MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA

VOLUME XLVI, PART 1.

THE SRIMANGAL EARTHQUAKE OF 8TH JULY 1918. BY MURRAY STUART, D.SC., ETC., *Offg. Superintendent, Geological Survey of India.*

Published by order of the Government of India.

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SOLD AT THE OFFICE OF THE GEOLOGICAL SURVEY OF INDIA,
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MEMOIRS

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THE GEOLOGICAL SURVEY OF INDIA

The Srimangal Earthquake of 8th July 1918. By Murray Stuart, D.Sc., etc., *Offg. Superintendent, Geological Survey of India.*

INTRODUCTION.

A preliminary report of this earthquake has already been published in the Records of this department,[1] and the reader is referred to it for a general account of the shock. This present larger work is an attempt to bring together a full descriptive record of such phenomena of the earthquake as have, or may have, a scientific bearing. As the whole of the investigation was carried out by me single-handed without the aid of any of my colleagues, it follows naturally that fewer first-hand observations were obtained than in the case of the Great Indian earthquake of 12th June 1897, or of the Kangra earthquake of 4th April 1905, for the former of which five officers were detailed from this department for the investigation, and for the latter four. Nevertheless a large number of interesting observations were obtained personally by myself, and many more were supplied me by scientific observers from personal observations in different parts of the area affected by the earthquake. It is therefore hoped that the observations given in the present Memoir are as reliable as those given in the reports on previous earthquakes. As it was impossible for me to visit all the areas affected by the earthquake I confined my tour to the area where the greatest damage

[1] *Rec. Geol. Surv. India*, Vol. XLIX, pt. 3.

had been done, and furniture and ornaments overturned. It was not possible even to visit the whole of this area, and for the remaining area over which the earthquake was felt it became necessary to weigh quantities of unco-ordinated evidence derived from local sources. Such evidence has been furnished by a great many local observers, on earthquake question-forms. From these I have drawn freely for my information, especially where no first-hand information was available, and their assistance in compiling the account of the earthquake has been invaluable. The number of such observers is so great that it is impossible to quote everybody, but it is to be hoped that all those contributors who have assisted me in collecting the material for this report, and whose remarks have gone without mention in this book, will not on that account conclude that their work was of no value. On the contrary it is just by means of a wealth of information that a compiler can with confidence give a general account of the phenomena concerned, a thing which he could not do from only one or two, often imperfectly agreeing accounts. I cannot leave this subject without expressing my gratitude to the tea planters of South Sylhet for their great kindness in helping me in every way in my investigation, often at very great inconvenience to themselves, or without expressing my appreciation of the great value of such assistance in my investigation. When it is realized that the area of greatest damage lay in the tea garden area of the Balisera, Doloi, and Luskerpore valleys, in which the local authorities were unable to provide me with any means of transport ; that throughout this area most of the bungalows were totally destroyed, and the planting community were living in tottering leaf-houses, or hastily constructed bamboo shelters, furnished with what little furniture and crockery they had been able to dig out of the ruins of their fallen bungalows ; when one realizes that, to make their discomfort complete, the rainfall, at the time, was generally 3 inches a day ; their great courtesy, and the manner in which they provided me with transport, and arranged changes of horses to enable me to carry the investigation through as fully and as quickly as possible, cannot ever be sufficiently acknowledged or appreciated. I should also like to mention the great courtesy of the Directors of Observatories, both Indian, British, and Foreign, who have given me full descriptions and records of the seismograms registered in their observatories, and of Dr. D. B. Meek, the Director of the Alipur Observatory, who has very kindly had the Simla, Bidston,

and Rocca-di-Papa seismograms, on Plates 8 and 9, reproduced by his draughtsman.

For the collection of evidence from all available parts of India where the earthquake was felt, a printed question form containing a request for information on the following points was issued and distributed all over the area likely to have been affected. The following is a reprint of the form :—

1. Time of occurrence, if possible exact Standard Time.	
2. Duration of shock in seconds . .	
3. Situation of observer, whether in or out of doors, asleep or awake, sitting or standing, etc.	
4. Number of separate shocks, if more than one was felt.	
5. Were any unusual sounds heard either before, during or after the shock, and what did they resemble ?	
6. What was the intensity of the shock, whether strong enough :—	
(1) To be felt by everyone . .	.....
(2) To be felt only by person at rest	.....
(3) To make doors, windows, etc., or loose objects rattle, and floors creak.	.....
(4) To make hanging objects swing .	.....
(5) To move the observer's seat .	.....
(6) To throw down loose objects .	.....
(7) To crack the walls of building .	.....
(8) To cause greater damage (to be specified).	.....

This brings me to a question that I mentioned in my preliminary note on the earthquake, and is one which has been the cause of

much confusion and difficulty throughout the enquiry. I refer to the matter of time. It is generally believed that the time kept in India is Indian standard time, and that, with the exception of a very few large towns such as Calcutta which keep their own local time, standard time is kept throughout India. This is not the case in Bengal and Assam. In these provinces every little place keeps its own time. It reports occurrences in its own time, and an enquiry has to be made in each case to ascertain what the difference is between this local time and Indian standard time. This custom is so habitual that the newspaper reports give the local times without feeling the necessity to state that they are local time, or that the time kept in each place is different from that kept in neighbouring places, so that no co-ordination is possible between these times until each is converted into some standard time.

It will perhaps make my meaning clearer if I quote examples. Barisal reported the earthquake as having been felt at 4-30 P.M., Faridpur at 4-20 P.M., Aijal at 4-30 P.M., without stating that the difference between local and standard time is at Barisal 32 minutes, at Faridpur 30 minutes, and at Aijal 43 minutes. The quoting of local times leads to the erroneous impression that the earthquake shock had been felt at the same time in both Barisal and Aijal, and in Faridpur ten minutes earlier. The reduction of all these times to the same standard shows that the reported time of the earthquake shock in Aijal was eleven minutes earlier than the reported time in Barisal, and three minutes earlier than the reported time on Faridpur. An instance of the confusion arising from the use of local time was quoted in the preliminary report. A further instance which may be cited is the official report of the earthquake in Assam in which the time of the earthquake was variously stated to be between 4-20 and 4-30 P.M., and the direction of the shock from west to east, or north-west to south-east. This report was compiled from a number of reported times, all of which were local times, and consequently the reported times made it appear that the shock had been travelling in a west to east, or north-west to south-east direction, instead of exactly the opposite direction. The reason being, of course, that owing to the variation of local time in an east-west direction, and the fact that the earthquake shock travels quicker than the rate of rotation of the earth's surface, the local times of the earthquake shock became earlier and earlier in an east-west direction.

A natural result of this habit of keeping local time in each place is that it is practically never kept correctly. There is generally no recognized public clock which keeps accurate local time.

Owing to the fact that there are exceedingly few *pucca* buildings over the area which was seriously affected and to the fact that such as do exist vary greatly in nature, and strength to resist shock, it was found to be impossible to map isoseists according to the Rossi-Forel scale. Most of the area where the earthquake was violent enough to damage all, or nearly all. brick buildings, consists either of jungle-covered hills such as the Hill Tippera area, or of low-lying land such as that seen in south Sylhet, practically all of which was under water at the date of the earthquake. Brick buildings are limited therefore almost entirely to railway buildings, and to those in isolated places such as Sylhet, Maulvie Bazar, Habiganj, Kishorganj, Brahmanbaria, Agartala, etc., and the buildings and factories of the tea estates in the valleys of south Sylhet. Consequently I have mapped isoseists on the plan adopted by R. D. Oldham in his investigation of the Great Indian Earthquake of 1897. In that investigation he found it impossible to attempt to define more than seven degrees of intensity lying within their isoseists, which he defined as follows :—

(1) the first isoseist includes all places where the destruction of brick and stone buildings was practically universal ;

(2) the second, those places where damage to masonry or brick buildings was universal, often serious, amounting in some cases to destruction ;

(3) the third, those places where the earthquake was violent enough to damage all or nearly all brick buildings ;

(4) the fourth those places where the earthquake was universally felt, severe enough to disturb furniture and loose objects but not severe enough to cause damage, except in a few instances, to brick buildings ;

(5) the fifth, those places where the earthquake was smart enough to be generally noticed, but not severe enough to cause any damage ;

(6) the sixth, all those places where the earthquake was only noticed by a small proportion of people who happened to be sensitive, and being seated or lying down were favourably situated for observing it.

This scale does not pretend to scientific accuracy, and it is probable that a slightly different interpretation has been put on the intensity represented by the isoseists, to that put by Oldham. Such indeed is almost inevitable but it has no effect on the results of the investigation.

In the following pages, Part I has been devoted to a detailed description of all the impressions and effects of the earthquake as recorded by myself, and also by the local observers through the medium of the earthquake-forms. It is divided into six chapters as follows:—Chapter I contains a description of the epicentral area. For this I trusted mainly to my own observations during my tour through the area. Chapter II contains a description of the area enclosed by Isoseist No. 2, Chapter III of the area enclosed by Isoseist No. 3, and Chapter IV, that enclosed by Isoseist No. 4. Chapters V and VI contain a description of the remaining areas where the earthquake was sensibly felt. For the last two the material at my disposal has been derived almost entirely from the earthquake forms, newspapers, and the reports of local observers. Part II is divided into two chapters in the first of which under three sub-headings I discuss certain of the more prominent features of the earthquake as embodied in the earlier descriptive part and also of the unfelt earthquake and attempt to generalise concerning them. The last chapter is devoted to the fore-shocks and after-shocks.

PART I.

Record of Observations.

CHAPTER I

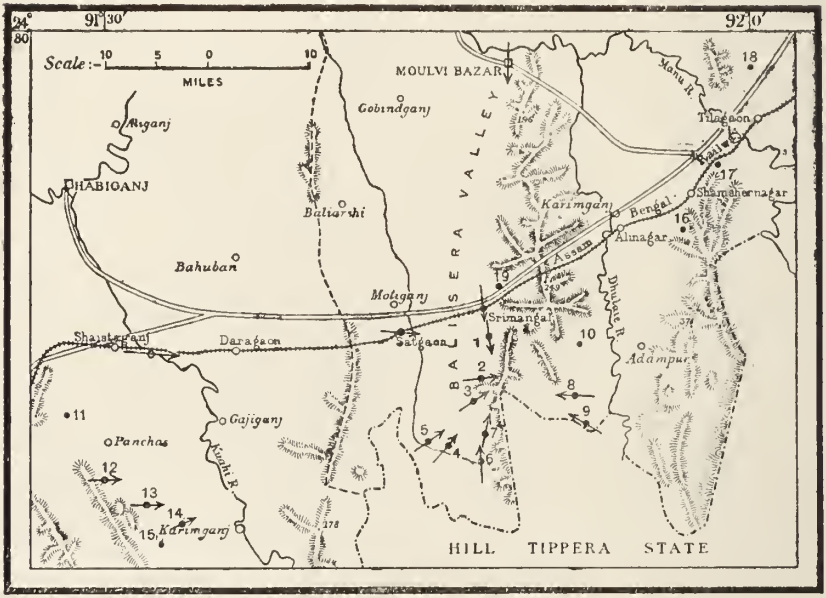
THE EPICENTRAL AREA.

The epicentral area is that of the Balisera valley and part of the Doloi valley.

With few exceptions all brick buildings were found to be destroyed wihin this area. Coolie lines on the tea estates, built mostly of sundried mud, and thatched roofs, were levelled to the ground. The usual type of planter's bungalow built of poorly burnt bricks, and very thick, exceedingly heavy, thatched roofs, also collapsed in almost every case. Tea factories and certain bungalows having steel girder frames were left standing, but the brickwork in them was either thrown down or left in a shattered and tottering condition in almost every case. The tea estates visited by me in the Balisera valley were the Phulchara, Kalighat, Lakhaichara, Kajurichara, Rajghat, Puttiachara, and Sisal Baria. At the Phulchara estate the Manager's bungalow was levelled to the ground, practically every leaf-house was down. The Assistant's bungalow had only one shattered room standing, and the factory, which had a steel girder frame, was left in a tottering condition. The factory boiler shifted, owing to the fracturing of its brickwork foundations, and two of the heavy drying machines were loosened from their beds. The general direction of fall was towards the south, and is shown on the plan given below on which I have marked all the general directions of fall over the epicentral area.

In addition to the earthquake effects described above, water and sand spouted up out of vents in the ground in various places.

Mr. Lauder, the Manager of the Phulchara estate, informed me that when the earthquake occurred he was outside and just in front of his bungalow. He began to run to the bungalow and was met at



PART OF SYLHET DISTRICT
SHOWING DIRECTION OF FALL OF BUILDINGS & OBJECTS(⟶)

The numbers on the above map refer to the various tea-gardens as given in the following list:—

Reference to Tea Gardens.

1. Phulchara.
2. Kalighat.
3. Lakhaichara.
4. Kajurichara.
5. Rajghat.
6. Sisal Baria.
7. Puttiachara.
8. Patrakhala.
9. Doloi.
10. Madhabpur.
11. Lalchand.
12. Deundi.
13. Luskerpore.
14. Chandpur.
15. Chandichara.
16. Alinagar.
17. Kanihati.
18. Langla.
19. Bharaura.

the bottom of the steps by Mrs. Lauder who had managed to rush out, although bricks were falling around her as she ran. By this time the intensity of the shock was so great that they were unable to keep on their feet, and were thrown to the ground, while the bungalow collapsed with a crash, and on the tennis-court numerous

vents occurred from which water and sand spouted up to a height of several feet. When vibration ceased the tennis-court, which beforehand had been quite level, was found to have settled irregularly into a series of mounds and hollows.

At Kalighat most of the bungalows were levelled to the ground. The Club was flat and all that was to be seen was the shattered thatched roof on the ground covering the débris of the walls (see Plate 1, fig. 1). The post office had fallen bodily towards the east. The doctor's bungalow had completely collapsed, and it was here that the only European death occurred. Mrs. Mumford, the wife of Dr. Mumford, being killed instantaneously, and another lady pinned down, and crushed, by the falling roof and débris. The roof had been removed before my arrival, but there was still sufficient evidence to point to the fact that the direction of fall had been towards the east. Plate 1, fig. 2, shows the débris as I saw it, and the twisted and bent steel girders testify to the intensity of the shock.

The Kalighat Manager's bungalow was not down, but was leaning over towards the east at a dangerous angle, and, its brickwork being badly shattered and cracked, was in danger of falling at any moment. The Kalighat factory was perhaps less damaged than the surrounding factories, possibly because it was near the actual epicentre, but the walls were badly cracked and portions of the roof had shifted towards the east. The leaf-houses were badly shattered and these again gave evidence of a fall towards the east. The walls of the Kalighat church were shattered and thrown down, but the roof and iron frame-work were left standing.

At Kajurichara the Manager's bungalow was thrown flat, and from the direction of fall of verandah pillars, and also of the gate-posts, the direction of fall seems to have been towards north-north-east. Here, as in the cases mentioned above, great damage had been done to leaf-houses and factory.

At Rajghat the Manager's bungalow was down, the Assistant's bungalow partially down, and the remainder tottering; many leaf-houses were down, and the factory was badly shattered and broken.

It was in the bungalow at this estate that I saw an eight-inch steel girder that had been broken across as if it had been a fragile stick. The general direction of fall at this estate was north-east. Between the factory and the Manager's bungalow on this estate is a small stream which for some distance flows south-west. During

the earthquake a wave is reported to have come down this stream travelling from north-east to south-west and to have washed the banks considerably above the stream-level.

The frame-work of the bungalows at Puttiachara and at Sisal Baria was in each case of steel girders and this undoubtedly was the reason why the roofs had not collapsed. In spite of this, however, the brickwork in the walls was shattered and in many cases thrown down, the direction of fall being towards the north. Plate 2, fig. 2, shows a photograph of the Puttiachara bungalow after the shock. The photograph is taken looking east and it will be seen that, although held up by its steel framework, the whole bungalow is leaning over towards the north. I do not propose to give detailed accounts of all the buildings in the valley and of the damage done to them, the above being sufficient to describe the general havoc wrought by the earthquake in the eastern portion of the Balisera valley.

