MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

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GEOLOGICAL SURVEY

OF

INDIA.

VOL. XIX.

PUBLISHED BY ORDER OF HIS EXCELLENCY THE GOVERNOR GENERAL OF INDIA IN COUNCIL.

CALCUTTA:
PRINTED FOR THE GOVERNMENT OF INDIA.
SOLD AT THE
GEOLOGICAL SURVEY OFFICE,
AND BY ALL BOOKSELLERS.
LONDON : TRÜBNER & CO.

MDCCCLXXXIII.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA.
1883.

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PREFACE.

The Report on the Cachar Earthquake of 1869 has after all returned to its birthplace for publication. This is most fortunate, for it will thereby obtain a wider circulation in this country than if brought out independently in Europe, as was the intention of the late Dr. Oldham when he took the materials home with him on retiring from the direction of the Geological Survey of India. Failing health and other causes prevented his carrying his wishes into execution. Under these circumstances it is singularly fortunate and appropriate that the duty of completing the work should devolve upon his son, who got possession of the papers, and who has since joined the service which Dr. Oldham had so successfully controlled for many years.

Only the descriptive part, the first two and a half chapters, belongs to the original manuscript; the weightier matter of discussing the observations is entirely the work of Mr. R. D. Oldham, and he has done it in a very efficient manner. In a country where earthquake phenomena are of frequent occurrence, it is most important to have one good local example put through the ordeal of scientific examination. I trust that Mr. Oldham's labours will lead to observations of a more satisfactory nature than those he has handled with so much skill in the following pages.

H. B. MEDLICOTT,

Superintendent, Geological Survey of India.

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INTRODUCTION.

On the afternoon of Sunday, the 10th day of January 1869, all Calcutta was startled by one of the sharpest shocks of earthquake ever felt there. On that evening I was myself sitting reading in a house at Barrackpore about 15 miles from the city when, without any warning, the chair was violently rocked under me, everything in the room was shaken, doors and windows rattled and the chandeliers hanging from the ceiling were set swinging with considerable force. At once noting the time of the shock by my own watch, and just then feeling a second but less violent shock pass under me, I got up to see more particularly what had occurred.

The loud cries of alarm raised by all the native servants in the compound, and from the bazaar at no great distance, first struck the ear. All stood in the open air, with mouths gaping or violently gasping out their short exclamations of entreaty or worship calling on their deities to protect them, and in the greater crowd of the bazaar surged back and forwards for a few minutes, when finding that no further shocks occurred, their amazement died away, and they quieted down to their wonted occupations as if nothing had happened.

During the succeeding hours a few trifling undulations were felt, but no distinct wave or shock. Carefully noting, from such indications as were available, the direction in which the great wave had passed under Barrackpore, we felt satisfied that, as soon as time admitted of the news reaching the capital, we should hear of some very violent and possibly very destructive shock in the country beyond the limits of the great alluvial plain far away in East Bengal, and, as we determined from such evidence as was then before us, in the direction of Sylhet and Cachar.

Nor were our anticipations in this respect without sound basis; for next morning the telegraph wires brought the intelligence that Silchar town had been shaken to its very centre, that serious destruction had ensued, and, allowing for the sensational terms in which some of the messages were conveyed, the result obviously of the first alarm before the facts had been realised, it was still clear that a very unusually severe shock had occurred, that much injury to property and possibly destruction of life had resulted and further that, as the news could be gathered up, it would be found that other places also as well as Silchar had suffered severely.

For some time, each successive morning's newspaper brought additions to the reports of damage done, and were filled with communications from various people who had experienced the shock. It soon became evident that the district of north Cachar or the hills between that and Assam must have been the centre of disturbance or near to it. Manipur also had been much shaken, and all the country between that and the Brahmaputra to the north.

I had noticed all these communications with great interest, trusting that some one of the numerous writers would give data on which to build up a satisfactory conclusion as to the true direction of the shock in various places, and so by inference as to the centre of disturbance. It was clear that among the buildings partly overthrown and injured, evidence could be obtained by careful investigation on the spot, which would lead to a knowledge of the position of the seismic focus, and possibly also as to the force of the wave and the rapidity of the motion of its particles. But no such information came in any of the published communications on the subject and all that could be made out was that the shock had been a serious one, and that much damage had resulted.

I had myself only returned a day or two before from the very extreme end of the Indian empire to the north-west, or in the opposite direction, whither I had proceeded at the request of the Government of India to examine and report on the feasibility of enlarging into a tunnel roadway the small drift which had been carried under the bed of the Indus at Attock: and finding some arrears of work which had accumulated during my absence, I was not very desirous of leaving office again immediately. Very shortly afterwards, however, Mr., now Sir, William Grey, then Lieutenant Governor of Bengal, asked me if I could make it possible to visit the principal places where the damage done was most severe, and note what had occurred on the spot. To this I at once acceded.

I was unfortunate enough to arrive at Silchar just as the military expedition against the tribes to the south, who had committed various depredations in British territory, was about to start, and every one in the place was fully occupied with the numerous and varied preparations necessary for such an attack. Mr. Edgar, the Deputy Commissioner, very kindly came round part of the station with me, and pointed out several places where the injury done had been serious; but it would have been most unreasonable to have expected that he could do more than this, in the midst of such pressing occupations.

I remained a few days at Silchar busily occupied in measuring and noting what was observable there. I was very desirous to get on to Munipur to see what had occurred there; but although the Deputy Commissioner said he could procure me the few coolies which would have been necessary for transport of baggage, &c., still, as it was obvious that this would have to some extent interfered with their more urgent occupation elsewhere, and as he stated that it would be essential also, in the then state of the country, that I should have a small escort, not from any actual fear of disturbance, but to guard against the chance of meeting some stragling band, I determined not to make the attempt, the more so as there was great reason to fear that there might have been serious delay in my getting back again.

After a few days, therefore, at Silchar, I returned to Sylhet, where I examined the buildings which had been injured; and then dropping down the river to Chattuck, turned northwards from thence, intending to cross the Khasi Hills by Cherra Poonji and Shillong to Gowhatty.

CHAPTER I.

GENERAL DESCRIPTION OF EFFECTS OF EARTHQUAKE.

Before proceeding to discuss in any detail such special facts as have been observed tending to elucidate the history of this great earth-shock, I will briefly relate the observations made by others and recorded either in official returns or in the public newspapers of the day. By this means, a general idea of the impression left upon others will be obtained, and it will also be seen how far any precise conception of the results, or of the force which produced them, can be expected from such notices.

Taking the observations somewhat in the order of the geographical position of the localities at which these were noted, we begin with Silchar and proceeding east thence round by north, west, and south, return again to the same vicinity.

SILCHAR.—The Assistant Engineer reported on the 13th January, three days after the earthquake :—" All the pucka buildings belonging to the department of Public Works have been injured beyond the possibility of repair; besides, most of the kutcha buildings have been entirely thrown down. The store-shed has been thrown down, and several articles injured or destroyed. All the works are stopped, and I do not see any possibility of recommencing them, without further orders. My own life, and those of my family, together with my property, were on the verge of destruction. For this reason, I am unable to submit a full report of the state of the buildings. I shall be able to forward the report by to-morrow. The whole of the Cachar bazaar, buildings, boats, merchandize, the jail, sepoy-lines, and villages on the peninsula are all in a complete scene of destruction."

I have quoted this verbatim, because it seems to me an excellent instance of how easily grossly exaggerated and therefore incorrect statements can find a place in the history of such phenomena; here is an official report by the Government officer in charge of the Public Works and buildings at Cachar made three days after the event and yet most largely at variance with the real state of the facts. But I suppose all allowance must be made for the alarm arising from his being on the verge of destruction.

Mr. McWilliam, the Assistant Commissioner of Cachar, on the morning after the shock, reported to the Commissioner of the division thus:—"In the absence of the Deputy Commissioner, I regret to report that Silchar was visited yesterday afternoon at 4 o'clock by a very severe shock of earthquake, which lasted for at least a minute; considerable damage has been done to property; but, as yet, I have heard of only two cases of death. Some idea of the force of the shock may be gained from the fact that the new pucka Church tower has fallen, and the walls of the jail compound are level with the ground. The bank of the Barak adjoining the bazaar has given way, and sunk about 15 feet over an area of from three to four hundred yards long by two hundred broad, doing more or less damage to all buildings upon it. The bazaar itself and the jail compound are cut up in all directions by gaps, in some places eight inches or a foot wide, from many of which dark sand and warm water were forced up during the night."

The *Friend of India*, on the 20th January, published a letter from a correspondent which gives a fair account of the facts:—Previous to the 10th of January, there had been nothing remarkable in the weather, which, so far from being sultry, had been rather colder than usual. The air was rather hazy and wanting in clearness; there had been no rain, either at Christmas, as is usual, nor in the first week of November, and October was also deficient in quantity. The year 1866 was remarkable for the number of its earthquakes, six or eight shocks, the greater part of which took place between January and April; 1867 and 1868 were free from them.

The shock of 10th January 1869 came on at $\frac{1}{4}$ to 5 P. M. with a gently undulating movement, which, however, rapidly increased, until neither men nor animals could keep their legs, but were thrown down, and such things as bottles, glasses, lamps, were upset, and the gumlas were half emptied of water. The water in tanks and rivers was violently agitated, and the Barak rose in huge waves, and wrecked numbers of boats. The landslips caused were numerous and extensive, and many homesteads were carried down into the stream.

The old cemetery at Silchar is a rectangular enclosure, secured by walls of coarse brick masonry with heavy mortar joints, the mortar showing only a very wretched power of adhesion. This wall had been built more than twelve years. Within the limits of the cemetery there are a good many monuments of various kinds, but the large space is by no means filled. Naturally I had anticipated that some of these structures would have shown evidence of the force of disturbance to which they had been subjected, and had been, therefore, surprised to find no reference, in any of the accounts published previously to my visit, to any injury done. I was, therefore, the more gratified to find, on visiting the place, some of the most valuable and important evidence that Silchar afforded as to the nature and direction of the shock; indeed the most valuable which I met with anywhere.

The first thing which struck me on approaching the enclosure, which lies a little to the north of the main road passing east and west through Silchar, was that the gate of the enclosure was all down. The gate was of wood, solid below with vertical bars above, in two parts or wings joining in the centre, and fastened solely by a bolt. These gates were carried by nearly square masonry pillars measuring 1′ 8″ × 1′ 6″ which again were supported by and connected with the walls surrounding the cemetery enclosure by a raised step in the wall. The plain square pillars were topped by simple capitals capped or finished by small spherical gurrahs or earthen pots inverted and secured by being imbedded in mortar on the summit of the pillar. This was 8 feet from the level of the ground. The elevation of the gates as they originally stood given in Pl.IX, fig. 1, will show the general character better than any detailed description. The opening of the gateway was 8 feet 6 inches. The entrance road passing through this gateway and straight on through the centre of the cemetery was here slightly raised above the general level of the ground, so that there was a little fall on either side of this road.

These gates were stated to have been secured, at the time of the shock, by the bolts in the middle; whether this really were so or not, it would be impossible to ascertain now, but they were doubtless closed to prevent cattle trespassing within the enclosure.

When I visited the place, the whole was in ruins, and stood as shown in Pl. V, fig. 2, reduced from a photograph which I had specially taken by Mr. Pearson at the time of my visit. Nothing whatever had been done to the place, and the ruined mass remained, as stated by every one, in exactly the same condition as it was the morning after the earthquake occurred.

The eastern gateway pillar lay flat on the ground not much broken up, having evidently fallen *en masse*, being simply overturned. It was, doubtless, held back partially by the supporting wall on the side, but all was upset, cleanly cut off along the smooth surface of the first course of bricks above the ground level. The mass of the brickwork was broken right across and partially separated at two distinct points, and the uppermost portion of the pillar lay in a separate heap overturned close by. These cracks in the mass appeared to me to be obviously the result of fractures caused by the falling of the pillar *en masse* on partially uneven ground, the whole having toppled over in all probability as one. The capital, however, which was separate from the shaft of the pillar and lay at a distance of 4 feet 3 inches from the top of the pillar, lay on the ground, in its natural position and not overturned, as it would have been had it rolled, would seem to have been shot off from the pillar, and being free to move, that is, not tied to the wall on one side and to the gate on the other, would seem to give a fair index to the direction and possibly to the force of the wave. The spherical cap of this pillar also was lying on the ground, and *apparently* as it fell, beyond the capital, though it would not be safe to assume as certain that the place where it was seen was the actual spot of its fall. It most certainly had not been moved by human hands for none of the people would voluntarily have touched it and no orders had been given for its removal; but it may very possibly have rolled a little after falling, to which its nearly spherical form would lend itself. The ruined portion of the adjoining wall which acted as a support to this gate-pillar, had also been thrown over in ruin and much broken by the fall. The eastern half of the gate itself, which was attached to the pillar by ordinary bolt and hook hinges, was lying flat beside the broken pillar, still attached by one of these hinges.

The western pillar of the gateway was also overthrown and broken up by the fall in similar way. The capital here also was separated from the shaft, and was lying overturned on the ground close by the top of the pillar. Its projecting mouldings had evidently struck the ground when the pillar fell over and the capital, separating from the pillar, was upset by the force of the blow. The spherical ball at the top was more than 7 feet from the capital, its position being no less than 17 feet 3 inches from the centre of base of the pillar over which it was originally placed; but the lie of the ground, sloping down from the roadway and the position in which this ball was found, with its base slewed half round towards the north-west, seem to prove that this position was due to its having rolled along the ground after it fell, rather than to its having been projected from the top of the pillar by the force of the wave.

The half of the gate attached to this western pillar was left standing on its side, leaning against, and supported by, the broken mass of the pillar. It had been thrown off its hinges, and been slightly moved towards the north.

In all there was abundant evidence of a sudden and violent force producing this general overthrow, but unfortunately not yielding as clear and convincing proof of the direction in which the force had acted as I had at first hoped; the peculiar conditions under which the gateway,

Fig. 1. Scene in Bazaar.

Fig. 2. House in Bazaar.

gate, and pillars, viewed as a mass, were held together, and tied on to the walls on either side, having materially affected the result. I shall notice this again.

Searching through the cemetery, only few traces of the action of the earthquake were noticed. A small simple monument, consisting merely of a flat plateau or table of brickwork with a head wall raised at the north end of it, into which a marble slab with inscription had been built was in ruins. The sides of the little table bore north and south, and of course the axis of the wall at the head, at right angles to this, was east and west. The whole of this wall was overthrown and lay in a heap of separate bricks, as it fell; this was clearly just overturned and lay unmoved, excepting in so far as it was shaken into its separate bricks, the brickwork being of the poorest kind, and the adhesion of the mortar more than usually slight. The direction of the fall, which could be ascertained with considerable accuracy was North 3° 20′ East.

None of the other smaller monuments showed evidence of the destructive force of the wave. A small plain stone cross, to the memory of the infant son of Captain Stewart, dating 1864, probably erected 1865, remained perfect. The shaft was rectangular of $5\frac{1}{4}$ by $4\frac{3}{4}$ inches, the total height being 3 feet 2 inches, and the breadth of cross arms 2 feet 1 inch. This was inserted into a plain terrace or plateau of steps, and it would give a good measure of the limits of the force, if needed.

But the most remarkable case of destruction remains to be noticed. Near the centre of the cemetery ground stood a very elaborate and costly white marble tomb or sarcophagus, erected to the memory of Charles Ruthnot Stewart, Esq., who died at Silchar in June 1864. This carefully-prepared and well-chiselled tomb had been constructed by Messrs. Llewellyn and Co., a well-known and long-established firm in Calcutta, and the parts had been by them transmitted to Silchar. It is but right, however, to add, with especial reference to any remarks I may have to make on the construction, that the monument was not put up by the Messrs. Llewellyn, or their workmen, but by some local masons. I am able to give a rough sketch of the tomb (Pl. X, fig. 2), as it stood prior to the earthquake of the 10th January, copied from a most faded photograph which is scarcely legible, and I took advantage of the fortunate presence of Mr. Pearson in Silchar, during my visit, to obtain through him a photograph showing the state of the mass as it appeared after the shock had passed, which has been reproduced in Pl. X, fig. 2. These views will give a much better idea of the wreck than any description; and yet this ruin in reality consisted only of the projection of the heavy upper slab, the rest of the tomb being almost uninjured.

As we shall return to this tomb, I will now merely state the upper heavy slab of marble was found fairly projected from the body of the tomb more than 8 feet towards the north-north-east, and thrown unequally, the west end of the slab being thrown further than the east. The tomb stood with its major axis bearing West 5° North and East 5° South; the sides of the heavy mass as it now lies bear West 10° North; the general direction of the throw or of the line joining centre of slab as it now lies with the centre of body of tomb over which it was placed, is 12° 30′ West of South or East of North.

The boundary walls of the cemetery enclosure had been cracked and broken in several places, but there was nothing very remarkable noticed. Still, in the absence of better observations, it may be noticed, that at 97 feet from the gateway to the west a marked crack extended from top to bottom of the wall, making an angle of 25° with horizon, and at 34 feet further in same direction there was another less marked crack, dividing as it passed to the bottom of the wall, and which gave an average angle of 16° with the horizon. These cracks were in all cases opened along the joints of the brickwork—nowhere across the bricks themselves. Between the two, the wall was slewed round fully 1 inch to the north at the east end, and $\frac{3}{4}$ of an inch to the south at the west end. Small thread-like fissures occurred at the corner also; at the north-east corner of the enclosure there were cracks in the wall, and several others showed, at varying intervals, in the northern wall, most of these being nearly vertical.

This cemetery enclosure is just on the edge of the Kandy lands; to the north the ground falls rapidly into the lower level of the peninsula of

Silchar, but no portion of this lower ground is included in the enclosure of the cemetery.

In the new cemetry, placed in a lovely spot, a slope of rising ground to the south of the town and at some distance from it, no mischief was done.

Among other buildings which had been injured by the earthquake prominence had naturally been given to the Deputy Commissioner's house which had received considerable damage. Mr. Edgar himself however at once said that this would afford no index to the force exerted, from the peculiar circumstances under which the shock occurred. The house was an ordinary bungalow with one of the heavy native thatched roofs; round the house was a raised verandah, at the outer edge of which a series of wooden pillars supported the lower edge of the roof, which was all in one slope. In the ordinary construction, each side of such roof is made in one piece, the whole is then merely tied together and slightly secured in addition by the plastering round the chimney, generally in the centre of the house.

When the earthquake of the 10th January came, preparations had been made for the removal of the old wooden pillars, with the view of putting in new ones round the verandah, and on one side these had been partially removed so that the very heavy roof had been deprived of the main support on that side. As the thatching was to be renewed, it had been weakened in other ways also, the natural consequence being that the whole of one side of the roof was dislodged and slipped bodily down, bringing with it of course portions of the walls, &c., and destroying some furniture in the verandah; part of the chimney, and of the internal dividing walls were also shaken down and falling in the rooms did some mischief; there was no one in the house as Mr. Edgar had moved into an adjoining bungalow to allow the repairs of his own to progress. This second bungalow and several others about were uninjured. Although the Commissioner's bungalow looked to be in actual ruins, it is more than probable that it would not have suffered at all but for the condition in which it happened to be.

The small hospital attached to the native infantry lines was a perfect ruin; this had been a simple rectangular building 80 feet long containing a central room round three sides of which was a verandah, the roof being supported on masonry pillars 2 feet square. The northern end of the building was open; at the southern end the verandah at either side was enclosed so as to form two small rooms for dispensing medicines, &c.; the brickwork of all was old, and of very poor quality; the plain ridge roof was of the ordinary heavy thatch in use in the country. All was in ruins, most of the debris had been removed before I saw the place, and the roof and much of the rubbish was gone, but the pillars still remained as they were first thrown down. That they went over *en masse,* was perfectly evident from the way in which they lay; portions of the pillars, more than 3 feet in length, were laid along the verandah floor quite unbroken and with as much regularity and parallelism as if they had been carefully alligned. All were separated from the base on the smooth surface of one course of bricks and simply turned over, and this was the case in both verandahs, whether to the west or east. The cross walls and additional division near the southern end of the building had to a certain extent so strengthened the fabric there that the walls were largely standing, but the whole of the heavy massive roof must have been started by the shock and have carried with it the pillars which supported it on either side, and the walls to the north. The axis of the building was magnetic north and south; the direction of the pillars as they lay was slightly affected by the action of the roof with which they were connected, but all lay at angles between 6° and 10° west of north.

The jail near the town at the south end of the bazaar presented a curious appearance. The high outside wall had been laid perfectly flat on the ground, a few courses next the ground here and there remained and a small portion of the curved corner of the wall, where each portion had supported the other, still stood as well as parts of the large gateway, where the walls had been strengthened by the heavier piers and buttresses, the rest was lying on the ground, every portion in its true position relatively to that which was next it in the wall originally, but all separated and disjointed. The whole must have gone over in one mass projected by the shock into the courtyard of the jail.

A small Hindu temple or *mal,* which lay under the shelter of a large banyan tree, was quite uninjured; and, naturally enough, the people, unaccustomed to reason as to the causes of these phenomena, attributed its safety to the protecting power of its sanctity. It was a small, nearly square cell, of solid heavy masonry and, as it stood close to the utter ruin of the jail wall and to the wild scene of destruction which the adjoining bazaar and banks of the river afforded, its preservation was striking. This was clearly due, not to any holiness in the ground which prevented the irreverent footsteps of the earthquake from penetrating there but to the binding effect of the wide-spread roots of the noble tree which covered it and which so tied together the whole ground that it must have been affected as a whole if disturbed at all. For this the force exerted was not sufficient, and the temple escaped.

The bazaar itself presented one almost unbroken scene of ruin. It had been chiefly composed of bamboo and mat structures, which, in other places, had remained undisturbed, yielding sufficiently to the wave by their elasticity, and quickly recovering themselves. With these there were a few *pucka* or masonry structures—some with flat-terraced roofs. But here all were in ruins. The views I have given, all taken from Mr. Pearson's photographs and therefore accurate and detailed representations of the facts, will convey a much better idea of the appearance of the place than the most detailed description.

However, it required very little examination to see that all this terrible destruction of property was due entirely—almost entirely—to secondary causes. This bazaar extended along the bank of the river, up the eastern reach of the great curve or bend which encompasses the town and peninsula of Silchar; and when one looked at the ground between the houses and the river the eye was met by a wavy sea of broken ground dropping to the river's edge by successive steps, trees thrown at every angle some buried or half-buried, the fragmentary ruins of houses and huts one-half standing here the other wildly thrown in a heap there, all in most inextricable confusion.

