Bull. Ind. Soc. Earthq. Tech. Paper No. 294, Vol.27, No.3, Sept. 1990, pp.91-103

GEODETIC EVIDENCE ON POSSIBILITY OF EARTHQUAKE OCCURRENCE NEAR DHEMAJI IN ASSAM

By

V.K. Nagar and A.N. Singh
Geodetic & Research Branch, Survey of India, Dehradun

ABSTRACT

Bapat, Arun (1986) had predicted occurrence of an earthquake of magnitude around 7.5 on Richter Scale near Dhemaji at location Lat. 27°35'N Long. 94°37'E within 300-400 days ± 30-40 days from 15th May 1986. Bapat, Arun (1986) had further modified his prediction stating that the earthquake may occur during the period July-August 1987 or December-January 1988 with a fore-shock of magnitude 6.0 ± 0.25 on Richter Scale about 100-150 days before the occurrence of the main shock.

The authors have investigated the precise levelling data acquired during 1987 summer in relation to the existing data of 1952-54 (Fig. 1). Geomorphological changes have also been investigated from existing topo sheets.. The analysis of results do not appear to give a conclusive evidence of occurrence of a devastating earthquake of Mag. 7.5 with epicentre at Dhemaji in the near future.

INTRODUCTION

Arun Bapat (1986) had predicted occurrence of an earthquake of magnitude around 7.5 on Richter Scale near Dhemaji. Analysis through "Seismic Grid Method" Bapat (1983 & 1986) and results of geomorphological changes have been combined by the previous authors to arrive at the above conclusion. Eight satellite imageries had been consulted by the author and field observations had been undertaken for predicting possible location of the earthquake (Lat. 27°35'N and Long. 94°37'E). Time of occurrence of the Earthquake (300-400 days ± 30-40 days from 15th May 1986) had been predicted through probabilistic approach. The magnitude of the earthquake was also predicted through probabilistic approach. Survey of India was approached by the Department of Science & Technology to investigate geodetic evidence on the possibility of the earthquake occurrence in the area. There was an existing precision levelling line in the area carried out during the year 1952-54. It was accordingly decided to undertake quick revision of the above levelling line during summer 1987 for the portion North Lakhimpur-Sisi Bargaon via Dhemaji with another line from Dhemaji-Dhakuakhana. Figure 1 gives the details of existing levelling lines and repeat observations carried out in the area. Major Tectonic Features and earthquake epicentres of Mag. ≥6.0 that have occurred since 1827 to 1980 have also plotted on this map. Existing Topo Map sheet 83 I for the 1928 edition (1911-24 survey) and 1976 edition (1960-70 survey) were compared to investigate the cause of geomorphological changes.

The Land-Sat Photo Map 1973 was also compared with the above Topo Map to investigate if any permanent changes in the course of the River Brahampurtra had taken place in the vicinity of the predicted epicentral area in the last few decades, especially after the famous 1950 Assam earthquake.

LEVELLING DATA AND ITS ANALYSIS

Changes in Heights

The levelling profile of 1952-54 was repeated during 1987 summer following same route as for the old survey. North Lakhimpur was accepted as starting B.M. with its height 0.0 m. The change in the height of a Bench Mark was obtained by comparison of the run down heights from North Lakhimpur for the two epochs of observations. Estimate of errors at each B.M. was obtained by analysis of the difference of fore and back values following technique suggested by Wassef, 1974 and Arur and Singh, 1986. There are in all 10 common permanent Bench Marks on the two levelling lines. The changes in heights alongwith the estimates of the errors for all the height changes are given in Table 1 below. The elevation changes at Bench Mark locations alongwith standard error at each Bench Mark are shown in Figs. 2 and 3.