The damage on the western side of the valley was similar to that caused on the eastern, though slightly less intense. The case of the Satgaon Tea Estate may be taken as typical. Here four iron columns in the centre of the Manager's bungalow held up the roof and undoubtedly prevented it from falling. The walls were shattered and most of them down. Every column on the verandah was broken right through at from one foot to eighteen inches from the floor level. From the Assistant's bungalow the windows and doors were all that could be salved. The roof was a complete wreck. In the factory the western end wall came down in one mass leaving the end of the corrugated iron roof unsupported. The eastern end wall of the original factory, which divides the latter from the new extension, was cracked and shattered from eaves to apex, and so also was the outer eastern end wall of the factory. All the other walls facing north or south were cracked, but not so badly as those facing east or west. Two withering-houses, running east-west and built with iron columns and braced together with iron beams, were intact, but the withering-house running north-south had all their brick columns cracked across the centre and in some cases shattered. Two walls of the fermenting-house collapsed but the corrugated iron roof was intact. The blacksmith's shop was levelled to the ground. Two walls of the hospital collapsed. The upper half of the western end wall of the office came down in one mass and left the corrugated-iron roof overhanging, and the lower half, though standing, was shattered. The eastern end wall was shattered

but did not fall. The north and south walls were badly cracked The Manager reports that—

"The direction of the shock at first seemed to be east and west, but finished up with a mighty upheaval combined with a motion like a riddle at its most intense effort. The shock then died away slowly."

This agrees with the evidence adduced from the direction of fall. The damage done to the other estates on this side of the valley was similar. Bungalows and buildings having thatch-roofs without iron columns were levelled with the ground, while those with iron framework and corrugated-iron roof had the brickwork shattered and partially thrown down.

The extraordinary escape of the Bharaura tea estate, owing to its being sheltered by the hills, has already been mentioned in the preliminary report. The Jagchara estate, two and a half miles to the north of Bharaura, although damaged much more than Bharaura, nevertheless owing to the same effect of earthquake-shadow suffered much less than would have been expected. The walls and columns on the verandah were much cracked and portions had fallen, but the leaf-houses and factory were merely cracked in places and masonry had not fallen to any extent.

The Patrakhala tea estate in the Doloi valley suffered badly. The Manager's bungalow was shattered and the southern end had fallen, the northern end, though shattered and tottering, was still standing. Part of the Assistant's bungalow was down and the remainder leaning over at a dangerous angle towards the east. The leaf-houses being built entirely of iron were intact, but the end wall of the fermenting-house fell out towards the east, the remaining walls being badly cracked. Plate 2, fig. 1, shows a photograph of the Manager's bungalow at Patrakhala.

An interesting description of the earthquake shock was furnished by a planter at Rasidpur, two stations west of Srimangal. He was standing at the side of the railway line at Rasidpur, when he heard a loud noise coming down the railway cutting which is situated between Sathgaon and Rasidpur. He concluded at first that it was the afternoon down train coming at great speed, but on looking in that direction he saw the railway line moving in waves, which travelled towards him. When the waves reached him he felt the ground shaking violently, and saw the tea factory and other buildings falling. The wave movements passed under him and he watched them recede down the line towards Shaistaganj ; in other words

from east to west.[1] The railway line at this point is running approximately east and west and Rasidpur lies west 6° north of Kalighat. After the earthquake it was found that the east and west gable ends of the leaf-house and factory had fallen, while the longitudinal east and west walls had all diagonal cracks.

There are three trolley systems running through the epicentral area, one running from Srimangal to Tiprachara, with a branch line to Rajghat and Udnachara; another from Satgaon to Huglichara; and the third from Rasidpur to Daragaon. All three systems run north and south, and on each system the line had bulged in places towards the east. This is of special interest since the trolley line in the Doloi valley, situated along the edge of and just outside the opposite side of the epicentral area, was found to have bulged towards the west. Other than the tea estates the only place of any importance situated within the epicentral area is Srimangal. Here many houses were thrown down in the bazaar and the station buildings damaged and partially thrown down. The direction of fall in this case was north and south.

Along the portion of the railway line that is situated within the epicentral area, the damage done does not seem to have been excessive. Between Srimangal and Satgaon, although the bridges and the line showed evidence of having been badly shaken, the alignment does not seem to have been very much upset. The Udna, Billash, and the Kalighat bridges show no side or end movement to speak of, but in both the Udna and Billash bridges the abutments sank and closed in.

In the pass through the Balisera hills, between Patrakhala and Kalighat landslips of considerable size were reported by the garden coolies.

[1] From information kindly collected for me by Dr. Mumford.

CHAPTER II.

THE AREA ENCLOSED BY ISOSEIST No. 2.

The area enclosed by Isoseist No. 2 included the Doloi and Luskerpore valleys, and the towns of Habiganj and Maulvi Bazar. Over this area, although the damage done was less than in the epicentral area, practically every brick or masonry building was damaged and many were thrown down.

In the Doloi valley the Doloi tea estate suffered considerably and most of the Leaf-houses were levelled with the ground. The eastern wall of the factory fell outwards towards the east leaving the corrugated iron roof unsupported at this end. The Manager's bungalow was badly cracked and left leaning slightly towards the east. It was possible, however, to shore up the roof with wooden beams and make it safe for habitation. A cottage piano which was standing in the middle of the drawing room with its front facing east-south-east was thrown over on to its back, *i.e.*, in a west-north-west direction. Plate 3 Figs. 1 and 2, show photographs of damage done at the Doloi estate.

At the Kurmachara Tea Estate the damage done was of the same order as that done on the Doloi Estate, walls in the bungalow, were cracked in both north and south, and east and west directions, while the walls of the fermenting house fell outwards. Some of the walls in the Manager's bungalow fell towards the north and others towards the east.

At Champarai the stove of the E. P. C. drier was moved one inch northwards, while the factory columns were bent eastwards. The shafting also had been moved two inches eastwards and had pulled the collar on the shaft through that distance. The west wall of the factory fell outwards while the east wall was cracked along the bottom, and had it not been supported by other parts of the building would have fallen towards the east.

The Madhabpur tea estate suffered less than the above-mentioned estates, the greatest damage being done in the factory, where walls fell towards the east.

All along the trolley line, which runs from Bhanugach to Patrakhala, stacks of country bricks had fallen, almost invariably towards the east, and the trolley line itself was broken in several places, and in others was bulged, with the bulge pointing towards the west.

The Doloi iron bridge which runs approximately north-east had some of the angle tie-bars sheared right through, while the approaches at both sides were found to have sunk at least a foot. In fact, the whole area surrounding this bridge is reported to have sunk considerably.

On the eastern side of the valley the Alinagar, Shamshernagar, and Kanihati tea estates suffered slightly less damage. At Kanihati factory the east-end gable wall fell out towards the east, breaking off about two feet above ground-level. An intermediate wall inside the factory, exactly similar to the east-end gable wall, was very badly cracked and leaning over towards the east. Part of the north wall of the boilerhouse fell towards the north. The leaf-houses, built with brick pillars, had those pillars damaged and in a few cases thrown down. The damage was most pronounced towards the north end of the building, the southern portion not appearing to have suffered so much.

One steel-framed leaf-house, oriented east-west had a slight lean towards the west. Two small hollows were noticed in the grounds outside the factory. These hollows did not exist before the earthquake shock; one of them was saucer-shaped, about 18 feet in diameter and 1 foot deep; the other was about 108 feet distant in a north-west direction from the first and measured about 21 feet long by 9 feet wide and about 9 inches deep.

At Shamshernagar and Bhagichara, the bungalows have iron columns and suffered little damage except cracks. No. 2 leaf-house, which fell, had a roof of corrugated iron supported on brickwork columns and wooden posts. The factory was only cracked.

The damage at Alinagar was similar. A water tank situated near Mr. Leather's bungalow, was thrown towards the west owing to the cracking of the brickwork columns supporting it. The tank was full at the time.

Fissures in the ground are reported from various places in the Doloi valley. According to reports they varied from a mere crack to a fissure six inches wide and as much as a foot in depth. Their

direction was generally east and west. In places a blue sand was thrown up, and at the same time water spouted several feet into the air.

In the Luskerpore valley the damage done was similar in intensity to that caused in the Doloi valley. On the Lalchand tea estate the buildings, being sheltered by the hills, suffered little damage beyond cracks in the walls. In the Manager's bungalow a full-sized billiard table standing on a perfectly level cement floor was rotated through a few inches in a clockwise direction; a plan showing its position before and after the earthquake shock is given below:

At the Deundi tea estate the Manager's bungalow was thrown down and much damage done to leaf-houses and factory. The general direction of fall was towards the east.

At the Chandpur tea estate the bungalow was shattered and part of it had fallen. The fermenting shed had fallen bodily to the east and many leaf-houses were down. The factory also was badly damaged and its walls badly cracked, and in places thrown down. A shed, near the factory, having a corrugated iron roof and used apparently as a store, had collapsed; the roof was supported partly by a wall and partly upon brick pillars and in falling it had acquired a counter-clockwise rotation.

The eastern gate-post of the bungalow had been cracked through just above ground-level and the upper portion moved bodily over the lower in a east-north-east direction through a distance of 8

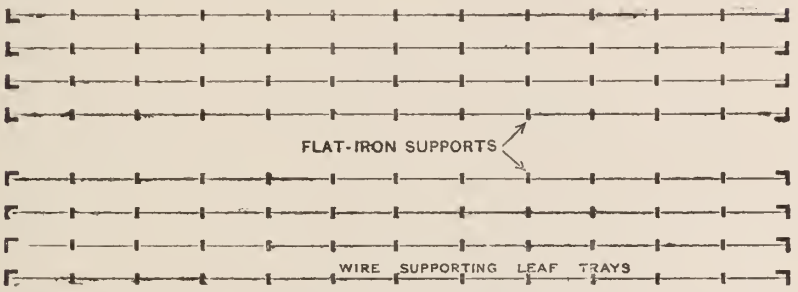
inches; but it had not fallen. The following sketch shows the position of the gate-post after the earthquake.

FRACTURED GATE-POST AT CHANDPUR.

At Luskerpore the Manager's Bungalow was badly shattered and some of the walls had fallen. The roof, having a steel framework, was intact and had not fallen. An interesting piece of evidence as to the direction of the earthquake shock was given by the leaf-houses on this estate. There were three leaf-houses, two running north and south, and one running east and west. The trays in the leaf-house were supported on an iron framework consisting of upright angle-iron at the corners and vertical flat-iron strips at equal distances throughout the length of the frame. These vertical pieces carried the wire trays arranged in tiers one above another. There were two such frames in each house.

The following plan will explain the arrangement. It is importan to notice that the vertical flat-iron supports had their flat sid

at right angles to the length of the frame, so that the frame could bend much more easily in the direction of its length than at right angles to it, or sideways.



PLAN OF THE WIRE AND FLAT-IRON FRAME SUPPORTING THE LEAF TRAYS IN THE LUSKERPORE TEA GARDEN DRYING HOUSES.

After the shock, the iron frames in the houses running east and west were found to be bent into a tangled mass of scrap iron, while those in the two houses running north and south were very little damaged; only a few of the upright flat-iron supports being bent. In this latter case the bending was always east and west, and the flat-iron support had rotated so that the flat surfaces were facing approximately east and west, thus enabling it to bend in those directions. The direction of the shock seems therefore to have been approximately east and west.

At the Chandichara estate, the Manager's bungalow and the factory had their walls shattered, and in places thrown down; the roofs, having iron frames, were left standing. The eastern and western end-walls of the factory fell outwards, and the iron chimney was bent over towards the east.

The trolley line to the factory, where it curves gently from approximately north-east to east-north-east, was considerably bent and in places broken.

On the Assam-Bengal Railway the chief damage was the fracturing of piers and abutments of the Doloi, Manu, and Sutang (157th mile) bridges. The direction of the shock was not apparent from damage done to the Doloi and Manu bridges, but in the case of the Sutang bridge the shock seems to have been approximately east and west. Piers Nos. 3 and 4 were cracked through below flood-level, and the girders over them showed a movement

of nearly 15 inches, indicated by marks made on the flanges of the rails by the screw spikes which held them down to the sleepers. The top portion of the broken pier No. 4 was thrown towards the west.

In Maulvi Bazar all the brick buildings in the bazaar were damaged and many of them were thrown down. The Mission bungalow, and that of the Sub-divisional Officer were badly damaged and partially thrown down and the High School building was completely ruined. The direction of shock was from south to north.

In Habiganj the damage done was similar to that done in Maulvi Bazar, the bazaar being badly damaged, and also the Sub-divisional Officer's bungalow. Wardrobes facing east and west were overturned and eastern and western walls were most damaged.

At Satiyajuri railway station the earthquake shock was experienced almost due east and west. Both east and west gable walls in the menials' quarters fell outwards, and the internal walls running east and west developed diagonal cracks.

CHAPTER III.

THE AREA ENCLOSED BY ISOSEIST No. 3.

The chief places situated within the area enclosed by this isoseist are Agartala, Akhaura, Brahmanbaria, Kishorganj, and Sylhet, and the tea gardens of the Langla, and Juri areas. At Agartala nearly all masonry buildings were damaged, some seriously. The domes of the palace and the inner walls were cracked badly, and four domes of the Lakshminarayan temple collapsed. The residence of the Private Secretary also suffered severely. The upper storey of the Kunjabon palace was so seriously cracked that it had to be subsequently dismantled. During the earthquake shock, the ground cracked and sand and water spouted out in numerous places and long fissures appeared generally running parallel to a road or embankment. In places the ground sank into small hollows.

At Akhaura the brick portion of the railway station collapsed completely, and the other railway buildings suffered severely. The damage done to the railway station was much greater than might have been expected and the explanation is, I think, that the mortar used in its construction was of very poor quality and consequently the building was weak and easily broken. I brought some of the mortar away and it consists mainly of mud, and can be crushed between the finger and thumb with ease. The iron-girder foot-bridge which crosses the railway line at the north-west end of the station had some hand-rails bent at its western end. A four-foot iron water-tank in the Assistant Engineer's bungalow which stands on a staging 25 feet high was shifted about three inches to the west and slightly to the north. The tank was full at the time of the earthquake. A trestle drawing-table in the Assistant Engineer's Office which stood east-west fell over towards the west. In almost every case cross walls in the railway quarters running east-west were found to have diagonal cracks from the wall plate on the west to the ground on the east. The shock at Akhaura is described as being first a tremble, then a rolling west to east, then a violent vertical movement followed again by a more violent east and west

movement. After the initial tremble a noise could be heard distinctly approaching from the direction of the Teesta bridge, growing in intensity until the vertical movement was experienced, when it resembled the sound made by a quick-firing gun of large calibre. It was the second lateral movement that caused the fall of those buildings which entirely collapsed and of the walls which fell in the buildings that were damaged. I did not visit Brahmanbaria, but the damage there was said to have been considerable, most buildings being cracked and several having collapsed.

In Kishorganj the damage done was also considerable. The Sub-divisional Officer's house was thrown down and also the First and Second Munsifs' houses. The jail was practically demolished, the northern wall fell bodily to the north, and the buildings within the jail collapsed. The southern wall and the entrance gate were very badly shattered and in places thrown down, and the remaining walls badly cracked. The Public Library fell bodily towards the east, and the two schools were badly cracked, and in places portions of the walls had fallen. The railway bridge just to the north of Kishorganj station had its abutments cracked and the girders permanently moved nearly eighteen inches in a southerly direction over the southern pier. The length of the bridge seems to have been permanently shortened by the amount mentioned.

