T1.5-P1

'SEISMIC CYCLE' AND OCCURRENCE OF LARGE EARTHQUAKES

D. Shanker

Department of Earthquake Engineering, Indian Institute of Technology Roorkee, Roorkee-247667, India; dayasfeq@iitr.ac.in

Abstract

Cyclicity in seismic activity is important for earthquake hazard studies, because these patterns may lead to the prediction of large earthquakes. The observations of temporal variation of seismic activity in Northeast India as well as Gujarat and adjoining region indicate that a periodic seismicity probably exists. In the present study, data from 1819 to 2006 of shallow earthquakes distributed over Gujarat and vicinity have been analyzed on the basis of stationary model of seismicity rates and seismic energy released in 11-years' time window, for future earthquake occurrences. Harmonic variation of seismic energy release shows a system of periodicities with predominant period in low seismicity rate intervals followed by in high seismicity rate intervals with a period of 105 years. However, the time interval of low seismicity rates is slightly larger than high seismicity rates. The frequency distribution of small magnitude (M 4.0-5.9) earthquakes follow the Poisson distribution while large earthquakes (M 6.0-7.8) follows the nonrandom distribution (exponential distribution). The non-randomness characteristics indicate that the prediction of magnitude and time of occurrences of forthcoming large earthquakes may be possible. The occurrence of large earthquakes lies on the maxima of the harmonic curve.

Introduction

The seismic "cycle" refers to the observation that earthquakes repeatedly rupture a given part of a fault. For obvious reasons, the earthquake cycle is frequently referred to as a "stick-slip" process - long periods of "stick" are followed by a short period of "slip", and the process then repeats itself. The word 'Seismic Cycle' was introduced by Fedotov (1968) for the tendency toward periodicity in the occurrences of large earthquakes in Kamchatka, the Kuril Islands and North-Eastern Japan. Several researchers of the world statistically analyzed the seismicity data for the study of seismicity rates, seismic quiescence and seismicity fluctuations prior to the occurrences of medium to large earthquakes (Habermann and Wyss, 1984; Wyss et al., 1984; Singh et al., 1994; Shanker et al., 2007). In the present paper we investigate the possible variation in the seismic activity of Gujarat and adjoining region using a reliable seismic data for the period 1819-2006 which shows that a periodicity probably holds.

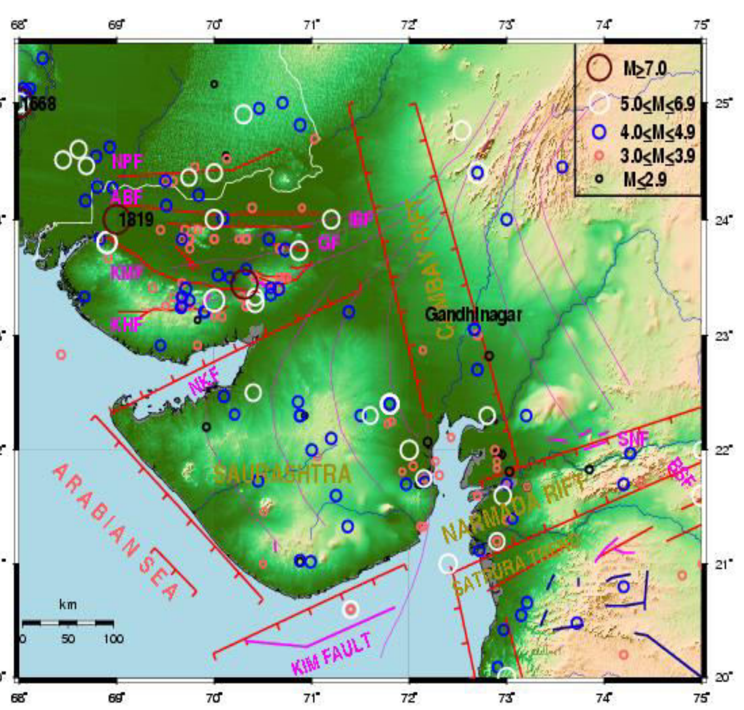

Fig 1. Study region

Geology and Seismotectonics of Study Region

Gujarat is situated in the highly tectonised zone along the western margin of the Indian continental plate. According to Biswas (1987), there are four distinct tectonic regimes associated with boundaries of Gujarat as shown in Fig 1.

