OBSERVATION OF SEISMIC GAP IN NORTHEAST INDIA

Arun Bapat (I)
R.C.Kulkarni (I)
Presenting Author: Arun Bapat

SUMMARY

It is observed that there exists a possibility of occurrence of an earthquake of magnitude $M > 7.0$ on Richter scale in the gap area defined by the geographical coordinates 26.0° N - 28.0° N and 94.0° E - 95.0° E in Assam State of northeast India. This observation is based on the analyses by seismic grid method, wherein an attempt has been made to quantify the quantities associated with the seismicity. The method consists in observation of occurrences of earthquakes in unit grid area of size 1° lat. x 1° long., in four different ranges of magnitude $M < 5.0$, $M = 5.0 - 6.0$, $M = 6.1 - 7.0$ and $M > 7.0$, per decade.
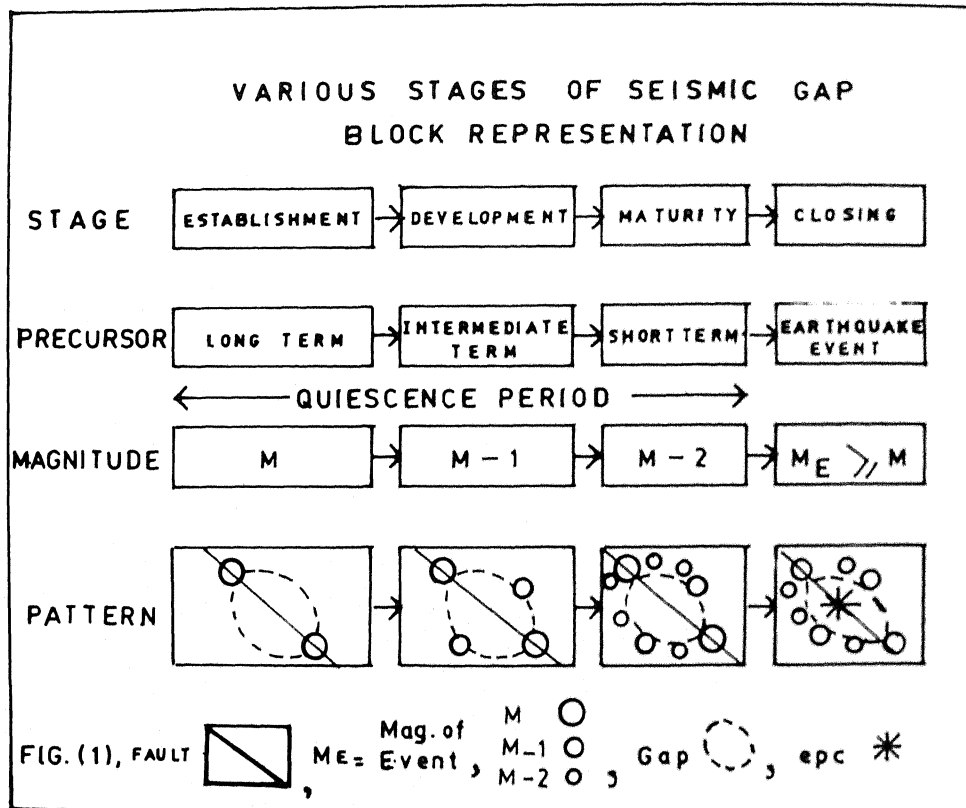
INTRODUCTION

During the last two decades or so interest in earthquake prediction has been increasing at a fast rate. Several methods have been proposed by various authors in China, Japan, Mexico, USA and USSR. An exhaustive list of references could be found in the two books by Rikitake (Ref. 1,2) and the recent International Review of Earthquake Prediction by Simpson and Richards (Ref. 3). The International Association of Earthquake Engineering, during the Honolulu meeting in July 1977, declared some areas of the world as vulnerable to earthquakes in the near future. This has created sufficient interest amongst seismologists in respective countries. Assam area is one of these vulnerable areas recommended by the Honolulu meeting. Khatri et al. (Ref. 4) have discussed the Assam gap and Seeber and Armbuster (Ref. 5) have given an exhaustive discussion about the rupture and long term forecasting along the Himalayan arc.