The sketches will themselves give the key to all this. In the foreground of several will be noticed long cracks or fissures even in the very road; and on looking from the bazaar road towards the river, the surface of which was there about 50 feet below the level of the bazaar, these cracks and fissures were seen to be repeated in successive steps down to the water's edge. Bamboo and mat huts, which on the unbroken surface of the ground adjoining to the west stood quite uninjured, here were torn to pieces and destroyed, not by the waves of short duration, which would have affected them here as little as elsewhere, but by the absolute separation and unequal sinking of the ground on which they stood. No elasticity and flexibility of material could withstand this, and these mat huts yielded with as much facility as the more permanent buildings.

One of the thoughts which first suggested themselves on the sight of such wide-spread ruin was that there must have been very serious loss of life in a place so crowded; but most fortunately this was not so. The earthquake occurred at a time of day when most of the inhabitants were outside their houses, or were sitting close to the doors and could therefore easily escape; while from a dread which had seized many, that they would be impressed as coolies, the number actually in the town was less than usual. The total number of lives lost, both in the town and district after very careful enquiry, were found not to exceed five or six, and very few serious injuries to persons were reported.

Kochela.—Near this a building had been years since erected as a saw-mill but had recently been disused. It consisted of a simple parallelogram, the walls enclosing the space being on all sides composed of a series of openings arched above. These openings, at the time of the earthquake, were quite free, having no wood-work or other enclosures. The sketch plan given in Pl. VII will indicate the proportions and mode of construction of the building. At one corner the masonry was enlarged and carried out so as to form a projecting square buttress as it were, through the centre of which a circular flue was carried up from the boiler of the steam engine which gave the motive power to the saw mills. The longer axis of the building bore south-south-east, the furnace chimney being placed at the north-west corner of the building.

After the shock of the 10th January, the only portions of this building left standing were the solid walls at the corners. All between these solid parts on the north, east, and south sides was overthrown, and of the five detached piers which supported the arched openings on the west side, three also were down. Two, those next to the furnace stack alone stood, together with the chimney, and very obviously owed their preservation to the additional strength given by the heavier and more massive construction of this part of the building.

The greater portion of the *débris* of the fallen walls lay in remarkably well-defined masses, the piers, arches &c. having clearly come down not piecemeal but in one mass, the breaking up being due to the fall and impingement on the solid ground. In this way, as will be more clearly seen by reference to the sketch plan Pl. VII, the east and west walls lay on the ground, so that the piers and arches of the original construction could readily be traced, the piers quite as parallel one to the other now that they lay shattered on the ground as they had been before, when standing in the finished building. The direction in which they were thrown was, therefore, very readily ascertainable; it was S. 39° W. At the ends, however, of the building the mass of *débris* seemed at first sight to have been simply broken out from the corner buttresses and laid down, so little broken was the larger portion of the brickwork; in both cases the walls were thrown outwards, that is in opposite directions—the southern wall being thrown to the south, and that of the northern end to the north. On the eastern side lay one solitary block of brickwork of no great size, a solid block originally part of the most northerly of the piers of the eastern wall near the base of which it lay after the destruction. It was not square with the base, but had been slewed round in its fall. But as I am unable, from the information at my command, to say how far this may have been due to a certain amount of rolling or changing place after touching the ground, and how far to the action of the disturbing force impressed upon it, I shall merely mention the fact, without attempting to base any conclusions on it. It is very possible that more careful examination might have shown how far its present position was due to each cause separately. From the top of the south-east corner buttress some bricks had been dislodged, and were found lying between the buttress and the fallen arch-work to the south.

The only two archways left standing, adjoining to the chimney shaft, were both badly cracked, these cracks passing right through the arch-work and wall above. I should mention that the building had no roof on when it was overthrown; it is said to have had a corrugated iron roof before.

It is clear that the mode in which the building was broken up has been materially affected by its construction; the corners had obviously far greater strength and power of resistance than any other portion, and not only had they this power of resistance due to the solidity and symmetry of the wall, but also from their being buttressed, as it were, by the two corner walls being at right angles to, and tied into, each other; the chimney stack in the north-west corner of the building acted still further as a buttress or support by its solidity and weight, and so supported the two adjoining arches, which, though seriously cracked by the rocking of the walls, stood. The walls were, in fact, precisely of the construction which would be most liable to result in an overthrow from such a wave shock as this earthquake sent through them—lofty arches, with slight piers and a comparatively heavy mass of masonry above, which could only act as the heavy bob of an inverted pendulum, producing a serious leverage on the whole and tending to prevent the possibility of recovery of the vertical when once moved therefrom.

The evidence which this building affords of the direction of wave transit I shall discuss in another place.

Sylhet.—Earthquake said to have been at 4 hours 22 minutes P.M., magnetic meridian time. The shock was sudden; lasted about a minute; direction toward the latter part of the shock was from north-north-east

Fig. 1 on Bazar road.

J. Schaumburg Lith:

Fig 2. Fissured ground on banks of river

to south-south-west. The palm trees all rocked so, and the ripples in the river were in this direction. From the peculiar tremulous, "almost stinging" sensation experienced in the feet, the Executive Engineer thinks there must have been two shocks at same time, one commencing from the west (? east) crossed by another from the northward. A second shock occurred ten minutes after, and another 50 minutes later. At 7 P.M. a fourth, all much slighter than the first; the steeple of the church was shattered in all directions, two pinnacles fell and two were shifted. Court-houses and circuit bungalow heavily cracked. Pendulum clocks were stopped, vessels of water had their contents thrown out, &c., a large looking glass in circuit-house was thrown from the table and broken to pieces.—(*Executive Engineer, 11th January.*)

Pola (58 miles east of Sylhet.)—The overseer of the Sylhet and Cachar road states that he was at Pola when a violent earthquake took place. The shocks were violent for five or six minutes, and then abated and ended in three minutes more. He was obliged to sit down and hold on to the ground. About 600 feet west of the Pola River and 200 feet south of the Barak River, the earth cracked in several places, and sank 4 feet deep. The shocks were from south to north, and the water of the Barak River boiled, shook, roared and ran with tremendous force against the current northward, rising 6 feet over a sandbank; the houses on the north bank of the rivers were shaken into an inclined position. All the country between the Pola and Dhullesur Rivers was rent into cracks from 3 to 9 inches wide, and from which hot water, and sand soft and black, were thrown out with considerable force and deposited on the ground to a height in some places of more than 3 feet. On the west bank of the Pola the road was 4 feet high, but has sunk level with the main land.

From Pola to Thittia, as he passed up immediately after the earthquake, the hot water was rushing out of the cracks in the road, producing great heat and a sulphureous stench, and hot, black, soft sand was deposited over the cracked ground and excavations, which were from 3 to 4 feet deep, and filled with the same.

The inspection bungalow at Panchgaon was thrown down. From Panchgaon to Budderpore the soil was cracked in many places.

He was informed that the road near Katta Khall has been cracked and sunk. The villages between the road and the rivers at Kalinuggur had sunk so much that little is to be seen of them.

"At Sealtic bazaar houses have sunk 40 to 50 feet below the surface. Nut trees (*Areca*) from 40 to 50 feet high had disappeared below the surface in some places, and in others were 2 feet or 3 feet above the ground. A merchant's godown had sunk 15 feet below the ground. The Barak River, at this place, had become so shallow that boats passed with difficulty.

"A boat, laden with lime, which was sunk some years ago, and became imbedded in the mud, has been thrown out. I have also been informed that the Katta Khall has been blocked up, and that passengers are crossing dry shod.

"There were two shocks of an earthquake this morning (14th January) at 3 o'clock, the sound of which was quite violent."—(*Overseer Babu Rameshur Ghosal.*)

Cherra Poonjee.—The station of Cherra is very peculiarly situated, and it is necessary, before describing the effects of the earthquake of January 10th at this station, to notice briefly the physical characters of the ground.

The station is built on a level flat or plateau of sandstone. From the surface of this plateau, whatever soil at any time existed, has been almost entirely washed away by the excessive rains of this part of the hills, leaving a great slab of bare rock, forming a slightly undulating surface cut up here and there by water-courses. To the north of this plateau, small irregularly waving hills rise, on which the station of Cherra Poonjee is placed; to the west, with rolling interruption, the flat ground is inclined to the village of Maomlo beyond which it is interrupted by the deep and narrow glen of the Um Nangnian River; to the south-west small isolated hills of limestone (nummulitic), overlaid with beds of coal and sandstone, dot the plain; while to the south-east the plateau is bounded by deep and lovely valleys or gorges. These drop suddenly and for a considerable distance nearly vertically, thence with rapidly descending incline to a depth of some 2,000 feet, and at the bottom runs a stream, which in the rainy season becomes a roaring torrent. This deep gorge on the east does not extend into the hills much further than the station of Cherra, terminating to the north in a vast curved line of precipices. To the east and east by north the plateau of Cherra is as it were cut off from all communication with the adjacent hills by this deep glen, seldom near there more than a mile wide at top and of more than 2,000 feet in depth, while all the houses at Cherra may be said to be close to the edge of the plateau, that is, within a few hundred yards of the precipitous side of the gorge. Consequently the earthquake shock, coming from the east by north, was superficially extinguished by the breach of continuity of this deep glen so that the shock was not felt, or only very slightly so, passing under and not again emerging at the surface till it had passed beyond the station.

Shillong, Khasi Hills.—The Executive Engineer at Shillong summarised the injuries done to the public buildings thus. *Overseer's bungalow:* Nineteen arches cracked in various directions, north and south gables, also partition walls cracked, &c. *Deputy Commissioner's cutcherry;* Five arches cracked, &c. *Native Infantry Magazine* very seriously injured. He gave three sketches taken the morning after the earthquake, showing the serious cracks which had been formed in parts of this building. Although roughly done these sketches are of interest as almost the only record I have been able to trace of the physical effects of the shock. The Executive Engineer obviously gave them simply as showing in the simplest and most effective way the injuries done, without attempting to argue back from them to their causes, but if others had done the same thing in other places, the data for the history of this earthquake of 1869 would now be far more complete and satisfactory than they are.

Nungpoh.—At this village, which is one of the stages between Gowhatty and Shillong, the shock was severely felt by the Deputy Commissioner, who happened to be there that evening in the travellers' bungalow. A despatch box full of papers was thrown from a camp table, ink upset from an inkstand &c. It was only a mat and timber building and sustained no injury.

Manipur.—Dr. R. Brown, the Political Agent, Resident at Manipur, reported as follows on the 18th January:—

"On the 11th instant, the day after the occurrence, I sent a telegram to Cachar to be forwarded to you, briefly mentioning the main damage and loss of life which had occurred, so far as I could then ascertain. I am happy to be able to state now that no further loss of life seems to have taken place, and those injured are all, so far as I can ascertain, progressing favourably.

"At the commencement of the earthquake I was standing in the centre room of my house. I did not take alarm at the first one or two vibrations, thinking that, as is usual, they would rapidly cease: the vibrations increasing, however, I made at once for the door of exit. I experienced some difficulty in making my way through the front room, the ground at this time undulating so strongly that walking was a difficult matter. Arrived at the outside of the house, the ground was in such violent motion, that I found it impossible to proceed more than a few paces, when I either was thrown down or sank down involuntarily, my face turned towards the house, and on my hands and knees. At this time the motion of the ground was most remarkable; it seemed to rise and fall in waves of about 3 feet in height. A very short experience of this wavy motion sufficed to settle the fate of my house; after swaying about, and creaking and groaning for a brief space,. the upper storey, built of wood and bamboo, settled down with a crash on the lower walls, which, fortunately, although much fissured and thrown out of the perpendicular, withstood the pressure.

"Almost immediately after the fall of the house the motion ceased, and I was enabled to regain my feet and see what damage had been done. I found the house inside in a deplorable state and one illustrating the wonderful force of the earthquake. Heavy book-cases and other articles of furniture had been literally thrown violently about, and the destruction of crockery, bottles, &c., was very great. Outside my compound I found the house, in which the treasure chest was kept, level with the ground, but no one hurt. A glance at the Rajbarrie close by showed me that the Raja's pucka house was in ruins, with many other less substantial buildings. In fact, in every direction fallen houses of all descriptions, slight or substantial, attested the great violence of the earthquake. Every one was in a state of very great alarm, never having experienced any thing of the kind, except the very slightest shocks, before.

"In a time of such terror and confusion, it is a difficult matter to make accurate observations as to time, &c. However I looked at my watch when the shock commenced, and found it 3 minutes past 5 (evening); on rising from the ground after the earthquake was over, it was exactly 5 minutes past 5. Allowing for errors, I think it may be almost assumed with certainty that the shock altogether lasted about a minute and a half. So far as I could observe, the lower animals did not seem to be at all affected by the phenomenon. There was nothing unusual in the weather or the temperature at the time of the shock. I had an excellent opportunity of observing the state of the weather on the day of the earthquake, as I rode into the capital from the foot of the hills to the south-west of the valley that morning; the only two things that struck me were the entire absence of the usual morning fog and the presence of a particularly dense bank of blackish cloud over the high hills to the north-west, the rest of the sky being clear.

"The Natives all say, and I agree with them, that the first shocks were almost due north and south, but, according to them, the undulations almost immediately after this assumed a circular character, and seemed to come from all quarters; this may be, but I did not at the time become conscious of any change of direction in the motion. About 15 minutes after the occurrence of the first shock, another took place, slight, however, in character. Without giving the particulars of every slight shock which followed the major one, it may be stated that up till

¼ before 10 P.M. on the 14th, the shocks, although slight, were very frequent, keeping the inhabitants in a constant state of alarm, most of them camping out all night, afraid to sleep inside their houses after the experience they had on the 10th. During the 15th, 16th, and 17th, I observed no shocks, but this morning, the 18th, they again recommenced, and I observed distinct shocks, slight, and not lasting more than a few seconds, one at 7 minutes to 2 A.M., another at 10 minutes to 8 A.M.

"On the morning after the occurrence of the earthquake, I visited the Rajbarrie and other places to witness its effects. In the Rajbarrie enclosure, which is of great size, there is a "Maidan" of some extent, which lies rather lower than most of the other parts of the ground. In this space were the remains of many openings, now closed with fine mud, where the ground had opened and great volumes of muddy water had been poured out; in this space also the ground was much fissured, and for 20 or 30 feet it was broken, and had sunk in portions more than a foot. Many of these closed apertures were quite soft, and allowed a walking stick to be pushed down 10 or 12 inches until the solid ground was reached. The main branch of the river which runs through the capital, flows at a short distance from the Rajbarrie, and an inspection of its banks showed most unmistakably that along the course of the river the disturbance of the earth had been much more severe than in places situated at a distance from it; the ground along the banks and near the river was most extensively and widely fissured, and it had sunk several feet in many places. On the morning of the 11th, the river had fallen about a foot, and the current was very sluggish, evidently the bed had been depressed; the following day the river had risen about a foot above its former level, and the current was re-established.

"In the fall of the Raja's two-storied brick house, a most substantial and ornamental building, and which had only been finished five years ago, I regret to say four women were crushed to death, and a number of people wounded. As intimated above, I have heard of no other fatal cases, and the wounded are all doing well; the more serious cases being looked after by the Native Doctor attached to the Agency acting on my instructions. The Raja's loss in property is very great, and is not yet fully known; he is especially sorry about his muskets, numbers of which, but recently received from Government, have been irretrievably destroyed.

"Full particulars from all the outlying districts and thannahs have not yet been received, but, so far as I can ascertain, the earthquake has been universal all over the valley and in every direction in the hills, and much damage has been done, but, so far as I can hear, without loss of life. At Morai Thannah, on the Burmese frontier, four days' journey from this, the earthquake is described as having been very severe, and the ground was extensively fissured. To the north, many villages belonging to the Nagas have been demolished. The hill streams have all risen from 1 to 2 feet. At the salt wells in the valley, some 14 miles east from this, but little damage was done to the houses, but the salt water in the wells is reported to have increased in depth 6 feet, and this increase was accompanied by much noise. I have made enquiries as to the behaviour of the large lake or jheel to the south of this about 14 miles, as I expected that it would show some remarkable phenomena, and I am informed that during the earthquake the water was violently agitated and became of a reddish colour. After the earthquake the water appeared permanently increased, and a most remarkably thick crop of water plants appeared on the surface, rendering the progress of boats very difficult. Altogether, I think that the surface of the valley has, so far as I have been able to observe, sunk probably a foot or more from its former level.

"The reports from the line of road between this and British territory all point to most extensive damage, the road in many places being completely destroyed. An enormous mass of rock, &c., is described as having blocked up the Eurung River close to the ford, leaving but a few feet for the passage of the water. So soon as matters somewhat settle down, I purpose visiting the damaged portions of the road, when I will report fully as to damage done, and if assistance will be necessary in order to effect the necessary repairs.

"I am much indebted to the Raja for the promptitude with which, in the midst of his own troubles, he sent men to build me a temporary house, my former one having been rendered uninhabitable by the earthquake.

"I have in preparation a few photographs illustrating the damage done, copies of which will be forwarded when they can be got ready."

In reply to enquiries made by Mr. Leonard, then Superintending Engineer in the Public Works Department for that Circle, Dr. Brown subsequently, under date of the 25th February, said :—" Since then I have heard that the earthquake penetrated a considerable distance into Upper Burmah, and was very severe. I have also had accounts from one of the Rajah's officers from a place in the hills north-east of this, seven days' march. He describes the earthquake as very severe ; the ground opened into fissures ; huts disappeared ; water was poured out and in fact the same phenomena were observed as in Cachar, and apparently more severely than there.

"I have received lately accounts of the state of the road between this and the frontier, and the former reports as to damage done I find were exaggerated. At only one place near the Jeerie River has there been any considerable landslip, and the road at this place would most likely have gone this coming rains.

"The statement (in para. 9) as to the whole level of the Manipur valley having fallen should be modified, as it is perhaps rather too startling. The river beds, however, have sunk much, else how account for the decrease in the volume of water, the stoppage of the current, followed by a rise (not owing to rains) and a re-establishment of the current; this occupying three or four days altogether.[1]

[1] This may easily be explained without any alteration of the levels. The earthquake very probably shook down large quantities of *débris* from the steep sides of the khuds, which damming the streams caused a decrease in the quantity of water in the river beds lower down; afterwards the water rose and rapidly swept away the barrier of rubbish ; this would cause the decrease and subsequent increase in the volume of water and the final return to its normal level.

Fig. 1. Inside of Church.

Fig. 2. Scene in Bazaar.

"One thing I omitted in my report. I was not conscious of any subterranean noise at the time of the earthquake; the noise struck me as entirely due to the swaying of trees and houses, and was exactly like the sound heard in Bengal when a storm is coming up during the rains.

"Manipur itself, that is the large basti called the Capital, is almost flat; the houses cover a very large extent of ground, and are without exception built of wood and bamboos. The only two dwelling-houses built pucka were mine and the Rajahs; they both came down.

"There are several small nullahs flowing through the above, but the earthquake distinctly followed the main one, which runs south-east, the banks of the others were unaffected to any extent more than the surrounding land.

"All the ground occupied by houses is flat without rock; a bluish clay is the substratum over that deep soil.

"The shocks noted by me are as follow :—

		h.	m.	
January 10th ...	First shock very severe	5	3	P. M.
	Second " not "	5	15	"
	Third " " "	5	55	"
	Fourth " " "	6	10	"
	Fifth " " "	7	5	"
January 11th ...	Slight	7	49	"
" 12th ...	Rather severe	6	45	"
" 13th ...	Slight	2	50	"
" " ...	Do.	4	40	"

"After this the shocks ceased until the 18th when two slight ones occurred,—time not noted.

"On the 21st February another very slight shock was observed, lasting about 2 seconds, direction from north-east to south-west; time 9h. 6m. A.M. The shock was so slight that many of the natives about did not notice it. I did so satisfactorily, as I had before me at the time on the ground, outside my house, two large dishes full of water; the water in these moved up the side about 1 inch.

"My impression about the weather here this season is that the temperature has been much above what it was last season, but having no observations to be relied on before May last, this cannot be proved.

"I might have gained more information, but I have unfortunately been tied down to my post here by the Lushai disturbances."

We have no futher information from Manipur, Dr. Brown being the only person there who seems to have taken notes of the phenomena. As I have already mentioned, it was a source of great regret to me that the Lushai disturbances should have prevented my getting to Manipur, and noticing on the spot the evidences of the direction and force of the shock-wave.

Sibsaugor, Upper Assam—From this station we have it reported :—"Severe earthquakes about 5 P.M., lasted four or five minutes, followed by several slight shocks throughout the night. Three or four large arches in centre of cutcherry cracked in the crowns, and also at east end; several of the smaller arches similarly cracked."—*Lieut. Peel, Assistant Commissioner.* The *Executive Engineer,* Upper Assam, says :—The undulation was from south to north, lasted upwards of a minute; pucka houses so violently shaken that he thought the portico and verandah would come down, yet there were no cracks. The first and bad shock was about 5h. 15m. P.M.; another much slighter 15 minutes after; and a third two hours after several slight ones during the night.

Golághát.—The shock was preceded by a low rumbling sound from the direction of the Naga Hills, due south of the station. This increased in strength till the passage of the earth wave. The first shock was so violent that the describer could with difficulty retain his seat. A glass of water standing on a small table discharged about one-half of its contents. Two shocks succeeded the first after an interval of two or three minutes, and a fourth about half an hour afterwards. Shortly after a great wave, 1½ foot deep, swept down the river, destroying many boats.

Kenomah (*Nága Hills*).—The earthquake began with a gentle motion followed by a great undulation, which produced several landslips, and fissured the hill sides; the fissures were about two fingers broad. Between Samanguting and Kenomah the rivers were discoloured and swollen, though no rain had fallen, and in the neighbourhood of the Dhunseri

River the ground was broken up, and water and sand were ejected from the fissures. The Dhunseri River rose 3 feet two days after the earthquake. The earthquake at Dimapur was accompanied by loud reports.—(*Deputy Commissioner.*)

Jaipur, Assam.—Mr. Peel, whose power of observation and carefulness in recording these I know, writes that the earthquake passed near Jaipur in a S. S. W. to N. N. E direction, or, to be more correct, from 5° to the west of south to 5° to the east of north. I had ample means of marking the direction of the waves, as about 30 men all stood together, and we could only *stand* at all by straddling our legs in that direction, which I noted. While they were passing it was impossible to stand steady with the feet close together. In about five minutes it was followed by *loud* series of *reports* like artillery that lasted about 5 minutes. I noticed a large semul or cotton tree, and it did not come to rest for 10 minutes and swayed (at first) in the same direction. A friend of mine, while riding over a flat plain, was thrown, the horse staggering, and he was regularly *sick* on the spot. Pucka work has suffered severely, but kutcha not at all, as far as I know.