Statistical Analyses

A probabilistic approach was performed to deal with this problem under the assumptions that the entire period is a stationary Poisson process. The probability of occurrences of 'x' earthquakes in a time interval 't' is expressed by a Poisson's distribution:

$$p(x) = \frac{e^{(-rt)}(rt)^x}{x!} \quad (1)$$

where 'r' is the mean seismicity rate. The probability P(x) has been calculated for the **low** and **high rate intervals** from above formula (1). **Very low probabilities** obtained with this approach suggest that the **seismicity rates are non-accidental.**

Figure 3 shows the 1819-1848, 1898-1956 low seismicity rate intervals were followed by the. 1856-1891 and 1962-2006 high seismicity rate intervals.

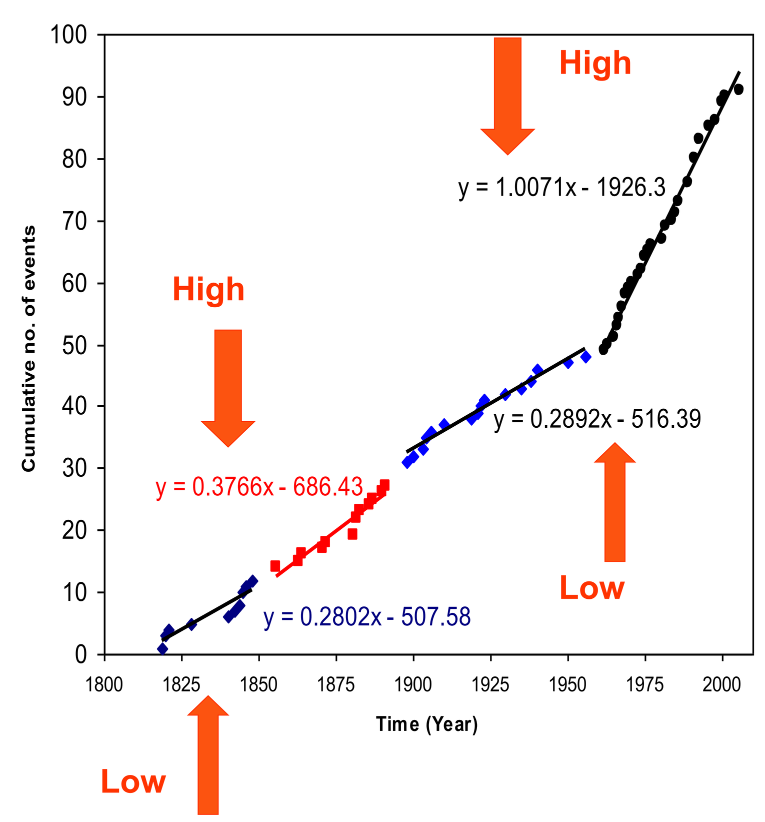

Fig. 2. `long term seismicity rate changes as determine on the basis of the cumulative number of shallow, strong earthquakes as a function of time`

Table 1: summarized the information about seismicity rates of various phases and its time variation.