TABLE 1

CHANGES IN HEIGHT OF THE BENCH MARKS FROM REPEAT PRECISE LEVELLING OBSERVATIONS

Sl. No.	B.M. Location	(New-old) in cm	Standard Error in cm
1.	North Lakhimpur	0.00	0.00
2.	Bagi Nadi	-1.56	±1.04
3.	Anand Bagan	+2.82	±1.33
4.	Bardalani	-2.12	±1.73
5.	Dhemaji	-2.55	±2.04
6.	Sisi Bargaon	-2.11	±2.33
7.	Batgharia	-1.94	±4.41
8.	Machkhua	-0.40	±4.71
9.	Kora-gurigaon	-0.08	±5.05
10.	Dhakhuakhana	-0.52	±5.24

Slope and Tilt Analysis

The two levelling profiles (Figs. 4 and 5) North Lakhimpur to Sisi Bargaon via Dhemaji and Dhakuakhana to Dhemaji have been redrawn indicating height changes between to epochs of observations in relation to the topography of the profile which has also been drawn for both the levelling lines. The first derivative of these two profiles with respect to distance have been worked out in order to evaluate apparent tilt and apparent slope associated with each Bench Mark. Figures 4 and 5 have been prepared for the two levelling profiles separately. On each profile four curves have been drawn. The curve with continuous lines indicates apparent elevation change vs. distance for the common Bench Marks. The curve with broken line gives relation between elevation vs. distance. The third curve gives tilt (derivative of the first curve with respect to distance). The last curve gives the topographic slope (derivative of second curve with respect to distance), (Jackson et al., 1983; Joshi et al., 1987). The data has been analysed using suitable mathematical model to investigate existence of regional uniform trend of tilt and coefficient of height correlated error.

MATHEMATICAL MODEL

The model used for the regression analysis is as under :

$$t_i = a + b.s_i + e_i$$

Where

t_i = Apparent tilt between the i^{th} pair of Bench Marks.

s_i = Geodetic slope between i^{th} pair of Bench Marks.

a = Uniform tilt.

b = Coefficient of height correlated error.

e_i = Random error.

(Jackson et al., 1983).

GEOMORPHOLOGICAL CHANGES

In order to study the geomorphological changes in the area two editions of Topo Maps of sheet No. 83I were selected. One was the 1928 edition surveyed during 1911-24 and the other was 1976 edition surveyed during 1950-70. In addition to these the Land-Sat Photo-Map 1973 was also compared against the maps to investigate whether permanent changes, if any, have taken place in the course of River Brahmaputra after 1911-24 especially due to famous Assam Earthquake, 1950 Edition of the above map was also available. This was, however, not used for the above study since this edition was only result of compilation from various sources and not on the basis of resurvey. Figure 6 indicates the geomorphological changes in the directions of the rivers that have taken place during an interval of about 50 years. In this figure, various developmental activities regarding road construction, railway, lines, embankment and canals have also been depicted to enable the authors to correlate geomorphological changes with the developmental activities. Figure 7 indicates the changes in the course of River Brahmaputra during the two epochs of survey and as seen from the Land-Sat Photo Map.

EARTHQUAKE EPICENTRAL DATA

Earthquake epicentral data for magnitude 6.0 in the area $3^o \times 3^o$ around Dhemaji have been plotted in Fig. 8. Known tectonic features and lineaments have also been shown in this figure (Kharshiing, et al., 1986). This has been done in order to study the pattern of occurrence of large earthquakes in the tectonic belt occupying Dhemaji, and to study existence of seismic gap both in space and time domain (Purcaru et al., 1984).

RESULTS OF TILT AND SLOPE ANALYSIS

Table 2 gives the results of Tilt and Slope analysis for the two levelling lines repeated for the present study.

TABLE 2

RESULTS OF TILT AND SLOPE ANALYSIS

Line No.	Description of Line	a(ppm)	b(ppm)
1.	North Lakhimpur Sisi-Bargaon	-57±1.58	5535±5257
2.	Dhakua-Khana	-0.67±0.53	1652±1869

* 1 ppm = 1 micro-radian

a = Uniform Tilt
b = Coefficient of height correlated error

ANALYSIS OF RESULTS

Elevation Changes

The results of repeat levelling observations indicated in Table 1 show that some movements of the order of 2 to 3 cms have been revealed at several Bench Marks, although none of these are significant at 95 per cent confidence. One Bench Mark located at Anand Bagan has shown upliftment while all other Bench Marks have shown subsidence. Whether the subsidences or upliftments of the order of 2 to 3 cm could be viewed as precusors of large impending earthquake appears to be doubtful especially when compared against theoretical deformations evaluated from the realtion :

$$\rho = 10^{0.433M - 2.73\sqrt[3]{e.M}}$$

Where

ρ = Distance from the epicentre at which the deformation is observed.
M = Magnitude of the impending earthquake.
e = Deformation (theoretical) at the distance 'ρ' from the epicentre.