Dibrooghur, Upper Assam.—Doctor J. B. White, the Civil Surgeon of the station, reports that the first shock occurred at 5h. 15m. exactly; that the direction of the wave course was from south-east to north-west; the shock lasting 2 minutes and 5 seconds. Other shocks are reported to have occurred on the following days, the 11th at 2h. P.M., at 3h. 45m., and at 5h. 30m.; also on the morning of the 12th (time not recorded) and at 3h. 30m. A.M. of the 14th.

A correspondent of the *Englishman* newspaper states that the first shock occurred at 4h. 58m., mean local time, a second at 5h. 10m. and a third at 7h. 2m. Two shocks also during the night. And again on the morning of the following day, the 11th, at 5h. 15m., 5h. 25m., and 5h. 38m. A.M.

The weather on the day previous to the earthquake (9th January) is said to have been unusually close and sultry. The shock was very severe. In one house, three clocks, one of which stood south-west and north-east, and one south-east and north-west, were stopped by the first shock. Twenty minutes after the great shock, repeated peals, like the sound of distant artillery, were heard in the direction of Sibsaugor. No damage was done beyond a few cracks in the pucka houses of the station ; the public buildings remained uninjured, except that a crack in the church, produced by an earthquake fifteen years before, was re-opened.

Lakhimpur.—The earthquake is said to have been felt at about 10 minutes after 5 P.M. on the 10th. The shocks lasted for nearly two minutes and-a-half, and appeared to proceed from the south-west passing off to the north-east. The movement was described as a vast undulation which seemed to invest the solid earth with the motion of a great storm wave, before which the trees bent and rocked in the most extraordinary and fearful manner. Riders were compelled to dismount from their ponies, and even then kept their feet with difficulty. It was accompanied by a low rumbling noise, the motion creating a feeling of nausea. Half an hour after the great shock there was a second one, less severe, which was accompanied by *several distinct reports like the firing of distant cannon.*[1] Nearly an hour after the first, a still slighter shock occurred, and second slight shocks were noticed during the night. They recurred again at 4h. A.M. on the morning of the 12th, at 3 P.M. on the afternoon of the 13th, and again at 4h. A.M. on the morning of the 14th (*Englishman,* January 27th). Another correspondent stated that "*shelling*" had been heard every day since the 10th. Another report states that the loud explosive noises were heard about a

[1] These noises, like artillery reports, are among the most unaccountable of all the concomitants of this earthquake, the area over which they were heard being at once so extensive and so limited--extensive, inasmuch as the reports from Lukimpur, Sibsagur, and Jaipur show that they must have been heard over an area of at least 200 square miles ; limited, inasmuch as they were not heard anywhere else over the vast area affected by the shock. The smallness of the area over which they were heard, coupled with the fact that that is placed at the extreme north-east of the seismic area, show that they can have been but a secondary effect of the earthquake.—R. D. O.

quarter of an hour after the shock, not half of an hour, as stated above. No Government buildings were injured, but the walls of two or three private houses were cracked.

Nowgong.—The Executive Engineer reported a terrible earthquake at 5h. 10m. P.M. on the 10th, which lasted more than two minutes. Furniture in houses was all thrown about; the water in the river rose and fell 2 or 3 feet; boats were torn from their moorings, &c. The Executive Engineer's office was reduced to a heap of ruins; hardly a square yard of solid wall being left. The Deputy Commissioner's Court suffered much, the walls were kutcha-pucka, and had either fallen down in a lump, or were left so insecure that they had to be taken down. The jail wall, although standing, was left in a very shattered condition. The hospital of the Jail, a new building lately completed by the Public Works Department, was cracked all over, but especially at the upper corners of the doors and windows. The school house escaped, "the brick-work seems to have been better put together than that of the other buildings." The old church was cracked all over.—*Executive Engineer,* under date January 11th.

The weather for a day or two before the 10th was exceedingly sultry. A rumbling noise like smothered thunder approaching from a distance preceded the shock, and accompanied its passage, sounding as if from deep in the earth. The undulations were very violent. The water in the river was affected as though a steamer had passed, and continued so for some time. It is rumoured that the earth is cracked and fissured in some parts of the district. The wall of the cutchery (court-house) was thrown down, and the whole edifice shaken beyond repair. The Jail wall and the hospital cracked; the church is cracked from top to bottom, and other brick buildings much shaken or destroyed. The shock was stated to have been from east to-west.—(*Major Lloyd,* Deputy Commissioner.)

Gauháti.—Colonel Davies, Chief Engineer of Assam, reported on the 22nd January that at this station the earthquake had been very severe, was felt at 5h. 15m. P.M.; the direction was north to south; the duration 45 seconds. The shock was not preceded by any rumbling noises, nor was the weather disturbed either before or after. The principal shock was followed by a slighter one ten minutes afterwards, and again by another two hours later. Several other shocks were felt during the night, and for the next two days, when the disturbances appear to have ceased. At the jail, the east and west walls have horizontal cracks, and are out of the perpendicular; wicket damaged, slight cracks in arches. The grave-yard porch shows one side of roof slipped down. The Native Infantry hospital has a bad crack owing to original faulty construction, or to settlement of wall.

The Deputy Commissioner reported that the earthquake was preceded by a loud rumbling noise compared to that of a heavily laden cart. The crows were much disturbed, flying about and cawing wildly immediately before the shock. The shock was very severe. Almost every brick building suffered more or less. The church spire badly cracked. None of the native houses in the bazaar suffered, and no loss of life was reported. The day had been warmer than usual.

Returning towards the north-west again, we find the first place from which any notice of the shock is given to be—

Goálpára.—There the shocks were severe and accompanied by loud rumbling. Several masonry buildings were slightly damaged; the motion was thought to be from north to south by one, from the south by another. Another slight shock was felt about 10 minutes after the first, and several others followed during the night. Again at 3h. 45m. A.M. on the 14th.

Jalpáiguri.—First shock felt at 4h. 55m. P.M. on the 10th. It was preceded by a loud rumbling, like that made by a railway train passing over a bridge. The oscillations continued about 50 seconds, at first smart, then decreasing, again smart, and then again the vibrations decreased. The direction as nearly as can be guessed was from north-west to south-east. A large pool of water in the bed of the river was slightly agitated, and objects, such as men and carts, coming up from the ferry appeared moving up and down. A building of bad masonry, and weakened by a former earthquake, was cracked through, but no other property was injured. Doctor Macleod reports that the sky was nearly obscured by clouds; the thermometer was two degrees higher than at the same hour on the previous day, and the wind was south-east.

Cooch Behar.—Shock occurred about 5 P.M., and lasted about four minutes, supposed to have come from the south-east.

Baxa (*Cooch Behar*).—Shock felt severely; no injury.

Mynagoree.—The earthquake occurred at 5h. 20m., and was preceded by a rumbling sound. It lasted two minutes, as timed by a watch. Two distinct shocks were felt in the direction of north-west to south-east as nearly as could be judged.

Rohimganj.—A rumbling sound, as of distant thunder, was heard at 4h. 40m., producing the impression that a storm was approaching. In an instant, before this rumbling had died away, the plain was heaved by a succession of earth-waves travelling from north-east to south-west at about the apparent rate of 4 miles an hour. The undulations continued 2 minutes 10 seconds, heaving up the earth 3 or 4 inches. There was then a pause of one minute, and then a second series of undulations, similar in character but of less extent, lasting 60 seconds. After one minute and a half, a third series lasted 6 minutes. No further movements took place during the night, and no vertical shock was experienced.

Darjiling.—Shock occurred at 4h. 50m. or 4h. 55m. P.M.; house shook considerably, wood-work of roof cracked and groaned. Buildings not injured very perceptibly at Silligoree; wall of dâk bungalow cracked at Punkabari.—(*Executive Engineer*, January 15th.)

There was but little oscillation felt at Darjiling. Shock first felt at 4h. 50m. Mr. J. Müller had constructed a seismometer consisting of four pendulums, so suspended as to oscillate in the north, south, east and west planes, but it was not at all affected. If there were any undulation, it was in the line north-west and south-east. The sensation produced by the shock was that of a violent concussion rather than a subterranean movement of any kind.—(*Deputy Commissioner's report.*)

Several observers concur in the statement that the shock of 10th January 1869 was felt at Darjiling, more as a vertical concussion or blow than as an undulating or wave-like motion.

Kursiong on road to Darjiling.—The earthquake is stated to have been severely felt here; people rushed out of their houses, fearing every moment they would come down. Trees seemed to roll from side to side in the most extraordinary manner.—(*Englishman*, January 18th.)

Purneah.—At 4h. 45m. P.M., shock smart, some cracks in abutting arches in the southern verandah of church.—(*Executive Engineer.*)

Dinajpur.—Shock severe, felt at 4h. 30m. P.M. Several distinct shocks during an interval of about 3 minutes: motion apparently from west to east, with a rumbling sound like that of a heavy train in motion. Buildings not injured.—(*Executive Engineer.*)

Maldah.—Two smart shocks, about 5 o'clock accompanied by a noise like that of a heavy railway train.—(*Englishman*, January 14th.)

Bograh.—Old cracks in roofs increased slightly.—(*Executive Engineer.*)

Pubnah.—Two shocks felt. No injury to buildings.—(*Executive Engineer.*)

Dacca.—Shock at 4h. 45m. P.M., seemed to be from north to south. Some slight cracks in barrack and hospital.—(*Executive Engineer.*)

Nuddea.—Said to have been at 4h. 35m. P.M. Two sharp shocks, each about 30 or 40 seconds in duration, and at an interval of about a minute. The second was the more severe of the two, both accompanied by a loud rumbling noise; the vibrations passed from south-west to north-east. Barometer not affected. Supposes "from the motion and noise being simultaneous, from the loudness of the latter, and the regularity of the waves of vibration, that Berhampore must have been near the centre of disturbance!"—(*Executive Engineer*, January 11th.)

Meherpore, Nuddea.—The shock was keenly felt, lasting 3 minutes; the house vibrated violently, seemingly from north to south. Strange sounds are said to have been heard underground. It caused a good deal of consternation among the natives, being considered additional evidence of the famine that is to be in 1870. The writer adds :—"I am not quite sure of the time of day, as my watch had stopped, and my clock is not to be depended upon. The shock occurred about half past three." (I quote this sentence *verbatim*, to show how unreliable such casual statements of the time of occurrence are for any purposes of accurate determination. With the most perfect good faith and honesty this gentleman tells us that he had neither watch nor clock to give him information as to the time, and then without any qualification goes on to say the shock occurred at half past three.)—*Englishman, January 12th.*

Berhampore.—No great damage done; old cracks exhibited through the skin of plaster which covered them, but there are no new cracks.

Baraset, Barrackpore, Ishapore.—Shocks felt at 4-30 P.M. very marked, some arched doorways in the barracks cracked. Punkahs, hanging-lamps, &c., were put in motion, and a few light articles upset; direction from north-west to south-east, lasted 30—40 seconds.

Calcutta.—The Honourable Justice Phear noticed the direction of the wave-motion as indicated by the oscillation of the water in a tank at his house close to Calcutta, and recorded it as from south-east by east to north-west by west.

Passing still further to west and north from Calcutta, the shock was experienced at

Raniganj.—Two distinct shocks were felt between 18 and 20 minutes before 5 P.M. Shock severe, but no injury done.—(*Executive Engineer.*)

Monghyr.—Some slight injury to the jail buildings.

Patna.—Sufficiently strong to set glass-doors rattling and a book-case rocking. No sound was heard.

Hazaribagh.—The earthquake was felt, but the shocks were not violent. Doors that opened to north and south were set swinging quickly on their hinges, but not so those that opened east and west. The air previously to the earthquake was still and hazy, and the temperature was slightly higher than usual.

Midnapore.—Very slight, between 4h. and 5h. P.M. No injury done.

Hidgellee.—Felt at 4h. 30m., appeared to come from the north-west to the south-east, and lasted 30 to 40 seconds.—(*Executive Engineer, January 11th.*)

I have not found any record of the shock being felt at sea by any of the ships in the Bay of Bengal. But on the east coast of the Bay we find it sharply felt.

Kussilong.—A correspondent of the *Englishman* (January 18th) writing from Kussilong, 90 miles from Chittagong, says:—"It burst with tremendous force. It was travelling apparently eastward and slightly north. The undulations were very severe and lasted nearly two minutes. It seemed as if some mighty wave were sweeping on under the earth, and as it passed the solid earth rose and fell with a motion distinctly visible along the banks of the river and in the hills beyond. The ground was seen to roll wave-like, the hills to reel, and the trees to wave to and fro. The spectacle was wonderful and fearful. Shock occurred at nearly 5h. 0m. P.M. on the 10th."

The shock was also felt sharply in Upper Burmah, but we have no detailed accounts of its effects.

In the preceding pages I have brought together all the notices of the results of this great earthquake which had been given by local observers and by local officers. That it was the same great shock which produced the rattling of the doors and windows at Patna, and the sharp blow-like sensation at Darjeeling as that which ruined Silchar, is, I think, abundantly established. But beyond this little else is fixed. The times, although sufficiently consentient to prove this, are of no use for any more accurate investigation as to rate of motion; while the naturally great difficulty of noting accurately the direction in which such wave oscillations occur is amply evidenced. In fact I think it will be obvious that so far as these notices go there is nothing to give a clue to the true direction in which the forces acted, to the position of the source from which those forces originated, nor as to the mode or rate of transmission of the shock. The only fact established seems to be that one and the same shock or group of shocks was experienced at slightly varying hours over an area, the extreme limits of which from north-west towards south-east must have exceeded 650 miles and in the conjugate direction of north-east to south-west of more than 400 miles, or, allowing for those districts over which the shock was felt, but from which we have no reports, an area of fully a quarter of a million of square miles, and independently of any other considerations, the immensity of this area will in itself give some index to the vastness of the forces developed.

CHAPTER II.

MORE LENGTHY NOTICES OF THE EARTHQUAKE.

In addition to these brief notices in the newspapers of the time and in the official reports of the engineers who had charge of the buildings in the stations visited by the earthquake, two or three other and more detailed statements were made public. H. Leonard, then Superintending Engineer of the division in which Cachar is located, visited Silchar and Sylhet a very short time previously to my own visit, to whom I am much indebted for having subsequently handed over to me all the information he collected, most of which is embodied in the preceding chapter. But he also made public his own impression. At a meeting of the Asiatic Society of Bengal, on the 3rd of March 1869, he stated that the reports regarding the severity of the earthquake, and especially as to its action in rupturing the earth, were considerably exaggerated, early reports were decidedly so, most people being so much surprised and alarmed by the shock and its results that they seemed to be incapacitated at the time for making anything like accurate observations and hence very great caution should be observed in accepting information as to the intensity of the shock or as to the direction of the wave. Highly exaggerated and most incorrect accounts had been received by himself on the subject.

Mr. Leonard was at first inclined to think that the point of greatest intensity was about Silchar or more to the west, but on subsequently seeing Dr. Brown's letters from Manipur, they seemed to prove that the shock had been as severe at Manipur as in Silchar. To the south of Silchar the shock seemed to have been felt less than at the station, while to the north-west again and on the road to Cherra Poonji the effects were decidedly less.

He noticed the great difficulty in deciding from observation of facts the direction of the wave. Individuals generally stated that the movement was from about the south. The church tower fell to the north, but an unfinished building of Mr. Snells, which consisted chiefly of unsupported pillars, was thrown down in all directions, the pillars really falling to all four points of the compass. Houses with the ordinary Indian flat roof all stood, while most of those with roofs which did not give support to the walls were thrown down or damaged.

The disturbances in the surface, in every case which he had seen, were caused by the slipping in of the banks of the large rivers or of old river beds, or partially filled up jheels; though he had travelled through the districts for over 150 miles, he had not seen a single case of disturbance or fracture of solid ground unaffected by rivers or jheels running through it. Many of the slips along the river banks were very extensive, in some cases being continuous for half a mile in length, from 500 to 1,500 feet in width, and the depth of the depression varied from a few feet to 30 feet. Very large quantities of sand and water were thrown up, but he considered that in every case the forcing up of the semi-liquid matter was due to the subsidence of the firm ground above.

The great majority of people said that the water thrown up was cool; a few, however, stated that it was decidedly warm; but generally the evidence went to show that it was very little, if it all, warmer than ordinary water.

Mr. Leonard has here brought forward his own careful observation on the nature of the remarkable fissurings and rupturing of the earth's surface, so well seen near Silchar, with singular force. Obviously unaware of the full bearing of the statement, he has not clearly shown that such elevations and depressions were *in every instance* only the secondary results of the earth-motion, their very existence depending on peculiar conditions of structure.

Dr. F. Stoliczka pointed out how easily this throwing up of sand and water, which had been also noticed in previous earthquakes, could be explained if there existed a distinct stratum of sand below the layer of surface clay or soil. As soon as the fissures were formed, the slightest undulating motion would shift and force up the loosened sand, the force with which it was brought to the surface depending upon the local pressure under which the sand and water stood.

Mr. H. F. Blanford noticed the contradictory nature of the reports. He was quite unable to form a correct idea as to the velocity with which the wave had travelled. In one case he was informed that the water, which came up through one of the fissures, was 9° higher in temperature than the annual mean temperature of the locality. This increase was more likely the result of chemical agencies, decomposition of organic substances, &c., than due to the great depth from which it was supposed to have come up.

At the same meeting, and in fact giving rise to the preceding verbal notices, a paper was read by Captain Godwin-Austen, who, in charge of a party of the Topographical Survey of India, was at the time of the earthquake encamped near Assaloo, in North Cachar. He notices that the shock came without the least warning, a sound or rumbling, more or less loud, being generally heard for a few seconds before. The elevation above sea-level of his camp was about 3,000 feet near the base of a range with peaks rising to 6,000 feet. He alludes to the state of the weather, and states that there was nothing unusual or peculiar about the appearance of either the sky or the weather, but notices a rapid clearing off of great haziness toward the west which had just before prevented his seeing the hills in that direction.

Captain Godwin-Austen states that the earthquake was ushered in by one or two long waves of motion, succeeded in about 20 seconds "by others much higher and following in rapid succession, followed by a great quiet rolling or heaving, without any jarring motion." All "save tremor" had disappeared in about 2½ minutes. Ten minutes intervened between this and the second well-defined shock. "The horizontal undulating motion was decidedly combined with another force, a kind of jerking from side to side; the surface not only rose and fell, but its parts seemed to shift about, each in segments."

He describes the position of his camp, on the principal northern spur of the conspicuous hill of Mahadeo (5,751 feet) in the line of the North Cachar hills, "as well as on the principal line of elevation, the whole mass being here tilted up and dipping over southward some 40° or 50°. In fact Assaloo lies on the northern flexure of the great uniclinal that runs thence towards the west, marked conspicuously by the Jatinga and Kayeng valleys, and ultimately continuous with the same great feature at the base of the Cherra Poonji Hills. It marks the great bend and break in the stratified rocks, when this mountain system was first upheaved."

He describes forcibly the swaying of the magnificent forest on the flanks of the hill "as if swept by a mighty wind," and notices a "confused din" from the ground below mingled with the noise caused by the swaying of the trees. Most people sat down, and with great difficulty he and one or two others could keep on their legs.

In speaking of the direction of the wave-motion, he notices the great difference of opinion which existed among those in camp, but says there is very little doubt that it was from west to east. "The noise and motion in the trees certainly subsided and passed off in the east." A heliotroper, who was on the top of Mahadeo, declared that he could see the mountain peaks near at hand and in the east heaving about; the noise of falling rock was very great. The effects upon these hills are very great; ravines choked with rocks and *débris*; and one party of my men out-poling found the body of a fine stag that had been killed by the falling rocks when standing by the water-course.

"On the Diyung its effect seems to have been very severe; the high steep banks of recent clay and sand gave away in many places falling into the river, the ground along the valley was much rent and the houses, structures of poles and matting, were in many instances thrown over."

The peak of Sherfaisip, also in the north Cachar range and one of its culminating points, 5,612 feet, is about 26½ miles almost due west of where Captain Godwin-Austen's camp was near Assaloo. On this peak a heliotroper was stationed, and his account is given:—"He was on the peak by himself, sitting at the station mark with his heliotrope, facing east ready in case he was required to show to Mahadeo; all was still, and he was likely to hear and notice any peculiar sound. He says that about 15 or 20 minutes before the shock, he heard the sound of a distant cannon (*tóp* was the word used) as if fired some 30 or 40 miles distant. Before the shock came on, he heard the rumbling coming from the east, and when he felt it he caught hold of the heliotrope, but that the motion was so great he was thrown backwards. He distinctly says the motion passed away towards Marangsi peak, situated west-north-west from his station."

I quote this paragraph at full, because this man's statement of the motion at Sherfainsip coming from the east, coupled with the observation of Captain Godwin-Austen himself at Assaloo that the motion there was from the west, is made the basis of a long discussion of the origin, locality, and direction of action of the earthquake forces. Here it is said "it is most interesting to find two well-selected points, 26 miles apart situated nearly due east and west of each other; at the first the waves were travelling eastward, at the second westward, this places the divergence of the forces between the two."

Now, if we examine the evidence on which the statement is based we shall first find that in neither case was the direction truly east or west; and in this latter case the only evidence of the force having come from the east was the impression on the man's mind that the rumbling he heard, before feeling the shock, came from the east. If we consider for a moment the exceeding difficulty of deciding correctly the point from which a sound comes, the frequent and constant reflections which any such sound wave in the atmosphere meets with, and the very numerous cases in which, even under favourable circumstances, such waves of sound appear to come up in exactly the opposite direction from that which indicates their true motion, we shall certainly hesitate to admit as evidence this belief of the man as to the direction in which the rumbling passed. But this hesitation will be strengthened into full conviction, I think, when the only real fact of observation is taken into account. The position of the man is stated to have been facing eastwards; the shock came and seizing hold of the heliotrope, he and it were thrown backwards, that is, he was thrown to the west. The shock therefore *must* really have come from the west, not from the east. It would seem to have been supposed that he was projected with the shock, but this could not have been the case. His feet were moved forward with the shock, his body remaining comparatively stationary, until the line from the centre of gravity of his body fell beyond the base of support and he fell, as is always the case with unsupported bodies, towards the point from which the wave of motion came, in this case towards the west. It is necessary to notice this here, because the fact renders it unnecessary to notice further the discussion regarding the origin of the motion which is based on this supposed divergence of the waves from a line between Assaloo and Sherfaisip. I would also notice the absence of any attempt to fix the true direction of the motion by careful observation of any fact. Very possibly no such observations were practicable, but in questions of this nature the mere statement of the wave-motion being east or west is far too lax to yield any satisfactory result, the more especially as the places of observation were in reality at a considerable distance from the seismic focus.

