TECHNICAL PAPER No. 5

Survey of India

GEODETIC AND GEOPHYSICAL ASPECTS OF THE EARTHQUAKES IN ASSAM

By
Mr. B. L. Gulatee, M.A. (Cantab.), F.R.I.C.S., M.I.S. (India)
Director, Geodetic and Training Circle, Survey of India

PUBLISHED BY ORDER OF
THE SURVEYOR GENERAL OF INDIA

June 1951.

Recd. from O.C. C.&T. Party.

GEODETIC AND GEOPHYSICAL ASPECTS OF THE EARTHQUAKES IN ASSAM

GEODETIC AND GEOPHYSICAL ASPECTS OF THE EARTHQUAKES IN ASSAM

BY

B. L. GULATEE, M.A. (CANTAB.), F.R.I.C.S., M.I.S. (INDIA)

1. **Changes of position.**—The following are some of the recognized major causes of earthquakes :—

(*a*) Volcanic explosion.

(*b*) Explosive outbursts of gas in a petroliferous region accompanied by eruptions of gas, petroleum and mud.

(*c*) Tectonic shocks arising out of faulting and folding movements.

The majority of earthquakes fall under category (*c*), the stresses responsible for movement at source being structural in origin. Assam is well known as a very unstable region of the world and has had several major earthquakes. The great Assam earthquake of 1897 was initially considered by Oldham to be due to a general movement along a thrust plane but later on he modified his views and thought it was a fracture produced by a deep seated impulse below the crust arising from expansion of the magma.

Some press reports have attributed the very great Assam earthquake of 1950 to volcanic activity but it is also really due to the same causes as the 1897 earthquake namely the yielding of the rocks to great strains.

In the areas where known faults exist, there may be a gradual drift of the region on one side of the fault with respect to the other and this may persist continuously over a long period of time until the stresses produced exceed the elastic limit of the crust resulting in a sudden jerk. A shattering earthquake can produce considerable relative displacements along the fault.

Revision of geodetic triangulation in the area can reveal the direction and magnitude of the displacements produced by an earthquake. And if any slow secular upwarping is taking place in a region, it can be delineated by a line of levels frequently repeated across the fault. Normally an earthquake is supposed to relieve local strain by causing an upwarp of the region in which it occurs, but this is not necessarily the case always.

It is not often realized, that to get a quantitative idea of the earthquake effects (amount and direction of movement) by geodetic observations entails work which can not be put into operation at comparatively short notice. It involves a great deal of detailed planning and much labour and expense. There is a real danger if incomplete exploratory work is done as it may lead even a distinguished man of science to subjugate the fragmentary results to conform to any of his pet ideas. Another complication is, that the geodetic and geological requirements differ and the difficulties of reconciling their needs become greater as more is discovered during the course of the work.

The truth of these remarks can best be illustrated by considering the work done after the great Assam Earthquake of 1897. The Geological Department was most anxious to get displacements in the interior of the

Garo-Khasi Hills (near the epicentre) and wanted rapid results of a not too precise nature on which to base their theories of crustal movements involved.

This did not tally at all with the geodetic point of view. There was no principal triangulation in the Garo-Khasi Hills at the time, nor is there even now. Only a secondary series (Khasi Hills) has been carried out there in 1909–13. The geodesists argued that the revisionary work should be confined to rigorous observations of principal series only. Revision of older topographical triangulations is not worthwhile as these were not carried out with sufficient accuracy ; and any changes found in the positions of stations would probably largely be attributable to errors of older work.

In the final programme prepared in collaboration with the Geological Survey of India, a compromise was arrived at, preference being given to geological requirements. Shortages of staff and geodetic theodolites precluded immediate implementation of a systematic geodetic investigation. Mr. Bond was deputed to start work with a 7-inch micrometer theodolite starting from stations Rangsanoba–Taramun Tila of Shillong Meridional Series (No. 44) and to work northwards observing at the principal stations of this series. It was very desirable to measure a new geodetic base outside the disturbed area on which to base the revisionary triangulation, but this could not be done. Along with the revision of this primary series which happens to lie at the extreme eastern edge of the epicentral tract, Mr. Bond was instructed to refix all the secondary points that lay between the Brahmaputra Series (56) and the Shillong Meridional Series (44). This area was supposed to be the core of the earthquake. (See Chart I).

At the principal stations, discrepancies between Bond's and older values ranged from $-14''$ to $+18''$ in angles, $-22''$ to $+9''$ in azimuths and to a maximum of 1/6,000 in sides. Heights of stations observed at ranged from 35 feet to 6,000 feet and they seemed to have risen by amounts varying from 6 feet to 24 feet. Only in one case, Mopen H.S. (height 2,581 feet) was there a subsidence of 4 feet.