(Mjachkin, et al., 1984 ; Joshi, et al., 1987).

Computed theoretical deformation upto a distance of 100 km. from the epicentre due to an impending earthquake of Mag. 7.5 have been worked out and are given in Table 3 below.

TABLE 3

THEORETICAL DEFORMATIONS AT VARIOUS DISTANCES

Sl. No.	Magnitude	Distance from Epicentre	Theoretical Deformation
1.	7.5	1 km	3.99 M.
2.	"	10 km	1.30 M.
3.	"	30 km	0.65 M.
4.	"	60 km	0.37 M.
5.	"	100 km	0.23 M.

The theoretically calculated precursors as indicated in table 3 may not be entirely possible at all distances in the real life due to changes in tectonic set up of various locations as also due to depth of the sources and its mechanism. However, close agreement with these precursors have been obtained by various authors at long distances (Mjachkin, et al., 1984). Prescott, et al., (1984) expect slip deficit of the order of 2 m for great earthquakes (M=7,8) with offset of meters of rupturing the entire length of the Hayward fault. With these arguments there does not appear to be a conclusive proof for an immediate threat of a possibility of a great earthquake in the area close to Dhemaji. However, the repeat observation was taken after a lapse of 30 years and subsidence, although marginal, from both the directions viz. from north Lakhimpur and from Dhakua Khana is converging towards Dhemaji. It is entirely impossible to assess the maximum deformation reached during the intervening period before any reversal trend, in the deformation has been noticed. This reversal trend, in many cases, is considered to be essential for the dynamic discharge of tectonic stresses to commence. For any meaningful earthquake prediction it would be absolutely essential to have yearly geodetic observations in the suspended area so that the stage of prolonged accumulation of tectonic stresses, the earthquake transitional stage and the stage of dynamic discharge of tectonic stresses are clearly discernible from the data set as per model given in Fig. 9.

These conclusions are, therefore, based on extremely scanty data. If significant variations occur in the rate or distribution of the stress accumulation and its reversal with time, these conclusions might require revaluation.

Slope and Tilt

Figures 2 and 3 reveals that none of the movements could be viewed significant at 95% confidence level. Figures 4 and 5 reveal a positive correlation in the slope and tilt in both the lines. However, in two sections of both the lines a negative correlation is seen.

The regression analysis reveals that the uniform tectonic tilt is not significant at 95% level in both the lines, the most significant uniform tectonic tilt of -0.67 micro-radians has taken place in the direction Dhakuakhana to Dhemaji during an interval of about 3 decades. The direction of North Lakhimpur-Sisi Bargaon has shown a uniform tectonic tilt of -0.57 micro-radians during the same period. Joshi, et al., (1987) had obtained Regional Trend of uniform Tilt to vary from -0.93 to +0.17 micro-radians for the Indo-gangetic Plains. From this it can be concluded that the tilt is not abnormal to cause concern. The height correlated errors in height changes in these two lines have been found to be exceedingly high. The above analysis points to the existence of systematic errors in the two levellings. However, topography is too smooth in this region, yet it may cause contribution due to height correlated errors to the extent of 2 cm at an average.

Geomorphological Changes

Figure 6 shows that the directions of several rivers in the area under study have shown changes in their directions. River Jiya Dhol on the western flank of the area has shown south-westerly shift of the order of 8 to 10 km. Similar trend has been seen on the river Şisi in the eastern flank. River Jhalki also on eastern flank has shown some changes in the direction in the opposite sense at the two ends of the river. The upper portion of river shows south-westerly direction of movements whereas the lower portion of the river has shown north-easterly shift. The river Dimu on the eastern flank has been found dried up in the 1976 edition map. River Tangani also on the eastern flank does not show any major changes in its direction.

The shift in the direction of River Ghai in central portion of the area is about 2 km in the east direction close to village Bhebeligaon.