Captain Godwin-Austen adds some interesting speculations as to the connection between the present form of the ground, the deep gorges of the rivers, and their coincidence with some very marked geological features of contortion and disturbance; and closes his notice by a detailed statement of the several shocks noticed at Assaloo from the 10th January up to the 2nd of February. He alludes also to the effect produced on streams by this earthquake, stating that a rise was caused in them. To these observations we may have to refer again.

Fig. 1. Earth cleft near River.

Fig. 2. Slipped banks of River.

Captain Godwin-Austen, writing to friends in England shortly after the occurrence of the earthquake, gave some particulars, subsequently published in the proceedings of the Royal Geographical Society, Vol. XIII, p. 370. Having just gone into his tent he heard the cry outside "an earthquake! an earthquake!" and ran out. He had just got out when the ground began to rise and fall tremendously and at last became so bad that it was with difficulty he could keep his feet. Children sitting on the ground all crying, the shouting of the servants, kicking of the ponies, prevented his hearing any particular noise, save the crashing of the large forest trees near the camp; these were tossed about in the wildest way, and one very large one came down.

The motion in addition to the waves that passed by consisted of a jerking or shaking. Everything upon tables or chairs was thrown off; no two-storied or even one-storied house of brick could have stood it; here where the houses are of wood and bamboo—a mere frame—it would require a terrible earthquake indeed to throw them over. After about fifty seconds he got out the chronometer. The intensity of the shock which must have occurred about twenty seconds from the time of first shock was then passed; the last waves "very like those of a gentle swell at sea" were just passing as he noted the time. "It was a curious sight to see the way in which the waves passed over the forest-clad mountain side, as if the trees were bowed by the passage of a mighty wind." The direction of the motion was from west to east.

After noting the several shocks which occurred up to the 14th he adds:—"I shall be anxious to hear whether these earthquakes have travelled from the westward far, but possibly they may have had their origin in this range. This part of Cachar is an area of great contortion and upheaval, where we may expect a weakness in the earthy crust, and a renewal of former disturbing action."

Later on, the 1st February, he wrote, quoting from newspaper reports, that the disturbances were still going on; the earth hardly ever seems firm; a constantly recurring tremor is very perceptible, and very disagreeable. The river Barak is stated to have flowed back for an hour, and near Sylhet to have been so lessened in depth that boats now navigate with difficulty. The earth opened in many places, swallowing up trees and houses; mud and hot water were thrown out of fissures; large areas have sunk, others have been raised. Near Cachar a village has been left on a slope where a long line of low hills has been formed. (I quote the writer's own words, as an excellent instance of how greatly exaggerated, and therefore absolutely unfounded, statements, made on the merest hearsay evidence, become part of the records regarding such phenomena.) His letter then concludes:—"It will be most interesting to find out how the levels of the country have been altered. I feel certain that great changes have taken place in the peaks. I am getting together all the data," &c., &c.

We may at once state that there has not been a shadow of evidence obtained to show that any change whatever has resulted in the general levels of the country. The local breaks, fissures, slips, falls, &c., were all merely secondary results of the disturbance, and produced no effect on the general relative surface of the country. To this we shall have to refer more fully again.

The Meteorological Repoter to the Government of Bengal, Mr. H. F. Blanford, in bringing together a tabular summary of the returns received by the Government, gave a brief but very interesting sketch of the phenomena so far as the information received enabled him to do so. He discusses some of the papers noticed above, shows clearly that Captain Godwin-Austen's inference as to the line of origin and its position, although in itself not improbable, required more evidence to warrant its acceptance. He points out the remarkable discrepancies between his statements as to the direction of the motions and the general conviction in Cachar, as obtained by Mr. Leonard, and justly remarks, "A careful observation of its effects on buildings, &c., will probably enable a more satisfactory opinion to be formed as to the progression of the earth-wave." He notices how easily the direction may be supposed to be, and stated to be, directly opposite to that which actually obtained. He briefly discusses the rate of the horizontal transmission of wave, and shows that as indicated by the observation at Asaloo, taken in connection with the time of stoppage of the astronomical clocks in the Surveyor General's Office, Calcutta, this rate would appear to be vastly greater than that of any earth-wave recorded, and while showing that this was highly improbable, he adds "it must be admitted that the data on which the calculation is based are at least as trustworthy as those of any earthquake quoted by Mr. Mallet," an assertion which certainly "requires confirmation." He proceeds to notice the geographical position of Cachar in relation to the great volcanic band stretching from the Sunda Islands to the east of the Andamans.

Mr. Blanford then refers to the structure of the surface in Cachar, &c., to show that the disturbance of the ground there was due not solely to the comparatively greater violence of the shock in those districts and their proximity to the centre of the disturbance, but in part also to the geological character of the surface rocks in these tracts, and notices also the remarkable similarity of these so-called sand-craters, earth-cracks, &c., to the results produced by the great Calabrian earthquake of 1783. And he also notices the absence of any peculiarity worth notice in the state of the atmosphere at the time or just previous to the earthquake. This report was dated the 13th March 1869.

In the *Christian Intelligencer* (Calcutta), Vol. XXXIX, April 1869, there appeared the most correct and trustworthy notice of this earthquake that I can refer to. The physical reasonings are sound and just, and the whole is characterised by that full appreciation of the facts which we should have expected from so distinguished a mathematician and physicist as its author, the late Archdeacon Pratt. He came to the district in the course of a visitation of that part of the diocese, and he gives the following notice.

Several indications were seen in passing up the river of the severity of the earthquake, but nowhere are they so strong as at Silchar itself. The church was nearly completed, but now the tower is a heap of ruins lying at the north-west angle. There is a piece of brick masonry

5 feet by 7 and by 9 which belonged to the tower, and now lies in one solid mass under a tree to the north-west, unbroken and without a crack, showing how excellent the masonry was. This mass fell and completely rolled over, for there are in it the remains of the top of a small window now upside down. The position of the ruins of the church tower, *viz.*, to the north-west, shows that the shock must have came from that quarter. The base of the tower would be evidently and abruptly carried towards the south-east, and, so to speak, leave the top to itself to fall over towards the quarter from which the shock came. In fact, a gentleman who saw it fall states that he saw it lean over to the north-west, a large crack occurring on the opposite side, that the crack collapsed, and then on a second wave coming the upper part of the tower, thus previously loosened from the lower part, fell over in ruins. Pieces of the tower fell on the chancel roof and the east end of the nave roof, and broke them both through. The roof is not of an expensive kind and can be replaced at a small cost. The Archdeacon has applied to Government to repair the two roofs, clear away the ruins at the base of the tower, and build a vestry in its place. He pronounces it to be the most elegant church he has seen in Bengal, and admirably built. Its walls are solid, lofty, and well buttressed; not a crack is to be found throughout them. The roof is of bamboo thatch, supported by elegant trusses, and is very lofty. In the older burial-ground, the gate and a new marble tomb have been completely thrown down. In the new cemetery, a most picturesque spot, no damage has been done.

The most striking permanent marks which the earthquake has left of its violence, besides the church tower, are to be seen near the river where the ground on being divided by the undulation into large parallel masses separated by cracks and ravines, did not resume its position from want of pressure on the river side to carry it back. The ravines still stand open. There is a tract called the Peninsula, round three sides of which, two longer and one shorter, the river flows. Here the ground is cut up excessively in this way. The line of ravines is north-east and south-west, showing that the undulations must have moved in the north-west and south-east, or in the south-east and north-west line, as the general run of the cracks would, of course, be perpendicular to the direction in which the wave moved. The ruins of the church show that it was the former. A sight of the peninsula gives a miniature view of the effects often seen in mountainous tracts of the breaking up of the earth's crust in former epochs by whatever cause. You see a series of (so to say, mountain) ridges parallel to each other, one side in each sloping up gradually, and the other, where the fracture took place, going down abruptly, and so of each in succession. The phenomenon, too, of what is called in Geology an anticlinal line, was distinctly visible in miniature, that is, the change of direction of the slopes, as it were, on that line of fracture there had been a greater force from below than on any other. There are still numerous accumulations of the slate-coloured mud or sand which oozed up through the cracks. It is said that Professor Oldham has taken specimens to Calcutta to have them analysed.

The bazaar is the scene of great havoc; and in the fish bazaar, or *haut*, between it and the river, the surface is gone down 40 feet or more. It is expected that when the rains set in, this and other parts will be under water, which have hitherto stood clear. The earthquake occurred at a time when the fish *haut* is generally crowded with natives. But it is said that on this occasion it was singularly unfrequented, a circumstance attributed to a panic which had seized the people that they were that day to be pressed into service as coolies for an expedition against the hill tribes, of which they already seem to have seen the probability. But for this many might have been killed in the crowd, heaped upon each other by the suddenly formed precipice of 40 feet in the midst of the space.

I have now given at some length every notice of this remarkable earthquake which I am aware of. I have done so with the object of showing how little even the most detailed of these notices afford of any data on which to base accurate conclusions as to either the nature, the direction, or the force of the shocks. With the exception of the reasoning of Archdeacon Pratt from the direction of the fall of the church tower in Silchar, there is scarcely a fact noticed which gives a clue to this direction based upon any thing more than conjecture or the rudest observation. Even the few facts which have been stated have led to erroneous conclusions, as it appears to us (the fall of the heliotroper in Sherfaisip for example), and when conclusions have been attempted to be drawn as to the rate of motion, the two entirely distinct and separate motions of the wave itself in translation, and of the particles of the mass affected by this wave, have been confounded.

One thing, however, remains clearly established, that a very serious shock or shocks did pass through the area; and that these were sufficient to destroy, or partially to injure, the most permanent buildings in parts of the area affected, and did result in certain very marked and serious disturbances of the surface of the earth. It was then the task set before me to see how far from these results it would be possible to reason back to the nature, position of origin, and force of this great wave or waves.

CHAPTER III.

THE EARTH FISSURES AND SAND CRATERS AND THEIR ORIGIN.

By far the most remarkable result known of this earthquake was the production of great fissures in the surface of the country, and the sinking of the ground over a very large area. This phenomenon was not confined to any special locality, but has been found to extend for many miles, showing a varying degree of intensity.

Almost immediately on entering the Soorma River the fissures in the banks became noticeable, and they gradually increased in intensity in proceeding up the river. These fissures were entirely confined to the newer alluvial deposits, what are called by the people of the district the *bhurti* lands, or 'filled in' lands; no trace of them being visible in the *kandy*, or old lands of the river valley, except indeed at the junction of the two where small portions of the latter in one or two places seem to have fallen in on the support of the others being removed. In every one of the many curves which the Soorma and Barak make below Cachar, and for scores of miles, these fissures might be observed, greatest near the river bank, but extending for miles across those peninsula-like extensions of the river flats, which have been formed by the river as it gradually worked further and further away from its original course.

In passing up to Silchar from Naraingunge, the effects of the earthquake became noticeable almost as soon as the steamer entered the defined channel of the Soorma River; there the high grassy banks, which formed either side of the river, were in many places cracked in long continuous and slightly open fissures, from which the lower portion had slipped down, not far but sufficiently to produce a marked, though slight, scarp in the bank. These cracks were seen along every reach of the river, notably along such as ran north and south or approximately so, and increased in intensity and number steadily as we progressed in the very winding and ever changing course of the stream towards the east. At Chattuck the steamer stopped, and there being no sufficient water for steamers higher up than this, I took to small country-boats. This enabled me to watch the effects more fully than I could otherwise have done, by getting out every day and following up the banks as the boat proceeded. Some of the long north and south reaches of the river afforded most remarkable instances of these winding fissures and dislocations of the banks, continuous cracks stretching away for more than half a mile, often 2 feet or more in width, open for depths of 8 feet, but they had all been partially closed by the falling in of the sides. These in places produced steps or irregular terraces along the sides of the banks, often marked by the disturbance which affected the scattered trees which had been growing on the sides and which had of course sunk with the earth in which their roots were imbedded. About here I could find no other injury that was done; the trees were said to have swayed visibly, some few came down, and the people were much alarmed; but beyond this little more,—they all ran out of their houses and of course cried at the tops of their voices, so that it was not likely that they would have heard any distinct noise which may have occurred. One rather more intelligent than the rest describes himself as being alone, away from the village and other people; he was nearly thrown down, but was just able to preserve his balance; he described a wave as coming up from the east before or almost accompanying the shock, which he described as marked with successive noises *ooom moom moom* like the roaring of an enraged bull. He was on the high bank of the river, and saw the earth open before his eyes in three long fissures and suddenly sink down for 5 or 6 feet, and asserted that this occurred with the first great shock, after which the second only led to a greater settlement of the disturbed mass, but to no more actual fissuring. Even in the high flat top of the bank, all cultivated ground, fissures could be traced within 100 yards from the edge of the bank. Hitherto I had seen nothing to account for this fissuring, but that the banks of the river were unsupported at the time in consequence of the river being at low water-level; all the fissures arranged themselves roughly parallel to the course of the stream and bent round with its course though they were not so visible when that course went in a direction approximately east and west, and it was clear that the true reading of the enigma was that the bank having been supported on the one side and unsupported on the other had given way when the wave or shock came. But as I advanced up the stream, and the bed of the river became more sharply cut into the mass of clay and sand on either hand, the cause of all this disturbance became evident enough.

Probably the point, in the river, at which these disturbances became most marked was just where the river divides into the Soorma, which flows down to Sylhet and the Barak or Koosteara, which keeps on to the south, and after winding in long sweeping curves through the flats of Sylhet enters the Brahmapootra. The stream here curves round nearly

Fig.1. Side view of Church.

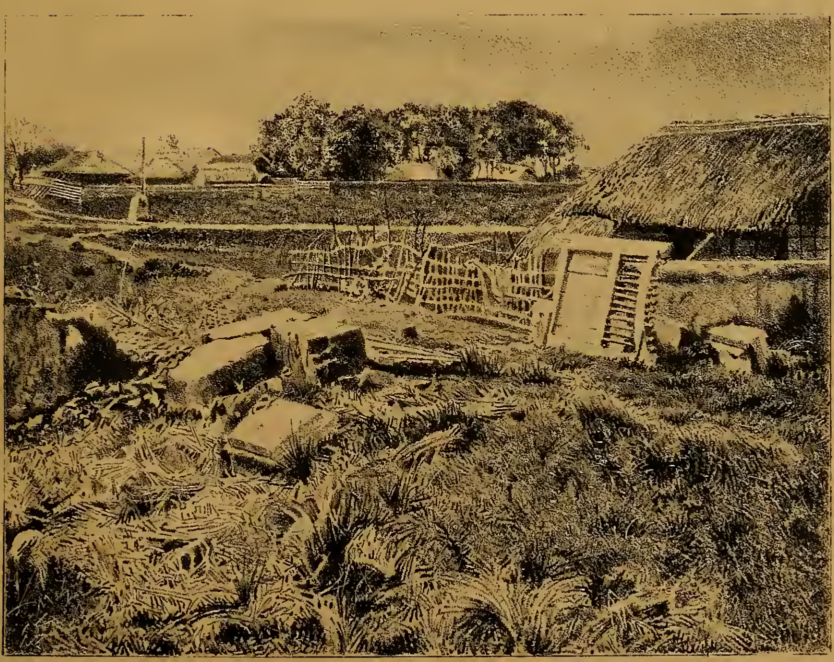


Fig. 2. Gateway of Cemetery.

at a right angle, in the winding course of which the Barák leaves it; the banks just at the point of junction are bold and lofty, while in general below the end of the Barák River they are lower, as is also the ground on the east of the curve. Here the left bank of the river had been shaken down, forming an almost precipitous face of more than forty feet in height, while the ground round the curve had also been separated and had slipped into the river in two rather long slices; the strong current sweeping along and against the left bank had, before I reached the place two months after the shock, removed the greater part of the fallen mass, but the portions which had fallen formed two small ridges, a few points of which were still above water, and on which the current was beating, with channels between. These great masses of fallen matter in the bed of the river had produced strong eddies and whirling currents, and it was with the greatest difficulty that the boatmen after a good deal of exertion, and only by getting out towing lines, succeeded in passing the boat up in safety.

Here for the first time the immediate cause of all this ruin became evident. Just at the water-level, and under a thickness of more than 40 feet of varying clays and sandy clays, was seen a band of soft and slimy, peaty stuff charged with ferruginous water, which oozed out on the edge of the cliff; this rested on, and was in fact mixed up with, a layer of fine arenaceous sand, which when wet and saturated with this black slimy water is dark coloured and nearly black, but which on drying became of a light blue colour; the whole bed is but little more than 3 feet thick. That the easy and unequal yielding of this soft slimy mass under the pressure of the heavy beds of clay above was really the source of the mischief, was very evident, because under this the recurring stiff clays formed a regular shelf sloping down to the water, but perfectly sound in places where the slips had been developed in the most marked way. In one or two small patches, before going thus far, I had been able to trace the existence of some such bed as this, and in other places the occurrence of a deposit of this light-bluish sand in the cheeks of some of the cracks had led me to suspect that it must have come up through the fissures and indicated the existence of some yielding layer below, which had been forced up by the pressure of the more solid beds above; but here the sand was disclosed. Just at the lowest level of the water, stretching for some hundred yards along under the bank, was this 3 feet of soft slimy peaty sand, oozing out its dark chalybeate water and slush.

Although the great mass of the cliff, which had been split up, had already come down and was being rapidly eaten away in the whirling current of the stream below, small flakes, as it were, were still hanging almost overthrown, and by applying a stick to one of these the whole theory of the motion became evident; after a few minutes' poking along the crack behind a solid mass, probably weighing on the whole a ton, it became sufficiently disturbed to be started by a very slight additional push. In a moment all that had been quiet before was suddenly broken up; the instant the support of the mass, by attachment to the bank behind, was separated, its unsupported weight bore upon the soft beds and it came down with a rush; the foul water and slimy stuff, mixed with sand, was spouted forth in forcible jets, covering one completely with its filthy stains and, almost before the motion could be noticed, the piece of clay above had settled down some 3 feet from its former position; this motion gradually continued in a slip or sliding motion till slowly the whole glided into the water of the river, and was at once subjected to all the degrading forces of its currents and whirls. A breadth of bank of at least 50 feet was stated to have gone into the river here, leaving an abrupt sheer precipitous cliff of more than 50 feet high. Just at the margin of this stood a fakir's hut or rather hole, and of course the man had traded largely on the wonderful evidence of his holiness which the fact afforded, that up to the very edge of his abode, but no further, had the fierce elements been able to wreak their destructive will. The horror with which he watched my little efforts to study practically the effects that had taken place by endeavouring to detach the already half-separated little mass which I threw down, and by so doing of course to that extent weakening the chance he had of being left in security, may be imagined, and though I did not see it at the moment, fully accounted for the violent curses and objurgations he called down upon my devoted head. After I had completed my trial, I climbed the banks and examined the country above; and I by no means assuaged the fakir's wrath by quietly indicating with my stick the existence of several commencing cracks inside his abode. I said nothing; but it was clear that his abstraction in his holy duties had by no means closed his eyes to the facts, and that he was fully aware of the force of the warning he had received; for I found that while he had been driving a roaring trade in mulcting every boat which passed of the richest offerings and other alms he could obtain, he had also been quietly making arrangements for removing his abode to a more secure locality, and I have no doubt that the part of the cliff where he had his wretched hole is now in the river.

Before passing on, I may as well state here that all the disturbance caused by the great mass of clay and earth which had fallen into the river, and the whirling currents and eddies resulting from this disturbance, which was stated to have been for some days so great as entirely to prevent the passing of boats at all, and which, even after the lapse of two months, was such as to require the best efforts of the boatmen in the small boat which did not draw more than 2 feet of water, extending over more than two hours to enable them to overcome, had ceased before I returned down the river in about a week's time and the stream had, by the gradual removal of all the debris, and its being carried down the stream and deposited elsewhere, resumed its normal or nearly its normal condition. The wide stretch of loose sand just opposite this sudden curve in the river, where the Barák diverges, shows clearly that the cutting back of the bank there has been progressing for many years.

There could be no trustworthy evidence derived from the direction of the fissures and cracks as to the direction of wave-motion for the reason that the action had been exerted on masses well and effectively supported on one side against the bank and without any support on the other, and so long as the motion was sufficient to produce a separation of the mass by cracks at all, these cracks or fissures must have followed the line of least resistance and must therefore necessarily have been nearly parallel to the face of the bank. Though from this cause the direction of fissuring varied from north and south to nearly east and west, it was here evident that the main lines of motion must have been in some line between east and north, or even, to note it more particularly, between north-east and north.

* * * * * *

One conclusion pointed out in the foregoing pages cannot be too strongly insisted on, and even at the risk of wearisome repetition, I will say that nothing is so conclusively shown, or so certain, as that these great earth-fissures and cracks were in every case purely secondary results of the earthquake shock; there being no reason to suppose that an earthquake shock can, but on the contrary every reason to suppose that it cannot in any case, by its direct action, open fissures in solid rock or clay.[1]

In order to make the mechanism of the formation of these fissures clear, I will first take the case in which the beds overlying the soft yielding stratum, already mentioned, may be supposed to be perfectly homogeneous, and the direction of the wave-path in azimuth, normal to that of the river bank. As the wave passes on its way, the particles of clay are forced, first forwards and upwards, and then return backwards and downwards to their original position; but as the vertical movement takes but little part in producing these earth-fissures, we may for the moment neglect it and only consider the effects of the horizontal motion impressed on the particles of clay. We may take it then that the belt in which the particles of clay are in motion at any one moment, under the influence of the earth-wave, is divided into two equal or nearly equal zones, in the first of which the particles are in motion forwards while in the other they are moving back; and as the

[1] For a discussion of this same point, Refer Quart. Journal Geological Society, London, Vol. XXVIII, p. 255, 1872.

motion in each case is away from a median plane, the momentum of the two zones, acting in opposite directions, tends to rupture the mass along that plane. But the action of this momentum is modified and restricted by three distinct causes: firstly, the molecular cohesion of the clay; secondly, the inertia of the motionless masses of clay in front of and behind the zones of motion; and thirdly, by friction on the sandy bed below. As long as the wave is at some considerable distance from the river's bank, the resistance offered by cohesion and inertia is sufficient to restrain the force of momentum and prevent the formation of fissures; but as the wave approaches the bank, the force of momentum remains, up to a certain point, unaltered, and of the various resistances, that of cohesion remains constant, that of friction may be neglected for though varying somewhat, it is always comparatively insignificant, but the inertia of the mass of motionless clays between the front of the anterior zone of motion and the river's bank diminishes as the wave approaches the latter, until at last it disappears just as the front of the wave reaches the river's bank; at this instant the momentum of the zone of forward motion is undiminished, the resistance of inertia has disappeared, and it is only resisted by cohesion and friction. As soon, however, as this critical moment has passed, the momentum begins to diminish as the motion of the wave particles is dissipated at the surface of the river's bank, and the strain rapidly diminishes till, when the central plane of no motion reaches the bank, it vanishes entirely; after this, as the momentum of the second or hindermost zone is away from the river, there is no tensional strain, and no tendency to fissure.