Stages of Seismic Gap

The gap has been much discussed in the recent past and provides a promising field for earthquake prediction, in a few cases it has been found to be quite useful. The various stages of gap proposed in the model are represented by block diagram in Fig.1. It is proposed that the seismic gap is established as a result of occurrence of two earthquakes of

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(I) Central Water and Power Research Station, Pune-411024,
                                                    INDIA

VARIOUS STAGES OF SEISMIC GAP

BLOCK REPRESENTATION

STAGE: ESTABLISHMENT → DEVELOPMENT → MATURITY → CLOSING

PRECURSOR: LONG TERM → INTERMEDIATE TERM → SHORT TERM → EARTHQUAKE EVENT

← ——QUIESCENCE PERIOD ——→

MAGNITUDE: M → $M-1$ → $M-2$ → $M_E \geqslant M$

PATTERN:

FIG. (1), FAULT, M_E = Event, Mag. of M ◯, M-1 ◯, M-2 ◦; Gap (dashed circle), epc ✳

comparable magnitude M along and active tectonic fault. This
is called as establishment stage of the gap. During the next
stage, the development stage, few earthquakes of magnitude M-1
occur on either side of the fault in this gap region. These
occurrences help in getting a better picture of the gap. The
last stage of the gap is the maturity stage during which
earthquakes of magnitude M-2 occur in sufficiently large number
along the peripheral areas of the gap. Various patterns
observed during these three stages are shown in Fig.1. When
the gap has reached the maturity stage, it is closed by the
occurrence of an earthquake within the gap and the magnitude
of the earthquake is either equal to or greater than M. During
the period of establishment to maturity the gap region exhibits
seismic quiscence. This model helps in understanding the
various stages of the gap. The establishment and development
stages of the gap are within elastic range while the mature
stage is within viscoelastic range. The transition from visco-
elastic to plastic is the culmination of seismic event. The
seismic grid method helps in understanding the magnitude

dependent spatio-temporal seismic variations (MDST). Similar
MDST variations have been studied for California, Mexico,
Balkan and Iran (Ref. 6). Similar observations have been
reported by Yamashina and Yoshihiro (Ref. 7) for Shimane
earthquake of 1978 in Japan. Mogi (Ref. 8) had proposed a
doughnut-shape model for occurrence for earthquake which is
similar to the above proposal. This model is studied with
the help of seismic grid method which is described below.

The prediction of earthquake needs that the parameters
which describe the earthquake be defined clearly. These are
the geographical coordinates, latitude and longitude, magnitude,
M and time, t. For seismological measurements the units of time
and space are not "quantified". Most of the researchers take
the seismically active area along the fault and account for
the entire list of earthquakes for the available period. On
several occasions the data are subjected to rigorous statistical
analysis and some useful results are often obtained. However
there is no fixed yardstick to measure the area and time. This
was thought as to be a shortcoming of the procedure followed
for earthquake prediction. It was thought that if these
quantities could be ´quantified´ the results obtained would be
more realistic.

THE SEISMIC GRID METHOD

From the available catalogue of earthquakes by Bapat et
al. (Ref. 9), Gutenberg and Richter (Ref. 10), Oldham (Ref.
11), the earthquakes in the region were tabulated in a
particular format. The instrumental records of earthquakes in
India are available from the beginning of the present century.
In addition, list of historical   earthquakes is also
available. But it was observed that the historical earthquakes
are at times overdescribed or underdescribed in the archives.
In order to have uniformity and homogeneity in the data it was
decided to use only the instrumentally recorded earthquakes.
The number of seismic stations and instruments has gone up
with increase in time and increase in instruments numbers has
shown proportional rise in detection potential of the region.
The area chosen for the purpose of present studies is defined
by the coordinates, 25.0^0 N - 29.0^0 N and 92.0^0 E - 97.0^0 E.
This has been divided in grids of size 1^0 lat. x 1^0 long.
Though the area of the grid may change for higher latitude
it could be considered as approximately of 100 x 100 km^2 for
the present studies. This is called a unit grid. Earthquakes
of different magnitudes in this grid have been considered to
have occurred in this grid irrespective of their individual
geographical coordinates within the grid.

