ANALYSIS OF SEISMICITY IN ARABIAN SEA BASED ON STATISTICAL MODEL

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Abstract:

In seismically active region Arabian Sea, only decision making for coastal areas of Pakistan would be based on probable characteristics of earthquakes to be expected in future. The data records of Pakistan Meteorological Department and international since 1905-2002 were used. Based on previous data record the probability of occurrence of earthquakes with different magnitudes was calculated. The character of seismic activity in the Arabian Sea is described by frequency-magnitude relationship according to Gutenberg and Richter relation LogN = a-bM.

Poisson distribution (P) method is used for the calculation of probability of occurrence of earthquakes in future. The value "a" and "b" for Gutenberg-Richter relation are calculated which are of special importance for seismic zoning of Arabian Sea. The tools for the determination of seismic regime parameters are provided by earthquake statistics. "b"- value has been taken into account for seismic activity that is obtained by calculation of 96 years data record. The data selected did not include events, which has body magnitude less than 3.0 Richter scale.

Introduction:

The tectonic setting of Arabian Sea is shown in Figure 1.1 and the seismicity of Arabian Sea is presented in Fig-2 and Fig-3. From the data record of Arabian Sea, it is found that, there were five earthquakes having body magnitude (Mb) greater than and equal to 6.0 since 1905. The ever-big earthquake Mag 8.3 Richter scale was occurred on 27 Nov 1945, which created Tsunami. The height of this Tsunami at the coast of Makran was about 40 feet. Four thousands people at the coasts of Pasni, Karachi and Mumbai were reported dead. No heavy casualty observed due to lack of population on the Makran coast. Again on 5 August 1947 another big earthquake with magnitude 7.3 Richter scale was recorded. Recently on January 26, 2001 an earthquake called Bhoje earthquake with surface magnitude 7.9 was observed at Indian Gujarat coast, which caused about 20.000 casualties. It occurred inland near coast. As the Indian plate continues to push into Eurasian plate, stresses accumulate at the faults marking the boundaries between these two gigantic crustal plates. For long geologic periods, these plates remained locked together. When suddenly strain becomes too much to bear near the breaking point,

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the faults rupture, setting off an earthquake. If this rupture occurs under sea, as it did on the Boxing Day, it can trigger a tsunami, which shook the globe. The giant sea waves often associated with under sea displacements of water due to sudden large-scale changes of level of the sea floor, e.g., by the fault movements along plate margins responsible for the earthquake or by submarine slumping set off by an earthquake. The word Tsunami, taken from a Japanese word that means high water in a harbor, is used by the Japanese for the rising surge that carries water onto the shore as a result of topographic changes on the sea floor brought about by powerful earth movements occurring along coastlines. It has nothing to do with normal ocean currents, tidal waves of weather phenomenon.

If the displacement causes a large depression of the ocean surface, water is drawn from all sides and throughout the whole depth, which may be very great. One manifestation of this inward flow is the menacing withdrawal of the sea from neighboring coasts that is the onset of dangerous tsunami. If the sudden sea floor displacement is the upwards and causes a wide spread upheaval of the ocean surface like a piston, vast volume of water flows outwards in all directions and at all depths.

Active fault line exists in the Arabian Sea which further links with the continental plate boundary. Figure-1 shows the seismicity mostly, in front of Pasni and Gawadar. Almost all strong and catastrophic earthquakes of this area took place in the upper crust. Maximum earthquakes occurred at the shallow depth less than or equal to 50 km.

The space and time distribution of earthquakes of the Arabian Sea is stated below.

Since 1905, the first earthquake having magnitude Mb=6.0 was recorded on 18 April 1932. All earthquakes greater than 6.0 magnitudes occurred before 1956. Hypocenters of earthquakes are located at shallow depths, and there are few earthquakes occurred at depth greater than 50km. The largest earthquake Mb=8.3 Richter scale occurred just about 98km from the Makran coast. The seismicity in the Arabian Sea is being recorded by seismic network of Pakistan Met department and before 1952; activities were recorded by international seismic network.

The information about major earthquakes before installation of seismic network has been taken from international seismic network. The data have been collected very carefully since 1905.

Analysis:

Magnitude – time, magnitude – frequency relations Abe, K. (1981) and expected number of years “K” within which “n” events will occurs etc are considered for the analysis of seismicity in the Arabian Sea.