By consideration of the above remarks two conclusions are evident: firstly, that fissures will only be formed along the plane of separation between the two zones, and secondly, that the strain tending to produce rupture is greatest at what I have called the 'critical moment,' at which moment the plane of separation, in which the particles have attained their maximum forward excursion, or in other words the 'crest' of the wave, is distant from the river's bank by the thickness of one of the zones of motion or one-half the whole 'length' of the wave.

If the force of momentum be only just sufficient to overcome the resistances of cohesion and friction, only one fissure will be formed, and that at the critical moment and at a distance of one-half the length of the wave from the river's edge; but if the momentum of the zone of motion towards the bank be more than sufficient to overcome these two resistances, it will be able to overcome the inertia of a certain mass of clay in addition, or else it may suffer a greater or less reduction before it ceases to have the power of overcoming them, and in that case fissures will be formed both nearer to and farther from the river's bank than the main fissure or fissures, which will always lie at one-half the whole length of the wave from the river's edge.

As the wave passes on its way, the motion of the particles is extinguished by the breach of continuity caused by the river bed; but though the motion is thus extinguished in the superficial stratum of clay, the impulse, being of deep-seated origin, passes under the bed of the river and emerges on the opposite bank, where motion is once more communicated to the superficial stratum, and the train of phenomena is just the reverse of what happened as the wave approached the river. At first the motion of the particles is away from the river, and consequently there is no tendency to fracture in the mass; but as the wave progresses, the particles of clay begin to move backwards, and a strain is set up, as when the wave approached the river, which gradually augments till it reaches its maximum as the rear of the wave just reaches the river's edge, the critical moment in this case, and then diminishes. The same reasoning and considerations which applied to the case of the wave approaching the river apply to that of its passing away from the river, the position of the main and secondary cracks being in every way similar.[1]

The explanation given above may perhaps be rendered more intelligible by a reference to Pl. VI, fig. 1, taken from the Quarterly Journal of the

[1] Though this is qualitatively it is not quantitatively true, the upper stratum not being able to take up immediately the whole motion impressed on the lower clays, owing to the intervention of the soft yielding bed of sand, and it is the vertical motion—that which has least effect in producing these fissures—which would be most rapidly acquired.

Cf. remarks on angle of emergence and velocity of wave particle at Silchar, pp. 68, 71.

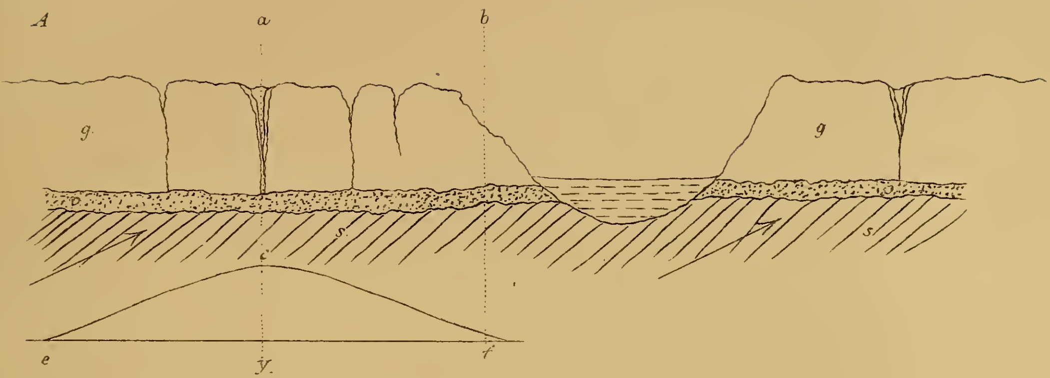


Fig: 1. Diagram to illustrate the formation of Earth fissure

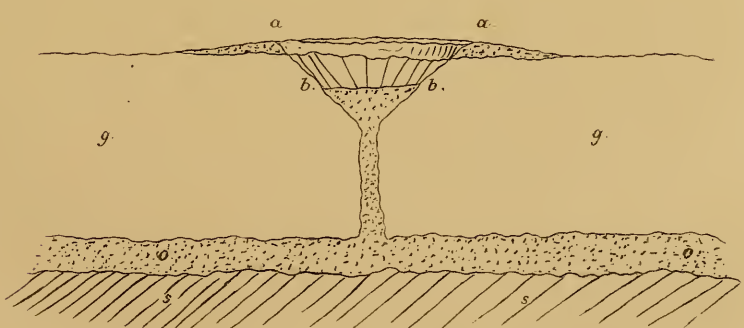


Fig: 2 Diagrammatic section of a sand crater.

Geological Society, Vol. XXVIII, p. 264; in it *s s* represent the lower strata of clay, *o o* represent the bed of sandy ooze lying on them, and on it lie the upper clays *g g*, in which the fissures were formed and through which the river bed is cut, the arrows serving to denote the direction of wave path. The line *e f* is meant to represent the length of the wave, while the ordinates of the curve *e c f* show graphically the relative amounts of motion of the particles from their normal positions, in the various phases of the wave, starting from zero at *e* gradually reaching the maximum at *c* and then diminishing to zero at *f*; in the semiphase represented by *f c*, which is the first semiphase, the particles are all in motion forwards, while in the semiphase *c e* the motion of the particles is backwards, in both cases away from *c*, at which point the particles are momentarily at rest, and which represents the 'crest' of the wave, along which the fissures are always formed. In the figure the wave is supposed to have reached that point at which the internal strain is greatest and the resistance least, here the front of the wave has just reached the river bank at *b* and the 'crest' of the wave is at *a* distant from the river's edge just half the length of the wave.

As yet we have only considered the hypothetical case in which the clays are perfectly homogenous and the direction of the wave-path is normal to the river bank; but as this can never be the case in nature, the fissures can never form mathematically straight lines normal to the wave-path, but will vary indefinitely from them. The first and foremost cause of this variation is of course that want of homogeneity which must be found in the clays forming the banks, in consequence of which the fissures will be formed along planes of weakness which need not be coincident with what would have been the planes of fissuring in a perfectly homogenous mass, thus giving rise to the irregularity and often branching or inosculation of the cracks as found in nature. Again if the wave course is not normal to the course of the river, the fissures will not be formed normal to the wave-path, but will tend to arrange themselves more or less parallel to the river course, and in this case any want of homogeneity in the clays will cause an irregularity in the fissures as great or even greater than where the wave is normal to the river banks.

The effects above described are produced almost, or quite, entirely by the mere throwing off of masses of clay, and the influence of those resistances tending to restrain the motion of the independent masses of clay have not been considered, except so far as they offer a resistance to actual rupture. We may assume that the effect of the momentum impressed on the clay is the same as that of a single force, equal to it in intensity, and acting at the centre of gravity of the detached mass, in the direction of the wave-path; if then the resultant of all the resistances passes through this same point, the centre of gravity, the mass will be thrown off without any tendency to overturning and the surface of the detached portion will retain its horizontality; but if, on the other hand, this resultant does not pass through the centre of gravity a dynamic couple will be set up tending to overturn the mass, the amount of overthrow being determined by the moment of the couple and the resistance of the contiguous masses of clay against which it may be thrown. To this cause, combined with the actual fissuring of the ground, the wildly broken and chaotic appearance, so strikingly shown in Pl. II fig. 2 and V, fig. 2, is due, which on examination is seen to be entirely owing to the fact that each separate portion of clay is more or less overturned on its base.

Having thus disposed of the earth-fissures, we may now turn to another very remarkable feature, likewise a mere secondary effect of the earthquake, and, like the above-mentioned fissures, due to the existence of a soft waterlogged stratum underlying a thick series of impermeable clays, and like them never found where this soft stratum does not occur, though not always found when it is present. The feature referred to is the production of the so-called 'volcanic mud craters,' about which there is nothing volcanic, being produced entirely by the washing down of soil by water, previously forced up by the earthquake shock, and which after the passage of the shock once more recedes. The action by which the water is forced up is two-fold. In the first place there is set up in the soft yielding bed of ooze a molecular motion precisely similar to that of the clays above and below, in virtue of which there are established two zones whose momentum drives them in opposite directions; and as the ooze is comparatively free to yield to any strain set up in it, the water contained in the bed, both in front of and immediately behind the wave will be subjected to an augmentation of pressure, and so the flow of a natural spring is increased, or in the case of an artificial well the level of the water rises and may even, if the water stands near the surface, rise above the level of the ground and overflow. But though this undoubtedly does take place to some extent, it may be, and in this case was, masked and eclipsed by a far more powerful action yet to be described. As the wave travels along, the lower clays are rapidly pressed upwards, and neglecting the horizontal component as not producing any effect in this case, the thrust is conveyed through the semi-liquid ooze to the mass of clays above, whose inertia prevents their rising at once, and so a sudden and tremendous pressure is brought to bear on the water-logged ooze; at the same or almost the same instant cracks are opened in the superincumbent mass of clays, and through these cracks the water is immediately forced out if the pressure is sufficient. But such a large quantity of semi-liquid matter, when once in motion, possesses a very considerable momentum and therefore cannot be suddenly brought to rest; so that, though the pressure due to the passage of the shock is but transient, the effects endure after it has passed away, the water still continues to rise in the fissure, and if it rises high enough will pour out on the surface. Further if, while the fissure is still full of water, the effect, whether primary or secondary, of the earthquake causes its sides to approach each other they will exert a pressure on the water contained in the fissure quite independent of that on the water-bearing bed, and thus the water will be forced to rise and overflow to a still greater extent. It can easily be understood that if the water-bearing stratum was impregnated with decomposing organic matter, this opening of connection with the surface, and forcing up of liquid matter, might be accompanied by the evolution of large quantities of gas which carrying with it spray and dust might, viewed through the light of a vivid imagination, produce all those appearances of fire, smoke, and sulphurous vapours which have been so often and so graphically described.

All these causes above described, however active and however powerful, are essentially transient, and soon the normal pressure is re-established in the water-bearing stratum; the water which has been forced up immediately begins to rush back, carrying with it the edges of the fissure at which it escaped, and ultimately leaving a funnel-shaped opening, either single or grouped with others, which is in fact the so-called 'crater.'

In the case of this shock the matter forced up was not pure water, but water charged with sand, a circumstance which has produced some important modifications in the aspect of these openings. Instead of the crack or opening through which the sand and water rose being left comparatively open or only choked by the debris of its sides, as soon as the current began to slacken there was deposited in and around its mouth a quantity of sand which has modified, and to a great extent reduced, the action of the water in rushing back again; the sharply washed and furrowed aspect produced by the water is only visible near the top of the aperture where the sand has been washed down, while the bottom, instead of narrowing down almost to a point, is broad and nearly flat, though slightly hollowed; this feature being produced by the filling up of the fissure with sand, through which the water filtered back as through a filter bed. The nature of these craters is shown in pl. VI fig. 2; *a a* represents the raised rim of sand, sloping gradually outwards, which is deposited round the mouth; from *a* to *b* represents that portion whose aspect is due mainly to the wash and scour of the water rushing downwards, and which is at most merely coated with a film of sand; the strong lines from *a* to *b* are continued downwards to show what would probably have been the form, had there been no sand forced up, while the slightly curved line connecting *b b* is the cross section of the actual base as found; below is the column of sand through which the water was returned to the bed *o o*.

The various appearances presented by these so-called craters, due to their combination in various ways, are well shown in the photograph [1] Frontispiece and Plates XI to XIII, which are reduced from those taken on the spot by Mr. Pearson of Silchar. The simplest case is shown in the Frontispiece; here there is a single, nearly round crater, the sloping bank of sand surrounding it is very distinct, and in it to the right of the picture a breach will be noticed; within this come the steep water-washed sides of the hollow, losing themselves in the nearly flat but slightly concave floor of sand, which has cracked in drying; in the same plate there are shown some other simple pits, one of which, it will be noticed, is surrounded by a very marked rim of sand. It is impossible to look at this photograph and the figures of the round ponds produced by the Calabrian earthquake of 1783, as given by Lyell in his Principles of Geology, without being struck by their resemblance; in fact, only fill the hollows at Cachar with water and the two are identical. This filling with water may be due to either of two causes, either the water may not completely drain out of the hollows, or it may do so leaving a more or less water-tight floor on which rain water could collect. The phenomena represented in Plate XI are rather more complicated, two 'craters' having run together and produced an irregular hollow. In Plate XII it will be seen that a number of vents have been formed, evidently along a line of fissure, and have more or less coalesced; while Plate XIII shows no distinct vents; but the sand and water has been forced out from a continuous open fissure, and this further shows the form of sides which is formed by the sand deposited from the ejected matter, there being only here and there any traces of those appearances produced by the washing down of soil by water, the whole presenting a much smoother and more rounded appearance than is the case in any of the other views.

[1] The vertical cliffs seen in these photographs represent one side of the fissure through which the sand &c., was forced up, the other having sunk; they are only 1 or 2 feet high.

In the foregoing pages I have endeavoured to show that, though these apparently vast and striking phenomena are in a certain sense due to the earthquake, they are equally due to the presence of a bed of oozy sand overlaid by a thick bed of clayey alluvium; the one being as important a cause as the other, but neither capable of producing the known results without the intervention of the other. Vast, however, as these effects appear, they are in reality insignificant, mere scratches in the paint of the earth in whose history they will leave no permanent record. Hundreds of acres of land may be broken up, thousands of tons of earth may be precipitated into the river, and for days and weeks, or even months, the stream may boil and foam through the wreck, carrying ton after ton of earth away in its turbid stream, but only to be deposited once more lower down, or even in its ultimate destination, the sea. Time, however, will put an end to all this disturbance; soon the river course will be cleared and once more the river will flow as placidly as ever; wind and rain will break down the sharp edges of the overturned masses, will fill up the cracks and holes, and in a few years at most the surface will be as smooth and as luxuriantly clad with vegetation as ever it was before the catastrophe. Indeed, so far from wondering at the wreck and ruin caused by this earthquake, we should rather wonder that no traditions exist of similar ruin produced by former earthquakes; for we know that before now earthquakes at least as violent have originated from the same region; and as the other determining cause, the existence of a soft yielding bed, has always been present, it is wonderful that we should have no record of such a striking phenomenon as would assuredly have been exhibited.

CHAPTER IV.

THE POSITION AND EXTENT OF THE SEISMIC VERTICAL.

The determination of the actual position of the seismic vertical, or that portion of the earth's surface over which the shock had a vertical emergence, is not in itself of great importance; yet, as a knowledge of its position is necessary for the determination of the depth of the focus and other points of great interest, it becomes a matter of much importance that we should be able to fix its position with accuracy.

In the case of this earthquake we cannot, unfortunately, obtain such a large number of observations mutually confirming each other, as was the case in the great Neapolitan earthquake of 1857, which has been so ably described by Mr. Mallet; but when we consider the circumstances of the case, it is not surprising that the number of trustworthy observations is so few. In the first place, there was not the same number of towns with their concomitants of numerous buildings whose injuries would point out the direction of wave-path. The native huts being wretchedly built, and mostly of mats, could give no evidence at all, and the masonry or brickwork buildings, which could give any indications of value, were few and far between. Then, again, the disturbed state of the country, which allowed of but a small portion of the seismic area being visited, combined with the fact that at the point nearest to the seismic vertical which could be visited, it was nearly 50 miles distant;—all tend to diminish both the quantity and the quality of the evidence obtainable.

But as no one now doubts that an earthquake is a wave of elastic compression originating in a definite region, and spreading from it through the crust of the earth, we no longer require a great weight of evidence to prove the existence of a seismic focus and a seismic vertical; and consequently the few observations obtainable, which certainly agree very well with each other, will be sufficient for the present purpose.

Before tabulating the observations and pointing out the position of the seismic vertical, I shall discuss some of the observations which have as yet been only casually noticed or omitted altogether.

In the first place, I shall take the sawmill at Kochela, a sketch plan of which is given on Pl. VII; at the first glance it would seem as if the direction here had been N. 40° E., being the direction in which the piers of the side walls have been thrown. A comparison of this with the observations at other places, and a more careful inspection of the plan itself, throw much doubt on this conclusion. In the first place if the direction of wave-path had made so obtuse an angle with that of the end walls it is difficult to believe that they would have fallen so directly outwards without the slightest obliquity; but if we imagine the shock to have come from the north, or slightly west of north, a direction which would accord with the observations elsewhere, this difficulty disappears, and further the apparent anomaly of a very instable body being overthrown towards a point from whence the shock could not possibly have come is explained. Supposing the direction of emergence of the wave to have been from the north, it would make an angle of about 30° with the direction of the side walls; this would, of course, tend to make the walls rock in a north and south direction, while their shape and position would cause them to rock easiest east-north-east and west-south-west, the actual direction in which they swung being compounded of these two motions; the obliquity of the shock prevented its overthrowing the walls during the first semiphase but if the wave-period corresponded at all with the period of vibration of the wall as an inverted pendulum, its swing would be increased during the second semiphase; and this, combined with the already weakened state of the wall, would throw it over beyond possibility of recovery; the diagonal swing induced by the action of the earthquake-wave would have loosened the bricks, and so the fact is accounted for that the bricks of the side walls were all separated while those of the end walls still adhered to each other, though the wall as a mass was fractured in its fall. The end walls being much nearer normal to the direction of the shock were overthrown with greater facility, though there is no evident reason for their being thrown in opposite directions, and not both towards the same point; this was probably due to the presence of the chimney stack at the north-wetsern corner; this stood firmer than the unsupported north-eastern corner and so during the first semiphase the north wall was, as it were, stretched, and so, being to a certain extent deprived of support, was overthrown easier than the south wall where both ends swinging over equally it was more fully supported, and then, gaining impetus during the second semiphase, was precipitated outwards. These considerations show that much

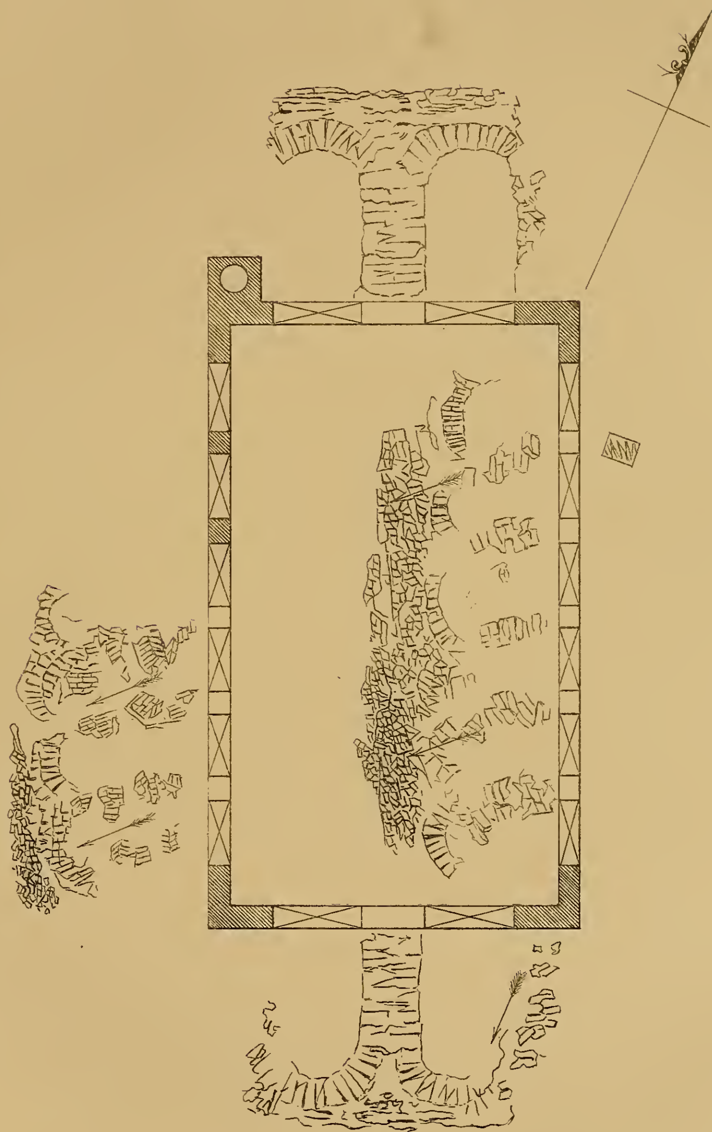


Fig 1. Sketch Plan of Saw Mill near Kochela-Cachar.

importance cannot be attached to any deductions drawn from this building, which I have noticed here chiefly because of its being a curious instance of how misleading what is apparently the clearest evidence may be.

From Sylhet I have drawings of cracks in the church tower, which give a direction of wave-path between N. 26° E. and N. 35° E., the true direction being probably N. 30° E. though the rocking of the tower might produce a difference between the true and the apparent direction of the emergence.

At Yeddo some chimneys were overthrown in a direction N. 30° E., and though their shape may to a slight degree have modified the direction of their fall, it could not introduce any very grave error. The cracks in the native hospital seem to give a much more easterly direction, as much as N. 60° E., but fissures are a much less trustworthy source of information than the overthrow of simple bodies.

At Silchar the direction as given by different bodies varies from N. 12° 30′ E. to N. 12° W.; the latter is that given by the verandah pillars of the native hospital, and is very probably modified by the effects of the heavy thatched roof; but at the same time it must be borne in mind that the same structure of the ground which gives rise to the formation of earth fissures will also to a certain extent modify the direction of the wave-path in the neighbourhood of the river.

Proceeding to the actual determination of the position of the seismic vertical, the first step will be to tabulate the direction of wave-path as observed at the various stations.

CLASS I.

Silchar—					
Mr. Stewart's tomb	...	...	...	N. 12° 30′	E.
Mr. Hunter's tomb	...	...	...	N. 3° 20′	E.
Infantry hospital	...	...	...	N. 6°	W.
			to	N. 10°	W.
Church tower	...	...	...	N. 12°	W.
Sylhet—					
Church tower	...	...	...	N. 26°	E.
				N. 35°	E.
			Mean	N. 30°	E.

Yeddo (the cantonment east of Shillong)—		
Chimneys overthrown		N. 30° E.
Native hospital, cracks		N. 63° E.
Gauháti[1]		E. 12° S.
		E. 17° S.
	Mean	E 14° 30′ S.
Class II.		
Barrackpore...		N. 45° E.
Calcutta		N. 56° E.
Sylhet		N. 22° 30′ E.
Supakatti		S. 5° W.

In the above table I have divided the observations into two classes; the first class contains those which were taken after the passage of the earthquake and deduced from its effects in fracturing or overthrowing solid objects; the second class contains those observations made at the time of the earthquake, and which may be called observations proper as opposed to mere impressions.