From the 1976 edition map we find that several developmental activities have taken place since the 1928 edition map was surveyed. Some embankments upto 3 m high and more have been constructed in the area to divert water especially near river Jiya Dhol. Railway track on embankment of about 5 m height has been constructed. Several roads have been constructed in the area. These are the man-made obstructions in the natural direction of the rivers. These obstructions may probably be one of the causes of the diversion of the river courses. Close to the original direction of the river Jiya Dhol one canal has been constructed which emanates from the catchment area to divert excess water.

Figure 7 indicates the changes in the course of Brahmaputra during the last 5 decades in the area close to Dhemaji. Changes in the river course to the extent of 3 to 4 km have been observed in the vicinity of this area. This is in much variance from the estimated amount of shift of 10 km by Bapat (1986). The river on the western bank has shifted to west and then again to east whereas the eastern bank remained shifted towards east direction.

EARTHQUAKE EPICENTRAL DATA

Figure 8 shows that in the area $3^{\circ} \times 3^{\circ}$ around Dhemaji 33 earthquakes of intensity 6.0 have occurred during the period 1827 to 1980. However, in the tectonic set up containing Dhemaji between the Brahmaputra river and the Main Boundary Thrust only 3 earthquakes have taken place. Several earthqukes are aligtned along the river Brahmaputra. All the three earthquakes are after shocks of the great 1950 Assam earthquake. From the above there does not appear to be a seismic gap both in space and time domain (Purcaru, et al., 1984) from the point of view of large impending earthquake in the immediate future. Since in this tectonic set-up all the earthquakes are only after shocks. It is not possible to prepare a migration chart for earthquakes for this area (Tian-chang, et al., 1984). From the above no conclusive proof of a large impending earthquake could be found.

CONCLUSIONS

The analysis of results do not appear to give a conclusive evidence of occurrence of a devastating earthquake of Mag. 7.5 with epicentre at Dhemaji in the near future. However, occurrence of an earthquake in any other area in the North-East India falling outside the area of the present study cannot be ruled out. The geodetic upliftment and subsidence donot corroborate with the expected theoretical deformations at the Bench Mark locations. Regression analysis of the levelling data does not show abnormal value of uniform tectonic tilt. Geomorphological changes appears to be due to man-made obstructions in the natural course of rivers. Analysis of the earthquake epicentral data for the period 1827 to 1980 does not appear to indicate seismic gap in the area both in space and time domain. Marginal subsidence at Dhemaji converging from two side points to continue monitoring of the area through geodetic levelling and geophysical means.

RECOMMENDATIONS

It is recommended that the area around Dhemaji be monitored at more frequent intervals both through geodetic and geophysical (including gravity and geomagnetic) means for arriving at conclusive evidences. Geological geomorphological and seismic observations in the area are also recommended till a conclusive decision is taken in the prediction.

ACKNOWLEDGEMENTS

The authors are thankful to G.C. Agarwal, Surveyor General of India (Redt.) and C.S. Joshi, Director, Geodetic & Research Branch (Retd.) for extremely useful discussions. R.S. Madame from No. 72 Party, Geodetic & Research Branch and team of his officers had completed the levelling repeat observations expeditiously during summer 1987. The authors are thankful to them. The authors are thankful to Atam Prakash of Seismotectonics cell, Geodetic & Research Branch, who has developed the Computer Programme and to K.L. Sawhney who has run the Computer Programme and carefully read the text of the paper. Thanks are also due to N.P. Sinha Roy, Vijay Kumar, V.K. Sharma, Harish Prakash and P.K. Uniyal of Seismotectonics Cell for scrutiny of field records, data processing and for drawing figures and to N.D. Kothyari for typing the script.

REFERENCES

1. Arur, M.G. and Singh, A.N., "Error Analysis of Levelling Data in the Shanan Extensions Project in Himachal Pradesh, India", Proceedings International Symposium on Neotectonics in South Asia, Feb. 18-21, 1986, pp. 353-365, Survey of India, G&RB, (1986).

2. Bapat, Arun, "Analysis of California Earthquake Using Seismic Grid Method", Project submitted for CE-590 Spring Semester 1983, Department of Civil Engineering, University of South California, Los Angeles, CA 90007, p. 26, (1983).