According to the empirical Gutenberg- Richter formula that describes the occurrence rate of each magnitude, larger earthquakes occur rarely and smaller frequently. The rate of smaller and bigger earthquakes is one of the parameters of seismicity Aki, K. (1965). The character of seismic activity within any region is described by frequency-magnitude relationship according to Gutenberg and Richter (1944).

Log N = a-bM

The parameter 'a' describes the level of seismic activity and 'b' indicates the proportion of larger to smaller earthquake and is also called the seismic regime parameter of Arabian Sea. The reliable determination of the parameter 'a' and 'b' is of special importance during the zoning procedure.

The b-value has been taken into account as an index of seismic activity of the Arabian Sea. This region has observed an earthquake of maximum magnitude (Mb 8.3) Richter scale in November 1945 that would be of the extreme importance for the tsunami as a hazard assessment for the coastal region of Pakistan. The best prerequisite for its estimation is a well-recorded earthquake history of this region.

Due to high seismic risk to the population of the area along Sindh-Makran coast, there is an urgent need to understand the seismic risk modeling. Presence of Murray Ridge and Owen Fracture zone in the Arabian Sea is a clear danger to Naval installations, mega projects like Gwadar seaport and the largest port of the country. Its closeness to Sindh and Makran coasts in the Sea and Pakistan steel in Bin Qasim and Allah Band fault near Rann of Kach on land should be a cause of concern to all of us. Any disturbance in crustal plates along these zones of weakness can bring a lot of destruction to the populous localities beyond the imagination to city administrators. There seems to be a relative seismic calm at present but nature knows no bounds and the calm may be deceiving.