On the map No. 1 I have plotted all the observations of the first class in firm lines, and it will be seen that the intersections of the lines, each of which should theoretically fall on some point of the seismic vertical, all or almost all fall close to each other and are spread over an area 40 miles long by 4 or 5 broad; and if we exclude the extremes given by the Sylhet church tower, the direction given by the cracks in the hospital at Yeddo and the directions obtained at Silchar, the intersections are all included in an area 20 miles long by about 3 or 4 miles broad.

Among the observations of the second class, which are plotted in broken lines, that from Barrackpore stands first; it was obtained from the swinging of a chandelier set in motion by the shock. As far as value goes this might well rank in the first class, and it is pleasant to find that a line drawn in the direction indicated falls in the midst of the intersections obtained from the first class.[2]

[1] I do not know the source of these observations, merely a note that such were the directions obtained, the original drawings and description having been lost or mislaid.

[2] This must to a certain extent be regarded as due to chance, for at the great distance of Barrackpore from the seismic vertical an error of a single degree in the observation would make a great difference, and the fact that it is plotted on a map and not on globe would also cause some difference in the true position of its intersection with the other lines.

From Calcutta we have one observation made on the direction of oscillation of the water in a tank; in an observation of this kind accuracy is not so attainable as in the more simple case of a pendulum, such as the chandelier above mentioned, and consequently it is not surprising that the direction given falls some way from the seismic vertical as already defined.

At Sylhet the direction was noted in which the trees were set swinging, and this, when plotted, also falls among the intersections of the first class.

At Supakatti the observation of S. 5° W. evidently does not point towards the seismic vertical; but we must not hastily conclude that this is altogether due to error of judgment, it being possible that the wave was reflected from the eastern portion of the Naga hills, which would give it a nearly north and south direction.

Thus we see that of the observations of the second class two agree well with those of the first class, one fairly well, and one is altogether at variance with them.

To sum up, then, there are 30 intersections of the first class and 6 of the second, in all 36, falling on an area 40 miles long by 4 or 5 broad; but of these it will be advisable to omit those obtained from the hospital at Yeddo and those from Cachar, where the direction seems to have been more or less modified by the proximity of the river banks. The intersections are comprised in an area about 3 or 4 miles broad and from 20 to 30 miles long, running approximately E. 15° N. and W. 15° S., situated in north latitude 26° and east longitude 92° 40″, lying on the northern borders of the Jaintia Hills.

The shock, we may conclude from this, probably originated in a fissure about 20 miles long running underneath the tract mentioned in the last paragraph and at a considerable depth below the surface.

Such is the direct evidence on this point. As regards the *position* of the seismic vertical, it is indeed satisfactory; but as to the shape of the seismic focus, it is incompatible with that obtained from other sources. As the discussion of this point will necessitate reference to matters as yet unmentioned, I shall defer it to another page.

CHAPTER V.

OF THE DEPTH OF THE SEISMIC FOCUS.

As the determination of the depth of the seismic focus, or in other words the depth at which the shock originated, is of great, and indeed primary, importance in the study of seismology, it is to be regretted that the data from which this point can be determined are of the scantiest, a fact which, as will presently be seen, is the more to be regretted since there is great reason for believing that the seismic focus was situated at an exceptionally great distance below the surface.

On account of this small number of trustworthy indications of the angle of emergence, it has been deemed advisable to describe and discuss the observations in a separate chapter, and not in the general description under the heads of the places at which they were obtained.

We will begin by considering the indications at Yeddo, as it is nearest to the seismic vertical, and because there the evidence is most complete and satisfactory. At this station the native hospital, magazine, and several bungalows were more or less severely cracked. The cracks in the native hospital building give an angle of emergence of 38°, but in one of the bungalows this is as low as 30°, the mean emergence being 34° at this station. These observations are quite the best that are accessible, and may be said to be good, as the buildings were well suited for seismometric purposes, and as there does not seem to have been any disturbing element which would augment or decrease the obliquity of emergence at this place.

The distance of the station of Yeddo from the seismic vertical being 46 miles by applying the formula—

$$D = C \tan E.$$

(where D is the depth of focus, C the distance from the seismic vertical, and E the angle of emergence), we obtain the depth of the seismic focus—

for an emergence of 38°

$$D = 35{\cdot}9 \text{ miles.}$$

for an emergence of 30°

$$D = 26{\cdot}5 \text{ miles.}$$

and for the mean value 34°

$$D = 31 \text{ miles.}$$

At Shillong the only building of which I have any drawings or notes is the magazine, which, like that at Yeddo, is a small rectangular building with a low-crowned roof and a sort of porch or ante-room attached, the buildings were unsuited for seismometry, and give no indications of any value.

At Teriaghat, a small village at the foot of the hills on the way up to Cherrapoonjee, the dâk bungalow was cracked; it is a small four-roomed building of rubble masonry, and the cracks show an angle of emergence of about 30°, which would give a depth of focus of 42·7 miles.

At Sylhet the church tower was cracked severely, and from the cracks the angle of emergence is deduced as 38°, which would give a depth of focus of 68 miles; this, however, is manifestly far too great, the obliquity of the cracks having been increased by the form of the tower, which would swing as an inverted pendulum and so alter the direction of the cracks considerably.

From Asalu and Kochela sketches of cracked and overthrown buildings have been communicated by Major Godwin-Austen. That from Asalu is of a guard-house severely cracked, but the cracks are evidently chiefly due to, or certainly very much modified by, the push of the heavy thatched roof of the building; while at Kochela the building, a disused sawmill, was almost completely overthrown, and the small portions left standing do not give any indication of the angle of emergence, though they seem to show that it was small.

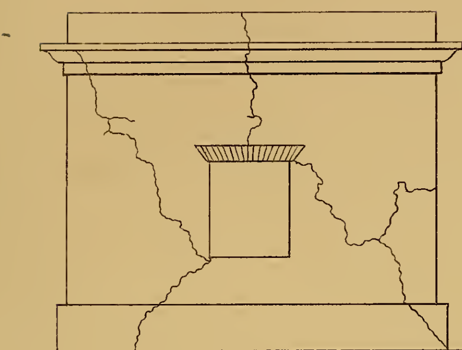
Before proceeding to the discussion of the data at the remaining station, Silchar, it will be advisable to sum up what has been said so far. As will have been noticed, there are but two stations from which observations of any value have been obtained, but as the results obtained at these two stations confirm each other, their accuracy is certainly probable, though a greater number of observations would have been desirable. The altitudes of these two stations above the level of the sea I have not been able to obtain with accuracy, but they are Yeddo and Teriaghat, about ·7 and ·25 of a mile respectively. Reducing the observations to a common datum line, we obtain the following depths of focus:—

Yeddo—Max.	35·2 miles.
Min.	25·8
Mean	30·5
from mean emergence	30·3
Teriaghat	42·7

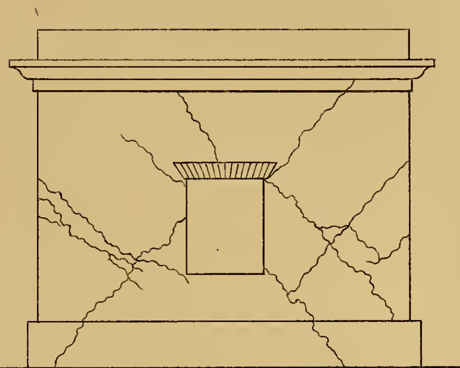
There is, it will be observed, a considerable discrepancy between the observations at Yeddo and Teriaghat; but the distance of the latter place from the seismic vertical would cause any slight error of determination to be greatly magnified. The observations from Yeddo do not, I am inclined to think, give too great a depth of focus, notwithstanding that, if true, the depth in the case of this great earthquake exceeds that of any other which has as yet been investigated. Yet when we consider the vast extent of country over which it was felt, the great depth of focus ceases to be astonishing; for to effect this, not only is a high velocity of wave-particle required, but the focus must also be situated at a considerable depth; for the greater the velocity of wave-particle, the further, *cæteris paribus,* will the wave be propagated; while if the depth of focus be not great, the angle of emergence soon becomes nearly horizontal, and so every inequality of the surface of the ground tends rapidly to extinguish the shock. There are therefore good grounds for declaring that in the case of this earthquake the mean depth of focus was not less than 25 miles, but more probably about 30 miles, and may have been as much as 35 miles.

At Silchar, the evidence as to the angle of emergence is conflicting and untrustworthy,—untrustworthy, as what it gives is not the angle of emergence for that district, but merely an angle of emergence differing from the true one on account of the peculiar situation of that town.

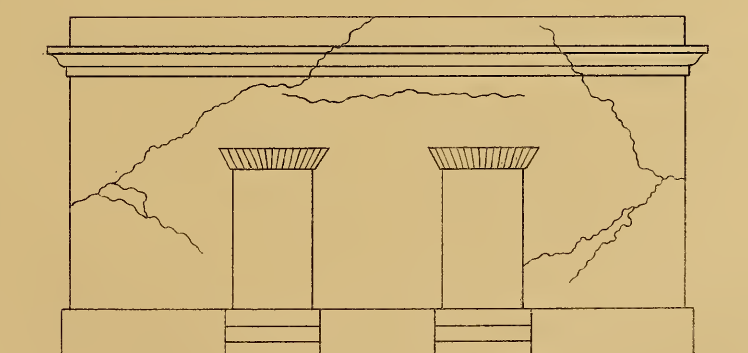
The first evidence I shall produce is that given by the Police guard a small two-roomed rectangular building shown in Pl. VIII. The walls of this building bear N. 5°E., so that the shock was a subnormal one and the angle of emergence, as given by the cracks, is evidently not far from 45°. Now, as Silchar is more than 80 miles from the seismic verti-



West Elevation.



East Elevation.



South Elevation

POLICE GUARD - SILCHAR

cal, this would give a depth of focus of not less than 80 miles, a result not only absurd in itself, but so totally different from that given by trustworthy evidence elsewhere, that it cannot be the true angle of emergence due to the distance from the seismic vertical. What then causes this high angle of emergence?

It will be remembered that in the neighbourhood of Silchar, as elsewhere, where fissures were formed, there was, at about the level of the river, a thin bed of soft slimy ooze, on which lay a mass of clays about 30 or 40 feet thick. Now when the earthquake-wave travelling from the north, came to the river, all motion in the superficial stratum was extinguished, and the shock was propagated through the deeper lying clays under the river bed; but when the river was passed and the wave once more emerged at the surface of the ground, motion had to be transmitted to the upper beds through this layer of ooze. As, however, the clays possessed considerable inertia, and as the ooze could oppose but a comparatively small resistance to change of shape, the full amount of motion could not be transmitted at once, and so the velocity of wave-particle could not, near the river, reach its full amount; further, this ooze, acting as a lubricant, would transmit less of the horizontal than of the vertical component of the motion, and consequently the angle of emergence would superficially and locally be increased. Supposing the motion of the wave-particle to be resolved into two components, one vertical and the other horizontal, and calling the first u and the last h, then

$$u : h :: \sin. \varepsilon : \cos. \varepsilon$$

Now, in the case of an emergence of 45°

$$u = h$$

and in the case of an emergence of 20°, which is close upon the true angle of emergence as deduced from the depth of the focus and the distance from the seismic vertical—

$$u : h :: 342 : 940$$

If we suppose the whole of the vertical component to be transmitted (and practically the portion lost would be small), then, in the alteration of the angle of emergence from 20° to 45°, the amount of horizontal velocity lost, or the amount of slips, would be

$$940-342=598$$

and the proportion of this to the whole would be

$$598 : 940$$

that is, about two-thirds of the whole velocity; so that to increase the angle of emergence from 20° to 45°, the whole of the vertical velocity must have been transmitted, but only one-third of the horizontal, or allowing for loss of vertical velocity in transmission, about three-quarters of the horizontal velocity must disappear by slippage.

This may seen to some rather a wild hypothesis, but I see no other way of explaining the abnormally high angle of emergence at Silchar. There is, however, confirmatory evidence at the station itself; about half a mile to the east of the Police guard stand the church and cutcherry; both were cracked, and though neither of them give very exact indications of the angle of emergence, yet they show it to have been much lower here than at the Police guard, not more than 30°. Thus at two places only half a mile apart the angle of emergence differs by at least 15°. This difference may be explained by referring to the map, plate A. Remembering that the shock was coming from the north, or nearly so, it will be seen that, after passing under the river, it had to travel twice as far to reach the church, as was necessary to reach the Police guard; and consequently in the former case the upper clays were able to take up a larger proportion of the horizontal component by which means the angle of emergence was decreased.

That this slipping of the deeper seated clays under the surface beds took place, is also suggested by the distribution of the earth fissures. As explained in chapter IV, they are caused by the momentum impressed on the clays by the earthquake-wave, and it is there shown that, provided sufficient motion was impressed on the clays, fissures would be formed whether the shock was travelling towards or away from the river. An inspection of the map will show that while almost the whole extent of the northern bank is marked as "much broken" or "great slips here," similar notes are placed against only two places on the southern bank; doubtless the bank was cracked in many places, but only in two sufficiently to deserve notice. These two spots have, both of them, *land to the north*, so that the clays had time to take up a certain amount of horizontal velocity, and the breakage and fissuring were certainly greatest near the bazaar, to reach which the shock would have to travel the whole length of the peninsula. Elsewhere, where the shock struck directly on to the southern bank, the ground is not fissured or but slightly so, showing that there the upper clays have not been able to take up at once any great amount of lateral motion, the lower clays at first slipping under the upper, but gradually more and more of the lateral motion is transmitted, till at last they move once more, appreciably as one mass.

I have put forward these ideas to try and account for the anomalously high angle of emergence, as shown by the Police guard at Silchar; but having propounded them here, I shall refer once more to this subject in the next chapter.

CHAPTER VI.

OF THE VELOCITY OF MOTION OF THE WAVE-PARTICLE.

The same causes which produced a paucity in the quantity of evidence from which we might obtain information as to the other main points of interest in connection with this earthquake have also affected this of the velocity of wave-particle. Fortunately, however, the evidence obtained at one station, that of Silchar, is unequivocal and, as giving a near approximation to the velocity of wave-particle, valuable.

The first piece of evidence which we will examine is that afforded by the overthrown gate-piers of the cemetery, and we will at present confine our attention to the cap of the eastern pier. This, as explained at p. 7, and as may easily be seen by an inspection of the plan, Pl. IX, fig. 2, has evidently been shot off the top of the pillar, and showed no traces of having been shifted from the position in which it originally fell, this being corroborated by the fact that it lies right side up in its natural position not having been overturned. What seems to have taken place in this case is as follows. During the first semiphase of the wave the pillar was, by its own inertia, thrown over towards the north; then, before it had fallen very far, the base was rapidly thrust backwards, and thus a thrust was communicated through the pier to its stone cap, by which the latter was thrown off towards the north or in the direction *from* which the shock came. The next question to determine is the angle that the line in which it was projected would make with the horizon. The line of motion of the top of the pillar would be complicated, for, in the first place, it would be moving in a circle due to the overturning of the pillar, and, in the second place, the movement impressed on it by the earth-wave would tend to cause it to travel in a straight line parallel to the direction of emergence at this point, and its actual line of motion would be produced by the combined action of these two causes. Thus, as far as the motion in space of the summit of the pillar goes, it would tend to throw the cap downwards at a greater angle with the horizon and with a greater velocity than that of the wave-particle; but as brickwork will not permit of the passage of stone through its substance, it is evident that the cap cannot have been shot off at a greater angle with the horizontal than that made by the upper surface of the pillar at the moment of projection. Now during the short time that intervened between the first and second semi-phases of the wave, the pillar could not have fallen over very far, and consequently the upper surface could not have been greatly inclined from the horizontal; further, as there does not seem to have been much adhesion between the pier and its cap, it is evident that the former could not have pulled the latter after it downwards to any great extent, so that little but the horizontal component of the shock would be communicated to the cap. The direction, therefore, in which the cap was projected may be taken as being as nearly as possible horizontal, and its velocity as that of the horizontal component of the velocity of wave-particle.

Taking the body as projected horizontally, and calling b the vertical

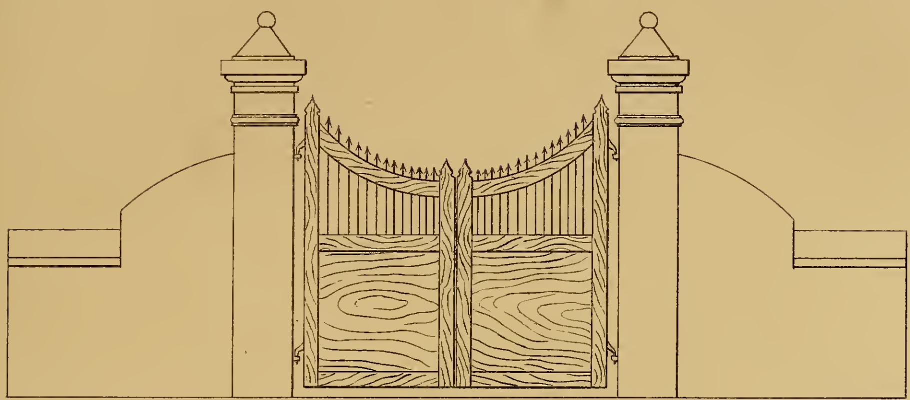


Fig 1 Elevation of Cemetry gate Silchar

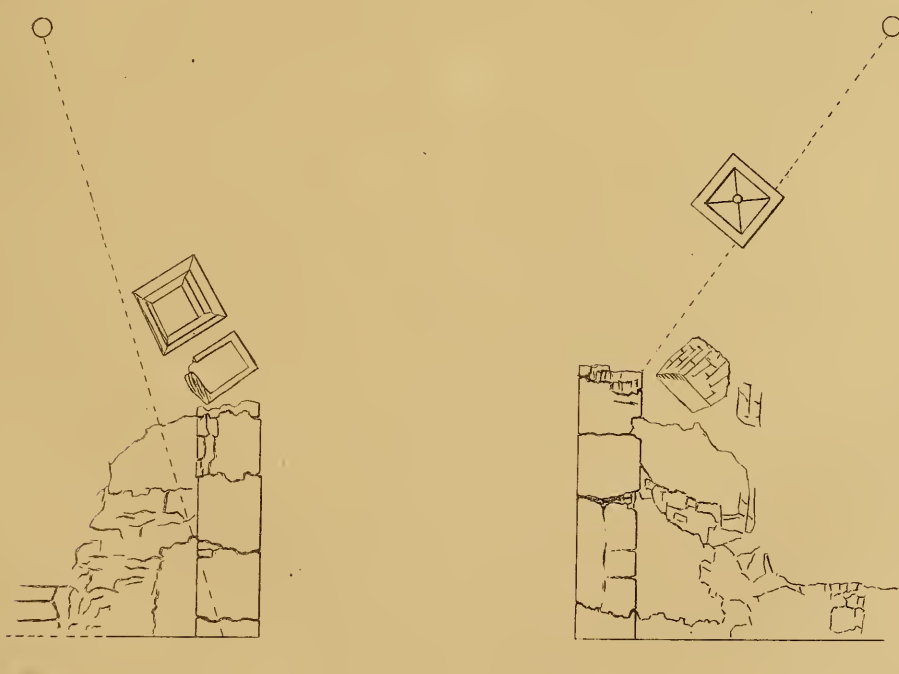


Fig: 2. Sketch Plan of overturned Cemetry gate pillars Silchar.

height through which its centre of gravity fell, and a the horizontal distance through which it was projected, then—

$$b = \tfrac{1}{2} g t^2$$
$$a = v t$$

where g is the accelerating force of gravity, t the time of flight and v the horizontal velocity of projection; since t is the same in both equations, we can easily obtain from them the formula—

$$v^2 = \frac{a g}{2 b}$$

In this particular case a=13 ft. and b=8 ft., and taking g as 32 ft. per sec.—

$$v^2 = \frac{169 \times 32}{16} = 338$$
$$v = 18 \cdot 4$$

If, as explained in the preceding chapter, we take the superficial angle of emergence at 30° and calling V the velocity of wave-particle at the surface—

$$V = v \sec. 30^\circ$$
$$= 21 \cdot 16$$

Thus much for the cap of the eastern gate pier. The western pier does not in this way give very much evidence; for, owing to the upper portion of the pillar being more shattered, and apparently owing to a greater want of cohesion in the brickwork, the cap was not so horizontally thrown off and consequently did not travel so far; it is also overturned, thus complicating the question; and altogether it does not give such definite information as its companion of the eastern pillar.

We will now speak of Mr. Stewart's tomb, and consider the evidence it affords. This tomb has been briefly described at p. 10, but it will be necessary to describe its construction more minutely than was there done, in order to realise exactly what took place; for without realising this, no satisfactory conclusions can be drawn.

The body of the sarcophagus was raised in the centre of a terrace or raised platform of two steps 5 inches each, and 1 foot 2 inches in breadth, or tread, made of Chunar stone, the gravel and grass had grown round the lower of these, so that it was partly hidden. From this rose the rectangular body or mass of the tomb, which was constructed of white marble admirably cut and moulded, and laid round and on a solid brickwork case or centre. The base mouldings rose to a height of 1 foot 1½ inches and above them were plain slabs of marble 1 foot 9½ inches high; in the centre of the southern face was inserted a black marble tablet which carried the inscription, and which measured 2 feet 8 inches × 1 foot 3 inches. The plaques or slabs of marble used for the sides of this portion of the body of the tomb were about 1 inch thick, and some had obviously been in use before, as they were polished on the back as well as face. They were built up against the brickwork core, but there evidently had been the slightest possible adhesion, the surface of the mortar between them and the brickwork being as smooth and polished as themselves; they were secured by being partially jointed and by small and much too slight copper clamps measuring ½ inch by ¼ inch in section let into the slabs and leaded.

The large upper slab, with small pillow ends, was then merely laid on the others. The lower surface was finely chiselled and dressed for a breadth of five inches all round, so as to admit of close neat joints, the rest of the under surface being roughly tooled down to the level. There had obviously been but very little mortar used in the bedding, and it may safely be taken as merely laid on the body of the tomb for the cohesion if any must have been exceedingly slight.

The railing round the tomb was of ⅝ inch square iron, let and leaded into the lower of the two steps of the floor on which the tomb was raised. The upright bars passed through and were leaded into a flat tie piece, of 2 inches by ½, and the upper ends, projecting 5 inches, had been flattened and shaped out into rude spear heads. There was also a second outer fence consisting of stone pillars, with chains suspended between, as seen in the drawings.

It will thus be seen that the tomb consisted of a brickwork core covered with *plaques* of marble; and this core was divided into two portions by a slab of marble which extended right through the tomb; this marked *a* in Pl. X, fig. 1, and can be seen lying almost in its original position in Pl. X, fig. 2.