The time has been divided in decades such as 1900 - 1910
(D1) 1911 - 1920 (D2) .... 1961 - 1970 (D7) and 1971 - 1980
(D8). A period of ten years or its multiple is considered to

be reasonable for various seismological analyses. Though this
distribution is arbitrary it was found to be useful. The
magnitudes have been divided in following four ranges :

Magnitude

1)   M < 5.0   .... R1
2) 5.0 to 6.0   .... R2
3) 6.1 to 7.0   .... R3
4)   M > 7.0   .... R4

The distribution of earthquakes in the above range could be
broadly described as 1) minor 2) mild 3) moderate and 4) major
earthquake. The advantage of quantifying time, space and
magnitude in different classes makes the method more rational
and purposeful and it does not suffer from inaccuracies in
magnitude and epicentral determination. In spite of advanced
instrumentation and sophisticated data processing techniques,
there are always some amount of uncertainties inherentaly
associated with the determination of epicenters. The epicen-
tral coordinates are mostly correct within certain ± errors.
Similarly there are several magnitude scales and they describe
the magnitude of the event as M_L, M_s, M_b etc.. These values
have their respective significances and usually the magnitude
value for a particular seismic event varies from scale to
scale. By using the unit grid of 1° lat. x 1° long. and by
separating the magnitudes in four different ranges these
seismological parameters undergo some sort of normalization
which adds refinement to the data based analytical procedure.
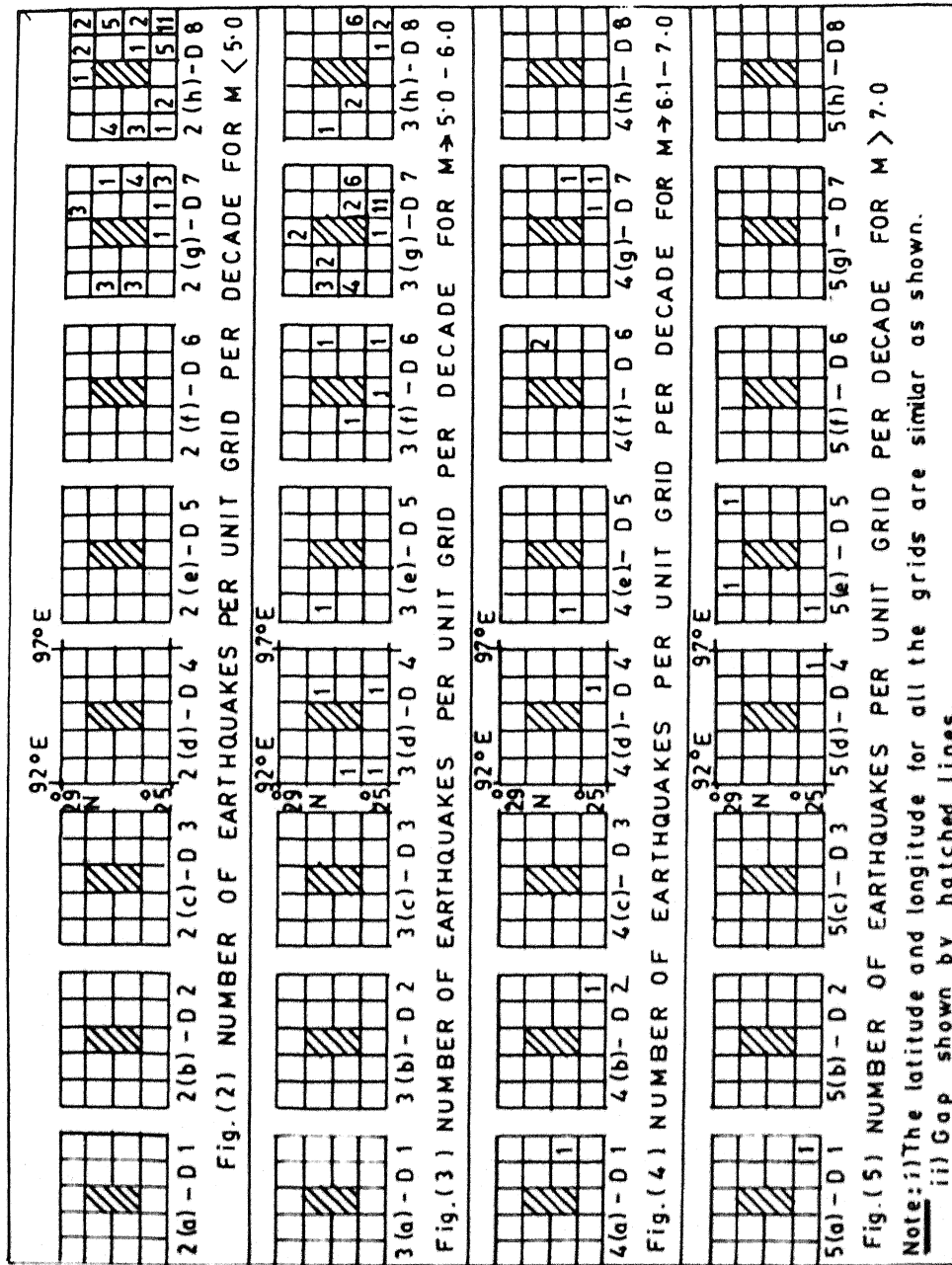
SEISMIC GAP IN NORTHEAST INDIA