In addition to the above many other houses in the bazaar were shattered and partly thrown down. On the other hand the Munsif's court and well-built houses were unharmed, and the railway station was only cracked in one place owing to subsidence of the bank on which it is built, and was not injured directly by the shock. The reason for Kishorganj having suffered so greatly seems to have been the extreme weakness of some of its buildings. The Jail and the bungalows of both the Sub-divisional Officer and the Munsifs were brick-and-mud buildings, not brick and mortar, and the mud was so sandy and contained so little clay that on being touched with the finger it ran like the sand in an hour-glass. The few good masonry and brick buildings that existed were unharmed by the earthquake. An exceedingly interesting phenomenon was noticed in the compound of the Munsif's court. A long stack of loose bricks about four feet wide and nearly five feet high stretched for a length of 120 feet in a north and south direction along the west of the compound. The bricks had fallen in places along the western face of this stack, not all the way along the face but at definite intervals, there being

a space of thirty-one feet unfallen between each place where the bricks had fallen and the next. Plate 5, fig. 1, shows a photograph of the stack of bricks as it was after the earthquake. The peculiar way in which the stack has fallen at definite intervals would appear to be connected with the amplitude and rate of propagation of the large waves, but as it would also be influenced by the natural period of oscillation of the stack itself of which nothing definite is known no deductions as to the amplitude or speed of the large waves of the earthquake can be drawn from the phenomenon.

In Sylhet the main shock seems to have been east and west, but considerable damage was also done in a north and south direction. Practically all the brick buildings in the bazaar were badly cracked and very many of them fell. The musjid on the river front, near the dâk bungalow was badly cracked and seven of its eight minarets fell outwards. The high School was exceedingly badly cracked and left standing in a tottering condition. Both these last-mentioned buildings came through the earthquake of 1897 unharmed. The Circuit House, which is a lath-and-plaster building with iron framework, of the earthquake-proof type constructed after the 1897 earthquake, had its lath and plaster walls shattered. It is worthy of note, however, that well-built modern brick buildings were only cracked and often only slightly. The outer walls of the Jail facing east and west were both cracked through close above the ground and both had bowed outwards above the crack, the upper portion of the western wall which had bowed outwards towards the west having moved outwards through a distance of 4 inches in the centre of the arc, and the eastern wall in a similar way 1 inch towards the east. The bow outwards did not result in a perfectly symmetrical curve; the radius of curvature was greater towards the southern end of the curve than it was towards the northern end, pointing to the existence of a north and south component as well as an east and west component in the movement which produced the effect. Speaking generally, cupboards facing east and west were thrown down while those facing north and south were not. Just outside Sylhet, along the Peterganj road, several instances were reported of cracks from which sand and water issued. These cracks were, in all the instances that I saw, parallel to a road or embankment.

In the tea garden area the damage seems to have been less severe. The two areas of which I have particulars are Langla and the

gardens near Juri. At Langla the manager's bungalow had its walls running east and west cracked and some brick work in the upper storey of one of them fell outwards. The factory runs east and west and has brick walls. Both the east and west gable ends were badly shattered and a portion of about 50 sq. ft. fell out of each. About 40 ft. of the upper portion of the southern wall of the factory was thrown down and the remainder badly cracked. The northern wall which is only about half the height of the southern wall was more badly cracked but none of it fell. The leaf-houses are all steel-framed and run east and west; after the shock all were found to be leaning slightly towards the east. Inside the buildings, an iron safe on a wooden stand with its back towards the east side of a wall running north and south was jerked round and left facing north-west, having come away from the wall $5\frac{1}{2}$ inches at the southern corner; after the shock, the northern back corner was $10\frac{1}{2}$ inches from the wall, and the southern back corner $15\frac{1}{2}$ inches. A 400-day clock which was facing east and standing on the top shelf of a whatnot was rotated in a counter clockwise direction and came to rest facing north. A book-case full of books, standing with its back towards the south wall was thrown forwards on to its face in a northerly direction.

At the Phultallah and Chandkhira tea estates near Juri the shock was felt still less. At Phultallah the buildings sustained merely a few cracks and a little plaster fell off. A clock which was facing east fell forwards on to its face and ornaments fell east and west. The tea-house is said to have swayed from east to west at least a foot out of the perpendicular during the shock.

The chief damage to the railway in this area embraced by isoseist No. 3 occurred at Fenchuganj. Here the embankment leading up to the south end of the Fenchuganj bridge settled as much as 20 feet in places, leaving the railway track hanging in mid air. The piers of the bridge have also been found to have cracked below high flood-level, a fact that was not known till the river level went down several months after the earthquake.

In many places cracks appeared in the ground and sand and water were ejected. This phenomenon was particularly noticeable by the side of the railway line between Mymensingh and Kishorganj, the borrow-pits by the side of the railway being, in many places, completely filled up with the ejected sand and mud.

CHAPTER IV.

THE AREA ENCLOSED BY ISOSEIST No. 4.

The area enclosed by isoseist No. 4 comprises the area where furniture and ornaments were overturned, but little or no damage was done to sound brick or stone buildings. The only places of any importance included in this area are Comilla, Mymensingh, Netrakona, and Cherrapunji. The remainder of the area consisting of swampy rice-fields and small villages. At Comilla ornaments were overturned and a certain amount of damage was done to old and weak houses, sometimes as a result of the earthquake waves, but more frequently as a result of the subsidence of the water-logged alluvial soil on which they are built. The principal buildings damaged and cracked were :—the Post Office, the Collector's bungalow, the District Judge's bungalow, the Bar Library, the New Zealand Church Mission quarters, the Brahma Mandir and several Hindu temples.

At Mymensingh ornaments were overturned and a cow in the Collector's compound was thrown off its feet. A number of old and weak buildings and walls in the town were cracked and in places thrown down. The old Brahmaputra railway bridge was unharmed.

At Netrakona, the damage was almost entirely due to the subsidence, in places, of the water-logged alluvium on which the town is built. The bungalows of the Sub-divisional Officer and of the Police Officer and the Court buildings were cracked owing to subsidence of the ground, and much sand and water were ejected from cracks in their neighbourhood. Part of the Dâk Bungalow sank a few inches and the Dâk Bungalow well broke away from its platform and sank eight inches. Many of the wells in the town filled up with sand and water and overflowed. The Railway station clock stopped at 15 hours 53 minutes.

At Cherrapunji ornaments and pictures fell. Mrs. Jones sent the following information from the Mission House Cherrapunji :— "In our house pictures and ornaments fell. Of a number of ornaments standing on a shelf, some fell while others, not apparently

different in weight and size, did not fall. The pictures fell from a wall running west and east. None of the bottles in the dispensary were overturned."

A certain amount of damage seems to have been done to buildings, but only such as were old or very weak.

The railway was little damaged throughout this area. The outpouring of sand and mud by the side of the railway was particularly noticeable along the Mymensingh-Netrakona line and the borrow-pits were filled up in many places. The railway bridge at Netrakona was damaged through subsidence of the river banks and the railway station well at Gourigram sank out of sight. Here also the two sides of a triangle of railway line used as a turntable were considerably bent, one rail being found to have a curvature equivalent to a radius of 30 feet. The base of the triangle, which was facing the epicentre, and approximately at right angles to the direction in which the waves came, was not affected.

The railway embankment between Mymensingh and Kishorganj sank in many places and effectually blocked the line. About 1 mile east of Biskra station, just to the north of the railway line, there were several stacks of newly made bricks. Most of the stacks fell over to east-south-east, and a few to north-north-east.

In addition to the area just described there seems to have been another area of intensity IV situated under the Bay of Bengal, just off the coast of Arrakan, the north-eastern portion of which includes Akyab. Its existence is indicated from the reports of the Meteorological Observer at Akyab and of the Deputy Commissioner, and also from the unexpected course followed by the two outer isoseists, Nos. 5 and 6, through central Burma. Its shape appears to have been elliptical with the long axis running approximately north and south, indicating a subsidiary slip along a vault running approximately north and south just off the coast of Arrakan. The only reports from this subsidiary area come from Akyab and are:—

Report of J. Goddard, Deputy Superintendent of Telegraphs, Akyab, Superintendent of Observatory, Akyab.—Time of earthquake, about 17 hours (Burma Standard Time); Duration of Shock, about 90 seconds; Situation of Observer, Standing out in the street; Number of shocks, two separate shocks, the second one being very severe; Sounds, towards the end a noise was heard similar to the breaking of a bundle of sticks; Direction, south-west and north-east. The shock was strong enough to be felt by everyone, to make doors

windows, etc., and loose objects rattle and floors creak, to make hanging objects swing, to move the observer's seat, to throw down loose objects, to crack the walls of buildings, to permanently tilt telegraph posts, and to throw a little boy of three years of age off his feet.

Report of the Deputy Commissioner, Akyab.—Time of earthquake, 5 P.M., approximately, Burma Standard Time; Duration of shock, 1st shock 6 seconds, 2nd shock 12 seconds (total duration of shocks and continuous light tremors was 2 minutes approximately). Situation of Observer, Indoors, sitting; Number of shocks, Two distinct shocks; Sounds, none noticed. The shock was strong enough to be felt by everyone, to make doors, windows, etc., and loose objects rattle and floors creak, to make hanging objects swing, to throw down loose objects, and to crack the walls of buildings.

This subsidiary area of intensity 4 is quite distinct from the main area situated round Srimangal, the strip of country lying between the two showing effect which can only be classed as belonging to the zone of intensity 5.

CHAPTER V.

THE AREA ENCLOSED BY ISOSEIST No. 5.

The information given for places situated within this isoseist is, with a few exceptions, derived from the reports of observers, newspaper accounts, and the earthquake enquiry-forms. The position of the Isoseist is shown on the map (Plate 14). The point of interest about it and also about Isoseist No. 6 is the unexpected curve outwards taken by them in Burma about latitude 21°. At this point, instead of continuing symmetrically round the four inner Isoseists, they both curve outwards, becoming concave instead of convex outwards for a short distance and then curve southwards to embrace the subsidiary Arrakan centrum as well as the main Srimangal centrum. The information obtained with reference to this area is derived from information supplied by local observers, and from earthquake enquiry-forms. It is as follows :—

AIJAL.—*H. A. C. Colquhoun, I.C.S., Superintendent, Lushai Hills.*—The treasury clock stopped at 4-30 local time, which is 43 minutes ahead of Indian Standard Time. Most of the masonry buildings in the station escaped lightly, showing only a few cracks. The Civil Surgeon's Bungalow, a stone building was more seriously damaged, the upper corners of one of the inner walls being shaken down, and falling mostly into one of the bedrooms. The direction of the earthquake shock is variously estimated as from west to east to north-west to south-east.

BARISAL.—*Meteorological Observer.*—The earthquake shock occurred at 15 hours 53 minutes, Indian Standard Time, and was felt for nearly two minutes. Two distinct shocks were felt. The walls of the telegraph office were slightly cracked and several Hindu temples also slightly cracked. A portion of the cornice of the Protestant church fell.

BARISAL.—*Newspaper report.*—A severe earthquake shock was felt by everyone at 4-30 P.M. (local time). It lasted about two minutes cracking church buildings, the bar library, a Hindu temple, and a number of houses.

BASSEIN.—*The Deputy Commissioner, Bassein.*—The earthquake occurred here at 4-50 P.M. Burma Standard Time. Two distinct shocks were felt, the first of three seconds' duration, followed after a short interval by a second shock of five seconds' duration. No noise was heard. The earthquake was merely a slight oscillating movement but was felt distinctly by everyone.

BHAGALPUR.—*District Magistrate.*—The earthquake was felt at about 4 P.M. Only small objects having small and circular bases, such as tumblers

and bottles were reported to have been overturned in some places. They fell from east to west. The shock was felt by everyone.

BORJULI.—*The Manager, Borjuli Tea Estate.*—The earthquake occurred at 15-38 Indian Standard Time. The duration of the shock was about 1½ minutes. Three shocks were felt at intervals of 20 and 30 seconds respectively. An unusual grinding sound was heard before the shock was felt. The shock was felt strongly by everyone. Several of the walls of the tea estate buildings sustained slight cracks, and one chimney in the tea-house fell.

BURDWAN.—*The Collector of Burdwan.*—No objects were overturned in the earthquake. The shock was felt by everyone.

CHANDPUR.—*Newspaper report.*—The earthquake occurred at 4-25 P.M. (local time) and lasted two minutes. The Criminal Court, Hospital, and a few private buildings were slightly cracked.

CHINSURAH.—*Newspaper report.*—The earthquake occurred at 4-18 P.M. and lasted two minutes. The walls of the Judge's room and the front verandah of the court were cracked and some bricks dislodged.

CHITTAGONG.—*Meteorological Observer, and newspaper reports.*—The earthquake occurred at 15 hours 52 minutes, Indian Standard Time and lasted for two minutes. There were three separate shocks of which the middle was the strongest. The earthquake was felt by everyone. A few old buildings collapsed, but otherwise no damage was done.

DACCA.—*Newspaper reports.*—The earthquake occurred about 5 o'clock (local time). The shock lasted nearly one minute and was felt by everybody. Several buildings were slightly cracked, and a few very old houses fell.

DACCA.—*R. S. Finlow, Fibre Expert to the Government of Bengal.*—The points I noticed about the effects of this earthquake were as follows:—

(1) About four light glass flasks on a shelf on a wall facing east were thrown to the ground. The shelf has a lip so that the throw of the shock must have been considerable. The flasks could hardly have rolled off the shelf on account of the lip.

(2) In a room used for bacteriological work, polished white tiles facing west in a doorway were thrown from the wall. The door faces north and south. The above took place on the ground-floor of the laboratory.

(3) On the first floor the plaster stripped from the top of two partition-walls facing east and west respectively. The portions stripped are just below the roof in each case.

(4) After the earthquake I looked down a large well in the laboratory compound. The water had been fairly violently disturbed and had oscillated through a foot or eighteen inches at least. The well is circular, but the water had moved through the greatest height in the east and west direction.

In my bedroom upstairs in my bungalow, of two almirahs standing opposite to each other, and facing east and west, the doors of both were flung open. In another room, almirah doors more easily opened than the above, but facing north were not affected. In the drawingroom a curtain pole above a door in a wall facing east was thrown down. Similar poles facing north and south

were not affected. No big articles were overturned. I unfortunately did not think of looking for rotatory effects."

DARJEELING.—*The Deputy Commissioner.*—No objects were overturned but pictures were knocked out of the perpendicular on the walls of some houses. The shock was felt by everyone and travelled from east to west.

Newspaper reports place the time of the earthquake in Darjeeling at 3-50 P.M. Indian Standard Time.

DINAJPUR.—*A. N. Chatterji, Deputy Collector-in-charge.*- No object was overturned by the earthquake in this district but the shock was felt by everyone, whether sitting, lying, or standing.

DUMKA.—*Santal Parganas.—E. L. Tanner, I.C.S., Deputy Commissioner,* Santal Parganas.

"At Dumka, no objects were overturned. The earthquake was attended by a roaring sound and the shock was felt by everyone."

FALAM, CHIN HILLS.—*The Superintendent, Chin Hills, Burma.*—The earthquake shock was felt in Falam between 4-53 and 4-55 P.M., Burma Standard Time, direction north to south. The duration of the shock was about two seconds.

FARIDPUR.—*Newspaper report.*—A smart earthquake shock was felt at about 4-30 P.M. (local time). The tremor lasted for about a minute and two of the shocks were particularly severe. Some of the buildings of the town suffered to a great extent. The Sub-divisional magistrate's Court room and the Sub-Registrar's office having suffered most. No building actually collapsed. Some of the arches of the two-storeyed Judge's court building were cracked in several places.

FENI.—*Newspaper report.*—A severe earthquake shock was felt at 4-30 P.M. (local time) and lasted for more than two minutes. Damage to masonry work was done especially in the school buildings.

GAUHATI.—*Meteorological Observer.*—The earthquake was felt at 15 hours 55 minutes, Indian Standard Time and lasted for 45 seconds. There was only one continuous shock and it was accompanied by a rumbling noise. It was felt by everyone.