The tomb may then be considered as being divided into two portions, one above and the other below this marble slab; we may consequently regard it as two solid rectangular prisms superimposed one on the other, and, practically, without any cohesion between them. A body of this description may be overthrown in either of two ways: the whole may fall as one mass, or the upper portion only may be overthrown. If the shock required to overthrow the whole is less than that which would overthrow the upper portion by itself, the whole must fall as one mass if overthrown at all; but if the upper prism requires a less violent shock for its overthrow than that necessary to overturn the mass as a whole, it will be overthrown separately and the relief thus afforded may enable the lower portion to retain its position unmoved. In this particular instance the only obstacle to the overthrow of the upper prism is its own inertia, while the lower one would in addition have to be fractured from its base.

The tomb, viewed as a whole, may be regarded, with sufficient approach to accuracy, as a solid prism, 5 ft. 9 inches high by 2 ft. 6 inches broad, the shock being in this case a *subnormal* one, *i.e.*, the direction was emergent, but very nearly orthogonal to the face of the prism in azimuth. The formula for the overthrow of the tomb as a whole is in this case—

$$v_1^2 = \tfrac{4}{3}\, g \times \sqrt{a^2 + b^2} \perp \frac{1 - \cos\theta}{\cos^2(\theta + \varepsilon)}$$

here * $\theta = 23^\circ{\cdot}30$, $a = 5{\cdot}75$, $b = 2{\cdot}5$, and ε as before$=30^\circ$: from this we get the result that

$$v_1 = 7{\cdot}9 \text{ feet per second.}$$

This is the velocity of wave-particle necessary for the overthrow of

* θ is the angle which a line, drawn through the centre of gravity of the prism and the arris on which it is overturned, makes with the vertical.

the prism, but in addition it must be fractured from its base, for which a velocity is required of

$$v_2^2 = \tfrac{2}{3} g \times \frac{L\,b}{a^2} \times \frac{\cos\theta}{\cos(\theta + \epsilon)}$$

whence

$$v_2 = 9{\cdot}9$$

where $L = 4$.* Adding these together we obtain the result that a velocity of 17·8 feet per second would be required to fracture from its base and overturn this tomb as a whole.

But what is the velocity of wave-particle which will suffice to overthrow the upper half of the tomb by itself? Here there is no adhesion to overcome, and the only resistance is that of inertia; we may regard this as that of a prism of 3 feet 3 inches in height and 1 foot 10 inches in breadth; here $a = 3{\cdot}25$, $b = 1{\cdot}8$, $\theta = 29{\cdot}^\circ 8'$—whence by the same formula as before we obtain the result

$$v_1 = 8{\cdot}6 \text{ feet per second.}$$

As the lower part of the tomb by itself would require for its overthrow a far greater velocity of wave-particle than can be conceived as possible, I shall not here enter into any detailed discussion of the subject.

These calculations show that if the velocity of wave-particle exceeded $8\frac{1}{2}$ feet per second, the upper portion of the tomb would be overthrown by itself, and that in consequence of the break of continuity in its substance, it could not be overthrown as a whole except by a velocity of wave-particle far greater than what we have any grounds for regarding as possible. The aspect of the tomb after the passage of the shock, as shown in pl. X, fig. 2, exactly fits in with the former supposition; the lower portion of the tomb is still standing, only the upper has been overthrown, and the slab marking the junction of the two portions can be seen almost in its original position. This proves that the velocity of wave-particle exceeded 8·6 feet per second.

* L is the modulus of dynamic cohesion, or the length in feet of a column of material whose weight, if suddenly applied, would produce a fracture in its substance by tension.

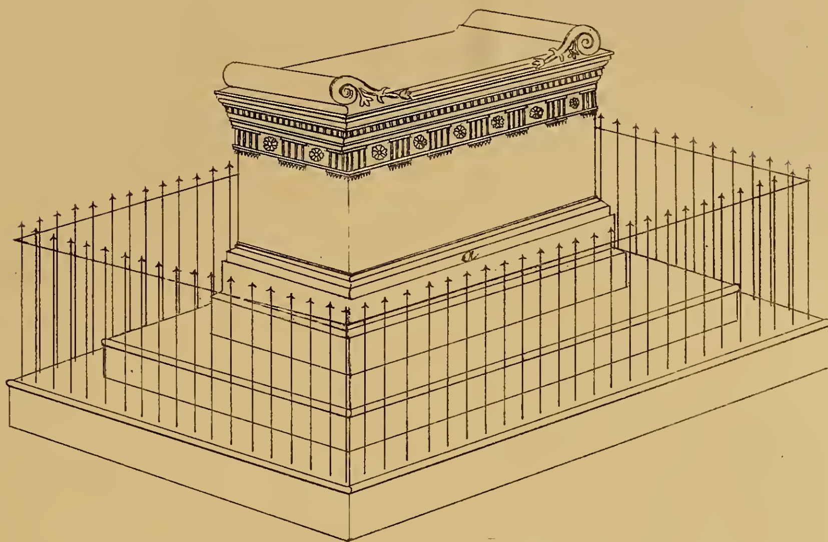


Fig. 1. Perspective Elevation of Mr Stewarts Tomb

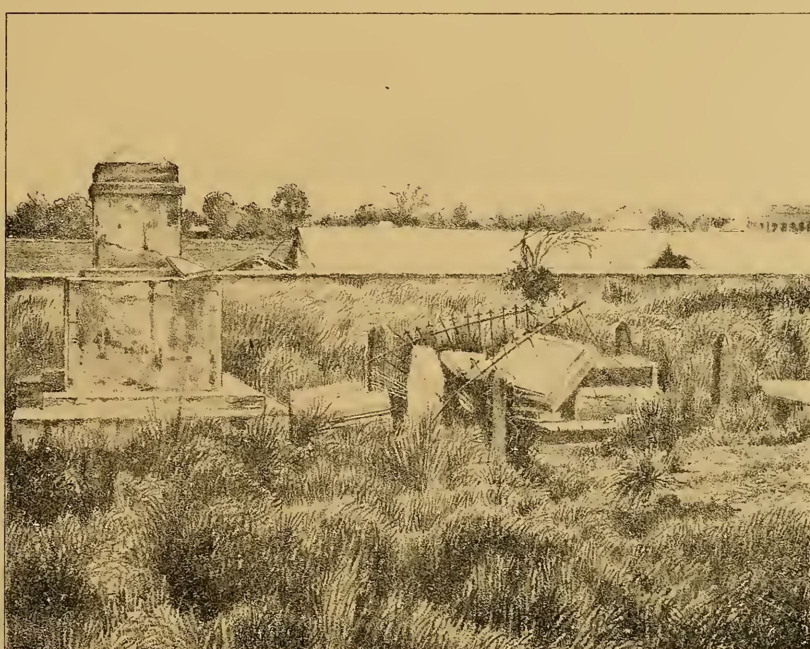


Fig. 2. The grave overthrown by the Earthquake

But this tomb can be made to yield more valuable data for the determination of the velocity of wave-particle. The top slab, described as having been shot clear off the tomb to a distance of 8 feet to the north, was evidently projected in the same manner as the cap of the gate pillar, but the case is not quite so simple. The twisting of the stone on its axis through an angle of 5° need not be noticed, as many causes might have led to this, and it will not affect the accuracy of the results to be obtained in any appreciable degree. A much more serious complication is introduced by the iron railings, which, as is shown in Pl. X, fig. 2, are all torn up and bent over; the question to be decided is how much of this must be attributed to the capping slab and how much to the weight of the upper portion of the tomb which was precipitated on to them and is shown in the figure lying on the bent-down rails. These railings were made of iron rods $\frac{5}{8}$ inch square, flattened out into a spear-head at the top, near to which they were leaded into a horizontal bar of iron 2 inches broad by $\frac{1}{2}$ an inch thick. The tops of those bars which lay in the path of the heavy marble slab were bent over at a right angle, evidently by its drive, thus showing that the slab was shot clear off the top of the tomb and that it must have hit the rails close to their upper ends; indeed, it is very probable that the bending was produced by the bottom of the slab knocking against the tips of the spear-heads, and as at the same or almost the same moment the whole of the overturned upper portion of the tomb was precipitated on to the rails, it is probable that the motion of the slab was arrested to but a small degree; in any case, this slab will give a useful minimum measure of the velocity of wave-particle.

The formulæ will, of course, be the same as in the case of the cap of the gate pillar; here a = 8 feet $1\frac{1}{2}$ inch and b = 5 feet 4 inches.

$$v = 14{\cdot}06 \text{ feet per second.}$$

This is a little more than 4 feet per second less than the value given by the cap of the gate pillar, the difference being due to the velocity absorbed in bending the rails. If, as before, we take the superficial angle of emergence at 30°.

$$\begin{aligned} V &= 14{\cdot}06 \sec. 30°. \\ &= 16{\cdot}22 \text{ feet per second.} \end{aligned}$$

There remains one more index as yet not noticed. The boundary wall of the cemetery, which, though cracked, was not overthrown, will give a maximum value for the velocity of wave-particle. It may be regarded as a rectangular prism affected by a subnormal shock, for the direction of the wall is orthogonal to the direction of emergence of the shock. Here $\theta = 18° 26'$ $a = 3$ and $b = 1$.

$$v_1^2 = \tfrac{4}{3} g \times \sqrt{a^2 + b^2} \times \frac{1 - \cos\theta}{\cos^2(\theta + \varepsilon)}$$

$$v_1 = 3{\cdot}96 \text{ feet per second.}$$

This is the velocity for overthrow when fractured from its base. The velocity for fracture taking $L = 4$ is

$$v_2^2 = \tfrac{2}{3} g \times \frac{L\,b}{a} \times \frac{\cos\theta}{\cos(\theta + \varepsilon)}$$

$$v_2 = 14{\cdot}17$$

Adding these together we obtain the total velocity required for fracture and overthrow

$$V = v_1 + v_2 = 18{\cdot}13$$

Or about 3 feet less than that given by the cap of the gate pillar. As there are not sufficient data for determining the proper value of L in this case, I have purposely taken it low. We are told that the mortar was indifferent, but if the bricks had only a low specific gravity, this would to a great extent counterbalance the want of quality and age in the mortar work; indeed, if we only take $L = 5$ feet instead of 4 feet, then

$$v_2 = 17{\cdot}89$$
$$\text{and } V = 21{\cdot}85$$

rather higher than that given by the cap of the gate pillar.

As it is almost certain that in this case L could not have had a very high value, it is evident that the wall was in a very critical state, and that a slightly higher velocity of wave-particle would have sufficed for its overthrow.

Placing the velocities obtained together they are—

1. Cap of gate pillar	21·16	
2. Cap of Mr. Stewart's tomb	16·22	
3. Cemetery wall	21·85	max.
Mean	19·74	
Mean, omitting No. 2	21·5	
Mean of means	20·62	

We may therefore say that the velocity of wave-particle at the surface was not far from 20 feet per second.

But, as I have before explained, there is good reason for supposing that, in transmission from the lower to the superficial beds of clay, the velocity of wave-particle was diminished, while the angle of emergence was increased. From this it follows that the true velocity of wave-particle was greater than 20 feet per second. Assuming that in transmission no part of the vertical velocity was lost, then the vertical component of the velocity of wave-particle, in what we may call the true shock, was the same as that of the surface shock, which for a superficial angle of emergence of 30° is one-half of the total velocity of wave-particle at the surface, or say 10·5 feet per second. Taking the true angle of emergence as 20,° we get the true velocity of wave-particle by the formula—

$$V = 10{\cdot}5 \times \text{cosec. } 20.^\circ$$
$$= 30{\cdot}7 \text{ ft. per second.}$$

This constitutes the evidence we have of the velocity of wave-particle in the case of this great earthquake. Though sadly deficient, it is at any rate definite; it only gives the velocity at one station, but at that station there is no lack of certainty. We have proofs of a velocity of wave-particle of at least 20 feet per second, and by what I believe to be a warrantable deduction we obtain a velocity as high as 30 feet per second. Thus giving a velocity of wave-particle double that observed by Mr. Mallet in the Neapolitan Earthquake of 1857, and that at a distance of 85 miles from the seismic vertical against a distance of

25 miles in the latter case. That the velocity of wave-particle should have been much greater in the case of this earthquake than in the Neapolitan one is, as I have already shown on *a priori* grounds, more than probable.

Yet although the violence of the shock was so much greater actually, there is little or none of that awful interest which attaches to the Neapolitan Earthquake of 1857, where the mind is bewildered by the utter annihilation of so many towns and the vast destruction of human life, that it can hardly look on the facts in that calm and philosophical manner that is essential for a proper understanding of the true course of events. Here it is but occasionally that we hear of lives being lost, and but seldom of a house being overthrown. The reason of this is not hard to find. Where, as is the case in almost all the native habitations, the houses are built of wood and bamboo, their elasticity protects them from overthrow, and where the buildings are constructed of brickwork or masonry, they are mostly large well-built buildings, all the rooms being on the ground-floor: a structure is thus produced composed of a series of walls of no great height running into each other and supporting each other against overthrow, and from the houses being always detached from each other the fall of one does not involve its neighbour in the ruin. When we hear of a building being overthrown, we also find either that it was badly built, or that it departed from the ordinary style of architecture. At Yeddo chimneys were overthrown, but the bungalows, though severely cracked, stood firm; at Silchar the cutcherry and bungalows stood, though more or less injured, the only structures overthrown were some walls and the church tower, which by its form courted destruction; at Kochela a deserted saw mill was ruined, but that again was structurally unstable as compared with the average bungalow; and lastly, at Manipur, where we hear that the Rajah's palace was overthrown, we also hear that it was a two-storied building. It is entirely to these peculiarities in the domestic architecture of the country that we must attribute the small loss of property and life by the overthrow and destruction of buildings.

CHAPTER VII.

OF THE RATE OF TRANSLATION OF THE WAVE.

We would at once declare that, in the present state of earthquake enquiries, the determination of the transit velocity of the shock, that is, the rate at which the wave-form is transmitted from part to part of the perceptibly shaken portion of earth's surface, appears to us of minor importance, and we shall not therefore delay to discuss it in much detail.

In truth, the difficulties which we have already indicated, as affecting our observation of the shock at all, the comparatively wild and uninhabited nature of the country, the absence of most of those ordinary indices of civilisation which could become the permanent indices of the extraneous forces applied to them and resulting in their overthrow or destruction,—all these difficulties combined with others most seriously affect any observations, which seek for precise and accurate measurements of time. Where the motion of transit is so rapid, as in the case of great earthquakes, that even fractions of a second become essentially important in ascertaining the true rate, it seems almost absurd to think of depending upon the ordinary measurements of time, by clocks in every-day use, unregulated and often differing by not only seconds, but minutes or even hours from the true time. During my own experience in India I have known the station gun—the gun usually fired with the intention of indicating midday in the more important military stations—to vary from the true mean time by not less than 53 minutes. I have more than once seen sun-dials which had been removed from one station to another, these stations differing in their latitude by four or five degrees, and reset the meridian being obtained by the use of a common magnetic compass without any consideration of variation, and the inclination of the gnomon left quite unaltered, and still the instrument trusted to in one place quite as unhesitatingly as in the other, and it is by no means an uncommon thing to find persons, who have really good watches, abandon the use of them, and trust to the gong or *ghurri* of the neighbouring barrack or court-house as their only guide to the hours. This is perhaps the only public announcement of the time, and as one of the chief objects is to bring people together, it is of little consequence, provided they do really meet, whether the meeting be a little later or a little earlier than the true time stated.

But with such sources of error, valuable as may be the indications of time given by many observers, and especially valuable as placing the identity of the shock felt at different points almost beyond the possibility of doubt, still they are open to far too many and too serious sources of error to admit of their being applied in the discussion of the transit velocity of the wave-form with any precision. The statements themselves are for the most part so vague and undefined, the errors of observation probably so great, and the errors in the time-measures so variable and so large, that out of some hundreds or thousands such statements of time, it is rarely indeed that we can find more than one or two, perhaps not even this small number, which can be trusted.

Nor will this pregnant source of error in any attempt to calculate with precision the velocity with which such a wave-form is translated from point to point be satisfactorily removed, until self-registering instruments have been established at favourable points within the areas subject to such disturbances. Even the possession of carefully noted and timed chronometers will be a very inefficient substitute for this. Observers cannot be always on the watch, and when such a shock comes there is often too much astonishment or even alarm, too much disturbance of all the elements that contribute to accurate observation, to admit of a careful and calm noting of the precise time, while further the moment of such observation is gone by before the instrument is ready for observation.

In the case of the great shock which we have now been describing, I find only two, among all the observations, which can be supposed to give even an approximation to data sufficiently accurate to admit of a calculation of the transit velocity of the wave. One of these we owe to the fortunate accident of Captain Godwin-Austin, an officer in charge of the Topographical Survey Party engaged in the north Cachar hills at the time, having been near the centre of the area shaken, and having noted his chronometer time almost immediately on the occurrence of the shock. The other observation is due to the circumstance that the two astronomical clocks used at the Surveyor General's office in Park Street, Calcutta, were actually stopped by the transit of the wave. As the shock occurred on Sunday evening no one was at the office, and we should have been without a careful record of the time, but for this. The observed times of the shocks on the 10th of January at Asalu, for which we are indebted to Major (now Colonel) Godwin-Austin, are given in the table appended.[1]

The time at which the clocks of the observatory at Calcutta were stopped was 4h. 43' 30".

Synopsis showing observed Chronometer Times of Shocks of Earthquake of 10th January 1869, with the error and rate of Chronometer from observations made on 12th and 24th January 1869, together with corrected times of shocks, at Asalu, North Cachar Hills.

Date.	Computed Time of Observation.	Observed Chronometer Times of Shocks of Earthquake on the 10th January.	Interval.		Rate gaining.	Correction for Rate for Interval Elapsed.	Correction to error of Chronometer for Interval. Error of chronometer on 12 observation + 1 14 18.	True Times of Shocks of Earthquake.
			In Hrs.	Decimals of Hrs.				
	H. m. s.	H. m. s.	H. m. s.	H.	D.	+	H. m. s.	H. m. s.
12th January...	9 2 56·2	3 45 50	41 17 6	41·285	24 Hours=17·38. Per Hour =0·724.	29·89	1 14 47·9	5 0 37·9
		3 46 10	41 16 46	41·279		29·89	1 14 47·9	5 0 57·9
		3 47 40	41 15 16	41·254		29·89	1 14 47·9	5 2 27·9
		3 58 30	41 4 26	41·074		29·74	1 14 47·7	5 13 17·7

The longitudes of the two stations are respectively—

Calcutta observatory	88° 23′ 59″
Asalu	93° 13′ 10″
Difference	4° 49′ 11″
Local time of shock at Asalu	5h 0′ 37·9″
Subtract for difference in Long.	0h 19′ 16·8″
Calcutta time of shock at Asalu	4° 41′ 21·1″
Time of shock at Calcutta	4° 43′ 30″
Difference	0° 2′ 8·9″

The distances from the seismic vertical are—

	Miles.
Calcutta	256
Asalu	76
	180

So that, to judge from these two observations, the time occupied by the earthquake-wave in passing over a distance of 180 miles could have been 2′ 9″, or an average rate of 7,375 feet per second, a velocity which, to say the least, is improbable.

Of the two observations from which this result has been obtained, one precludes all possibility of error, yet it is difficult to believe that so experienced an observer as Major Godwin-Austin could have made a serious error in his observations;[1] such, however, is the conclusion forced upon us by a comparison of these, the only two observations which can have even the slightest pretence to trustworthiness.

We are consequently unable to determine, with accuracy, the rate of transit of the wave-form in the case of this great earthquake; but as there is no reason to suppose that it differed much from what is known to have been the velocity in other earthquakes, this is of little importance.

[1] The inaccuracy is probably only in the time of the first shock, and represents the time taken in unpacking the chronometer; unfortunately we have not any accurate observations of the later shocks besides those of Colonel Godwin-Austin.

CHAPTER VIII.

OF THE SHAPE AND EXTENT OF THE SEISMIC AREA.

On account of the vast extent of country over which this earthquake was felt, of the unsatisfactory nature of the reports obtained from most of the places at which it was felt, and of the unsettled and uncivilised state of other districts where the shock must have been sensibly felt but no records could be obtained, we are not able to lay down isoseismal lines as numerous, or with the same accuracy, as is desirable. We can, however, form a very good idea of the shape and extent of the area affected by the shock; and with this object in view I have laid down on the map No. 1 a line which marks, as near as can be ascertained, the boundary of the area over which the shock was perceptible to the unaided senses.

Starting from a point on the western shore of the Bay of Bengal, not far from Hidgellee, the line runs north-westward to Hazaribagh, thence northward to Patna; it then passes over a tract in which its course is uncertain, and the next definite point is Darjiling, which must have been situated not far from the boundary of the area whose limits we are describing; far to the east of this station we hear of the shock being severely felt at Lakhimpur; we may therefore take the line as passing through the Himalayas, and perhaps extending beyond them on the north; eastward again we hear of the shock being severely felt at Dibrughur, and from further east we have no reports and could expect none. At Manipur the shock was very severe, and this, combined with the report that the shock was felt in Upper Burmah, justifies us in taking the line down through Upper Burmah to Kussilong and Chittagong. The boundary thus drawn includes an area of roughly oval form, from 650 miles long from north-east to south-west, and 400 miles in the co-ordinate direction of north-west and south-east, thus enclosing a total area of a quarter of a million (250,000) square miles.

We have not sufficient information to enable us to draw any isoseismal lines within this area, but on the map I have laid down part of a line which would enclose that area over which the shock was really severe; this starting near Gowhatti runs east to Nowgong, and then curves down to Munnipur whence it turns westward and passes to Silchar.

An inspection of these lines shows that the dimensions of the area included are much greater in a north-east and south-west direction than in the co-ordinate direction of north-west and south-east. This of course, to a certain extent, depends on the fact that no reports could have been obtained from the country lying to the north of the southern boundary of the Himalayan range, nor from all that portion of Burmah over which the shock may very probably have been felt; but yet the fact remains that the area affected undoubtedly extended much further East and West than North and South. This extension might have been produced by either of two causes,—firstly, the structure of the country, which might be such as would favour the transmissions of the shock further in one direction than another; and secondly, the direction of the fissure from which the shock originated. We will examine the circumstances of the case, and see to what extent the action of one or both of these causes must be invoked to explain the facts.

