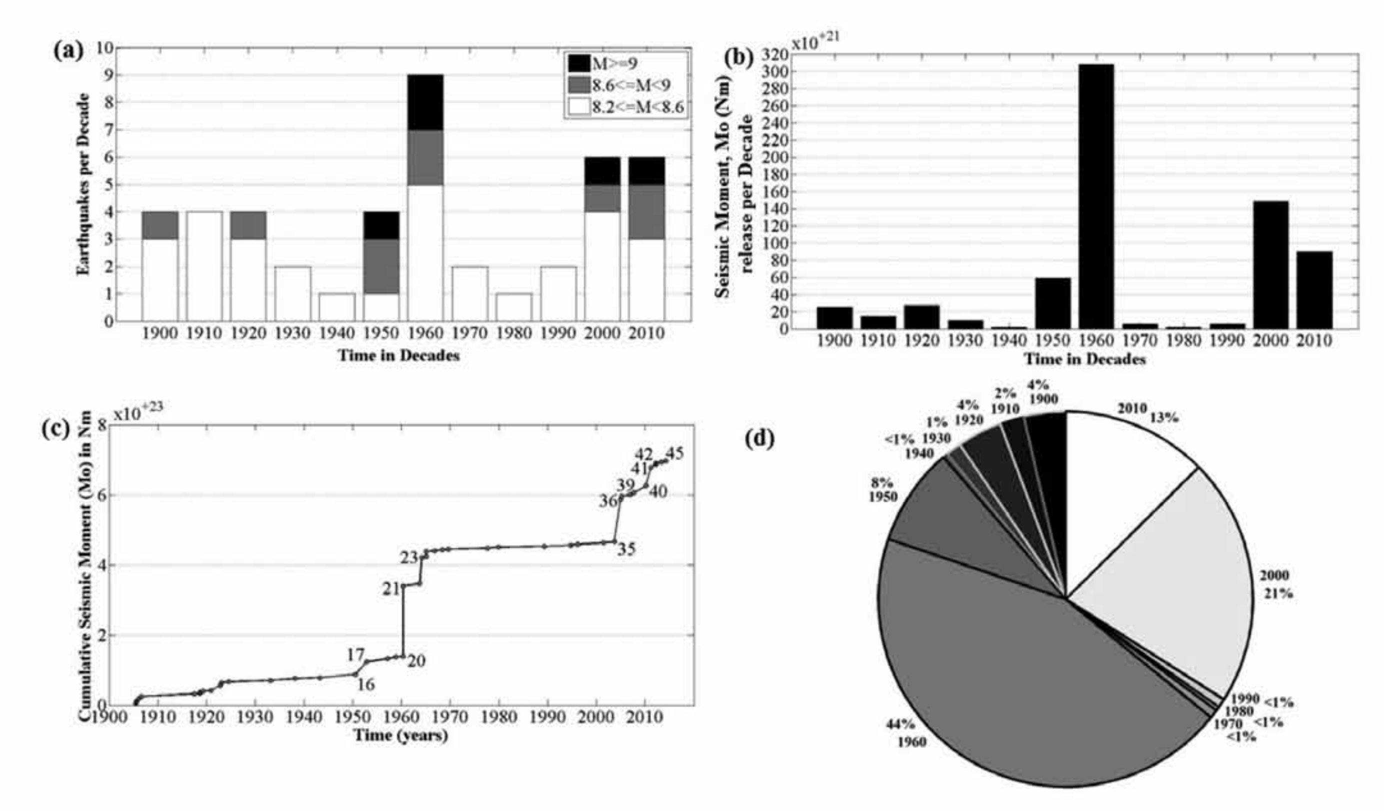

Figure 2. Plot showing (a) Decadal histogram illustrating temporal clustering of global great earthquakes of $M_w \geq 9.0$ (black), $M_w \geq 8.6$ (black+gray), and $M_w \geq 8.2$ (black+gray+white).The bar for the decade 2010 represents earthquakes of the first 4.5 yrs, (b) Decadal histogram illustrating seismic moment, M_o (Nm) release of $M_w \geq 8.2$ earthquakes by using catalogue presented in Table 1, (c) Cumulative global seismic moment release, 1900–2014, for $M_w \geq 8.2$ earthquakes by using catalogue presented in Table 1, and (d) Seismic moment release per decade (in percentage of total moment release in 114.5yrs) decade wise of earthquakes $M_w \geq 8.2$.