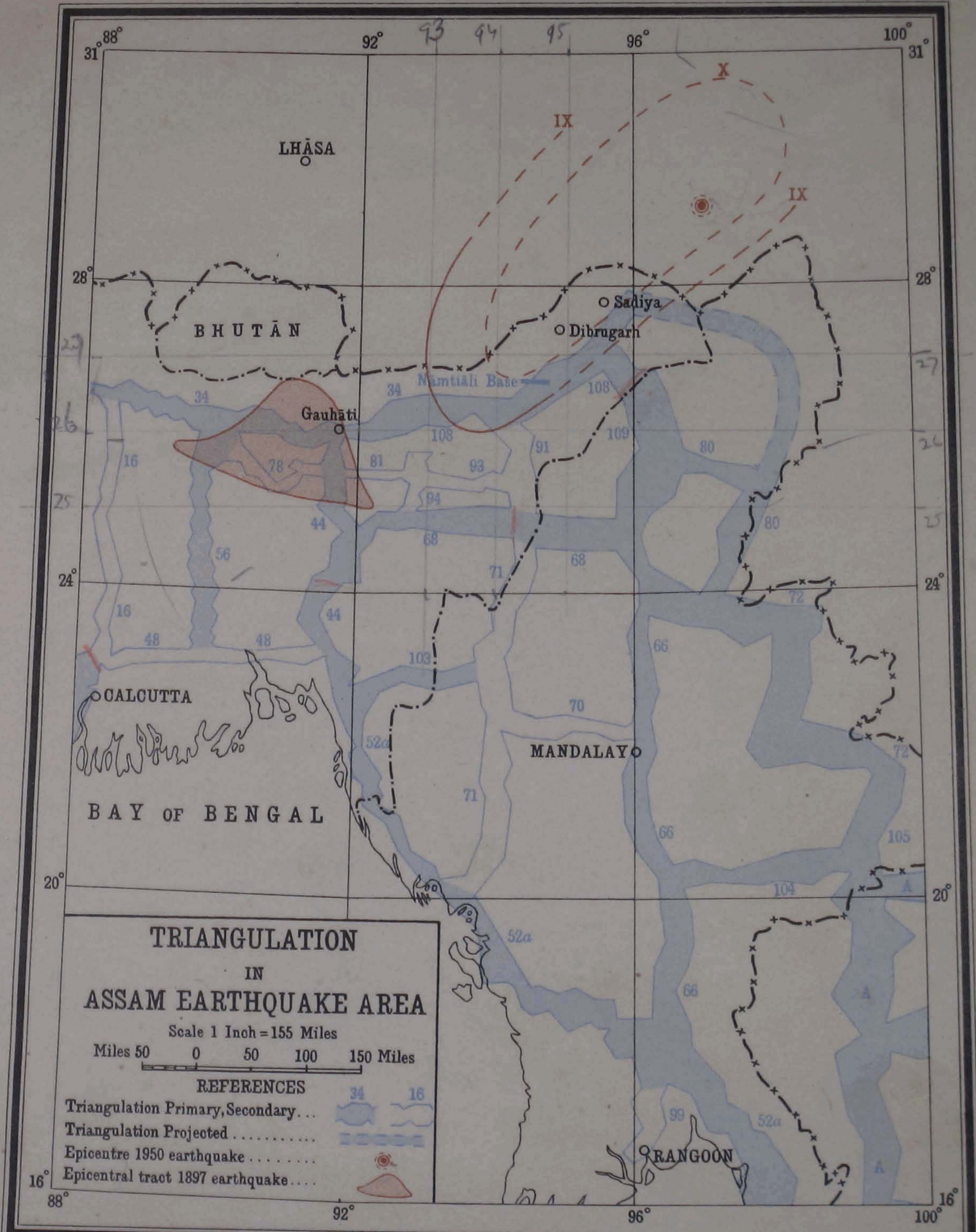
The geodesists were chary of drawing any firm conclusions from Bond's work as it was of too rough a character and could not be described as a real revision of the earlier primary triangulation. The only firm conclusion that could be derived from it was, that all his work lay in the disturbed area. Making the questionable assumption that the base Rangsanoba–Taramun Tila of Shilling Meridional Series was undisturbed Burrard* concluded that the average horizontal displacement was 7 feet in north-westerly direction and that there was on the whole an upheaval. He, however, pointed out that these discrepancies were relative and were of the same order of magnitude as the errors of Bond's triangulation.

There is a tendency on the part of the geologists to relate movements associated with any earthquake in India with the process responsible for the formation of the Himālayas. It is well known that the Himālayas have been folded by compressional forces from the north which started at the end of Cretaceous period and are believed to be still continuing and so the geologists expected the Shillong plateau to have moved southwards as a result of the earthquake. Oldham† tried to bring Bond's results in line with this hypothesis and postulated that the real shift produced by the 1897 earthquake was a compression of the Khasi

* Report on the Trigonometrical results of the Earthquake in Assam by Major S. G. Burrard 14-10-1898.

† Memoirs of the Geological Survey of India, Volume XXIX, page 365–366.

Chart I



No.	Name of Series	Season	No.	Name of Series	Season
16	Calcutta Meridional	1845–48	80	Upper Irrawaddy	1909–11
34	Assam Longitudinal	1854–60	81	Jaintiā Hills	1910–11
44	Shillong Meridional	1860–64	91	Nāga Hills	1913–14
48	East Calcutta Longitudinal	1863–69	93	Kohīma	1913–15
52*a*	Burma Coast	1864–82	94	Cāchār	1914–15
56	Brahmaputra Meridional	1868–74	99	Rangoon	1925–27
66	Mandalay Meridional	1889–95	103	Chittagong	1928–30
68	Manipur Longitudinal	1894–99	104	Mong Hsat	1929–31
70	Mandalay Longitudinal	1899–1900	105	Great Salween	1929–31
71	Manipur Meridional	1899–1902 & 1915–16	108	Assam Longitudinal	1934–36
72	Great Salween	1900–11	109	Mandalay Meridional	1936–37
78	Khāsi Hills	1909–13	A	Foreign Triangulation	

Reg. No. 670 M/N.C.D'51(G. & T.C. 1"=155 Miles)-412.
Printed at the Survey of India Offices (P. Z. O.).