HENZADA.—*Deputy Commissioner.*—The earthquake was felt at 5 P.M. (Burma Standard Time). No objects were overturned. The earthquake was felt by everyone.

JAMALPUR (MYMENSINGH).—*Sub-divisional Officer.*—The earthquake shock was felt about 4-20 P.M. (local time) and lasted for about 30 seconds. The direction appeared to be north-east and south-west. No great damage was caused in the sub-division though small cracks appeared in the walls of some of the Government buildings.

KRISHNAGAR.—*Newspaper report.*—A smart earthquake shock was felt about 4-12 P.M. (local time) lasting about 2 minutes. The direction seemed to be from east to west with a slight northerly component. Only small damages are reported.

KURSEONG.—*Meteorological Observer.*—The earthquake was felt at 15 hours 55 minutes, Indian Standard Time and lasted for nearly 60 seconds. Only one shock was felt which was accompanied by a rattling sound. A few light and unstable objects were overturned and the shock was felt by everyone.

KYAUKPYU.—*Meteorological Observer.*—The earthquake shock was felt at 16 hours 55 minutes, Burma Standard Time, and lasted for 80 seconds. Only one shock was felt and no unusual sound was noticed. A few objects were overturned and the shock was felt by everyone.

KYAUKTAW (AKYAB).—*Sub-divisional Officer.*—The earthquake shock was felt at 4-45 P.M., Burma Standard Time and lasted for 1 minute 45 seconds. Three distinct shocks were felt with an interval of 15 to 20 seconds between and a rumbling noise was heard which approached from the south and passed away towards the north. The shock was felt by everyone, but was not strong enough to overturn objects.

LUNGLEH, LUSHAI HILLS.—*The Sub-divisional Officer, Lungleh.*—The earthquake shock was felt for about thirty seconds all over the sub-division. No damage has been reported.

MAWLAIK (UPPER CHINDWIN).—*Deputy Commissioner.*—The exact time of the earthquake was not noticed. The shock was felt by everyone, but no damage was done to buildings.

MIDNAPUR.—*Meteorological Observer.*—The earthquake was felt at 16-14 Indian Standard Time and lasted for about two seconds. Three separate shocks were felt accompanied by a sound likened to the noise made by a rapidly moving train. Was not strong enough to overturn objects.

MINBYA (AKYAB).—*Sub-divisional Officer.*—The exact time of the earthquake shock was not noted. Two distinct shocks were felt, the second being much stronger than the first. The duration of the earthquake was about 10 seconds and it was felt by everyone. It was not strong enough to overturn objects.

NAGRAKATA (JALPAIGURI DISTRICT).—*Meteorological Observer.*—The earthquake was felt at 15-35, Indian Standard Time and lasted nearly 60 seconds. Two shocks could be distinguished and a sound like the sound made by a rapidly moving railway train accompanied the shock.

NARAINGANJ.—*Meteorological Observer.*—The earthquake was felt at 15-51 Indian Standard Time and lasted for about one and a half minutes. Only one shock was felt and it was accompanied by a sound likened to that made by an approaching motor car. The shock was felt by everyone and a few light ornaments were overturned. Cracks appeared in places from which sand and water gushed out for nearly an hour.

NOAKHALI.—*Meteorological Observer.*—The earthquake occurred at 15-50 Indian Standard Time and lasted for nearly $1\frac{1}{2}$ minutes. The shock was continuous and no unusual sound was noticed. It was felt by everyone and light objects were overturned in some cases. A few small cracks were caused in the walls of buildings.

PABNA.—*Newspaper report.*—An earthquake shock of rather severe nature was felt at about 4 P.M. (? local time). No damage was done to property.

PURNEA.—*Deputy Commissioner.*—The earthquake shock was not sufficiently violent to overturn objects although it was felt by everyone. A motor car standing under a porch and facing north was seen to move slightly towards the north.

RANGAMATI.—(*Chittagong Hills Tracts*).—The Superintendent, Chittagong Hill Tracts. The earthquake occurred at 15-50, Indian Standard Time, and

lasted from two to three minutes. Only slight damage was done, weakly constructed buildings sustaining cracks.

Rangpur.—*District Magistrate.*—From the report of the Sub-divisional Officer at Kurigram it appears that only small objects such as empty tumblers were overturned, and they felt towards the west. The Sub-divisional Officer of Nilphamari also reports the overturning of certain light objects. No damage has been reported. The shock was felt by everyone in the district.

Salonah.—(Nowgong District, Assam.)—*Meteorological Observer.*—The earthquake was felt at 15-52, Indian Standard Time and lasted for two minutes. A sound as of distant thunder accompanied the shock, growing in intensity until it resembled the roar of a motor car passing close by full speed. The shock was felt by everyone.

Tura (Garo Hills, Assam.)—*Deputy Commissioner.*—Little damage was done beyond the cracking of plaster. No ornaments were overturned.

CHAPTER VI.

THE AREA ENCLOSED BY ISOSEIST No. 6.

The area enclosed by Isoseist No. 6 is the area where the earthquake was only felt by certain people and where no damage was done to buildings of ordinary strength or stability. The information regarding it is all derived from information supplied by observers or on earthquake enquiry-forms. It is not proposed to give a detailed list of the observations received from all the places in this area but only to give those which have been made use of to fix the position of Isoseists Nos. 5 and 6.

The most important are :—

ALLAHABAD.—*The Collector of Allahabad.*—Only one member of my staff noted the earthquake. The place was the Manjhanpur Tahsil where the tahsildar noticed the earthquake while in court. It occurred at eight or ten minutes to four in the afternoon and the oscillations seemed to be east and west. No objects were overturned and the shock was only felt by him, his Tahsili Siahanawis and the Sentry standing at the Sub-Treasury.

AGRA.—*The Commissioner of Agra.*—The exact time of the earthquake was not noted. The shock lasted about $1\frac{1}{2}$ seconds. During the shock the woodwork of doors creaked. The shock was not felt by everyone.

BANKIPORE.—*The Collector of Patna.*—The earthquake was felt at Bankipore only by people sitting or standing still in a room. No objects were overturned.

BILASPUR.—*The Deputy Commissioner.*—The shock was felt by a number of people, the exact time was not noted. No objects were overturned, but the padlock on an almirah rattled.

CALCUTTA.—The earthquake was felt by nearly everyone. Only people who were walking or moving out of doors did not feel it. The following extract is taken from a report of the shock published by the newspapers next morning :—

> *Report by the Meteorological Observatory at Alipore.*—"The earthquake shock was a local shock of considerable intensity. It was recorded on the Alipore seismograph at 15 hours, 53 minutes, standard time, or 4 hours 16 minutes, Calcutta time. It must have occurred at a comparatively short distance from Calcutta. The oscillation was so large that the seismograph recording pens were thrown completely off the recording drums. The severe oscillation continued for more than five minutes and at five-thirty the seismograph was still recording a small oscillation.

Vibrations which could be felt continued for more than five minutes, and while the vibrations were greatest buildings and trees could be seen swaying slightly and the motion of the floor in the Observatory at Alipore was quite distinctly visible. The time-clocks in the Observatory were all affected more or less. Some stopped altogether, but, what is more interesting, the pendulums of two of the clocks instead of beating seconds began to vibrate very rapidly and indicated 2 or 3 seconds in a period which was not longer than one second. This made the clocks apparently go fast, and the best clock in the Observatory, which has during the last three years not varied its rate by more than a few hundredths of a second, gained more than $2\frac{1}{2}$ minutes during an interval of less than 10 minutes. This clock is fixed to a north and south wall and its pendulum swings in the meridian. This clock happened to be recording its time against a time-signal from Madras just when the earthquake was on, and thus an actual record of the irregular beating of the clock against the regular seconds beats from Madras has been obtained, showing that at one point the Calcutta clock beat three seconds while the Madras one only gave one second. After the earthquake all the clocks in the Observatory were wrong and complete reliance had to be placed on the time given by the chronometers, all of which had remained unaffected. Unfortunately the night was cloudy and it was only at four o'clock in the early morning that a few stars could be obtained for transits. These transits showed that the standard clock, which had gone almost perfectly for the last three years, had suddenly gained 2 minutes 38·8 seconds during the earthquake."

The following extracts relate to damage to buildings:—

"Not a great deal of serious damage was done, but ominous cracks appeared in several new and old buildings in and about Clive Street. In Messrs. Gillanders Arbuthnot & Co.'s offices a crack eight inches long occurred on the second storey, just above the main entrance; and the north-east corner of the Chartered Bank was cracked for about ten feet. At the old Telegraph Office, a zig-zag crack about fifteen feet in length appeared almost under the tower facing Old Court House Street, and the Currency Office showed a 12 feet-forked crack over the Mission Row entrance. The Calcutta Town Hall, the upper floor of which is utilised as a home for soldiers and the ground-floor for the Municipal Magistrate's Court and offices, suffered from the earthquake." There are also cracks occurred in the walls. . . . . The New Municipal Market in College Street showed a considerable crack over the entrance on Harrison Road."

"In Howrah a one-storeyed house next-door to the Howrah Roman Catholic Church in Cullen Place, came down within a few minutes of the upheaval; while a number of huts were razed to the ground."

"An old dilapidated two-storeyed building in Telipara Lane near Shambazar also came down."

CUTTACK.—*The Officiating Collector of Cuttack.*—Small objects such as tumblers, bottles, etc., were overturned towards the north. Only some people who were sitting, standing, or lying down felt the shock slightly.

CHHATISGARH.—*The Commissioner of Chhattisgarh.*—Of the three districts in this division, no shock was felt in Raipur and Drug. A shock was however felt in Bilaspur.

DALTONGANJ.—*The Deputy Commissioner of Palamau.*—The earthquake was felt in Daltonganj only by a few people. No ornaments were upset but the punkha was set in motion.

DEOGHUR (SANTAL PARGANAS).—*The Deputy Commissioner, Santal Parganas.*—The earthquake was attended by a roaring sound. I myself was at Deoghur. I heard the noise for a few seconds before realizing that it was an earthquake, taking it to be the noise of a sudden gust of wind shaking the tiles on the roof. I then went into my bedroom and saw the things on my dressing-table, *e.g.*, shaving brush and shaving stick box, jumping about. They did not overturn, but reminded me of the sand on a Chhadni's plate. People at Deoghur standing outside houses did not notice it. The duration of perceptible shock was about 20 seconds.

FORT HERTZ (PUTAO, NORTH-EAST FRONTIER).—*The Deputy Commissioner of Putao.*—The earthquake was felt by me and several others. The exact time was not noted. The direction of the shock seemed to be north and south.

HUKITALA (FALSE POINT, CUTTACK).—*Meteorological Observer.*—The earthquake occurred at 15-55 Indian Standard Time and lasted for 3 or 4 seconds. No sound was heard and the earthquake was not felt by everyone.

KATMANDU (NEPAL).—*Meteorological Observer.*—The earthquake occurred at 16-4 Indian Standard Time and lasted for about 40 seconds. Three shocks were felt, but the earthquake was not felt by everyone.

MAGWE.—*The Commissioner of Magwe.*—No objects were disturbed and the shock, which was a slight one, was not felt by everyone.

MANDALAY.—*The Deputy Commissioner, Mandalay.*—I enquired from the gazetted officers stationed at Mandalay. Of the fourteen officers who were consulted, nine reported that they did not feel the earthquake; two felt it while sitting and one while standing; two others reported that it was felt by their people but not by themselves. I did not feel it myself.

MEIKTILA.—*Newspaper report.*—An earthquake shock of 5 seconds' duration was felt at 16-55 Burma Standard Time.

MONYWA (LOWER CHINDWIN).—*The Deputy Commissioner.*—The earthquake was felt at 5 P.M. Burma Standard Time for about a minute.

MUZAFFARPUR.—*The Collector of Muzaffarpur.*—It does not appear that any objects were overturned in this district, except a small number in the Sadr Sub-division which are reported to have fallen towards the east. The shock was so slight that it was not perceptible to all.

MYITKYINA.—*The Deputy Commissioner of Myitkyina.*—The shock appears to have been felt only in Kamaing and very slightly in Mogdung.

The shock felt in Kamaing appears to have come from the west.

PROME.—*The Deputy Commissioner, Prome.*—The earthquake was mostly felt by those sitting, lying, or standing still in a room. A few small objects such as vases, tumblers, bottles, etc., were said to have been overturned. The direction in which these fell is rather doubtful, some say towards the north, while others declare to have seen them fall in an easterly and westerly direction.

RANGOON.—*The Collector of Rangoon.*—The time of the earthquake shock at Rangoon was 4-55 P.M. Burma Standard Time. It was not felt by everyone but only by certain people.

SAMBALPUR.—*The Deputy Collector, Sambalpur.*—No objects were overturned. The shock was not felt by everyone, but by some of those only who were sitting, lying, or standing still in a room.

SANDOWAY.—*The Deputy Commissioner, Sandoway.*—The earthquake occurred about 5 o'clock, Burma Standard Time, and lasted for about 8 seconds. It was not felt by everyone.

THAYETMYO.—*The Deputy Commissioner, Thayetmyo.*—No articles were overturned. The shock was only noticed by people who were more or less still.

YAMETHIN.—*Deputy Commissioner of Yamethin.*—Hardly anyone noticed the earthquake.

YATUNG (TIBET).—*The Director-General of Observatories, Simla.*—The earthquake occurred at 3-55 P.M. and lasted for about a minute.

Reports from Ambalła, the Andaman Islands, Cawnpore, Dehra Dun, Delhi, Mergui, Moulmein, Nagpur, Naini Tal, Namtu (Lashio), Puri, Sutna, Taunggyi, Tavoy, Vizagapatam , show that the earthquake was not felt in any of these places and it is from this information, coupled by that given above that the position of Isoseist No. 6 has been fixed.

PART II.

CHAPTER VII.

(*I*) TIME OF THE EARTHQUAKE AND RATE OF PROPAGATION.

In the preliminary report on this earthquake I have already gone into the question of the time of the earthquake at its origin, and have shown that the locally recorded times are too inaccurate to have any reliance placed upon them. I therefore confined myself to the consideration of the records that I had received at that time of automatically registering instruments from the various Observatories in and around India. On the assumption that the large waves of an earthquake travel at something approximating to 110 miles per minute I deduced that the time of the earthquake centre was approximately 15 hours 50 minutes Indian Standard Time (10 hours 20 minutes Greenwich Mean Time). Further consideration of the Indian seismograms, and especially of foreign seismograms, has indicated that this first estimate was too early, and that the time at the earthquake centre was approximately two minutes later.

The reports from the various Indian and neighbouring Observatories are as follows :—

Bombay Observatory.

Plate 6, Fig. 1 shows a reproduction of the Milne Seismogram registered at Bombay.

It will be noticed from the following table that the Director of the Bombay Observatory has assumed the value 3·5 km. per second for the rate at which the long surface waves travel. If, as I shall show later, this value is too low for the present earthquake, then the calculations in which he has used this value will have yielded too low results, thus improving the figures in the last column.

Bombay Observatory.

Seismic Records.

Disturbance of 8th July 1918.