Seismic observations for the period 1900 - 1980 for the
above region are given in Fig.2 to Fig.5. It is observed that
the two consecutive grids 26.0^o - 27.0^o N, 94.0^o - 95.0^o E and
27.0^o - 28.0^o N, 94.0^o - 95.0^o E have not experienced a single
shock during last eighty years. In the highly active region of
Assam (Northeast India) this observation is itself very
interesting.

It is observed from Fig.5(e) - D5 that the present seismic
gap was formed as a result of following two earthquakes of
range R4

 i) 11th Feb 1943, epc at 26.0 N and 93.0 E, Mag 7.2
ii) 15th Aug 1950, epc at 28.5 N and 96.6 E, Mag 8.6

It is also noted that the direction of fault in this region is
in NE to SW direction. During the decades D6 and D7 there were
two and one earthquakes respectively of range R3 in the south-
east side of the gap. During the same decades D6 and D7, the
five surrounding grids have experienced one or two earthquakes

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2(a)-D1 2(b)-D2 2(c)-D3 2(d)-D4 2(e)-D5 2(f)-D6 2(g)-D7 2(h)-D8

Fig.(2) NUMBER OF EARTHQUAKES PER UNIT GRID PER DECADE FOR M < 5.0

3(a)-D1 3(b)-D2 3(c)-D3 3(d)-D4 3(e)-D5 3(f)-D6 3(g)-D7 3(h)-D8

Fig.(3) NUMBER OF EARTHQUAKES PER UNIT GRID PER DECADE FOR M → 5.0 - 6.0

4(a)-D1 4(b)-D2 4(c)-D3 4(d)-D4 4(e)-D5 4(f)-D6 4(g)-D7 4(h)-D8

Fig.(4) NUMBER OF EARTHQUAKES PER UNIT GRID PER DECADE FOR M → 6.1 - 7.0

5(a)-D1 5(b)-D2 5(c)-D3 5(d)-D4 5(e)-D5 5(f)-D6 5(g)-D7 5(h)-D8

Fig.(5) NUMBER OF EARTHQUAKES PER UNIT GRID PER DECADE FOR M > 7.0

92°E   97°E   29°N   25°N

Note: i) The latitude and longitude for all the grids are similar as shown.
      ii) Gap shown by hatched lines.