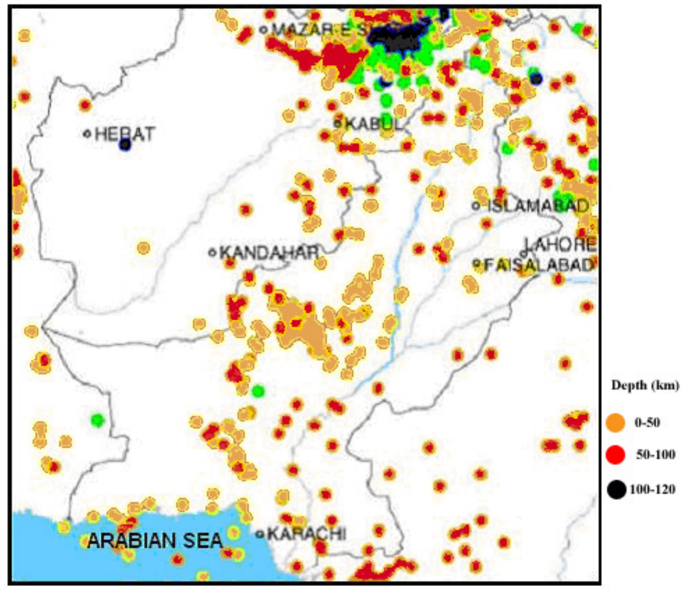

Figure-1: Seismicity of Pakistan and Arabian Sea Sea

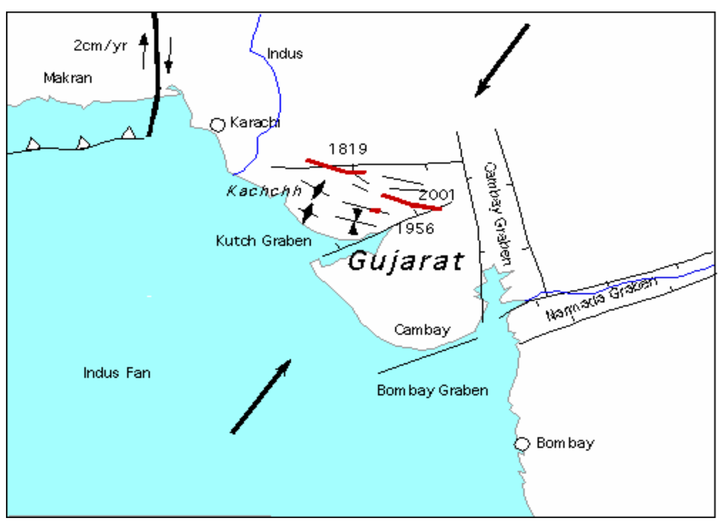

Figure 1.1: **Tectonic setting of Arabian Sea**

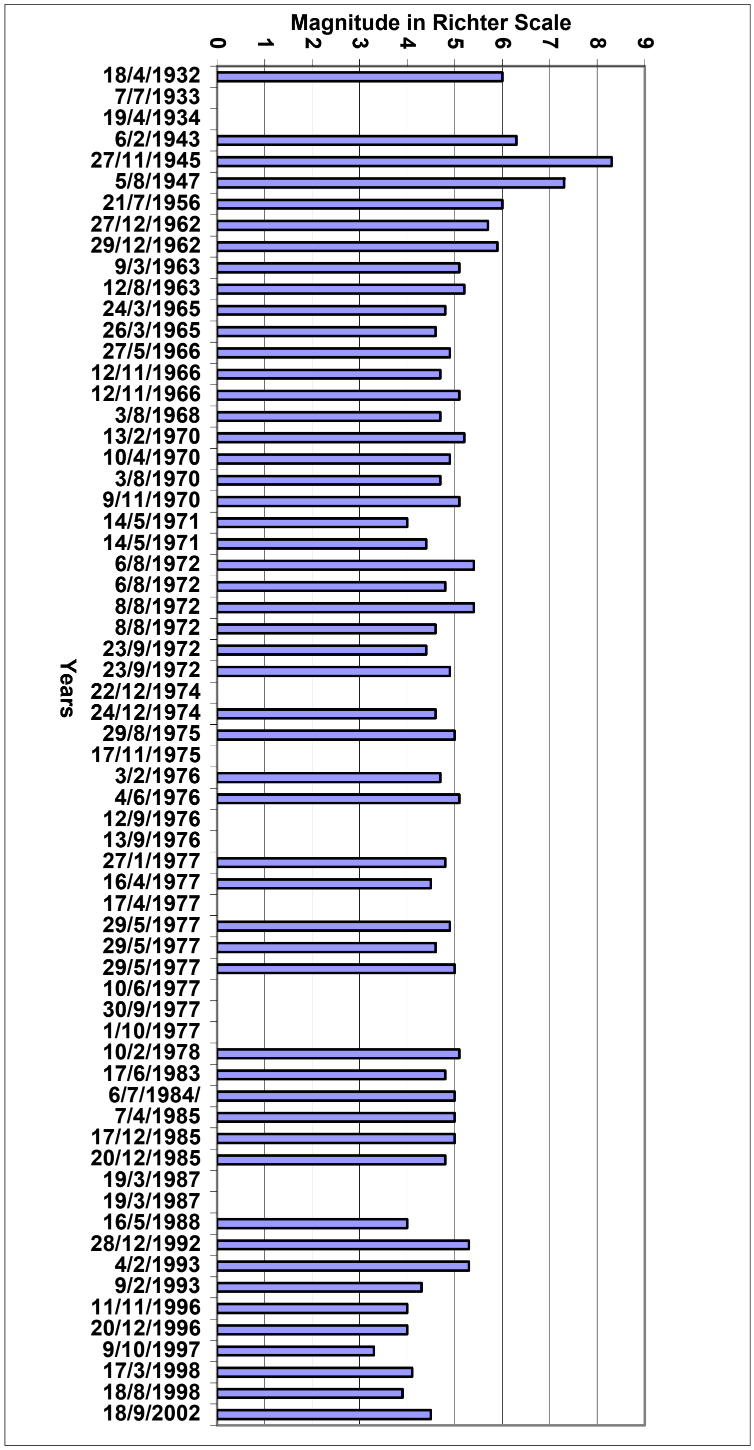

Figure-2 shows the complete seismicity for the period 1905 to 2002.