Time period	r (events per year)	T(Year)	X (events)	P(x)	Rate difference ($r_i - r_{i+1}$)	Confidence level by t-test (%)
16.06.1819-26.04.1848	0.28 ± 0.04	47.9	12	0.001800	-0.10	95
25.12.1856-27.071891	0.38 ± 0.03	33.6	15	0.085400	0.10	95
01.04.1898-21.07.1956	0.28 ± 0.02	58.3	21	0.017400	-0.72	95
01.09.1962-30.09.2006	1.00 ± 0.02	43.1	43	0.000036		

Frequency Distribution

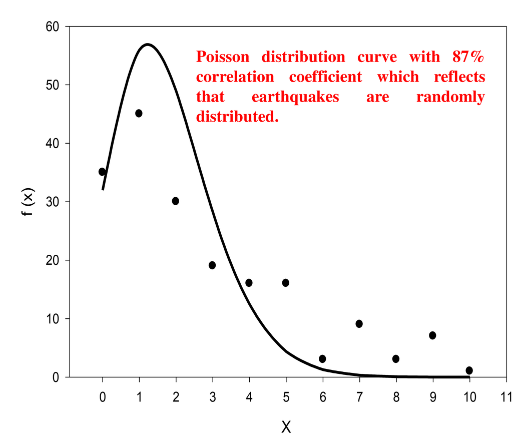

Fig. 3 With M≥4.0 observed in 7 year time window during 1819-2006.

.

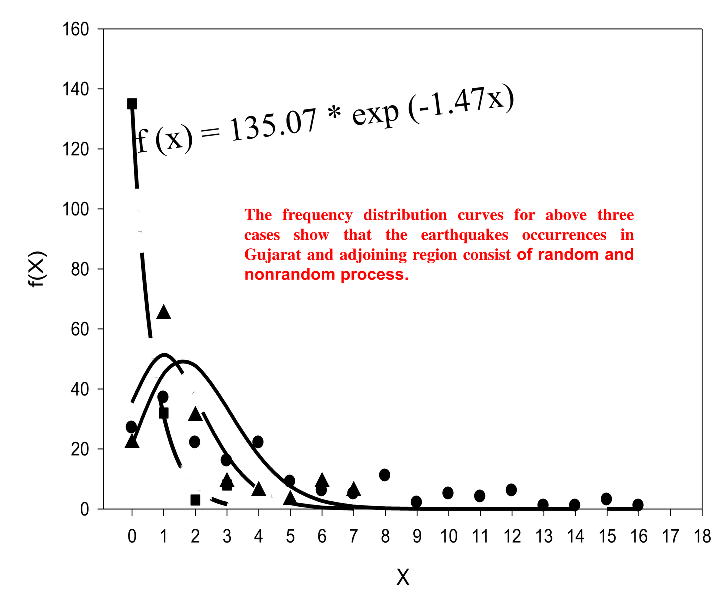

Fig. 4. For three different magnitude range 4.0-4.9 (a), 5.0-5.9 (b) and 6.0-7.0 (c); 11-Year time window . The curves (a) and (b) shows Poisson distribution while (c) shows exponential distribution.

From the previous results, it is observed that a probable cyclic variation of seismicity rates exits. Therefore, a periodicity in the **relaxation of seismic energy** must be expected. Temporal variation of the logarithmic of the total amount of seismic energy (in ergs), is shown in Figure 5. The data from 1819-2006 shows the harmonic variation, which can be fitted in the form of

$$\log E_q = \overline{\log Eq} + (\log Eq_0)\sin\left(\frac{360t}{T} + \emptyset\right)$$

Where

$\overline{\log Eq}$ is the average of log E_q values and $\log E_{q_0}$ represent the mean of the five Largest $|\log Eq - \log E_{q_0}|$ values.. Where,. 'T' represent the time period. A least-square method is used for the determination of phase Φ. The best fitted equation can be written as:

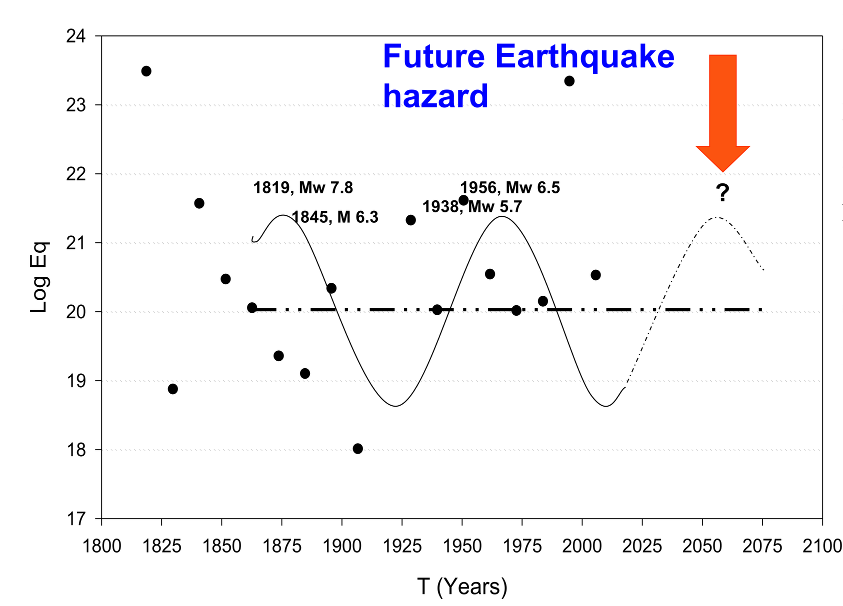

Fig. 5. Temporal variation of the Log Eq, where Eq is the total seismic energy in ergs released by strong and shallow events within 11 years time window

$$\log E_q = 20.51 + 1.73\,sin\left(\frac{360t}{105} + 45\right)$$

The start time't' is measured from the year 1819

Discussion and Conclusions

The results exhibits a network of periodicities with predominant period at 1819-1848, 1898-1956 in low seismicity rate intervals followed by the 1856-1891 and 1962-2006 in high seismicity rate intervals with a period of 105 years in a harmonic variation of seismic energy release. The time interval of low seismicity rates is slightly larger than high seismicity rates. The low seismicity rate varies from 0.2 to 0.3events/year whereas the high seismicity rate varies from 0.4 to 1.0 events/year. The frequency distribution of earthquakes show that the earthquakes of small magnitude (M 4.0-5.9) follow the Poisson distribution and hence such earthquakes can not be predicted. However, the frequency distribution of large earthquakes (M 6.0-7.8) follows the nonrandom distribution (exponential distribution). The characteristics of non-randomness of earthquakes indicate that the prediction of magnitude and time of occurrences of forthcoming large earthquakes may be possible. The temporal variation of earthquake magnitude for three different magnitude ranges (4.0-4.9, 5.0-5.9 and 6.0-7.8) reflects that large earthquakes are preceded by high seismic activity in lower magnitude ranges. The seismic energy released in 11 year time windows shows a harmonic variation with a period of 105 years. The maxima of the harmonic curve coincide with the occurrence of large earthquakes. The detection of such kind of periodicities is important in earthquake study, because these patterns may lead to the prediction of large earthquakes.

Acknowledgements: Full Grant provided by: PTS, CTBTO is gratefully acknowledged.

References

- Fedotov, S. A. (1968), On the seismic cycle, the possibilities for quantitative seismic zoning and long range seismic prediction, seismic zoning in the USSR, Moscow, Nauka, 121-150, in Russian
- Habermann, R. E. and WYss, M. (1984), Background seismieity rates and precursory seismic quiescence: Imperial Valley, California. Bull. Seism. Soc. Am. 74, 1743-1755..
- Singh V.P. Shanker, D., and Hamada, K. (1994), A study of seismicity of Northeast India and adjoining areas based on statistical analyses, Curr. Sci., 66 (12), 922-926
- Shanker, D., Singh V. P., Singh, H. N., Yadav, R. B. S., Banergee, M. (2007), Evidence of conducting fluid was the real cause for the generation of Gujarat earthquake (mw 7.7) of 2001, India, Geophys. Res. Abstracts, 9, 01835
- Wyss, M., Habermann, R. E. and Griesser, J. C. (1984), Precursory seismicity quiescence in the Tonga-Kermadec arc, J. Geophys. Res., 89, 9293-9304.