3. Bapat, Arun, "Possibility of Earthquake Occurrence Near Dhemaji in Assam", Paper submitted to the Department of Science & Technology, New Delhi, p. 20, (1986).

4. Jackson, D. David; Cheng, ABE; Liu, Chi-Ching, "Tectonic Motions and Systematic Errors in Levelling and Trilateration Data for California", Crustal Movements 1982, Developments in Geotectonics 20, pp. 73-83 Elsevier, (1983).

5. Joshi, C.S.; Singh, A.N.; Manohar Lal, "Vertical Movement of the Indo-gangetic Plains", Presented XIX General Assembly of IUGG, Vancouver, Canada, Aug. 9-22, (1987), (Proceedings in Press).

6. Kharshiing, A.D.; Khattri, K.N.; Moharir, P.S.; R. Chander, "Neotectonics in Shillong Massif and Neighbouring Regions", Proceedings International Symposium on Neotectonics in South Asia, 1986, pp. 407-416, Geodetic & Research Branch, Survey of India, (1986).

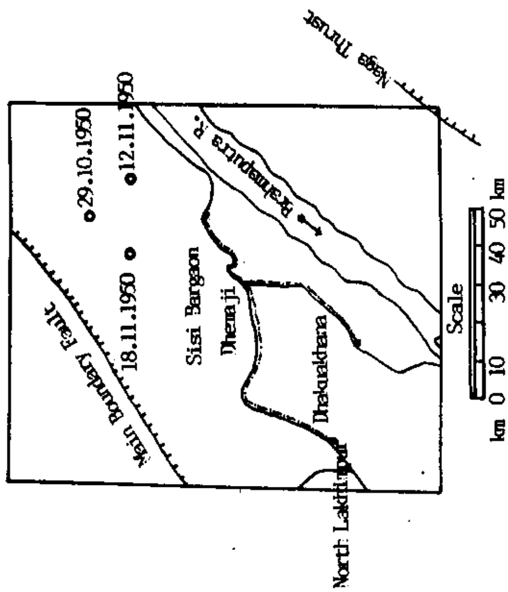
7. Mjachkin, V.I.; Kostrov, B.V.; Sobolev, G.A.; Shamina, O.G.; "The Physics of Rock Failure and its Links with Earthquakes", Proceedings of the International Symposium of Earthquake Prediction, pp. 319-341, Terra Scientific Publishing Company Tokyo, UNESCO, Paris, (1984).

8. Prescott, W.H.; Lisowski, M.; "Strain Accumulation Along the San Andreas Fault System East of San Francisco Bay, California, Recent Crustal Movements 1982, Developments in Geotectonics 20, pp. 41-56, Elsevier, (1983).

9. Purcaru, George; Berckhemer, Hans; "Pattern of Occurrence of Large Earthquakes in the Mediterranean Region", Proceedings of the International Symposium on Earthquake Prediction, pp. 523-537, Terra Scientific Publishing Company, Tokyo, UNESCO, Paris, (1984).

10. Tian-Chang, Chen; Dao-Chang, Jiang; Nong Chen; Zhuo-li, Lo; Wei-Bin, Han; Haï Zhang; Dun-li, Xi; "Characteristics of Seismic Activity of the Songpan-Pingwu Earthquake of 16 August 1976", Proceedings of the International Symposium on Earthquake Prediction, pp. 79-89, Terra Scientific Publishing Company, Tokyo, UNESCO, Paris, (1984).

11. Wassef, A.M., "On the Search for Reliable Criteria of Accuracy of Precise Levelling Based on Statistical Considerations of the Discrepancies", Bulletin Geodesique No. 112, pp. 149-163, Central Bureau of International Association of Geodesy, (1974).