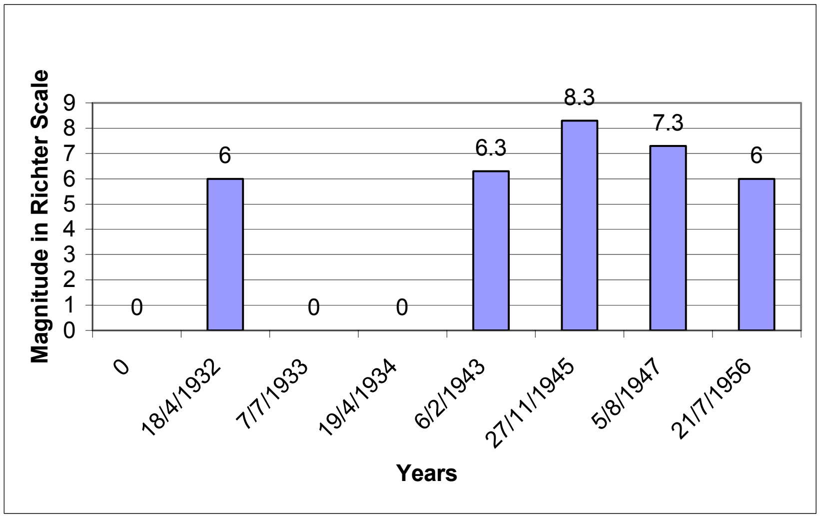

Figure-3 shows that earthquakes having magnitude ≥6.0 occurred before 1956 only. The earthquakes having Mb=5.7 and 5.5 were recorded in 1974 and 1979.

The seismicity pattern from 1956 to 2002 is shown in the figure-4, which indicates that most of the earthquakes after 1957 were of the magnitude between 4.0 - 5.0 Richter scale. Figures 5 to 8, show the expected years when earthquakes of particular magnitude will be occurred in the next 96 years data. Using Poisson distribution 'P' did the statistical analysis. The frequency of earthquakes above a certain magnitude and within fixed time intervals is a fairly good Poissonian distribution when foreshocks and aftershocks are removed from the data set. The equation for calculation of Poisson distribution is given below,

$$P [N= n, t] = (\nu t)^n/n! \exp(-\nu t)$$

Where

$n = 0,1,2,3,\ldots$

ν = Mean occurrence rate per 't'

't' should be one year.

Figure-5 is a simple graphical representation of expected years when earthquakes will occur and the figure-6 is plot on the logarithmic scale. This clearly shows that in the next 96 years there may be 34.5 years when no earthquake will occur in the Arabian Sea and there is a possibility that in 35.2 years when one earthquake may be occurred every year. The whole future scheme, probability of occurrence of earthquakes, is shown in the Table-I.