No.	Seismograph.	P	S	L	M	F	Remarks.			
		H. m. s.	H. m. s.	H. m. s.	H. m. s.	H. m. s.	S—P	Δ (derived from B.A. table).	L-P	Δ1 Velocity of "L" waves 3·5 km. per second.
1	Milne's Seismograph (E—W) .	15 56 11	15 59 28	16 0 33	16 2 56	18 8 44	197″	17° 4′	262″	15° 5′
2	Vertical (tilt) movement . .	15 56 19	movements too large and rapid for photographic action.				..	..	..	..
3	Omori-Ewing (E—W) . .	15 56 11	15 59 29	16 1 18	amplitude too large stopped by guards.		198″	17° 5′	307″	18° 0′
4	Colaba No. 1 (E—W) .	15 56 13	15 59 30	16 0 15	16 2 53	..	197″	17° 4′	242″	14° 4″
5	Colaba No. 2 (N—S) . . .	15 56 12	15 59 33	16 0 57	16 2 58	..	201″	17° 8′	285″	16° 8′
					Mean of 1. 3, 4 and 5=		198″	17° 5′	274″	16° 2′

All times given above denote Indian Standard time which is 5 hours 30 minutes fast of Greenwich Mean Time.
P=First arrival of the longitudinal waves (preliminary tremors).
S=Arrival of transverse waves.
L=Arrival of long surface waves (3·5 km. per second).
M=Time of maximum amplitude recorded.
F=End.
=Distance in arc between the epicentre and the recording station derived from difference (S—P) as given in the British Association Tables.
Δ1=Distance in arc between the epicentre and the recording station derived from difference L-P, the velocity used being 3·5 km. per second, the distances are expressed in degrees and decimals of a degree.

Colombo Observatory.

The instrument here is of the Milne type with horizontal pendulum which is set N-S. Its period is about 17 seconds, and its sensitivity is 0·405 for 1 mm. of trace. The time of commencement of the shock is 15 hours 57 minutes 30 seconds Standard Mean Time (10 hours 27·5 minutes Greenwich Mean Time): Maxima 16 hours 2 minutes and 16 hours 13 minutes Standard Mean Time: ending about 18 hours 16 minutes Standard Mean Time: amplitude 17 mm.

Plate 7, shows a reproduction of the Colombo seismogram. A check mark had been made by obscuring the light by hand commencing at 16 hours 23 minutes Standard Mean Time. The Director of the Observatory informs me that there has been the inevitable loss of fine detail in reproduction, and that there is a slight thickening of the line slightly previous to its displacement towards the west by the large waves.

Madras Observatory.

This observatory has not an earthquake-recording instrument, but there is evidence to show that the observatory clocks were affected by the shock, and as the earthquake occurred while the daily time signal was being sent out from the observatory there is an exact record of when this disturbance occurred. I have already quoted (*supra*, p. 32) the report furnished by the Calcutta Observatory to the press, shortly after the earthquake, and this contains details of the effect of the earthquake on the Observatory clocks. Plate 5 shows a reproduction of the time signal that was being recorded in Calcutta when the earthquake occurred. The solid line represents the record of the Calcutta clock while the broken line immediately below it represents the time signal from Madras, both being recorded electrically. It will be seen how irregularly the pendulum of the Calcutta clock was moving, but the great interest of the record lies in the fact that the Madras record also becomes irregular at about 15 hours 57 minutes 58 seconds and continues so for twelve or thirteen seconds, the maximum disturbance being apparently at about 15 hours 58 minutes 7 seconds. Star observations taken in Madras on 9th July showed that something very unusual had happened to the Madras sidereal clock and there seems

little doubt that it was considerably affected by the earthquake. The following is the rate of error (seconds gained per day) of that clock, from observations of well-placed stars for the period around 8th July, 1918:—

	Seconds.
June—	
5th	+0·50
7th	+0·64
11th	+0·54
20th	+0·62
25th	+0·42
July—	
5th	+0·48
9th	−0·02
10th	+0·09
15th	+0·36
19th	+0·51

To explain the above, the following is given for illustration. The error of the clock was obtained by star observations on June 5th and again on June 7th. The difference between these errors divided by the interval in days between the times when the observations were taken gives 0·64 seconds as the daily rate of error during that interval, and it is put down against the 7th June. On studying the above list the big jump in rate against the 9th July is at once obvious, as is the gradual recovery to the old rate during the week following. The change in rate revealed by the observations of the 9th was so great, that observations were taken again on the following night. The chronometers which are systematically compared with the clock also showed that something happened to the clock between 10-30 A.M. and 7 P.M. on 8th July.

The above is not merely of general interest. In view of the distance of Madras from the earthquake centre at Srimangal and the time that the irregularity of beat of pendulum occurred it seems that the disturbance to the Madras clock had nothing whatever to do with the long waves from the Srimangal centrum, but that the disturbance was caused by earthquake waves emanating from some other centrum such as that of the sympathetic shock which was discussed in the preliminary report as having occurred near Madras and which will be discussed more fully in a later portion of this Memoir.

Kodaikanal Observatory.

The following are the particulars supplied by the Director of the Kodaikanal Observatory :—

—	Preliminary Tremors.	Large Waves.	Maximum.	End.	Duration.	Amplitude.	Remarks.
	H. M.	H. M.	H. M.	H. M.	H. M.	mm.	
1918, July 8	..	10 26·4	10 31·5	12 2·8	1 36·4	14·0	Very destructive in Assam. Commencement of large waves abrupt (not gradual). No preliminary tremors.

(Greenwich mean times).

The seismogram is shown on Plate 6, Fig. 2.

Simla Observatory.

The following information was given by Dr. G. T. Walker, C.S.I., F.R.S., Director-General of Observatories in India :—

"The earthquake was recorded on our two Omori-Ewing horizontal pendulum seismographs with masses of 50 kg. and natural periods of 45 seconds. There was also a slight local shock easily perceptible without instruments at two or three minutes to sixteen hours I.S.T.

2. The instrumental records show the first preliminary tremors starting at 15 hours 55 minutes 20 seconds with periods of about $1\frac{1}{2}$ seconds. At 15 hours 57 minutes 45 seconds stronger oscillations are superposed, which, I guess, indicate yielding on some fault probably within two or three hundred miles of Simla. Then large oscillations began at 15 hours 59 minutes 5 seconds, both the weights swinging backwards and forwards between the steps for about $2\frac{1}{4}$ minutes: after this the movement gradually subsided, lasting until 17 hours 10 minutes. At first there is considerable temptation to regard the second preliminary vibrations as beginning at 15 hours 57 minutes 45 seconds and the main shock at 15 hours 59 minutes 5 seconds; for in general the amplitude of the oscillations in the main shock is much larger than in the second preliminary vibrations. But this interpretation would, I consider, be incorrect. In the first place these times would indicate that the origin was only 520 miles distant, and in such cases previous records show that the main shock has a smaller amplitude

than the second preliminary; the damping out of the oscillations of short period has not been powerful enough to bring the long waves into prominence. In the second place the distance of 520 miles is too short to give an origin in Assam, and if we treat the large oscillations beginning at 15 hours 59 minutes 5 seconds as the second preliminary vibrations, the distance of origin is about 1,020 miles, which is of the right order of magnitude. Lastly the second preliminaries are transverse oscillations and we should expect them to be more marked on the instrument registering north-south movements than on that registering east-west. This actually happened, for the former beat the steps so violently that it did about 8 complete oscillations a minute while the latter did about $2\frac{1}{2}$."

I offer, with some diffidence, a different interpretation of the Simla seismogram. The natural period of the instrument seems to have been long and the first two series of oscillations are accompanied by the natural swing of the pendulum; also the instrument was registering badly against the time marks.

I would suggest that the three series of oscillations recorded on the (Simla) seismogram are P., S., and the long waves. If the second series of oscillations is taken to be the second preliminary vibrations, and the large oscillations to be the long waves, then the measurement of the seismogram gives S—P=$2\frac{1}{3}$ seconds which gives a distance of origin of 15°, or approximately 1,050 miles, which is of the right order of magnitude. It will be seen below that the readings fit in with the readings of other observatories if they are regarded as preliminary, second preliminary vibrations, and long waves, rather than as suggested by Dr. Walker and this has led me to offer a different interpretation of the seismogram to that suggested by him. Plate 8 shows a reproduction of the Simla seismogram.

Dehra Dun.

The seismograph in the laboratory of the Survey of India at Dehra Dun shows a precisely similar record to the Simla seismogram. The first preliminary tremors are registered at 15 hours 54 minutes 15 seconds. Stronger oscillations come in at 15 hours 56 minutes 22 seconds and large oscillations at 15 hours 58 minutes 45 seconds. These large oscillations persist for about $2\frac{1}{4}$ minutes and then begin to diminish, but at 16 hours 4 minutes become equally strong again, last for just over 2 minutes and then gradually diminish.

Rome.

The following information has been sent to me by the Director of the "R. Ufficio Centrale di Meteorologia e Geodinamica," Rome.

Rocca di Papa.

Main Earthquake.

1. "Microsismometrografo Agamennone" with 2 components :—

N—S. Arrival of preliminary vibrations, 10 hours 32 minutes 47 seconds ±3 seconds.
Second preliminary phase, 10 hours 41 minutes 58 seconds.
Long waves, 10 hours 56 minutes 28 seconds.
End, 11 hours 16 minutes 6 seconds.

E—W. Preliminary tremors, 10 hours 32 minutes 48 seconds.
Second preliminary phase, 10 hours 41 minutes 58 seconds.
Long waves commence vaguely about 10 hours 57 minutes 6 seconds.
End about 12 hours 0 minutes 6 seconds.

2 "Pendolo Orizontale" :—

Arrival of preliminary vibrations, vague ; about 10 hours 32 minutes 59 seconds.
Second preliminary phase, 10 hours 41 minutes 37 seconds.
Long waves, 10 hours 55 minutes 36 seconds.

3. "Microsismometrografo Universale Agamennone" with 3 components :—
Light registration on all three components.

Second Earthquake.

During the phase with slow waves of the above earthquake, a second and distinct group of light instrumental waves were superposed on both the records registered by instrument No. 1, at exactly 11 hours 1 minute 38 seconds, indicating a second earthquake shock. These grow to a maximum of 0·2 mm. on the N—S component, and 0·6 mm. on the E—W at about 11 hours 2 minutes 12 seconds and then decrease and fininsh about 11 hours 7 minutes 54 seconds.

On instrument No. 2 these superposed vibrations are not identifable because of the remarkable oscillation which still persisted from the registration of the big earthquake shock.

On instrument No. 3 however, the lightest waves the instrument can record are found again corresponding to those registered on instrument No. 1 but only on the horizontal component.

The Rocca di Papa seismograms are reproduced on Plate 9. The recorded times at other Observatories are :—

Observatory.	P.	S.	L.	M.	End.
	H. M. S.	H. M. S.	H. M. S.		
Barcelona	10 33 42	10 43 4	10 58 11	..	..
Batavia	10 28 54	..	..	10 38 0	12 8 0
Bidston	10 33 38	10 43 2	..	..	..
Catania	Neither of two seismographs showed any trace of an earthquake.				
Dyce (Aberdeen)	10 33 36	10 42 48	..	..	..
Edinburgh	10 33 50	10 43 0	..	11 14 40	14 21 0
Eskdalemuir	10 33 40	10 43 0	..	..	..
Georgetown (Washington)	..	10 47 41	..	..	..
Ischia	10 32 53	10 41 21	..	..	12 30 0
Manila	10 28 16	10 33 39	10 37 0	..	..
Ottawa	10 36 37	10 47 8	..	..	..
Perth	10 33 32	10 40 40	..	..	..
Riverview (Sydney)	10 34 24	10 44 33	..	..	..
San Fernando	10 34 18	10 44 30	..	..	..
Shide	No record as the paper was being changed at the time.				
Taihoku	10 27 57	10 32 50	..	..	..
West Bromwich	10 33 37	10 42 51	..	..	..

A photograph of the Bidston Seismograph is shown on Plate No. 9.

Both this and the Rocca di Papa seismograms were reproduced at the Alipur Observatory, Calcutta, by kind permission of Dr. D. B. Meek, the Director of the Observatory.

On studying these records it becomes evident that the time at origin deduced by me in my preliminary report, *viz.*, 10 hours 20 minutes G. M. T. (15 hours 50 minutes Indian Standard Time) is too early and that the correct time was approximately two minutes later. This was first pointed out to me by Mr. J. J. Shaw, Secretary to the Committee of the British Association for Seismological Observations. He writes :—

" You will be interested to note that the British times support you in putting the time of occurrence onward to 15 hours 50 minutes I.S.T. (10-20 G.M.T.) in fact our times seem to indicate that the time of origin was even later still. I

enclose a tabulated list of times and deductions for the stations in Great Britain I have used Zoeppritz tables and a 14-inch globe for measurements ;—

Time of occurrence of the Srimangal Earthquake deduced from observations in Great Britain, G.M.T. Use made of Zoeppritz Tables. Also 14″ globe for measurement.

	Δ as measured on globe.	Δ calculated from S—P.	Arrival of P.	Arrival of S.	Time at origin deduced from Δ measured on globe.		Time at origin deduced from S—P Δ.
Aberdeen . . .	72°·3	70°·5	10 33 36	10 42 48	10 22 4	10 21 54	10 22 16
West Bromwich . .	73°·3	70°·8	10 33 37	10 42 51	10 21 59	10 21 45	10 22 15
Eskdalemuir . . .	74°·0	72°·0	10 33 40	10 43 0	10 21 58	10 21 46	10 22 10
Bidston . . .	74°·0	72°·6	10 33 38	10 43 2	10 21 56	10 21 48	10 22 4
				G.M.T.		I.S.T.	
Average by Δ measured on globe				10 21 54		15 51	54
Average by Δ calculated from S—P				10 22 11		15 52	11

From the average of three methods you will see we obtain the figure 10 hours 22 minutes 2 seconds (or 15 hours 52 minutes 2 seconds I.S.T.).”

“ Riverview, Sydney, lies 80° 1′ on the directly opposite side of your epicentre from here. Their times are :—

P . . . 10 34 24 S . . . 10 44 33

by the respective methods used on the above list the time at epicentre, works out :—

(1) From arrival of P	10	22	4
(2) „ „ S	10	22	8
(3) By measured on globe	10	22	0
AVERAGE . .	10	22	4

only two seconds different from the average of the British Stations.

Professor H. H. Turner's hypothesis (1918).—Professor Turner, F.R.S., in the 1918 Annual Report of the Seismological Committee of the British Association, pointed out that when a pair of stations are on directly opposite sides of an epicentre—and preferably distant towards 90°—the conditions provide an opportunity for checking the values of SP in the tables.

In this instance we have two stations, Riverview and West Bromwich, distant from the epicentre 80° 1′ and 73° 3′ respectively, and where the great circle, joining the two passes within 270 miles of the origin.

His method is as follows:—

West Bromwich to Riverview		153° 4′
West Bromwich S—P 554 seconds		70° 8′
therefore to Riverview should be 153° 4′—70° 8′ . .		=82° 6′
S—P for 82° 6′	=619	
Riverview observed S—P . .	=609	Differ. . . 10 seconds.

This difference of 10 seconds must be divided between the two stations, *viz.*, 5 seconds each, *i.e.*, the tabulated time is 5 seconds too great. Professor Turner's investigation suggested a correction of 6 for 73° 8′, agreeing very well with the present example."

The time of occurrence at origin as deduced from British records is therefore 10 hours 22 minutes 2 seconds. Turning now to the Indian observatories, one finds that the best seismograms are those recorded at Bombay. Both the Kodaikanal and Colombo records are unusual, and are much obscured by that of the local sympathetic shock the existence of which was deduced in my preliminary report. This sympathetic shock will be discussed in a subsequent chapter. For the present the beginning of the Colombo and Kodaikanal records will be taken to represent approximately the arrival of the Preliminary tremors from the Srimangal centrum, and the maximum at Kodaikanal, and the first maximum at Colombo, both of which are such marked features on the records, to represent the arrival of the long waves from the Srimangal centrum,—an assumption which, it will be seen, makes the two records agree remarkably closely with the records of other observatories.

The arrival of the Preliminary tremors at Bombay at 10 hours 26 minutes 12 seconds gives a calculated time of origin at the earthquake centre of 10 hours 21 minutes 50 seconds, and, adopting this provisionally, the differences between the observed and the calculated times of arrival of P at other stations are shown in the following table (on next page).

The times of arrival of P at Dehra Dun and Colombo would appear to be incorrect. The Colombo time certainly is, as Mr. Evans, when sending me the copy of the seismogram stated "there has been the inevitable loss of fine detail in reproduction, but there is a slight thickening of the line slightly previous to its displacement towards the *west* by the large waves."