References
1. Existing Precision Levelling
2. Repeat Levelling 1987
3. Faults/Thrusts
4. Earthquake epicentre ≥6.0

Fig. 1 : Repeat Levelling tectonic features and earthquake epicentres

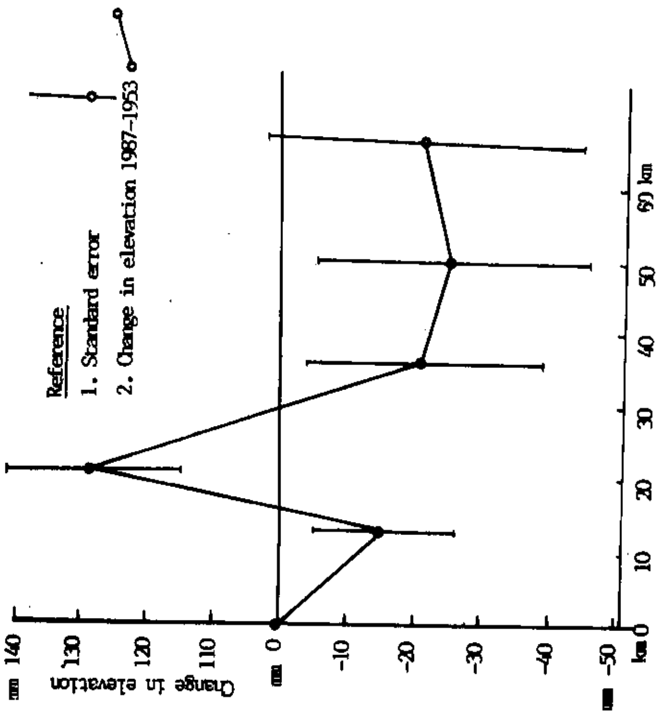


Fig. No. 2 : Elevation changes and standard error on profile North Lakhimpur - Sisibargaon via Dhemaji.

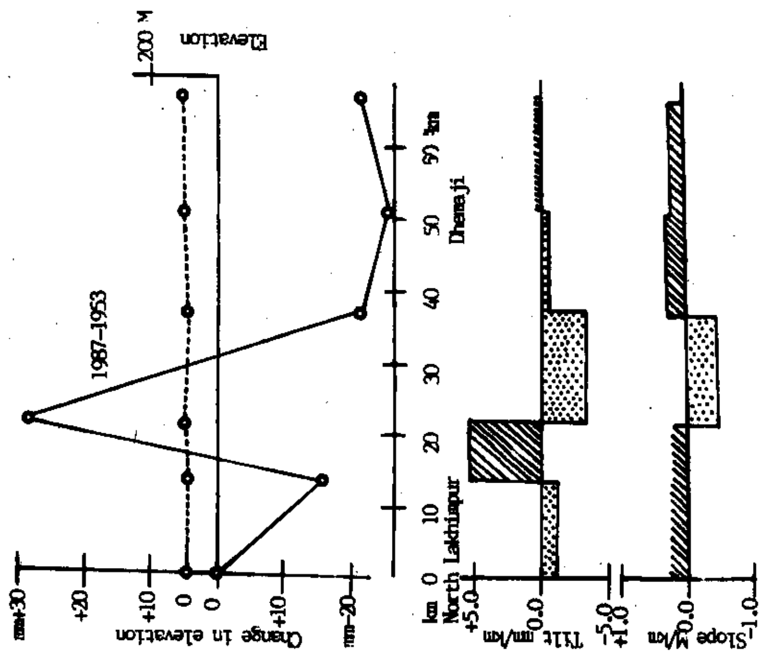


Fig. No. 4 : Levelling data for line No. 1. The curve with continuous line indicates elevation changes vs. distance. The curve with broken lines gives relation elevation vs. distance. The third curve gives tilt. The last curve gives the topographic slope.