TRIANGULATION CONNECTION INDIA, ASSAM & BURMA

Scale 1 Inch = 96 Miles

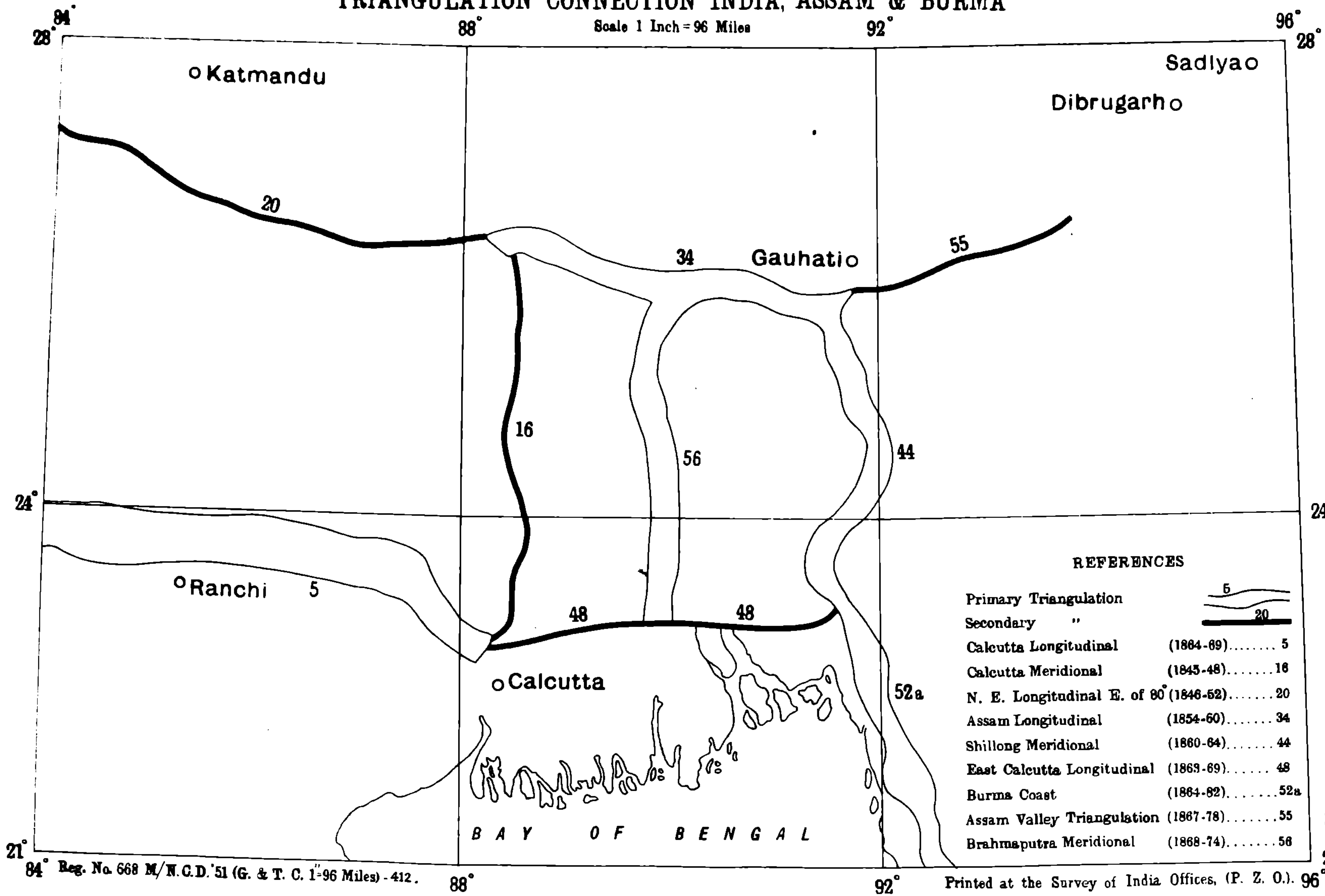


Chart II

Reg. No. 668 M/N.C.D.'51 (G. & T. C. 1"=96 Miles) - 412.

Printed at the Survey of India Offices, (P. Z. O.).

Hills in a north and south direction. He explained away the apparent changes of position in north-westerly direction as disclosed by Bond's triangulation as being due to the fact that the initial base lay in the affected area and was disturbed and that an excessive value had been taken for it in the computation of the triangulation. This is really not justifiable, as by suitably changing the length of the opening base side, results can undoubtedly be derived to harmonize with any preconceived theory. The only way to prove it is to determine the length of this opening side independently and it has not been possible to do it so far. Oldham's conclusions can thus only be regarded as mere speculations.