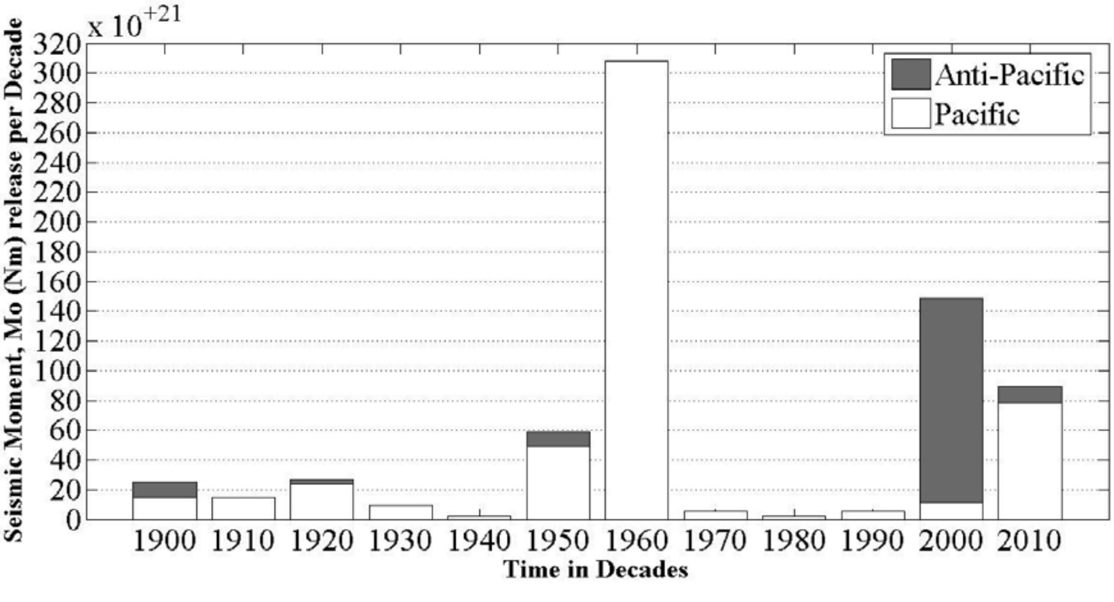

Figure 3. Decadal histogram illustrating seismic moment, M_o (Nm) release of $M_w \geq 8.2$ earthquakes in Pacific and Anti-Pacific hemisphere using catalogue presented in Table 1.