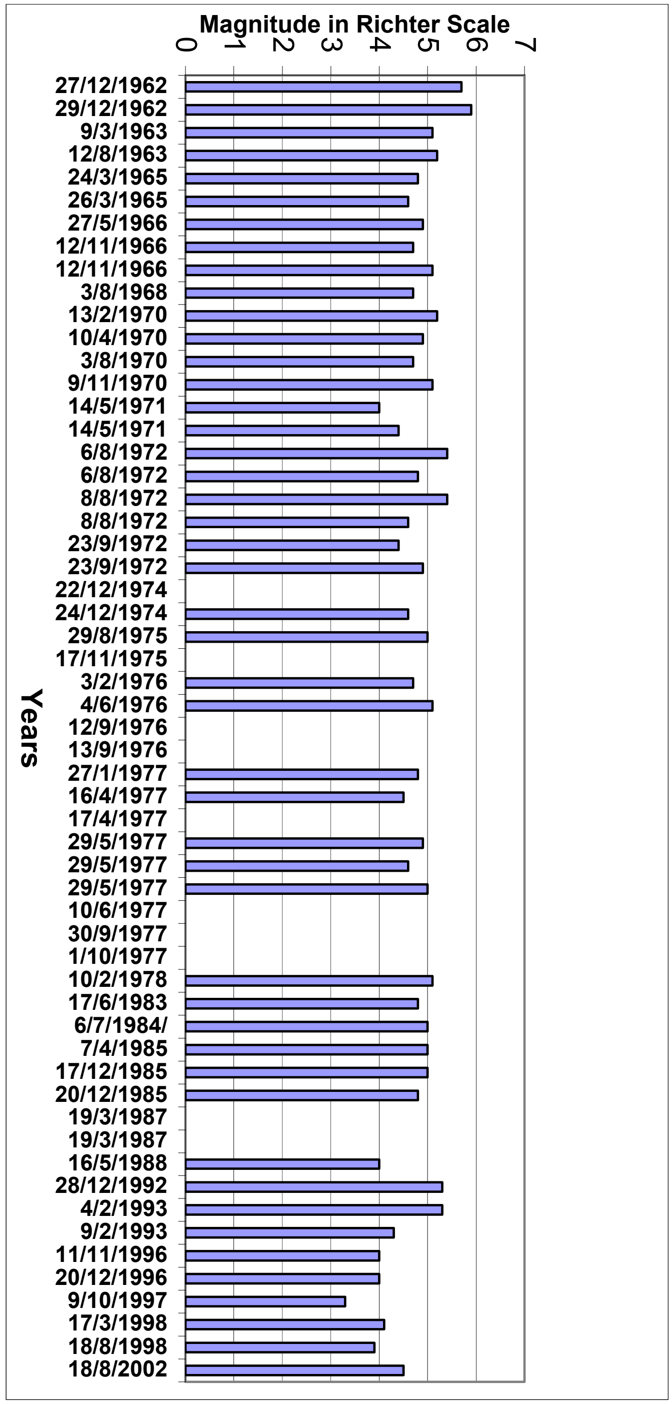

Figure-4 Earthquakes in Arabian Sea from 1957 to 2002

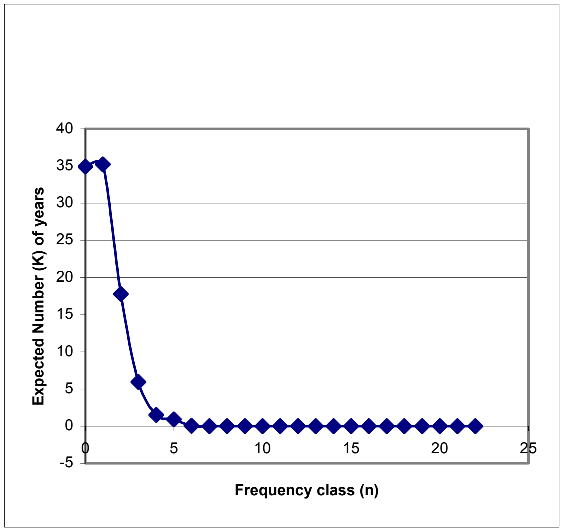

Figure-5 Expected number K of years within **w**hich 'n' events will occur

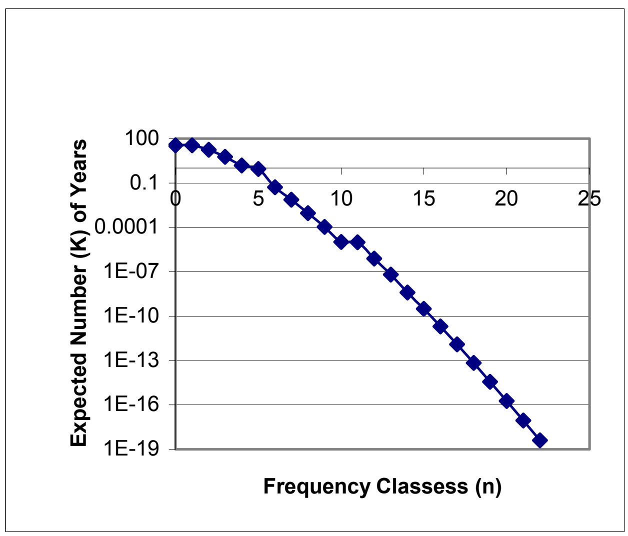

Figure-6 Expected number K of years within **w**hich 'n' events will occur (logarithmic scale)

For better comparison of Poisson distribution with observed number (Fig-7) which is the plot of expected number K of the years within which 'n' events occurred.