The bulk of the principal triangulation of India was executed in the last century and its principal deficiency was that India was neither connected to Assam nor to Burma by primary triangulation. Chart II shows the state of affairs at the time of the 1897 Assam earthquake.

The single lines denote secondary series and the double lines primary series. On account of difficult terrain, the connecting series 16, 48 (from Calcutta to Chittagong) and 55 could only be observed to secondary precision. It was for this reason that when the Indian triangulation was adjusted rigorously in 1880, Burma triangulation was not adjusted along with it, as not only were its connections with India weak but also the entire network contemplated for Burma had not been completed by then. During this century, the main efforts have been directed towards fulfilling these deficiencies. Several primary series have been measured in Burma itself and in 1934–36, the Assam Valley series No. 55 of 1867–78, which was of secondary quality was revised according to geodetic standards, observations being taken with the large Wild theodolite.

The observations were started from a side of the main Assam Longitudinal Series (No. 34), but this was considered suspect as check observations to other older stations revealed that angles had changed from $+3''$ to $-5''$. Accordingly in 1938, the Assam Longitudinal series was also revised for about 60 miles westwards from this opening side. This series was in the epicentral area of 1897 earthquake and its further revision was desirable, but it was impracticable to do more work on it.

In so far as the revisionary work went, it was of very good quality and enabled a reliable comparison to be made with the old precise series of 1854–60. The results are discussed on page 5 of the Survey of India, Geodetic Report 1938.

To make the most of the incomplete data available and to get some idea of the displacements involved, it was assumed that the terminal stations of the revised portion of Assam Longitudinal Series in longitudes 90° 30′ and 92° 16′ were undisturbed. Comparisons then revealed southerly movements relative to these stations, assumed fixed, of as much as 10 feet. The magnitude of these relative errors is beyond doubt as the triangulation was of superior quality and its errors in this short distance would be negligible. Resting as it does on the above questionable assumption, however, it offers only a weak confirmation of the theory that the earthquake was produced by tangential stresses from the north.

The present situation is, that despite the large amount of revisionary triangulation done, the results admit of alternative explanations and the evidence is not free from ambiguity. So great is the cost of geodetic work and so slow its progress that the Survey of India has not yet managed to choose the base for their work outside the isoseismal area with the result that the question of absolute shift due to the 1897 earthquake is unanswerable even to-day.

This shows how difficult it is to delineate movments due to an earthquake by determining changes of position as revealed by means of revisionary triangulation. It is necessary to go quite a long way to start from an undisturbed base and then the triangulation scheme may become so long that the accumulated errors of triangulation may well be equal to the actual shift due to the earthquake.

It is of interest to record the effects of the 1950 Assam earthquake on the existing triangulation series and also lay down suggestions for future triangulation control data in the areas affected by it. The epicentre of this earthquake as determined provisionally (29°, 97°) is beyond Indian frontiers and is in an out of the way barren region. The only existing triangulation inside Isoseismal X is a part of the secondary Assam valley triangulation spanning the Brahmaputra river and terminating at Sadiya. It was executed in 1874–76 under very difficult conditions due to which accuracy had to be sacrificed. This series which was made up of triangles of very small sides has now been deleted from our list, because most of its stations were on masonry pillars and on marshy land and have now completely disappeared..

As mentioned above, to strengthen the Assam-Burma triangulation link, the western half of the Assam Valley series which comprised triangles of reasonable size was revised in 1934–36. This portion lies in Isoseismal IX of the recent earthquake (see Chart I), and some of its stations if not all must have been rendered unreliable by the recent shaking. Another series which comes within the zone of the 1950 earthquake is the northern portion of the primary Mandalay series which had been executed in 1936–37 to make the junction with Indian triangulation complete. We thus see, how the earthquake of 1950 has been instrumental in weakening the precise link that had been established between the primary frameworks of Assam and Burma.

A precise astronomical azimuth had been observed at Namtiali base in 1934–36. Its revision this year may throw important light on the relative shift of stations in this locality.

A new triangulation series (see Chart I) starting from near Dibrugarh to Sadiya and thence to the primary Irrawaddy series in Burma would cover a very important area. Its execution would depend upon conditions extraneous to the earthquake as it passes along the Chinese frontier. It would entail heavy expense as apart from difficult terrain, much of the country is uninhabited and some parts fall in unadministered tribal areas where special military escorts and the help of Political Officers is necessary. Its immediate implementation is out of the question, as the Burma Survey Department is not yet in a position to undertake any geodetic work. But when it does materialize, it will provide good control points in the present earthquake zone for future reference purposes.

2. Changes of levels associated with earthquakes.—Every severe earthquake is associated with visible changes of level at some places and quite often very exaggerated accounts are given about them in the press. It is often argued that land tends to rise as a result of the earthquake to relieve the accumulated stresses which have given rise to it.

In the Survey of India Geodetic Report, Volume VI (1929–30), it was inferred from levelling data that parts of the alluvial plains of north Bengal had been rising at the rate of about ½ inch per year for the last 70 years relative to the neighbourhood of Calcutta, Calcutta itself having remained stable. When the Bihār earthquake occurred in 1934, this hypothesis assumed special importance as it fitted in with the usual theory that the earthquake had produced a sudden rise of the land in continuation of this secular rise. A plausible corollary followed naturally from this, that it represented a tendency of the crust to reach isostatic equilibrium.