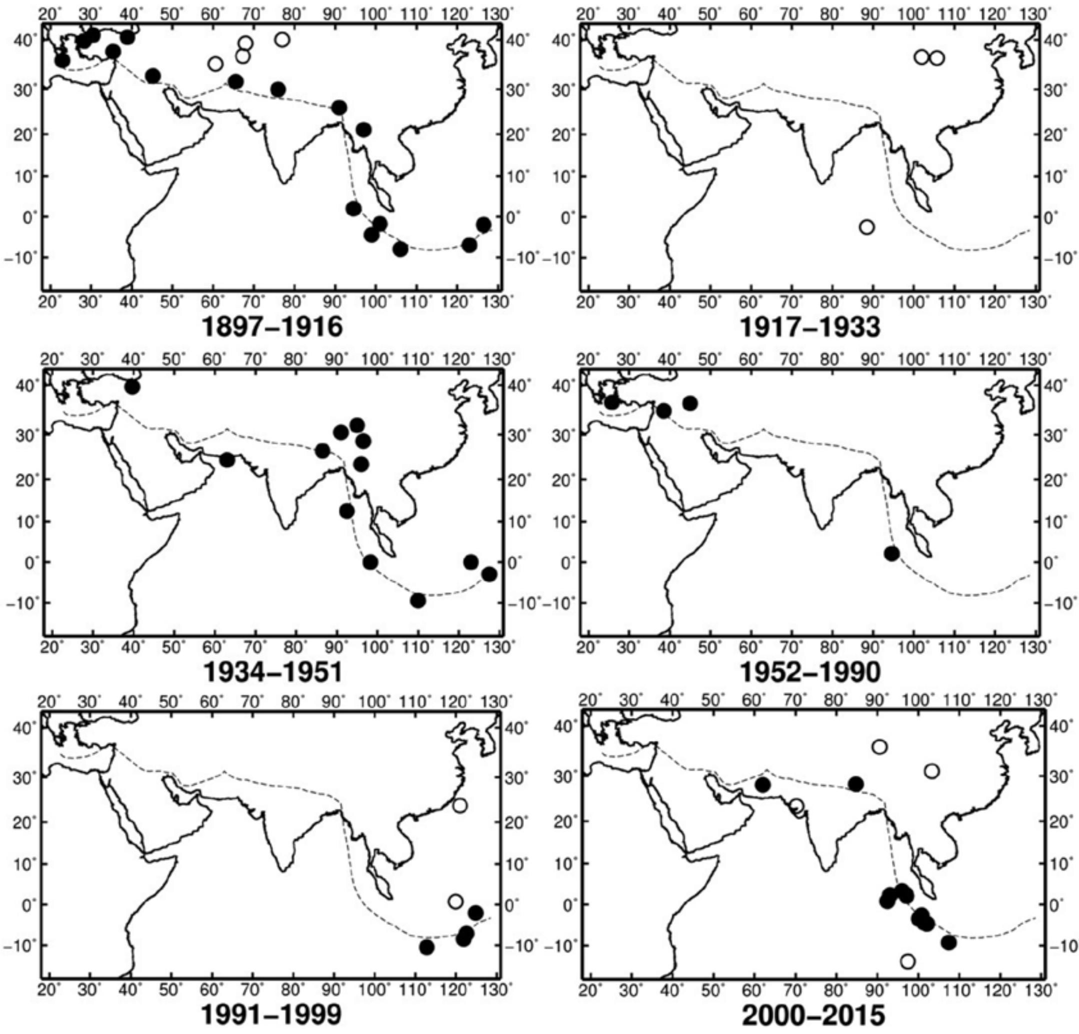

Figure 4. Seismic temporal pattern in the Alpine-Himalaya-Andaman-Sumatra belt for shallow earthquakes of focal depth 100 km and M≥7.7 (up to 1981 after Hamada, 1981 and later on modified till 1990 by Gupta, 1992). Subsequently, after 1990 USGS catalogue has been used (refer Table 2). Solid and open circles represent M≥7.7 earthquakes. Open circles indicate epicenters away from the belt.

in a single cycle. Besides this Romanowicz (1993) provided a different category of global seismic pattern, representing alternating temporal pattern of toroidal (strike-slip) and poloidal (thrust or normal) energy release. The period of high moment release during 1950-1960 and 2010-2014 corresponds to the poloidal seismic pattern, while 1965-2003 represents the lower-moment toroidal seismic pattern.

The similar kind of repeated alternative temporal pattern of low and high seismicity has also been observed for the AHAS and stable Indian Peninsular region (see Figure 4). The high seismicity has been observed for AHAS belt during 1897-1916, 1934-1951 and since 2000. While, low seismicity was observed for 1917-1933 and 1952-1999. The present observation for the AHAS and stable Indian Peninsular region is based on the M ≥ 7.7 earthquakes. Also, around the same period 1965-1999, rest of the world has also seen low seismicity. Hamada (1981) and Gupta (1992) have also reported the alternative temporal pattern of clustering and quiescence for M ≥ 7.7 earthquakes for the AHAS region. Contradictory to this, stable Indian peninsular region was active during 1965-1999 with large number of earthquakes of M ≥ 5.0, as shown in Figure 5. It has also been observed that during the periods when there are no great earthquakes in the Himalaya, the Peninsular India has seen more number of M ≥ 5 earthquakes (see Figure 5). Since 1960s Peninsular India has unusually experienced a large number of M ≥ 5 earthquakes. It may be explained on the basis of long range migration of the strain energy between the mechanically coupled fault systems in the continental interior, on the basis of Liu et al., (2011) explanation for the North China. Liu et al., (2011) have observed the similar pattern of