As one millimetre of record represents slightly more than one minute of time in the case of the Colombo Milne seismograph, the slight thickening of the line (representing the arrival of P from

ORIGIN. 24° 15′ N., 91° 42′ E. TIME AT ORIGIN. 10 H. 21 M. 50s. G.M.T.

Station.	Seismo-graph.	Dist-ance of Origin.	Time of arrival of P—Time at Origin.	Arrival of P.	P. due (calcula-ted.)	Observed minus calculated time of arrival of P.	Arrival of S.	Arrival of large waves.	Velocity of large waves.	DISTANCE OF ORIGIN. Km.		REMARKS.
		Seconds.	Seconds.	h. m. s.	h. m. s.	Seconds.	h. m. s.	h. m. s.	km. per s.	Arc.	Chord.	
Calcutta . .	O	3°·5	70	10 23 0	10 22 44	+16	..	..	..	388	388	
Dehra Dun .	O	13°·5	145	10 24 15	10 25 10	—55	10 26 22	10 28 30	3·7	1,498	1,495	
Simla . .	O	14°·5	210	10 25 20	10 25 23	—3	10 27 45	10 29 5	3·7	1,609	1,605	S—P=145″=△15°.0.
Bombay . .	Cn	18°·4	262	10 26 12	10 26 12	..	10 29 33	10 30 57	3·7	2,042	2,034	S—P=201″=△17°·8.
Kodaikanal .	M	19°·5	274	10 26 24	10 26 23	+1	..	10 31 30	3·7	2,164	2,154	
Colombo . .	M	20°·7	340	10 27 30	10 26 38	+52	..	10 32 0	3·7	2,298	2,285	
Manila . .	W	29°·2	386	10 28 16	10 28 10	+6	10 33 39	10 37 0	3·6	3,241	3,206	S—P=323″=△32°·3.
Batavia . .	W	33°·8	424	10 28 54	10 28 53	+1	..	..	..	3,752	3,698	
Barcelona . .	Mk	73°·9	712	10 33 42	10 33 31	+11	10 43 4	10 58 11	3·8	8,203	7,646	S—P=562″=△72°·3.
San Fernando .	M	81°·8	748	10 34 18	10 34 19	—1	10 44 18	11 7 30	3·3	9,080	8,328	S—P=600″=△79·2.

the Srimangal centrum) mentioned by Mr. Evans is estimated by him to represent 12 seconds and so the observed time—the calculated time of arrival of P at Colombo falls from +52 to +40 seconds. The case of Dehra Dun is at present inexplicable. The suggestion of an error in the clock does not seem tenable because S and L on the record seem to be approximately in accord with the times registered at other observatories. The early arrival of P at Dehra Dun giving abnormal values for S—P and L—P, must therefore remain inexplicable. In the remaining cases quoted in the table between the observed and the calculated time. The difference for the arrival of P are exceedingly small and appear to indicate that the assumed time of 10 hours 21 minutes 50 seconds G.M.T. for the time of origin is practically correct. This time indicated by the Indian and surrounding observatories differs by only 12 seconds from that indicated by the times of arrival of P at the British Observatories, and seems to be the preferable of the two.

To advance the time suggested by the British records from 10 hours 22 minutes 2 seconds to 10 hours 21 minutes 50 seconds for the time of occurrence at origin would mean that the observed times of arrival of P at the British Observatories were a few seconds later than one would have been expected, whereas a retardation of the time suggested by the Indian and surrounding Observatories, from 10 hours 21 minutes 50 seconds to 10 hours 22 minutes 2 seconds would mean that the observed times of arrival of P are several seconds earlier than they should be according to calculation. The former alternative appears to be the more acceptable, and I therefore suggest 10 hours 21 minutes 50 seconds G. M. T. as the Time of the earthquake at its origin.

RATE OF PROPAGATION OF THE LARGE WAVES.

Accepting 10 hours 21 minutes 50 seconds G.M.T. as the time of the earthquake at its origin then the speed of the long waves becomes 3·7 km. per second. This speed seems to be indicated by the records from Dehra Dun, Simla, Bombay, Kodaikanal, Colombo, Manila and Barcelona, and there can be little doubt that it is the correct speed to assume for this earthquake.

(2) DEPTH OF THE FOCUS.

In attempting to determine, as far as possible, the depth below the surface at which the focus lay, only one method, of the many

proposed by different authors can be applied in the present case, and that is the method proposed by Major C. E. Dutton. This depends upon the assumption that, in a uniform medium, the intensity varies as the square of the distance from the origin, and it is shown that the variation of *surface* intensity along a horizontal line drawn from the epicentre is most rapid at a particular point which depends upon the depth of the focus only; a point also where the intensity must be $\frac{3}{4}$ of the maximum intensity at the epicentre. The relation between the distance of this point from the epicentre and the depth of the focus is exhibited by the formula $X=Q \tan 30°$ where X is the horizontal distance of the place from the epicentre and Q the depth of the focus. If X is known, then $Q=X\sqrt{3}$.

On applying this formula to the present earthquake by making a section across the epicentral tract near Srimangal at right angles to its long axis, it appears that the intensity declines or varies, most rapidly at points situated about 6 miles from the epicentral line. The focus, therefore, under Balisera valley must lie at a depth below the surface of about $6\sqrt{3}$ miles, *i.e.*, between 8 and 9 miles.

Owing to the fact that buildings are few and scarce over the epicentral area it is impossible to fix the point where the surface intensity declines most rapidly, with any degree of accuracy, and the above estimate of the depth of the focus under the Balisera valley is, at best, only vague; nevertheless it is the nearest approximation that can be made. At the west-north-west end of the epicentral area the observations are too few to enable any calculation to be made, most of the country being low-lying rice-fields which at the time of the earthquake were inundated owing to the unusually heavy monsoon.

Owing to the inaccuracy of practically all the observations in respect of the time at which the earthquake occurred at different places, it is impossible to calculate the depth of the focus by the method proposed by Dr. Aug. Schmidt based on the observed rates of travel.[1] The times observed in different places are obviously inaccurate and unreliable. The various Railway companies very kindly furnished me with the times at which the earthquake was recorded at railway stations, but unfortunately these records contain so many obvious inaccuracies that they are useless for the purpose required. Consequently the construction of a hodograph is impossible.

[1] *Jahreshefte Ver. f. vaterl. Naturk. in Wurttemberg.* XLIV, 227 (1890).

(3) THE SYMPATHETIC SHOCKS.

In my Preliminary report I deduced the existence of two sympathetic shocks, one having an origin under the Bay of Bengal off the Madras coast, and the other under the Bay of Bengal off the Arakan coast near Akyab. Further information seems to confirm the existence of both, but has modified the position of the centrum of the more southerly shock. The evidence of the existence of this Southern Indian centrum is given by the unusual character of both the Kodaikanal and the Colombo seismograms and by the behaviour of the sidereal clock at the Madras Observatory. I will take them *seriatim*.

The Kodaikanal seismogram begins abruptly with waves of large amplitude and shows no evidence of the usual preliminary tremors. It apparently commences with the record of long waves. This is the reading of the seismogram by Mr. J. Evershed, F.R.S., Director of the Madras and Kodaikanal Observatories, and I agree with him. In order to decide whether this is actually the correct interpretation, or whether it is possible that the record really commences with the register of preliminary tremors which so were intense that they might be mistaken for large waves, I visited Kodaikanal, and went carefully through all the seismograms that have been recorded by the instrument since it was erected. The result was to confirm the opinion that this seismogram does commence with the record of large waves. In every other instance preliminary tremors on the usual scale have been recorded, commencing as small vibrations gradually increasing in intensity. In no other case does the record commence abruptly, as in this earthquake, with waves registering a large amplitude and decreasing in intensity. The present seismogram commences with waves showing an amplitude vastly greater than has been recorded at the commencement of any other earthquake, and I am convinced that the view that the commencement of the record is a register of the preliminary vibrations from Srimangal only, and nothing else, is quite untenable in the present instance. A further point which is against this view being tenable is that the Kodaikanal seismogram has no resemblance to the record which is of a perfectly normal type, given by the Bombay Milne instrument, although Bombay and Kodaikanal are situated at nearly the same distance from the epicentre at Srimangal.

The Colombo record is very similar to that registered at Kodaikanal with the exception that just before the abrupt start of vibrations

of large amplitude there is a small thickening of the line equivalent to that indicating the commencement of preliminary vibrations in normal records.

Finally there is the case of the Madras clock. There can be little doubt that the time of the earthquake at Srimangal was within 12 seconds of 10 hours 21 minutes 50 seconds G.M.T., as indicated by the recorded seismograms of observatories situated all over the world. The rate of travel of the long waves in this earthquake seems to have been high and approximately 3·7 km. per second. Even granting this rate, the long waves from the Srimangal centrum could not have reached Madras until more than a minute had elapsed after the disturbance had occurred which affected the Madras sidereal clock. It is reasonable to assume therefore that the disturbance of the Madras clock was not due to the long waves from the Srimangal centrum but to something else.

In the Preliminary Report already published I have already indicated the probability of a subsidiary sympathetic shock having occurred not very far from Madras and it seems probable that the disturbance of the Madras clock was due to this subsidiary shock and not to the Srimangal shock. The Madras clock commenced to record irregularly at 10 hours 27 minutes 58 seconds G.M.T., the Colombo seismogram commences with the record of long waves at 10 hours 27 minutes 30 seconds, and the Kodaikanal seismogram with the record of long waves at 10 hours 26 minutes 24 seconds. If these three observations are due to long waves from the subsidiary sympathetic shock (they are all too early to be due to long waves from the Srimangal centrum), then the long waves from this subsidiary sympathetic centrum reached Kodaikanal first, they reached Colombo 1 minute 6 seconds later than they reached Kodaikanal, and they reached Madras 18 secs. later than they reached Colombo. That is to say, that the centrum was nearer to Kodaikanal than to Colombo, and nearer to Colombo than to Madras. The above times of arrival of the long waves at three different places approximately fix the position of the centrum. If the long waves from this centrum travelled at the same rate as the long waves emanating from the Srimangal centrum, namely 3·7 km. per second or 139 miles per minute, then at the moment when the long waves from this subsidiary centrum commenced to register on the Kodaikanal seismograph they had still approximately 195 miles to travel before they would reach Madras, and 152 miles to travel

before they would reach Colombo. If therefore a circle is described having Madras as centre and a distance of 195 miles as radius, and another circle is described having Colombo as centre and a distance of 152 miles as radius, then the long waves emanating from the subsidiary sympathetic centrum must have reached the circumferences of these two circles and also Kodaikanal at the same moment. A centrum a few miles south of Madura would be equidistant from Kodaikanal and the circumferences of these two circles and therefore would appear to be about the position of this subsidiary sympathetic centrum.

If the rate of travel of the long waves from this subsidiary centrum be supposed to be 3·5 km. per second however, then the position of the centrum would be a few miles further east. In either case the position coincides closely with the centrum of a previous earthquake recorded by M. de Ballore in *Mem. Geol. Sur. Ind.*, Vol. XXXV, page 28, and map.

If we assume a rate of propagation for the large waves from this centrum similar to that deduced for the rate of propagation for the long waves from the Srimangal centrum, then it would appear that the time of the subsidiary shock at the Madura centrum was shortly after 10 hours 26 minutes, a time which agrees almost exactly with the calculated time at which the preliminary vibrations from the Srimangal centrum would reach Madura. Plate 12 shows the position of the Madura subsidiary centrum and also shows the position reached by the long waves from both the Srimangal centrum and the Madura subsidiary centrum at 10 hours 27 minutes 58 seconds, the moment when the Madras clock commenced to be affected. From this map it will be seen that one would expect the arrival of the preliminary tremors from the Srimangal centrum, and the arrival of all the waves from the Madura subsidiary centrum to have been approximately simultaneous, giving a seismogram commencing abruptly with the register of large waves which is actually how the Kodaikanal seismogram does commence. On the other hand one would expect the preliminary tremors from the Srimangal centrum to have arrived at Colombo earlier than the waves from the Madura subsidiary centrum giving a seismogram showing a slight thickening of the line, due to the preliminary tremors from the Srimangal centrum, slightly previous to its displacement by the waves from the Madura subsidiary centrum, which

is how the Colombo seismogram does commence. The Colombo seismogram gives further evidence. The Colombo instrument is a Milne seismograph with horizontal pendulum which is set north-south, so that the line on the seismogram is first displaced *towards* the direction from which the long waves arrive. If the long waves first registered on the Colombo instrument came from the Srimangal centrum, therefore, the line on the seismogram should first have been displaced towards the *east*. This is not what actually happened. On the Colombo seismogram the first displacement of the line, after the slight thickening due to the preliminary tremors from the Srimangal centrum, is towards the *west* indicating that the long waves causing the displacement came from a centrum situated west of Longitude 79° 55′, E., and not from the Srimangal centrum.

Furthermore there is the record from Rocca di Papa near Rome. There on three different records the waves of a second earthquake of small intensity are recognized superposed on the long waves registered from the Srimangal centrum, and these smaller waves commence practically exactly where one would expect the long waves from the Madura centrum to commence recording.

The assumption of a sympathetic shock from a centrum situated near Madura seems to me the simplest explanation of the observed facts. Its occurrence is not improbable because a previous earthquake has been recorded from nearly the same spot, and its occurrence would be an explanation of the Kodaikanal and Colombo seismograms, which otherwise are extraordinary, of the disturbance to the Madras clock which otherwise seems inexplicable, and would explain the Rocca di Papa seismograms which indicate a second shock from a centrum other than the Srimangal centrum.

I therefore think that the occurrence of a sympathetic shock with a centrum situated near Madura has been reasonably established. The other sympathetic shock described in my Preliminary report of the earthquake, is sufficiently substantiated by the earthquake reports and the unusual course followed by the isoseists. There is, however, one point of interest about it which I have not yet mentioned, and that is its effect upon the Batavia seismogram.

Batavia records M. at 10 hours 38 minutes which if due to the long waves from the Srimangal centrum necessitates the assumption that the rate of propagation of the long waves between Srimangal

and Batavia was more than 3·9 km. per second. But if the effect of the Akyab sympathetic shock is considered, the rate of propagation of the long waves need not necessarily have been so great.

Akyab is situated $\triangle = 4°$ (or approximately 280 miles) from Srimangal and for this distance L-P is approximately 1 minute 15 seconds. The long waves from Akyab would be expected therefore to reach Batavia nearly 1 minute 15 seconds earlier than those from Srimangal.

CHAPTER VIII.

FORE-SHOCKS AND AFTER-SHOCKS.

There is evidence of two, or possibly three, fore-shocks before the main shock on 8th July. Dr. Mumford reports two from Kalighat in the Balisera valley. The first woke him up at 2 or 3 A.M. on 2nd of July. The bed was vibrating and at the same time there was a loud report at the back of the bungalow as if something had knocked against it. This shock was also noticed at Phulcherra, where a bumping and knocking noise was heard. A second fore-shock was felt in the very early hours of 7th July at what Dr. Mumford estimates to have been 12-30 or 1 A.M. In this case the noise was likened to a loud report followed by two or three thumps as if large rocks had been hurled violently against the house. Another, or possibly the same, foreshock was reported from the neighbourhood of Badarpur. It is reported to have occurred in the early hours of the morning of 7th July, and was noticed by a number of oil-drillers who were at Tintikri (Hilara railway station, near Badarpur). They gave the time as 4 A.M. local time. It was also felt on the Badarpur oilfield, and was sufficiently strong to rouse slight sleepers. No damage was reported, but the shock formed the topic of conversation on Sunday, 7th, the day before the main earthquake.

A number of after-shocks are reported, some of which were strong enough to be recorded on the seismograph at the Alipur Observatory, Calcutta. The most important are given on the next page.

Unless specifically stated to be Indian Standard Time, the times quoted here are local times.

CONCLUSION.