Later investigations* based on more material covering wider areas revealed that the postulate of secular rise was based on insecure data and was quite untenable.

Considerable levelling was carried out in the earthquake area to see what kind of general changes had occurred. The final indications were that the Bihār earthquake had actually caused a general subsidence over north Bihār up to a maximum of about 1½ feet. Many individual bench-marks suffered much greater subsidence up to 4 or 5 feet but this was purely local.

Many theories can be advanced about this unexpected sinking connected with the earthquake instead of upheaval, bringing in isostatic agency. This sinking may be taken to connote that the earthquake has tended to increase the lack of isostatic equilibrium in this area which may be a region of mountain formation. Quite a good commonsense explanation, however, would be that there might be a certain amount of consolidation as a result of the heavy shaking to which the alluvium has been subjected by the earthquake and the amount of silt and mud that has come out through the fissures.

Normally, the rise or fall of land due to a severe earthquake need not always be great. It is the largeness of the mass that plays an important part. Thus, in the great Kangra earthquake of 1905, Dehra Dūn was raised by 5 inches only while Saharanpur and Mussoorie were in tact. To get this result, very elaborate levelling had to be done. This sudden rise of the Siwalik axis due to the earthquake is in accordance with geological conception. The geologists have always suspected this region to be subject to secular upwarping and repitition levelling seems to bear out this hypothesis†.

The changes in height produced by the 1897 earthquake are not definitely known. Bond's work indicated upheavals of over 20 feet at some stations but then a lot of it may be due to errors in his work. The later precise revisionary triangulation (1934–36, 38) of Assam Longitudinal Series was equally inconclusive. At the majority of stations there was no change. Some of the stations exhibited rises of 4 feet or so but these may well be due to refraction anomalies.

There is a precision levelling line (No. 77 G) running from Gauhati to Dibrugarh along the south bank of the Brahmaputra, which was executed in 1910–11. At Dibrugarh itself, there is a standard bench-mark and en route there are some good rock-cut and embedded bench-marks. It is contemplated to relevel this line next field season and to extend it to Sadiya and it should provide a very accurate quantitative picture of the amount of changes wrought by the 1950 earthquake.

At the same time it is intended to take the opportunity to run a level line and establish permanent bench-marks at intervals of 10 miles along the north bank of the river as well and to connect this line to the line along the south bank of the river by crossing the river at Tezpur and at a number of other places. The proposed levelling is shown on Chart III. It will take two detachments over six months to do it.

* Geodetic Report, Survey of India, 1935, p. 97; 1936, p. 93.

† Survey of India, Technical Report 1948-49, Part III, Chapter II, para 13.

A tertiary levelling line was run in 1949 from Dibrugarh to Rengging via Bar Hapjan, Kobo and Pasighat along the Dihang river. A number of bench-marks were cut on rock but not suitably protected. It has recently been reported in the press that the Dihang river has suddenly risen by about four feet. It would be interesting to relevel this line precisely and to establish some permanent bench-marks along the route.

3. **Geophysical Considerations.**—It is a common belief that seismic areas are associated with significantly large negative gravity anomalies. This belief originated from the striking results obtained by Vening Meinesz in his submarine cruise in the Netherlands East Indies some twenty years ago. He obtained a narrow strip of pronounced negative anomalies bordered by positive anomalies throughout a whole length of 5,000 miles or so. These anomalies had no semblance with the surface topography and were interpreted as manifestations of a great phenomenon going on in the main crust, which is beyond the reach of geologist's observations. To give a physical explanation for these striking anomalies, Meinesz brought forth his buckling hypothesis that in this region there are enormous compressive forces which are producing folding. This in its turn brings about accumulation of light surface matter in the denser magma of such considerable proportions as to produce these large negative anomalies in question.

In India, Bihār and Upper Assam are regions of underload and earthquakes have occurred in them. Some investigators have regarded this as confirming the same general principle of correlation between seismic zones and negative gravity anomalies. There are, however, marked contradictions.

For example, Vening Meinesz did not find any strip of negative anomalies in seismically active parts of the Atlantic Ocean.