while one grid in SE direction has experienced 11 earthquakes of range R2. The Fig.3(f), 3(g), 4(f) and 4(g) aptly illustrate the development stage of the gap. During D7 and D8 there were several earthquakes of range R1 as seen from Fig.2(g) and 2(h). These observations indicate that the gap appears to be heading towards the maturity stage. The gap region has not experienced any seismic event. This observed period of quiscence is very interesting. Considering the fact that the gap lies almost midway between the epicenters of the two great Assam earthquakes of 1897 and 1950 (both of magnitudes 8.6) the estimated magnitude of $M > 7.0$ appears reasonable. However the magnitude of the culminating event would depend upon the pattern of seismic activities during the coming years.

Discussion of the Method

The immediate criticism of the method may be on the choice of the grid size. It could easily be argued that if the size of the grid is as small as 0.1° lat. x 0.1° long. there would be infinite gaps and if the size of the grid is 3.0° lat. x 3.0° long. there may not be any gap at all. The point which has prevailed in the choice of the grid size is the length of rupture. Wyss (Ref. 12) has compiled magnitude versus length of rupture for worldwide data. It is observed that for earthquakes upto 7.0 - 7.5 the observed surface ruptures are of about 100 km or less length. The surface rupture defines the size of earthquake and this length is accommodated in 1° x 1° grid. As an exercise, 0.5° lat. x 0.5° long. size grid was used for the analysis of Balkan earthquakes and it was observed that the picture obtained by half degree grid is similar to that of one degree grid. The distribution of magnitude has already been described . However, this could be altered depending upon the degree of seismicity of the region. For example, while studying seismicity of Mexico, where there are large number of earthquakes of magnitude $M > 7.0$ (As per the mexican earthquake catalogue, there are 31 earthquake of $M > 7.0$ during 1900 - 1981 in the region $15^\circ - 20^\circ$ N, $94.5^\circ - 105.5^\circ$ W). The magnitude range could be chosen as 6.0 - 7.0 (R1), 7.1 - 7.5 (R2), 7.6 - 8.5 (R3). In the case of Iran or Balkan region, where there are no cases of earthquakes $M \geqslant 8.0$, but the number of earthquakes in the range 7.0 - 7.5 is considerable, the magnitude range could be chosen as 5.0 - 6.0 (R1), 6.1 - 6.5 (R2) and 6.6 - 7.5 (R3).

The choice of time window could also be selected depending upon the degree of local seismicity. For example, regions like Kamchatka, Japan where the frequency of 6.0 - 6.5 magnitude earthquake is quite high the time window could be taken as five years.

The method has not been tried for smaller magnitude earthquake ($M < 5.0$). Prediction of these events would need

reading of small magnitude earthquakes which is only possible
with the help of dense seismic net. Moreover, these earth-
quakes normally do not cause much damage are not considered as
hazardous or destructive. It is therefore seen that by using
unit grid with appropriate time and magnitude window the
available seismic data could be subjected to seismic grid
analyses. The earthquake event could be considered as floating
along the established geotectonic fault and its position could
be seen by different windows of time, space and magnitude and
the MDST variations.

CONCLUSION

It is inferred on the basis of seismic grid analyses that
there exist a seismic gap in Assam area of northeast India in
the region defined by $26.5^{\circ} - 27.5^{\circ}$ N and $94.0^{\circ} - 95.0^{\circ}$ E.
The magnitude of the event would be more than 7.0 on Richter
scale.

ACKNOWLEDGEMENT

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