There seems to be little doubt that the time of the earthquake at its origin was within 12 seconds of 10 hours 22 minutes G. M. T. The average calculated time arrived at by the British observatories

Date.	Time.	Duration.	Observing Station.
July—			
8th	5 P.M. . . .	1 second .	Shillong.
8th	10 P.M. . . .	1 second .	Shillong.
9th	4 P.M. . . .	4 seconds	Shillong.
11th	20-7 I.S.T. . .	...	Calcutta.
11th	11-5 P.M. . .	3 seconds	Shillong.
11th	11 P.M. . . .	5 seconds	Srimangal.
11th	11 P.M. . . .	2 seconds	Mymensingh.
11th	22-41 I.S.T. . .	10 seconds	Narainganj.
11th	22-40 I.S.T. . .	20 seconds	Gauhati.
11th	22-42 I.S.T. . .	7 seconds	Berhampur.
11th	22-39 I.S.T. . .	...	Calcutta.
11th	11-10 P.M. . .	Few seconds	Chandpur.
12th	6-31 I.S.T. . .	5 seconds	Narainganj.
12th	7 A.M . .	1 second .	Srimangal.
12th	7-15 A.M. . .	2 seconds.	Shillong.
12th	6-31 I.S.T. . .	...	Calcutta.

is 10 hours 22 minutes 2 seconds while that suggested by the Indian Observatories is 10 hours 21 minutes 50 seconds G.M.T. Of the two I prefer to assume the latter as being more probable as it does not mean that the arrival of the Preliminary vibrations at the various observatories was earlier than it is calculated that they should have been due.

In any case there is only a difference of 12 seconds between the two times. The speed of the Long waves seems to have been high, *viz.*, 3·7 km. per second. It is difficult to explain why this should have been so, but with the agreement of so many observations that the time at origin must have been approximately 10 hours 21 minutes 50 seconds G.M.T., there does not seem to be any doubt that 3·7 km. per second was the actual rate of travel of the Long waves in this earthquake.

The sympathetic subsidiary shock, which I first supposed to have had its origin under the Bay of Bengal, now appears to have originated in the neighbourhood of Madura and to have occurred at about 10 hours 26 minutes. Its existence is further indicated by the disturbance to the Madras sidereal clock about a minute before the long waves from the Srimangal centrum could have reached Madras, and the subsidiary earthquake record superimposed on the Rocca di Papa seismograms corresponding with the time when the long waves from this Madura centrum would be expected to reach Rome tends to confirm this. It is not recognizable on the British seismograms, presumably because Britain is too far for such a weak shock to be recorded, and it is not recognizable on the Indian seismograms, other than those of Colombo and Kodaikanal since the calculated time of arrival at the various observatories corresponds to a time when the recording instruments were recording violent long waves from the Srimangal earthquake, although certain maxima on the records are somewhat significant. Rocca di Papa however, seems to have been sufficiently far away for the record of the Srimangal Long waves not to be too violent to obscure superimposed waves, and at the same time not to have been too far away for the detection and registration of the long waves from the Madura centrum, and its seismograms practically prove the existence of the subsidiary shock.

POSTSCRIPT.

Since the foregoing was sent to press to be finally printed off, the following information has reached me from the Superintendent, Trigonometrical Survey, Survey of India, embodying the results obtained by No. 17 party (Levelling) in the area affected by the earthquake. As the results obtained by the Levelling Party not only confirm the results of my investigation, but also add to the information hitherto available, I am appending them as a post-script to the report. The following is a copy of a portion of the report submitted for the Board of Scientific Advice, by the Superintendent, Trigonometrical Surveys, who writes :—

"This portion relates to the subsidence shown by re-levelment of the Silchar-Comilla line due to the Srimangal earthquake of 8th July 1918. The results will, I believe, be of interest to the Geological Survey, and seem to confirm the theory that the earthquake was due to a subterranean fault parallel to the major axis of the epicentral area, inclined to the west south west.

MEMORANDUM ON THE RE-LEVELMENT OF THE LINE SILCHAR TO COMILLA.

The line Silchar to Comilla was originally levelled in 1911-12. Revision was undertaken in the winter of 1919-20 to investigate whether any disturbance had taken place during the earthquake of 8th July 1918, the epicentre of which was reported in the Records of the Geological Survey of India, Volume XLIX, Part III, 1918, to be in the Balisera Hills near Kalighat, 3½ miles south of Srimangal Railway Station. It is to be regretted that the mark-stone of Charamani, H. S. which was connected by spirit levelling in 1911-12 and the location of which cannot have been a quarter of a mile from the epicentre, was destroyed by the earthquake and the pillar razed to the ground. Thus no comparison of this point was possible. The knoll on which the H. S. stood and the spurs immediately south of it bore deep fissures zig-zagging down the hillsides.

The G. T. S. bench marks north of, and within a quarter of a mile of, Srimangal Railway Station, which was practically destroyed by the earthquake, show no subsidence, nor is there any evidence of regular disturbance west of Srimangal until the low range of hills six miles west of it, and lying between Satgaon and Rasidpur, is crossed. Three quarters of a mile north of Rasidpur Railway Station, a tree bench mark at Kamaichara shows practically no alteration; a mile and a half west of this the settlement of all bench marks begins. The settlement varies from one and a

half inches to nine inches according to the nature of the soil and type of bench mark, and continues uninterruptedly past Mirpur dâk bungalow, Shaistaganj, and Shahaji Bazar up to a railway bridge 30 miles from Srima gal near telegraph post No. 149-14 which shows practically no alteration in height (see table below). Thereafter settlement is occasional but very small to Kamalasagar, beyond which no appreciable disturbance has taken place. The bench marks that have settled include two of the embedded type, but unfortunately none on rock, which is situated some distance beneath the alluvial soil.

Comparing results with plate 11 of the Report in the Geological Survey of India Records, as far as can be ascertained, no settlement took place in the epicentral area of north east of the epicentral axis, but in the area between the epicentral area and Isoseist No. 2, west south west of the former, settlement up to nine inches occurred. Those bench marks situated on masonry above ground have generally been disturbed more than those embedded in the soil, the latter, however, show distinct settlement.

The following table shows the bench marks disturbed in the area between Kamaichara and the railway bridge near telegraph post No. 149-14 mentioned above":—

REVISION LEVELLING.

Discrepancies between the old and new heights of bench marks.

Bench marks of the original levelling that were connected during the revisionary operations.			Distance between bench mark.	Observed heights above (+) or below (—) the starting bench mark.			Difference (Revision—Original). The sign(+) denotes that the height was greater, and the sign (—) less in 1919-20 than when originally levelled.	Remarks.
Number.	Degree Sheet.	Description.		From original levelling.	Date of original levelling.	From revision 1919-20. (Unadjusted.)		
			Miles.	Feet.		Feet.	Feet.	
35	83 D.	Embedded bench mark, Karimganj.	0·0	0·000	1911-12	0·000	—	*In 77·6 miles, that is practically unaltered. Differences in level from Tree B. M. in Kamaichara village (origin of subsidence).
50	78 P.	Tree in Kamaichara village	77·6	+4·390		+4·336	—0·054*	0·000
51	„	On wing wall of road bridge.	1·4	—15·008	„	—15·103	—0·095	—0·041
52	„	On kerb of well at Minpur, I. B.	1·2	—13·131	„	—13·263	—0·132	—0·078
53	„	Embedded bench mark at Minpur, I. B.	0·0	—17·523	„	—17·705	—0·182	—0·128
54	„	On wing wall of road bridge.	2·4	—14·304	„	—15·065	—0·761	—0·707
55	„	On wing wall of road bridge.	1·8	—16·824	„	—17·365	—0·536	—0·482
56	„	On verandah floor of Shaistaganj, I. B.	0·7	—20·170	„	—20·469	—0·299	—0·245
57	„	Wing wall of road bridge	1·7	—24·698	„	—24·845	—0·147	—0·093
58	„	On railway boundary stone.	2·9	—3·693	„	—3·806	—0·113	—0·059
60	„	Embedded bench mark at Shahaji Bazar, I. B.	0·9	—4·799	„	—4·991	—0·192	—0·138
61	„	Tree opposite telegraph post No. 153-7.	2·5	—6·067	„	—6·270	—0·203	—0·149
62	„	On wing wall of railway bridge.	2·8	—12·835	„	—12·863	—0·028	—0·026 *i.e.*, within probable error of levelling.

From the above facts there is little doubt that the earthquake was due to subsidence along the southern side of a normal fault cutting the rocks below the alluvium of the Sylhet district, and situated approximately under the major axis of the epicentral area.

INDEX OF INDIAN LOCALITIES.

Those whose position is sufficiently indicated in the text are omitted from this list.

—	Latitude N.	Longitude E.	Pages.
	° ′	° ′	
Agartala	23 50	91 23	5. 19.
Agra	27 10	78 5	31.
Aijal	23 44	92 45	4, 26.
Akhaura	23 52	91 16	19.
Akyab	20 7	92 56	24, 25, 48, 52.
Alinagar	24 22	91 53	14.
Allahabad	25 26	81 55	31.
Amballa	30 22	76 52	34.
Badarpur	24 53	92 37	53.
Balisera valley	24 15	91 48	2, 7, 47, 53.
Bankipore	25 37	85 13	31.
Barisal	22 42	90 24	4, 26.
Bassein	16 46	94 48	26.
Bhagalpur	25 15	87 2	26, 27.
Bilaspur	22 5	82 12	31.
Biskra	24 32	90 40	53.
Bombay	18 55	72 54	35, 45, 48

——	Latitude N.		Longitude E.		Pages.
	°	′	°	′	
Borjuli	26	46	92	45	27.
Brahmanbaria	23	58	91	9	5, 19, 20.
Calcutta	22	34	88	24	4, 31, 37, 42, 45, 53, 54.
Cawnpore	26	28	80	24	34.
Chandpur	23	13	90	42	27, 54.
Cherra Poonjee	25	17	91	47	23.
Chhatisgarh	21	15	81	41	33.
Chinsurah	22	54	88	26	27.
Chittagong	22	21	91	53	27.
Colombo	6	55	79	55	37, 45, 48, 49, 50, 51, 55.
Comilla	23	28	91	13	23.
Cuttack	20	29	85	54	33.
Dacca	23	43	90	26	27, 28.
Daltonganj	24	2	84	7	33.
Darjeeling	27	3	88	19	28.
Dehra Dun	30	19	78	5	34, 40, 45.
Delhi	23	39	77	16	34.
Deoghur	24	30	86	45	33.
Dinajpur	25	38	88	41	28.
Doloi	24	13	91	50	2, 7, 13.
Dumka	24	16	87	17	28.

	Latitude N.		Longitude E.		Pages.
	°	′	°	′	
Madras	13	4	80	17	37, 38, 48, 49, 50, 55.
Madura	9	55	78	10	50, 51, 55.
Magwe	20	10	95	0	33.
Mandalay	21	59	96	8	33.
Maulvie Bazar	24	29	91	47	5, 13, 18.
Meiktila	20	49	95	46	33.
Mergwi	12	11	98	38	34.
Midnapur	22	25	87	21	29.
Minbya	20	20	93	10	29.
Monywa	22	7	95	6	33.
Moulmein	16	22	97	43	34.
Muzaffarpur	26	11	87	23	33.
Myitkyina	25	24	96	27	33, 34.
Mymensingh	24	46	90	27	22, 23, 24, 54.
Nagpur	21	9	79	7	34.
Naini Tal	25	54	81	56	34.
Namtu	23	1	97	41	34.
Narainganj	23	37	90	31	29, 54.
Netrokona	24	53	90	48	23, 24
Noakhali	22	48	91	9	29.
Pabna	24	0	89	17	29.
Prome	18	43	95	15	34.

——	Latitude N.	Longitude E.	Pages.
	° ′	° ′	
Vizagapatam	17 42	83 20	34.
Yamethin	20 19	96 14	34.
Yatung	27 25	88 56	34.

SUBJECT INDEX.

CALCUTTA: PRINTED BY SUPDT. GOVT. PRINTING, INDIA, 8, HASTINGS STREET.

FIG 1. THE CLUB AT KALIGHAT.

Photographs by Murray Stuart. *G. S. I. Calcutta*

FIG. 2. Dr. MUMFORD'S BUNGALOW AT KALIGHAT.

FIG. 1. MANAGER'S BUNGALOW AT PATRAKHALA.

Photographs by Murray Stuart. *G. S. I. Calcutta.*

FIG. 2. ASSISTANT'S BUNGALOW AT PUTTIACHARRA.

FIG. 1. EASTERN END OF FACTORY, DOLOI.

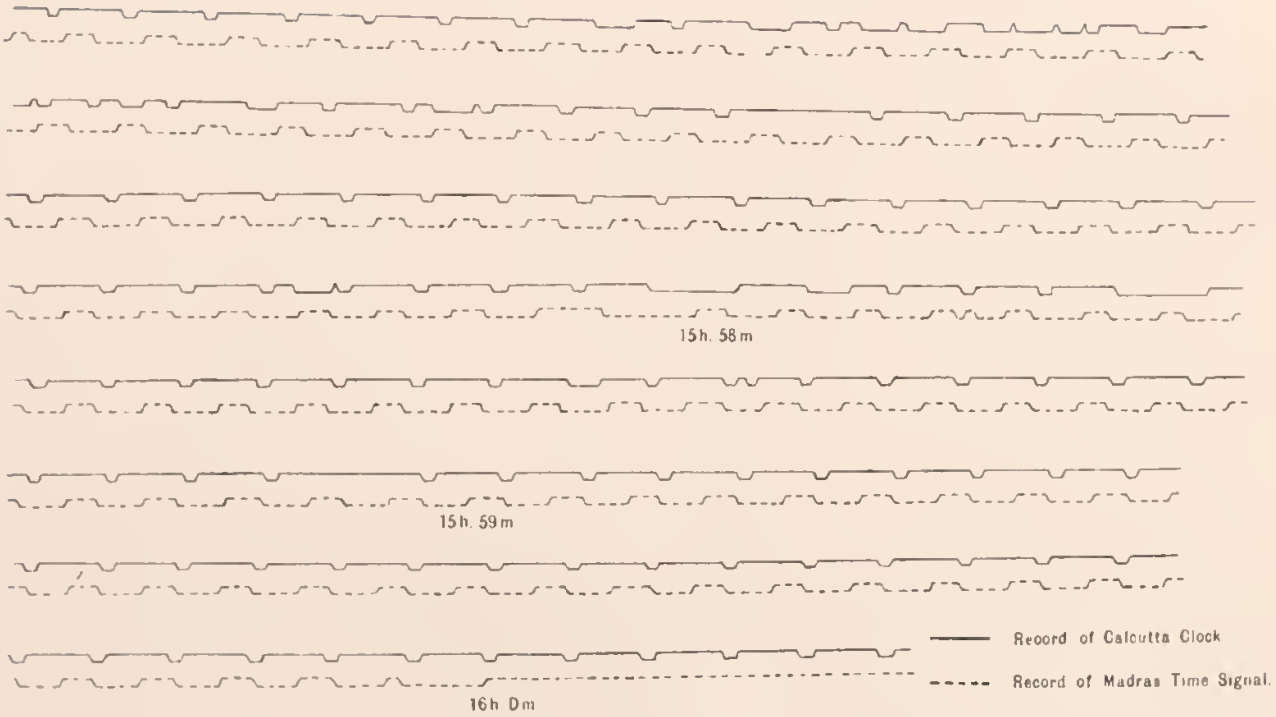
Photographs by Murray Stuart. *G. S. I. Calcutta.*

FIG. 2. FALLEN LEAF-HOUSES, DOLOI.

FIG. 1. STACK OF BRICKS AT KISHORGANJ

Photographs by Murray Stuart. *G. S. I. Calcutta.*

FIG. 2. SUB-DIVISIONAL OFFICER'S BUNGALOW AT KISHORGANJ.



Litho G. S. I. Calcutta.