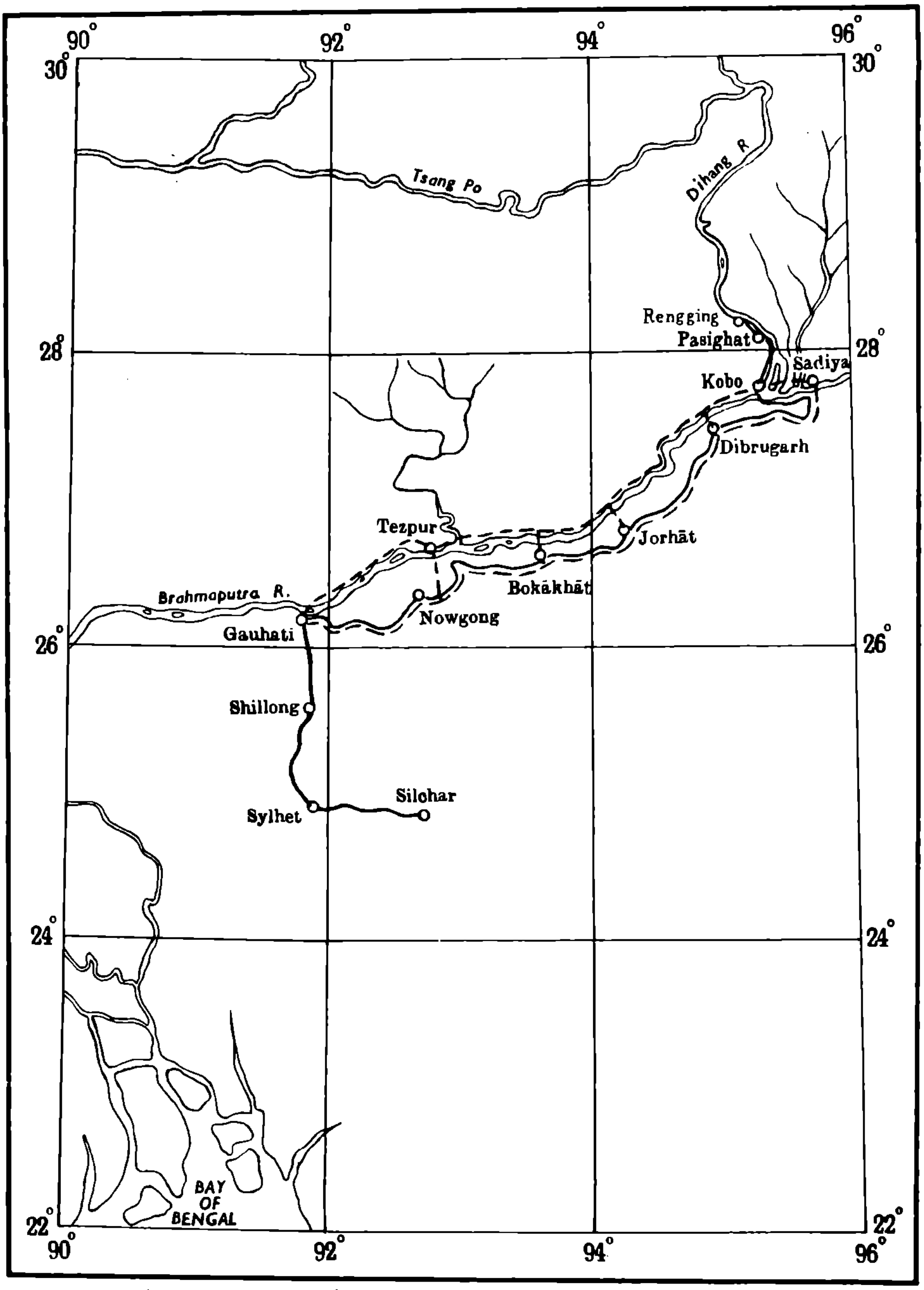
Then again South India, which is a very stable region exhibits negative anomalies while the Shillong Plateau which is the seat of the great 1897 and other earthquakes is markedly positive.

Several attempts have been made in the last few years to evolve some sort of gravity anomalies which would be directly correlated with subsurface structure and seismic zones. The aim is, that such anomalies should provide certain simple basic characteristics for regions in which devastating earthquakes can occur. If this were possible, it would mark a great step towards the prediction of future earthquakes. Experience shows, however, that nature does not permit of such simple generalizations. Indeed so complex and varied are the physical causes of earthquakes that any unduly simplified correlations are bound to be utter failures in the long run and whatever success is claimed for some individual cases is entirely fortuitous.

The gravity anomalies in each region have to be considered on their own merits for explanation and this depends considerably on the history of the region. The line of pronounced negative gravity anomalies extending from the seas to the south-west of Sumatra and Java to Malacca Passage is a tectonic line of structural instability and characterises a region which is in the first phase of mountain formation. It is reasonable to consider it as an extension of the Himālayan line of negative anomalies (Ganges valley and outer Himālayas) to which it is joined up by the north-south line of pronounced negative anomalies in the centre of Burma. But this does not entitle one to infer that every region of underload as evidenced by gravity or geoidal results is ripe for an earthquake.

LEVELLING IN ASSAM

Scale 1 Inch = 96 Miles. Chart III



Reg. No. 669 M/N.C.D' 51 (G. & T. C. 1"=96 Miles)-412. Printed at the Survey of India Offices, (P. Z. O.).

REFERENCES.

Existing levelling. ————

Projected levelling. - - - - -

At this stage it will also be well to be clear about the types of gravity anomalies that may be used. There are a considerable variety of them these days and they are often indiscriminately mixed up with each other. Every type of anomaly is based on certain assumptions and has certain limitations and unless these are clearly understood their use can lead to erroneous interpretations.

In the main, the anomalies may be denoted as A, B, C, D, E, F, G and H. Of these the first two are the usual Free Air and Bouguer anomalies and are well known. The C anomaly is the Isostatic anomaly. It can be computed now-a-days in more than a dozen ways depending on the particular type of compensation assumed. A rigorous computation of these involves estimation of heights all round the globe for each station and is laborious and time consuming. For quite a number of investigations, a reasonable working compromise is sought by introducing some simplification in the reduction.

Of the remaining types of anomalies, two deserve special mention as their implications are not so clearly understood. These are the F anomalies brought forth by Glennie* and the G—anomalies by Evans and Compton*.