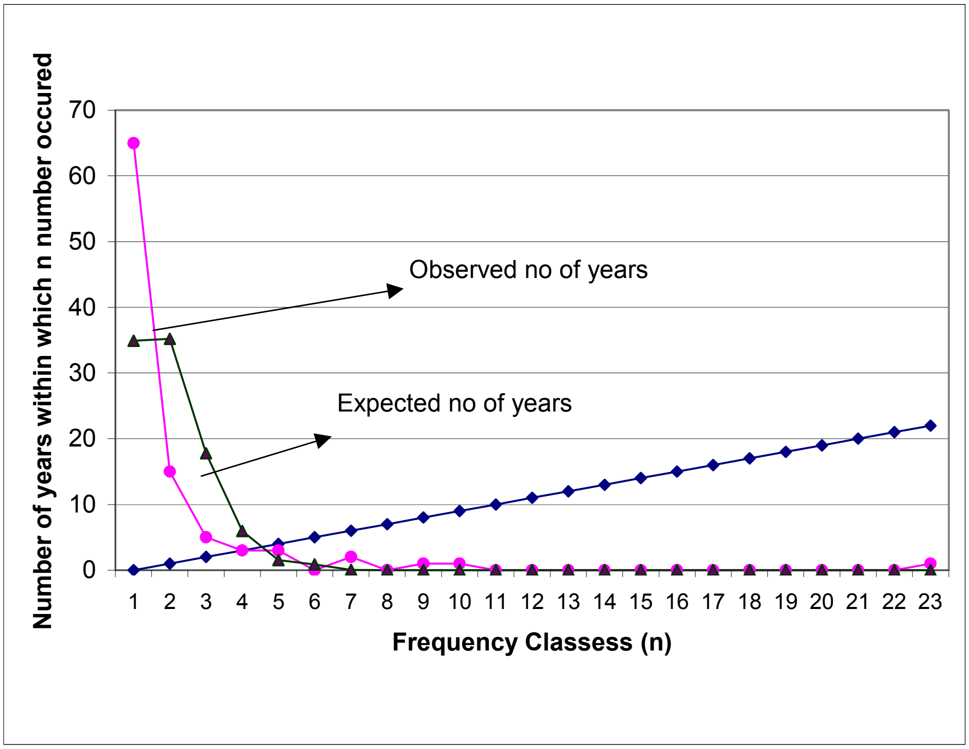

Figure-7: Comparison of observed number of years and expected number of years

K[N=n,t]= k.P[N=n,t]

K= number of time interval used.

Figure-8 indicates that for particular magnitude how much earthquakes will occur in Arabian Sea. It is clear from this figure that maximum earthquakes of small magnitude increase the number of occurrence of earthquakes will be decreased rapidly.

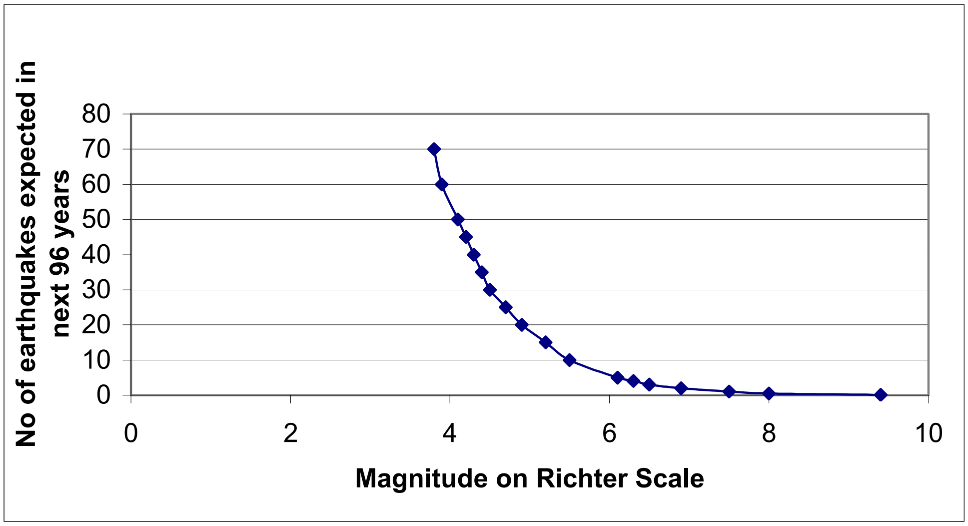

Figure-8: Frequency Magnitude relation for Arabian Sea

Figures 5 to 8, show the expected years when earthquakes of particular magnitude will be occurred in the next 96 years as the calculation was bases on previous 96 years data.

Conclusion:

The analysis of seismicity pattern of the Arabian Sea revealed that it has moderate seismic activity. As the b-value varies from 0 to 1, b-value calculated by Gutenberg relation is 0.512 which indicated the moderate seismicity. The seismic energy is liberated from this region time to time in the form of moderate seismic events. The chances of big earthquakes (Mb≥8.0) in this region are very rare (Table-I).

There is a probability of occurrence of earthquake with magnitude Mb=7.5 on the Richter scale is only 1 but the possibility of earthquake with magnitude Mb=6.0 - 6.3 Richter scale is five time more.

These earthquakes would be shallow and cause tsunami in the Arabian Sea.

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