RECORD OF THE MADRAS TIME SIGNAL AGAINST THE CALCUTTA OBSERVATORY CLOCK.

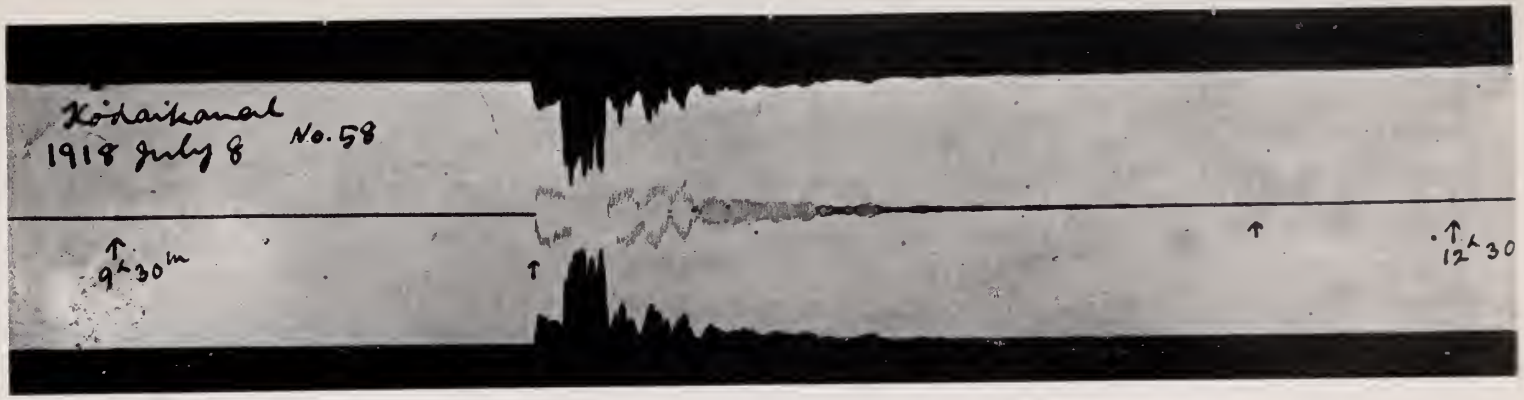
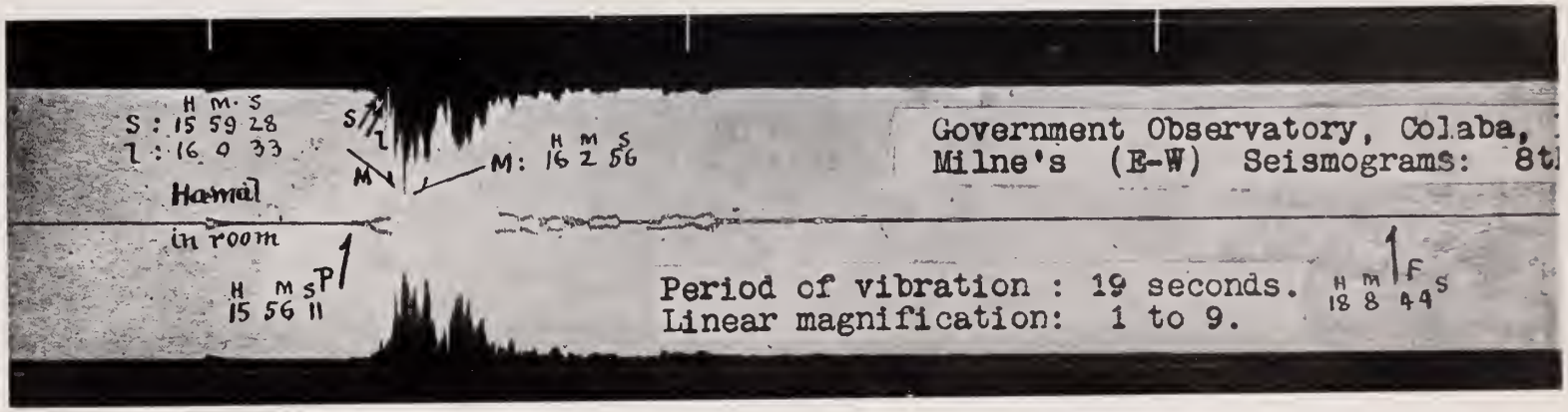


FIG. 1. THE KODAIKANAL SEISMOGRAM.

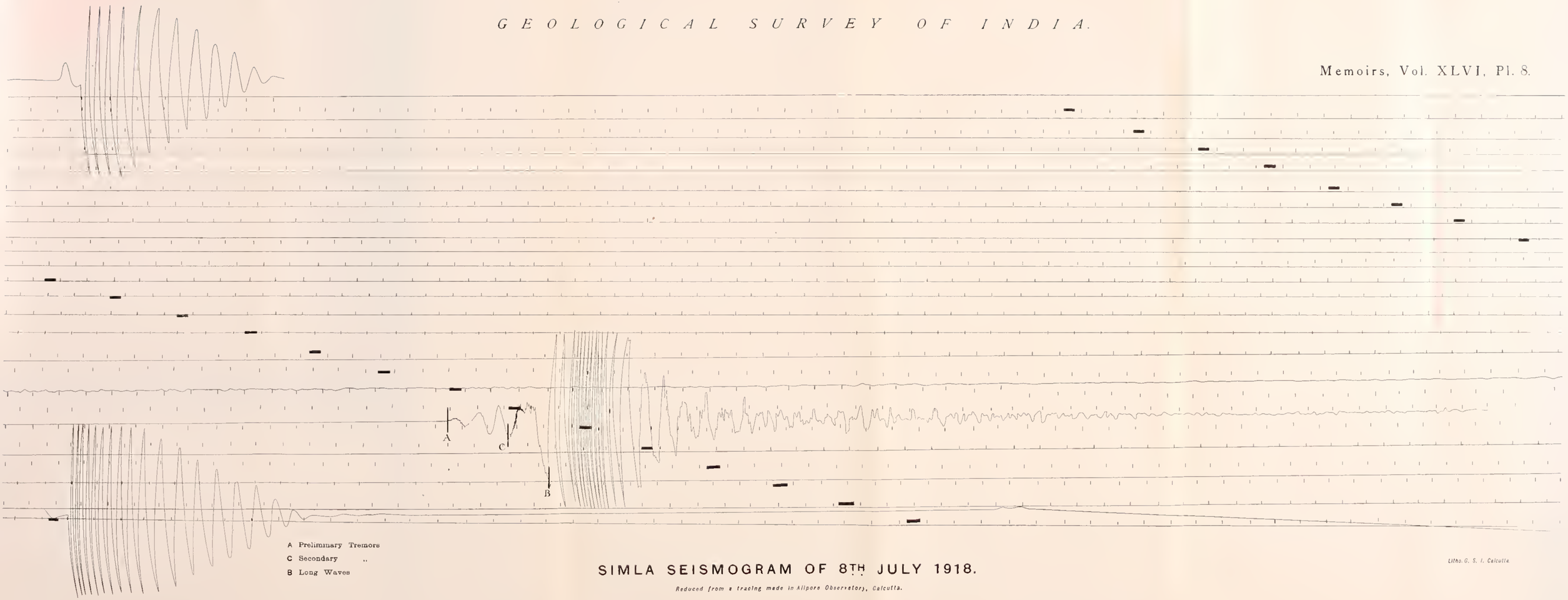


G. S. I. Calcutta.

FIG. 2. THE BOMBAY MILNE SEISMOGRAM.

G. S. I. Calcutta.

THE COLOMBO SEISMOGRAM.



A Preliminary Tremors
C Secondary ,,
B Long Waves

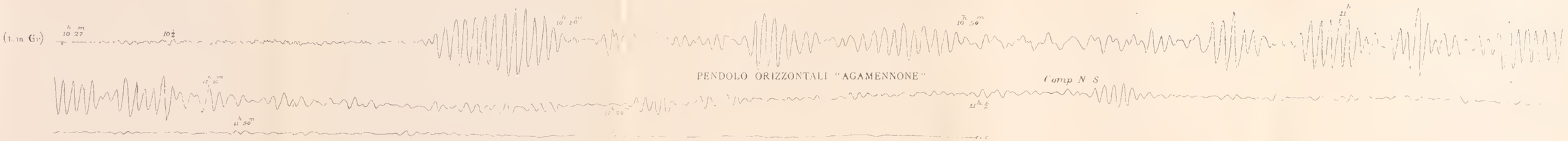
SIMLA SEISMOGRAM OF 8TH JULY 1918.

Reduced from a tracing made in Alipore Observatory, Calcutta.

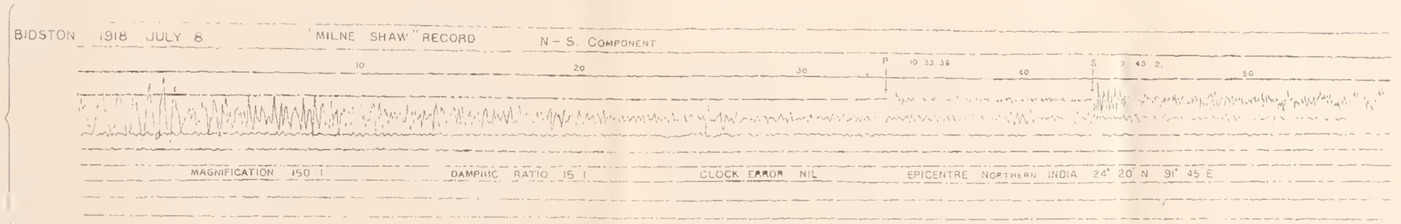
Litho. G. S. I. Calcutta

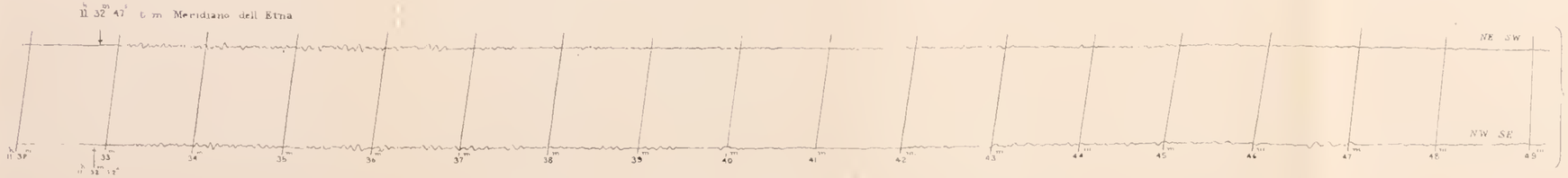
R. OSSERVATORIO GEODINAMICO DI ROCCA DI PAPA

Correzione del cronometro=+5″ 8′



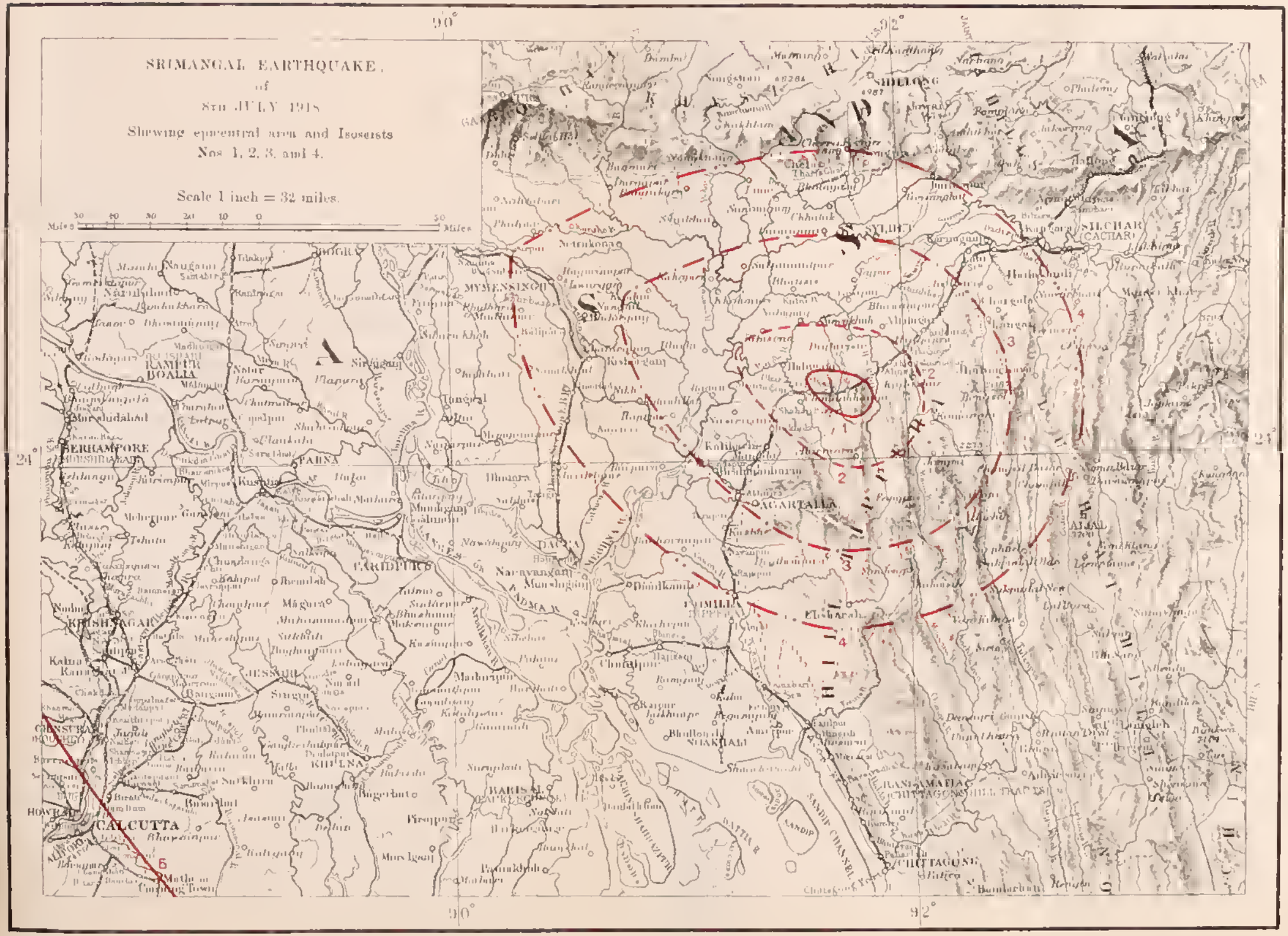
BIDSTON OBSERVATORY





R UFFICIO CENTRALE DI
METEOLOGIA E GEODINAMICA-ROMA

SISMOGRAFO "AGAMENNONE" A PENDOLI ORIZZONTALI MASSA KY 50


SRIMANGAL EARTHQUAKE,
of
8TH JULY 1918
Shewing epicentral area and Isoseists
Nos 1, 2, 3, and 4.
Scale 1 inch = 32 miles.
Miles
Miles
90°
92°
24°
SHILLONG
SILCHAR (CACHAR)
MYMENSINGH
RAMPUR BOALIA
SERAMPORE
PABNA
FARIDPUR
AGARTALA
KRISHNAGAR
JESSORE
KHULNA
BARISAL
CALCUTTA
HOWRAH
CHITTAGONG
1
2
3
4
5
6


SRIMANGAL EARTHQUAKE
of
8TH JULY 1918
Shewing Isoseists Nos. 4, 5, and 6 (the boundary of the "felt" area).
Isoseist No. 4
" No. 5
" No. 6
BAY
BENGAL

MAP

SHOWING POSITION REACHED BY THE LONG WAVES FROM BOTH THE MAIN SRIMANGAL CENTRUM AND THE SYMPATHETIC MADURA CENTRUM AT 10h 27m 68s G.M.T.

—— LONG WAVES — PRELIMINARY TREMORS

Rec. No. 2163. E 18

HELIO S. I. O. CALCUTTA