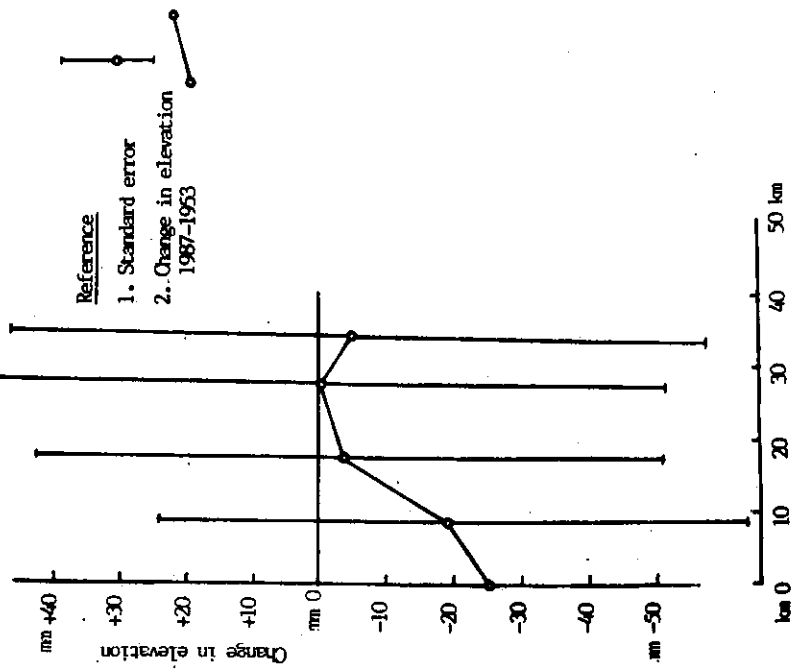


Fig. No. 3 : Elevation changes and standard error on profile Dhemaji - Dhakuakhana.

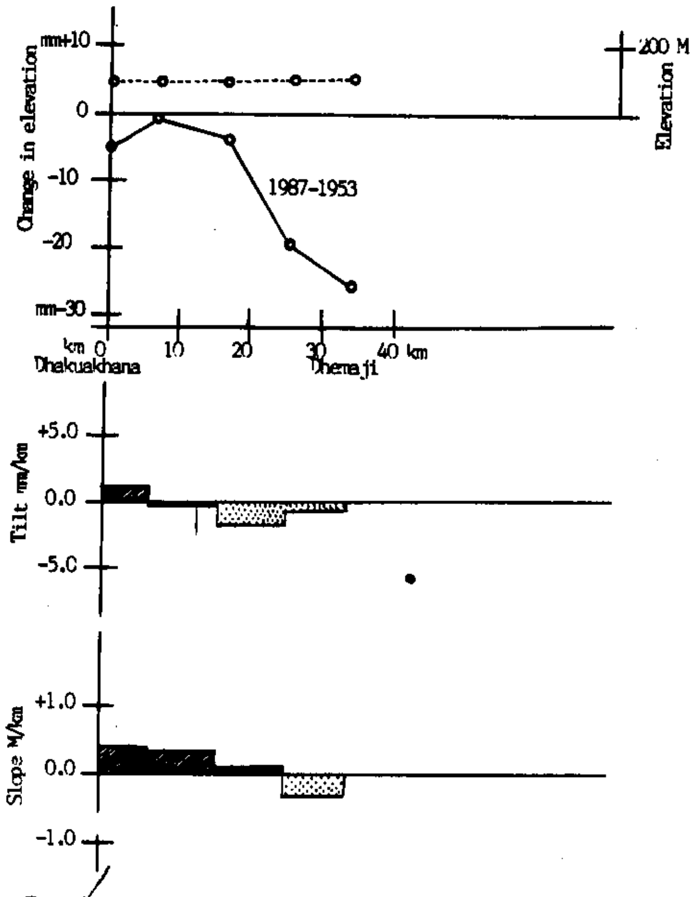


Fig. No. 5 : Levelling data for line No. 2. The format is the same as that of figure 2.