The F anomalies have been used as the basis for deriving the crustal structure lines for India. The lines of crustal downwarping are claimed to be indicative of regions where shattering earthquakes can occur. Such anomalies come under the category of what are called mixed anomalies and suffer from several serious objections. They are based on *ad hoc* assumptions and are only useful when applied to a study of limited regions. Amongst other things, their derivation involves Hayford compensation being taken as usual in outer zones and being neglected in inner zones up to 120,000 feet. It also involves an assumption about the magnitude of the "Hidden Range" and its excess density which is liable to a considerable error. From their very nature such anomalies cannot be applied to India as a whole, as they would lead to the following inconsistency. Consider two stations Shillong and Dibrugarh (say). For deriving the anomaly at Shillong, the area of about 24 miles round it is considered uncompensated but for deriving it round Dibrugarh, the same area is reckoned as compensated. The anomalies at the two stations are thus not comparable.

Such mixed anomalies are only useful when small areas are involved and when it is desired to obtain correlation by trial and error between the anomalies and the geology and are not at all suitable for the study of sub-crustal features of India as a whole.

Evans and Compton have in their paper† advocated the use of G—anomalies. These are rigorous Bouguer anomalies corrected for local geology. The Bouguer anomalies are usually computed on the assumption that the crustal rocks have a density of 2·67 and can only be regarded as preliminary due to the fact that vast areas in India are covered by light alluvium and by dense traps where the above density value does not hold. The desirability of allowing for local geology had been recognized by previous workers but there were difficulties in computing it. Just before World War II, the Burma Oil Company established 6,000 gravity stations with gravimeters in Eastern Bengal, the Shan Plateau and Burma and considerable attention was given to the method

* Survey of India, Geodetic Reports 1937, 1938.

† "Geological factors in gravity interpretation illustrated by evidence from India and Burma"—Quarterly Journal of the Geological Society of London, December 1946.

for their reduction. It was considered desirable to make adequate allowance for the geological structure round each station and to avoid laborious computations ; special templates were devised by the Survey of India, under whose direction the reductions were carried out for some stations. The density data was provided by B.O.C. geologists up to a depth of 30,000 feet for a radius of 20 miles round the station.

This is the most comprehensive work done so far with such a type of reduction, but it has to be realized that the uncertainty of geological correction can be extremely large. It is really a method of successive approximations. The objective of the gravity survey was to derive underground geological formations from gravity data. As a first approximation, a rough guess is made of the densities and allowance made for them in the computation of the gravity anomaly. But such conjectural data may be very wide of the mark. Hence, although the G—anomaly is of the rigorous variety, it includes a correction which is subject to a large uncertainty. This uncertainty is inevitable under the present circumstances and the only proper course is to increase our knowledge of geological data in this respect. The computation of such anomalies has, however, served a very useful purpose in that it has given an idea of the geological effects, which are very significant indeed in such areas as Assam and Burma tertiaries.

In view of the shortcomings explained above, no dogmatic conclusions should be based on such anomalies. Any theory advanced on the basis of such anomalies must be considered provisional and subject to modification in the light of more reliable data.

A further important point is, that in the Assam area, even the ordinary Isostatic anomaly is burdened with considerable errors of reduction due to the fact that no reliable topographical maps exist for this area for getting the heights of the various zones for evaluating the effects of topography and its compensation. Normally one-inch maps are used for estimating the heights for the inner zones, but in this area for some cases even the ¼-inch or 1/M maps were not available and the Average Height Map of India on the scale 1/5 M had to be used, which is very generalized and as a consequence of which the estimated heights can be in error by 200 to 300 feet. Fortunately, the anomalies are of such large magnitudes in this area, that an error of a few milligals in the reduction does not alter the pattern materially.