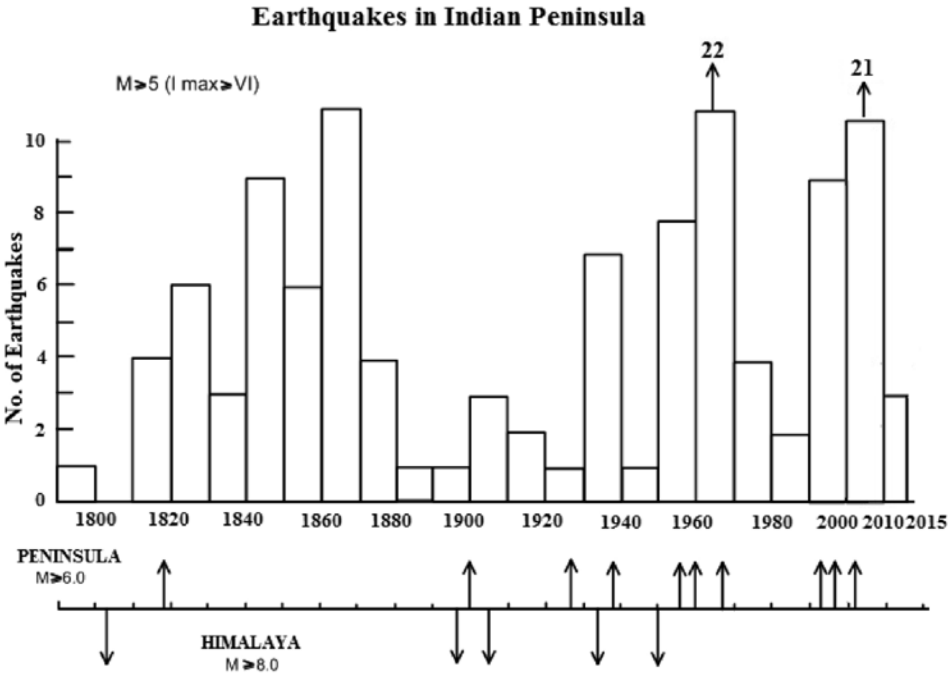

Figure 5. During the shadow periods when M8 earthquakes are absent in Himalaya (lowermost part), earthquakes are more in SCR India and vice-versa.

migration for earthquakes of M ≥ 4.0 in North China region. They have proposed a simple conceptual model for intra-continental earthquakes, in which slow tectonic loading in mid-continents is accommodated collectively by a complex system of interacting faults, each of which can be active for a short period after a long dormancy, and the resulting large earthquakes are episodic and spatially migrating. However, since 2000 AHAS Belt and its nearby regions again have seen many large earthquakes of $M_w \geq 7.7$ including 2004 Andaman-Sumatra (M_w 9.3), 2013 Iran (M_w 7.7) and 2015 Nepal (M_w 7.8), which may be possibly indicating enhanced seismicity in AHAS Belt for M ≥ 7.7 earthquakes. The pattern of high and low seismicity in AHAS Belt is similar to the global seismicity pattern, including enhanced seismicity since 2000.

The similar kinds of seismicity temporal pattern have also been reported by many other earth scientists (Mogi, 1969; Evison, 1982; Wyss and Habermann, 1988; Sornette and Sornette, 1990; Sykes and Jaume, 1990; Bufe and Varnes, 1993; Sornette and Sammis, 1995; Sobolev and Tyupkin, 1999; Bowman and King, 2001; Bufe and Perkins, 2005) for different source zones around the world. Mogi (1969) has explained the enhanced seismicity on the basis of "doughnut pattern", according to which increased seismicity during a certain period before the occurrence of strong earthquake concentrates around the periphery of the future earthquake rupture zone. The rupture zone of the oncoming earthquake remains relatively quiet. Wyss and Habermann (1988) have also reported the precursory quiescence, lasting for months or years before the occurrence of large earthquakes. Bufe and Varnes (1993) have observed accelerating seismic moment release within a broader area around the epicentre of a future earthquake. Sobolev and Tyupkin (1999) have also reported the similar findings by using region-time-length (RTL) method. Bowman et al., (1998); Jaume and Sykes (1999) and Simpson and Reasenberg (1994) also supported the change in seismicity over a wider zone before the occurrence of a major event. Moreover, on the basis of Evison (1982), and Bowman and King (2001) observations, occurrence of large earthquake can be identified on the basis of increased seismicity and increase in stress level around the seismic active zone; large seismically active region indicates the large magnitude earthquake. On the basis of Evison (1982), swarms of special pattern in time and space may indicate a precursory signal to an impending large earthquake. Based on the earthquake swarm hypothesis of Evison (1982), Gupta and Singh (1986) tested the precursory phenomena of the 1984 Cachar earthquake (M5.8, USGS) and made a forecast of the August 6, 1988 Manipur-Burma border earthquake (M 7.2). The 1988 earthquake occurred within the stipulated time and space window and they claimed it to be a successful forecast (Gupta and Singh, 1989). Hence, all precursory studies based on seismic rate changes and acceleration of seismic activity prior to large earthquake can be considered as a decisive phenomenon in understanding the Earth as coherent, non-random and non-linear system of stress redistribution.