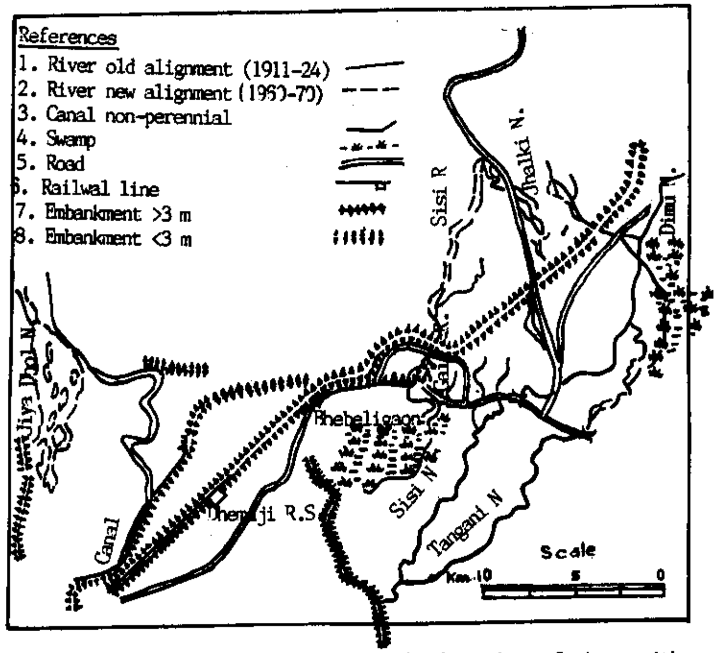


Fig. No. 6 :Geo-morphological changes in the directions of rivers with various development activities.

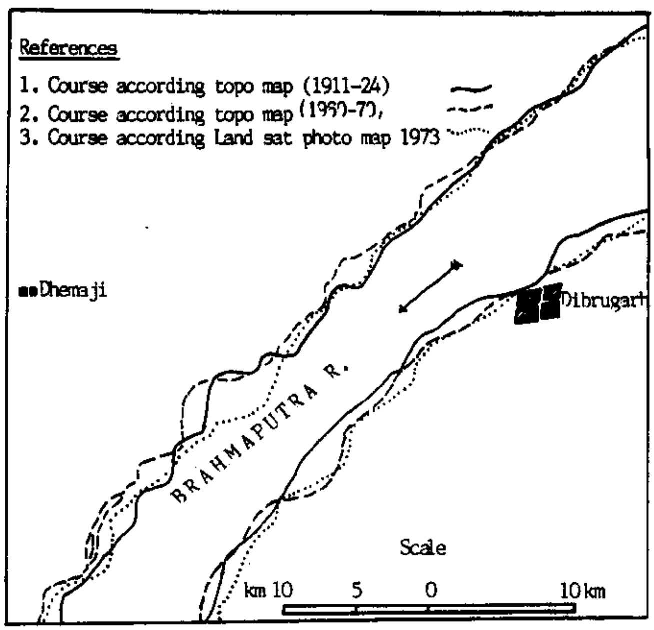
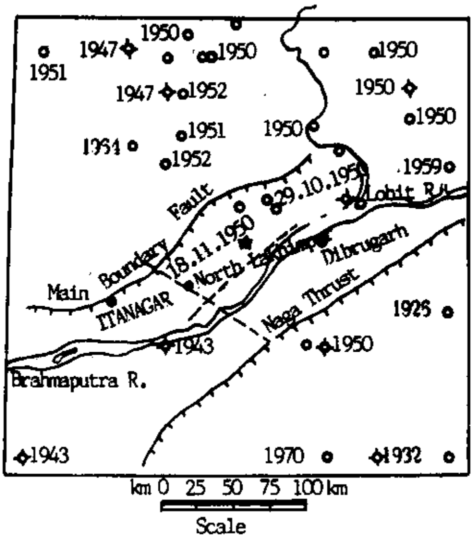


Fig No. 7 : Changes in the course of River Brahmaputra.



References

1. Earthquake Mag. >6.0, >7.0
2. Predicted position of earthquake
3. Lineament

Fig. No. 8 : Earthquake epicentral data for magnitude >6.0 around Dhemaji.

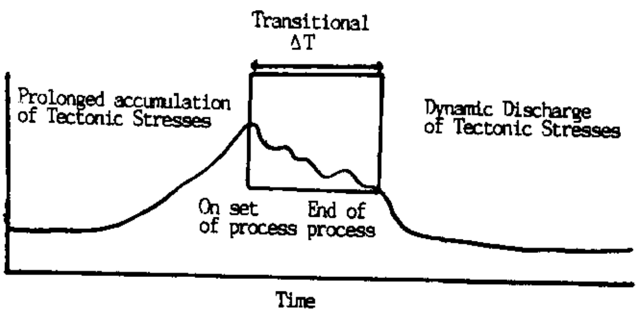


Fig. No. 9 : Model for Earthquake Preparatory Process (Mjacjkin et al., 1984).