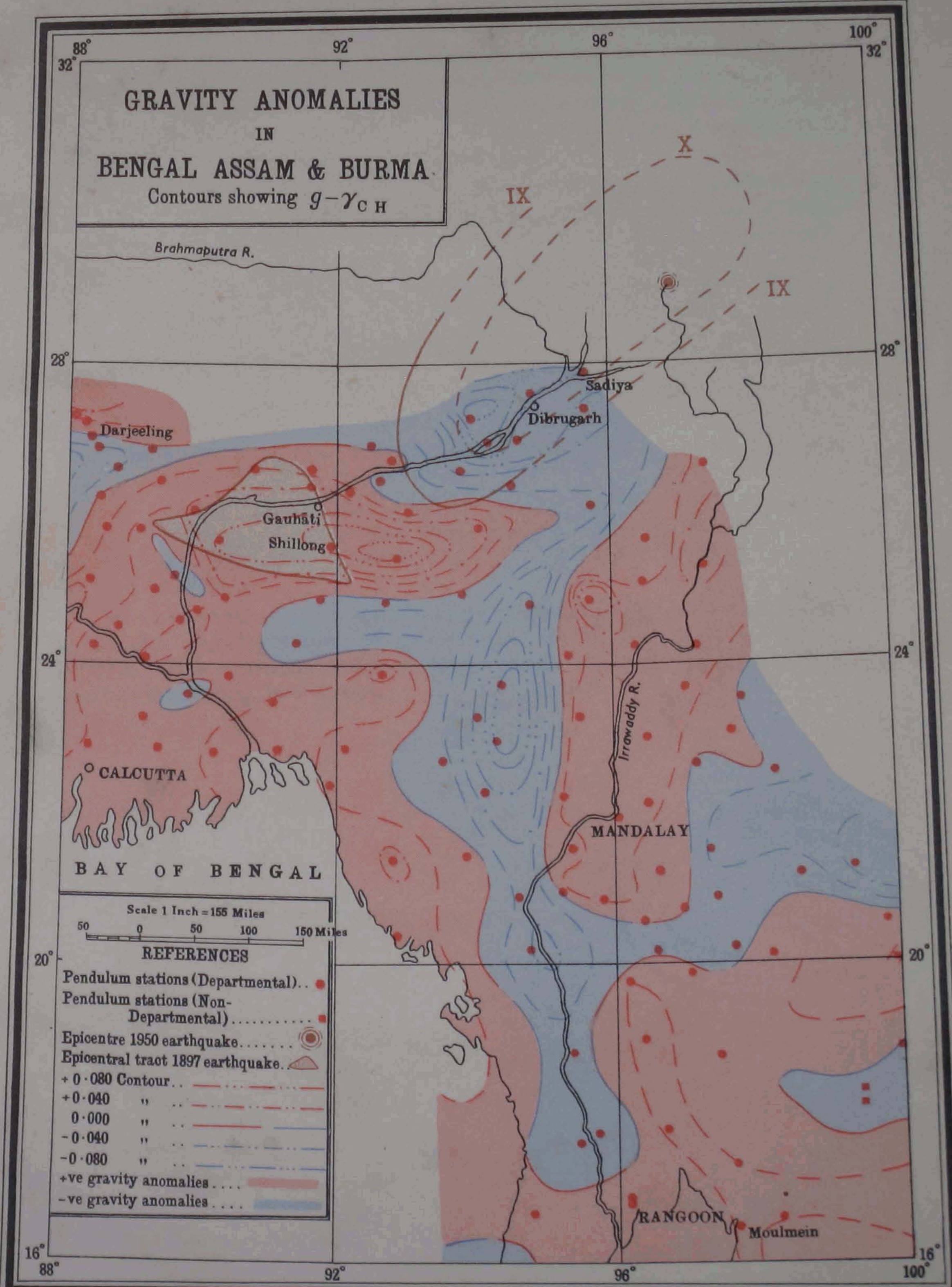
While no universal relationship between gravity anomalies of a particular pattern and seismic zones can be laid down, it is of interest to put forth the indications as given by the gravity results in Assam. The amount of gravity material is, however, insufficient, and much more detailed observations are needed.

A study of the iso-centres of the numerous earthquakes in Assam reveals that they are distributed at random irrespective of the sign of the gravity anomaly. Quite a few of them are situated even on the zero anomaly line.

From Chart IV which shows the isostatic gravity anomalies in Assam, we see that the epicentral tract of 1897 earthquake lies in a region of elevated geoid and positive gravity anomalies, while the indications are, that the 1950 one is in a markedly negative region. The plumb line deflection data in this area is practically non-existant.

The range of the Isostatic anomalies in Assam is considerable. It varies from -120 mgals. to $+108$ mgals. Allowance for geology does not materially alter this range. This may be taken as indicative of the instability of the region.

Chart IV



Reg. No. 671M/N C D 51 (G. & T. C. 1"=155 miles)-412

Printed at the Survey of India Offices, (P. Z. O.).

The picture of G—anomalies is naturally very different from that of Isostatic C—anomalies. The former are necessarily much more negative as they do not include the effect of compensation. Evans and Compton claim that they show a close correlation to main tectonic lines. Thus, Upper Assam valley is a region of strongly marked negative anomalies and so also is the line of maximum uplift in hills separating Assam and Bengal from Burma. The volcanic line of Burma and the Bengal and Irrawaddy deltas are regions of excess gravity. From what has been said above, it is apparent that these conclusions should only be regarded as broad tentative generalizations until more definite data is available, or the computation of geological effects.

A point of considerable interest is, that the greatest positive and negative anomalies in the whole of India are to be found in Assam. Thus, North Lakhimpur (Lat. 27° ·2, Long. 94° ·1), where considerable damage has been done by the 1950 earthquake has the largest negative Isostatic anomaly :—$\Delta g_B = -224$ mgals. $\Delta g_C = -120$ mgals. Haflong (Lat. 25° ·2, Long. 93° ·0) has the largest positive anomaly in the whole of India $\Delta g_B = +0 \cdot 039$, $\Delta g_C = +108$ mgals. At Dibrugarh also, the anomaly is very large.

The region in which the epicentre of the 1950 earthquake lies is very difficult of access. It would be of great interest to take gravimetric observations there and delineate the limit of the pronounced belt of negative anomalies to the south-west of it.

To add to our knowledge of lack of isostatic balance in Assam area, it is also proposed to run gravimetric traverses during the next field season along the north and south banks of the river Brahmaputra from Gauhati to Sadiya.

No observations for deviation of the vertical have been made so far in this area and information about the height of the geoid there is entirely lacking. It is contemplated to do some observations in this respect also during the coming field season.

G. & T.C.—P.O.—J.S. 213—21-5-51—400