Earthquake triggering and Temporal pattern of Seismicity

The mechanism behind the global triggering of earthquakes, and following a specific seismic pattern can be explained on the basis of following assumptions/possibilities: (1) Large or global scale processes take place in the lithosphere (Barenblatt et al., 1983; Press and Allen 1995); (2) Propagation of viscoelastic deformation in the asthenosphere (Piersanti et al., 1995; Pollitz et al., 1998); (3) Stress transfer from great slow earthquakes migrating along the base of the seismogenic zone along plate margins (Bufe and Perkins 2005); (4) Redistribution of mass in the hydrosphere or mantle (Cox and Chao 2002; Dickey et al., 2002); (5) Long range correlation of complex non linear hierarchical dynamical systems (Kelis–Borok, 1990, 2002; Sornette and Sammis, 1995; Turcotte et al., 2000), for example, the lithosphere can be considered as a complex hierarchical-dynamical system where strong earthquakes are critical phenomenon; (6) Quasi-static changes in fault properties or pore pressure induced by transient dynamic stresses of seismic waves or free oscillations of the earth generated by distant great earthquakes (Bufe and Perkins 2005). (7) Attainment of a global tectonic state of self-organized criticality.

CONCLUSIONS

The present study provides some facts to elucidate that the large earthquakes do not occur randomly in space and time. They generally follow a specific pattern.

The present study also provides underlying physics behind the earthquake temporal pattern that can be incorporated into seismic hazard analysis.

The present study helps in illustrating the existing seismicity scenario of the World in general and AHAS belt and stable Indian Peninsular region in particular.

The great earthquakes ($M_w \geq 8.2$) follow a specific pattern of quiescence (stress shadow) and clustering globally. In our study, we have observed two such temporal patterns during the periods of 1925-1965 and 1966-2015 (still continue).

The AHAS belt has seen repeated alternative temporal pattern of high and low seismicity for large earthquakes ($M_w \geq 7.7$). The AHAS belt has seen low seismicity during the periods, 1917-1933 and 1952-1999 and high seismicity during 1897-1916, 1934-1951 and 2000-2015 (still continue). The AHAS belt represents the similar temporal pattern of high and low seismicity, almost during the same period as observed globally.

The stable Indian Peninsular region has also seen the seismic pattern of low and high, but reversely. When seismicity is high in Himalaya region, Peninsula has observed low seismicity and vice-versa.

The present day scenario is showing enhanced seismicity, globally as well as in AHAS region. In future, it may lead to the occurrence of another great earthquake like 1960 Chile (M_w 9.5).

The seismicity modifies or high seismicity is observed with a clustering of great earthquakes before the major event and stress shadows follow great earthquakes.

The evolution pattern of cumulative seismic moment prior to the occurrence of great earthquake can be used as an additional tool for seismic hazard assessment, besides the duration of our current seismic record is not representing a complete cycle of large earthquakes.

ACKNOWLEDGEMENTS

The authors are grateful to their organization for support of this research. The authors are thankful to the USGS, USA and Global Centroid-Moment-Tensor (CMT) Project resource persons; Prof. Göran Ekström, Prof. Meredith Nettles and Prof. Adam Dziewonski for earthquake catalogues. The authors are also thankful to Dr. J. R. Kayal and an anonymous reviewer for their useful comments and suggestions in improving the quality of the manuscript.

Compliance with Ethical Standards

The authors declare that they have no conflict of interest and adhere to copyright norms.

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