From the Jaintia hills in which the shock originated a range of mountains composed of more or less hard and crystalline rocks extends eastwards; through these cystalline rocks the shock would be transmitted with great readiness; but as we know neither the structure of the country nor the effects of the earthquake in Upper Burmah with sufficient detail, no further reference will be made to this portion of the seismic area. To the north of the Khasi range, but separated from it by the valley of the Brahmapootra, lies the range of the Himalaya mountains. These are composed of indurated rocks well adapted for the transmission of the shock; this superior elasticity of the rocks is to a certain extent counterbalanced by the fact that the shock would have to cross the strike of the strata flanking the range, and its force would therefore be lessened in passing from stratum to stratum; but the flattening of the isoseismal on the north is to a great extent due to the absence of records from that region. To the south and south-west the structure of the country does not offer any special impediment to the transmission of the shock, but it is on the west that the shock was transmitted for the greatest distance. Westward from the Khasi hills the crystalline rocks soon give place to the great alluvial plains of the Ganges and Brahmapootra which, with those of the Barak, surround the Khasi range on three sides and form a very large portion of the area affected by the shock. These alluvial plains extend westward, far beyond the furthest point at which the shock was felt; but in the south-west the shock was felt over a district in which the gneiss of the peninsula forms the groundwork of the country, in whose hollows are lodged the principal coal-fields of British India. On the gneiss, which, from its elasticity, is well adapted for the tansmission of the earthquake-wave, the furthest point at which the shock was felt was Hazaribagh, 454 miles from the seismic vertical; while Patna, to reach which the shock would have to travel for two-thirds of its journey through the alluvial plains of the Ganges, is 446 miles from the seismic vertical, from which it would seem that the shock would travel as far through alluvial plains such as those of the Ganges as through the highly crystalline gneiss of the peninsula, the absence of joints in the former case compensating for deficient elasticity; we must therefore consider the country to the west of the Khasi hills as rather suitable than otherwise for the transmission of the earthquake-wave.

Though, as has been shown, the nature of the country, whether as to its structure or accessibility, would to a certain extent account for the east and west elongation of the isoseismal, it is not in itself sufficient and the facts noticed cannot be explained without calling in the action of some other cause. If, as it would seem to be the case from an inspection of map No. 1, the seismic focus took the shape of a rent running nearly east and west, the impulse communicated to the surrounding rock would be greater in a direction north and south than in the orthogonal direction of east and west, and the impulse would tend to propagate itself further in the former than in the latter direction. On the north we cannot hope to trace any great extension of the isoseismal, but no such difficulty would exist to the south; nor would the structure of the country oppose any great obstacle to the transmission of the shock in that direction; and we should therefore be able to trace the shock down the shores of the Bay of Bengal to a point further from the seismic vertical than the furthest point on the west at which the shock was felt. But such is by no means the case, and we must consequently acknowledge that the fissure in which the shock originated ran nearer north and south than east and west.

How then is this conclusion to be reconciled with that obtained from the evidence of the direction of the shock? If the map is examined, it will be noticed that, with a single exception, all the stations at which the direction of shock was obtainable bear from south to south-30°-west of the seismic vertical and that the single station which is not so situated lies nearly due west. Of lines so drawn, the intersections must necessarily form a series very narrow from north to south and broad from east to west. It is therefore evident that, though the observations of direction of the shock have given the *position* of the seismic vertical, we cannot trust them in determining the size and dimensions of the seismio focus which, unfortunately, cannot be otherwise determined.

APPENDIX.

Simple instructions for earthquake observations.

The foregoing pages, which contain many notices and extracts which are fair samples of ordinary unscientific descriptions of an earthquake, show well how little is known by most of the true nature of an earthquake, and consequently what very imperfect observations it is possible to collect in a country so well suited for systematic seismological enquiry as the Assam province, and, to a less degree, nearly the whole of India; and yet there are few who could not make observations which, when collated with those made by other observers in different positions, would not be of considerable value.

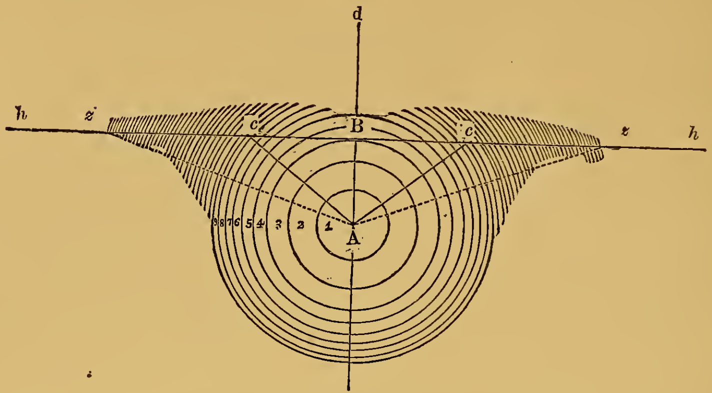
As it is impossible to make observations of an earthquake, which will be of any use, without some previous knowledge of what an earthquake really is; and as, even up to the present day, the common manuals of geology contain erroneous or misleading notices of this branch of terrestrial physics,—it will be advisable to devote some space to the description, in as few words as possible, of what an earthquake really is; and on this point the vaguest ideas and wildest impressions are prevalent—not unfrequently it is spoken of as a heaving of the solid earth, caused by the pent-up forces beneath, which find an outlet in the fissures and rendings of the earth which they produce. Now this, which may be looked upon as a fair and impartial description of the ordinary idea of an earthquake, could not well be more at variance with the facts than it is.

Suppose a long beam of wood to be lying on the ground—against one end of this hangs a small weight suspended by a string, the opposite end of the beam being struck by a hammer this weight is driven away from the wood without the beam being moved the fraction of an inch; what has happened is that a wave of elastic compression has been sent through the beam: when the end was struck by the hammer the particles were driven before it, but by their elasticity recovered their original position; meanwhile they had pushed forward the particles immediately in front of them, which, in their turn, having communicated the motion to those in front of them, returned to their original position, and so the impulse was transmitted through the beam, and on reaching the opposite extremity the outermost particles were pushed forward, and, in doing so, communicated their motion to the small weight hanging against the end of the beam, which was in consequence thrown off: it is just such a wave of elastic compression which passes through the earth's crust when what is commonly called an earthquake takes place.

We must now explain how it is that we can, from observations at the surface, deduce the position and depth below the surface of the focus from which the shock originated.

In figure 1, let h h represent the surface of the earth, and A the focus at which, from

Fig. 1.



whatever cause, an impulse of an explosive nature is communicated to the surrounding rocks; the particles of rock immediately surrounding A are driven asunder and then return to their normal positions, thus originating a wave of elastic compression, which spreads outwards in every direction from the focus, as is represented by the concentric circles surrounding the point A. Now, as the motion of the particles of rock is, except where interfered with by want of homogeneity in the rock, always directly outwards from the focus, it will be seen that the direction of motion of the particles is the same at no two points of the area over which the shock is felt, and that at each point the direction of motion points to the focus or point of origin of the wave; if then, at any two or more points, we can get the true direction of movement of the wave particles, we can deduce the true position of the focus.

The object of all seismological observations should be, primarily, to determine both the true direction and velocity of motion of the particles set in motion by the earthquake wave. This motion, which is at an angle to the horizontal, may be considered as being composed of a vertical and a horizontal component. For the determination of these two components, we have to depend on observations which may be divided into two great classes—subjective and instrumental; the first consisting of those impressions or sensations which may be personally noted during the passage of the earthquake shock; the second, of those observations made with properly designed instruments; while a third sub-division consists of observations, made after the passage of the wave, of damage done to permanent structures.

Beginning, then, with the subjective observations, I would say at once that all impressions of the direction in which the shock travels are, from a scientific point of view, almost, if not utterly, useless, for it is but seldom, and then mainly by accident, that these impressions agree with the facts. But, though guesses at the direction in which the shock travels are useless; general impressions of the nature of the shock should be carefully noticed, as also any effects it may have on the lower animals.

The time at which the shock is felt should, of course, be noted; but this, which in India it is impossible to expect done with accuracy, is fortunately of comparatively small importance, its purpose being mainly to obtain the rate of transmission of the wave impulse through various media; but, though the actual time at which the principal shock is felt may not be determinable with accuracy, the intervals between a great shock and the numerous minor ones which follow it should, if possible, be determined with rigorous accuracy. And here we may diverge to say that it is not by any means the great and disastrous shocks which are of greatest scientific interest; in them the chief wave is so interfered with by minor cross undulations that the general motion, instead of being simple, is much complicated. Let every fact that can be ascertained about such a shock be recorded, but let it be taken rather as a warning to be on the alert and notice any following shocks, to read off the instruments and set them again ready for the next shock, than as the main point to which observation should be directed.

The duration of the shock should be noticed; this, as given in most ordinary accounts, is very misleading: for instance, the shock may be said to have lasted for 'several minutes' or 'quarter of an hour,' whereas what is really meant is, that during that period there was a rapid succession of shocks. If possible, in the case of a violent earthquake, the main wave should be distinguished from the accompanying minor undulations, and it should be noticed to what extent the latter precede or follow it.

The nature of any sounds heard should be recorded, and whether they accompanied, preceded, or followed the shock.

It is but seldom that any of the Indian earthquakes originate under the sea, and consequently sea-waves are seldom found accompanying earthquakes; but in the case of observers residing near the seashore, any such pheuomenon should be carefully recorded.

Often chandeliers, trees, or other flexible objects are set swinging by the shock, in which case the direction of movement, with reference to external objects, should be noticed, and the actual direction of this motion afterwards observed with the compass.

Among those observations which should be made after the passage of the shock, the principal are those of damage done to buildings. These should in every case be carefully observed, and drawings should be made of the faces of the building cracked, and particulars given of size and construction, thickness of walls, number and size of doorways and other openings. From these particulars valuable information may often be derived; but as a rule little can be expected, unless the observer is acquainted with the principles on which these facts are interpreted. Should, however, any walls or other structures be overthrown, they should be most carefully described. A rough, or, if possible, a detailed ground plan of the overthrown structure should be made, accompanied by drawings and a description of the structure as it originally stood. The direction in which the mass is overthrown should be carefully recorded; in the case of bodies projected by the shock their dimensions and nature should be detailed, and the horizontal and vertical distances through which they have travelled should be noted.

The effects of an earthquake in altering the superficial features of the ground should be recorded; but here care must be taken not to confound such a purely secondary cause as that to which the sinkings and fissurings of the river banks in the Cachar earthquake of 1869 were due, with actual alteration of level accompanying the earthquake.

We now come to such observations as can only be made with the aid of instruments, of which the simplest, and one which may often be of considerable service, is—

(1) A round tub or basin half filled with water, which should be coloured—a little ink answers as well as anything else—while the sides of the tub are whitened; when the shock comes, the water surges up on that side from which the shock is travelling and leaves a mark.

(2) An elastic rod firmly fixed in the ground, with a heavy weight, such as a spherical 4-pound shot, at the top; the free portion of the rod, which may be of stout rattan, should be the length of a second's pendulum, and the spherical weight must be surrounded by a wooden hoop, leaving an annular space of 6″ or 8″ in breadth between it and the surface of the ball. In this, eight holes are to be bored and fitted with cylindrical rods of wood, such as lead-pencils, sliding easily in their respective holes; these rods to face the cardinal points and their bisections.

(3) The best of all pendulum apparati is that suggested by Mr. R. Mallet, which consists of four inverted pendula, with broad, thin, flexible, supports, capable of vibrating only in one direction and placed facing the four cardinal points of the compass. Each of these is provided with a ratchet and pawl, which allows of its bending over in one direction only, and retains it in position when so bent.

Besides the above, several other forms have been suggested, all considerably complicated; but as they all suffer from the drawbacks inherent in any seismometer which depends on the principle of the pendulum, it would serve no useful purpose to describe them: we will therefore pass on to a consideration of the advantages or defects of those already described:—

(1) The water in the circular basin is, theoretically, set in motion in a single plane, but practically the unequal friction with the sides gives it a swirling motion, which causes it to surge round the basin, often making it a very difficult matter to decide where the mark reaches highest, and consequently from whence the shock came. When, as is the case in most violent shocks, the main wave is accompanied by minor oscillations, more or less transverse to it, this swirling is very much exaggerated. There is another drawback; in that, under the action of violent shocks, the water first rises against the side from which the shock came, but is then dragged forwards and thrown up against the opposite side of the basin, and if the period of oscillation of the water in the basin at all corresponds with that of the earthquake wave, it will rise highest on that side towards which the earthquake is travelling. Notwithstanding these drawbacks, the ease with which this instrument can be impro-

vised, and, for moderate shocks, the accuracy with which it gives the horizontal direction of motion of the wave particles, make it particularly useful. In the case of a great earthquake, one should, if no other instruments are set up, be immediately improvised, and the intervals between, and direction of, subsequent shocks be noted.

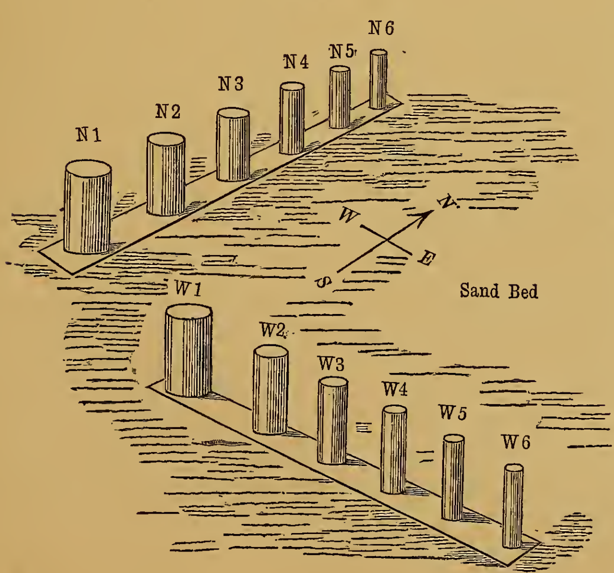
(2) This is one of the most untrustworthy forms of seismometer that has been suggested. It is impossible to arrange it so that the centre of gravity shall lie in the axis of oscillation, and consequently the pendulum, first set in motion in a vertical plane, will very soon acquire a circular motion; added to which, the dragging of the bob by violent shocks, and the subsequent throwing of it forwards, are more noticeable than in the first described form.

(3) This is undoubtedly that form of pendulum seismometer which is least open to objection; but as it is more troublesome to construct than the instrument which will be described below, while at the same time its observations are both less exact and not comparable with those of other instruments not very carefully constructed to be duplicates of itself, we will not here describe it further.

These pendulum seismometers, though under certain circumstances of great value, should be regarded rather as makeshifts than as instruments to be permanently established; but the two which will be now described differ from them in that they give absolute and not merely roughly comparative determinations of the velocity of motion of the wave particles.

The first of these depends on the circumstance that a solid right cylinder will be overturned towards the point from which an earthquake shock comes, and that it requires a definite minimum force to overthrow it, which can be readily calculated. In fig. 2 we have given a rough perspective view of an instrument of this sort, which is copied from Mr. R. Mallet's article in the Admiralty Manual of scientific enquiry. The instrument consists of two series of right cylinders, all of equal altitude but of gradually diminishing diameters, the two series being exactly similar. These stand on a pair of slips of wood, which

Fig 2.



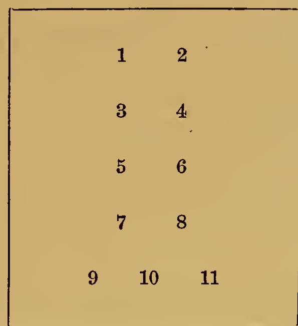
taper so that their width shall equal the diameter of the cylinders standing on them at various points, the two slips being placed one due north and south, the other east and west; soft, dry sand is then filled in up to the level of the two slips. Under the influence of an earthquake shock a greater or less number of the cylinders are overthrown, and the horizontal component of the shock is then intermediate between that required for the overthrow of the largest cylinder overturned and the smallest still standing.

The cylinders may be made of stone, pottery, metal, or any other homogeneous material whose density is immaterial, as the overthrow is due to inertia, which is proportional to the mass: probably the most convenient material will be found to be good, straight-grained, seasoned wood, free from knots, which can be turned to the requisite diameter with great ease. The dimensions for a series of cylinders, 12 inches in height, are given below, with the horizontal velocity of shock required for their respective overthrow:—

	Diameter of cylinder in inches.	Horizontal velocity of shock for overthrow in feet per second.
1	11½ inches.	5·54
2	10¾ „	5·08
3	9¾ „	4·48
4	9 „	4·05
5	8 „	3·50
6	7 „	2·98
7	6 „	2·50
8	5 „	2·03
9	3¾ „	1·49
10	2½ „	·98
11	1½ „	·57

It will be seen that this form of seismometer is only adapted to the measurement of moderate shocks, but it is just these which are most important from a scientific point of view.

As regards the fixing of the instrument, the following modification of Mr. Mallet's plan will, we think, be found advantageous, as it allows of equally accurate results being obtained with a single series of cylinders; or if the same total number is used, the instrument may be made to give more closely accurate results. If, then, it be determined to set up an apparatus consisting of 11 cylinders, as given in the table, a patch of ground, 12 feet by 10 feet, should first be carefully levelled and smoothed, with the longer axis running preferably north and south. Then let a series of stands be made for the cylinders, each exactly the same diameter as the cylinder intended to stand on it; for the larger sizes they may be discs of about 2 inches in thickness, to be firmly fixed to the ground by long spikes driven through them; while for the smaller cylinders they may be rods of about a foot long, pointed at one end, and driven into the ground. The cylinders should be arranged as below:—



By this arrangement a clear space of 18 inches can be left between each pair of cylinders and a clear margin of 3 feet round the outside of the group. The stands being all fixed in position, and all projecting the same distance above the previously levelled ground, and dry sand filled in up to the level of the tops of the stands, nothing now remains but to place the cylinders each on its respective stand and await the arrival of an earthquake.

To use this instrument, it will be necessary to have some means of reading off the exact direction in which the cylinders are overthrown; and for this nothing could be more convenient than a compass with a swinging card, mounted in a square wooden box; the edges of this box should be square to each other, and on the side of the circular well in which the card works there should be a vertical mark so placed that a line drawn through it and the point of suspension of the card will be parallel to two of the sides of the box; then by simply placing one of these against the overthrown cylinder, the mark will coincide with the exact direction in which the cylinder has fallen. If such a compass is not obtainable, one with an ordinary needle will do, using it in the same way as before, and remembering that whatever number of degrees the needle may stand over, the true direction is that number of degrees on the opposite side of north; thus, if the needle stands over north 50° east, the direction in which the cylinder has fallen is north 50° west. It will be well to add here that the readings should always be taken in degrees east or west of north; such phrases as north-west or south-south-east are far too vague.

Observations taken by this instrument should be entered in a regular form in a special book. The first page should be occupied by details of the number of cylinders, the dimensions of each, and the variation of the compass.[1] The remaining pages should be ruled according to the form given below. The first column is for the date, and the second for the time at which the earthquake was experienced; and for this it would be well to abolish A.M. and P.M., and consider the day as divided into 24 hours; thus, 3-40 P.M. would be written 15 *h.* 40′. The third column is for the number of cylinders overthrown; the fourth for the direction in which they are overthrown, and if, as is probable will be found to be the case when more than one or two cylinders are overthrown, the direction is not the same in every case, the direction in which each separate cylinder is overthrown should be noted; in the fifth column this direction should be entered, corrected for magnetic variation; the sixth column should contain the velocity of shock corresponding to the largest cylinder overthrown; and the last column is for any remarks as to the general nature of the earthquake, or its effects, that may be noticed. These directions will, perhaps, be made clearer by the examples given below, which, it is probably needless to remark, are purely imaginary:—

Record of Earthquakes during the month of January 188 at Cachar.

Date.	Hour.	No. of cylinders overthrown.	Observed direction of overthrow.	Corrected for mag. var. =2° 30′ E.	Velocity of hor. comp. of shock.	REMARKS.
January, 2nd	3 h. 30′	1	N. 15° W.	N. 12° 30′ W.	·6	
Ditto, 8th	12 h. 27′	3	N. 5° E.	N. 7° 30′ E.	1·5	
Ditto, 26th	0 h. 40′	10	...	...	5·0	
		1	N. 5° E.	N. 7° 30′ E.		
		2	N. 4° E.	N. 6° 30′ E.		
		3, 4, 5	N. 3°·30′ E.	N. 6° E.		
		6, 7, 8, 9, 10	N. 3° E.	N. 5° 30′ E.		

This instrument gives us the direction and velocity of the horizontal component of the shock, the only other elements needful to form a complete seismometer are the exact time and the velocity of motion of the vertical component; of these, the former necessitates an accurate time-keeper, while for the latter no simple instrument has yet been proposed, but we would suggest that the following modification of one of Mr. Mallet's self-registering seismometers will be found effective: Let a piece of wood, say 6 inches square and 6 or 7 feet long, be taken; then at each corner of one end a

[1] This may be obtained by so placing two plumb lines that a line drawn through both of them may point to the pole star when the pointers of the Great Bear are either vertically above or vertically below it, and then observing the angle between the direction given by these two plumb lines and that given by the compass.

cubical recess must be cut, into which a spherical leaden ball will just fit,—a 12-bore spherical bullet will do, but a larger size would be better; now, taking the inner corner of each cube as a centre and the length of its side as radius, describe a quadrant on the base of each; up to this quadrant the wood must be bevelled, and the bevel continued along each longitudinal edge of the log to a point exactly 4·05, or 4 feet ½ inch approximately, from the centre of the ball as resting in its cubical hollow, where the bevel will end abruptly in a horizontal ledge; the bevel should have been increased so that this ledge shall be a quadrant of exactly similar shape to that forming the base of the recess above, but of course reversed. These directions may seem rather complicated, but the three sections given on plate XIV will, we fancy, render them easily intelligible. On each of these lower ledges a projecting pin should be placed, so that when the whole affair is set upright the pin will be vertically underneath the centre of gravity of the ball above it. This post must be set absolutely vertical in the ground, and dry sand be filled in up to the level of the lower ledges. To read the instrument, a straight-edge of some 6 feet in length should be made, with one edge bevelled and one end cut away towards the bevelled edge, at an angle of about 30°. Close to this pointed end a small notch must be made on the bevelled edge, and from this notch a scale of inches and tenths of an inch carefully laid off.

After the passage of a shock it will probably be found that all four balls are displaced, two will be found lying on the ground, more or less directly underneath their original positions, while either one or both of the others have been projected to some distance; one of these should be cautiously lifted, and the point which lies directly underneath the centre of the ball as it lay on the ground should be marked. Then take the wooden straight-edge and place the notch against the pin, underneath the original position of the ball, and bring the edge over the mark, showing where the centre of the ball lay; then read off the direction and length of the line joining these two points. Should two balls be projected, the same must be done in the case of the second, and both results recorded separately. The results may be entered on the same form as those of the cylinder seismometer by adding two columns, one for the direction and the other for the distance to which the balls are projected.

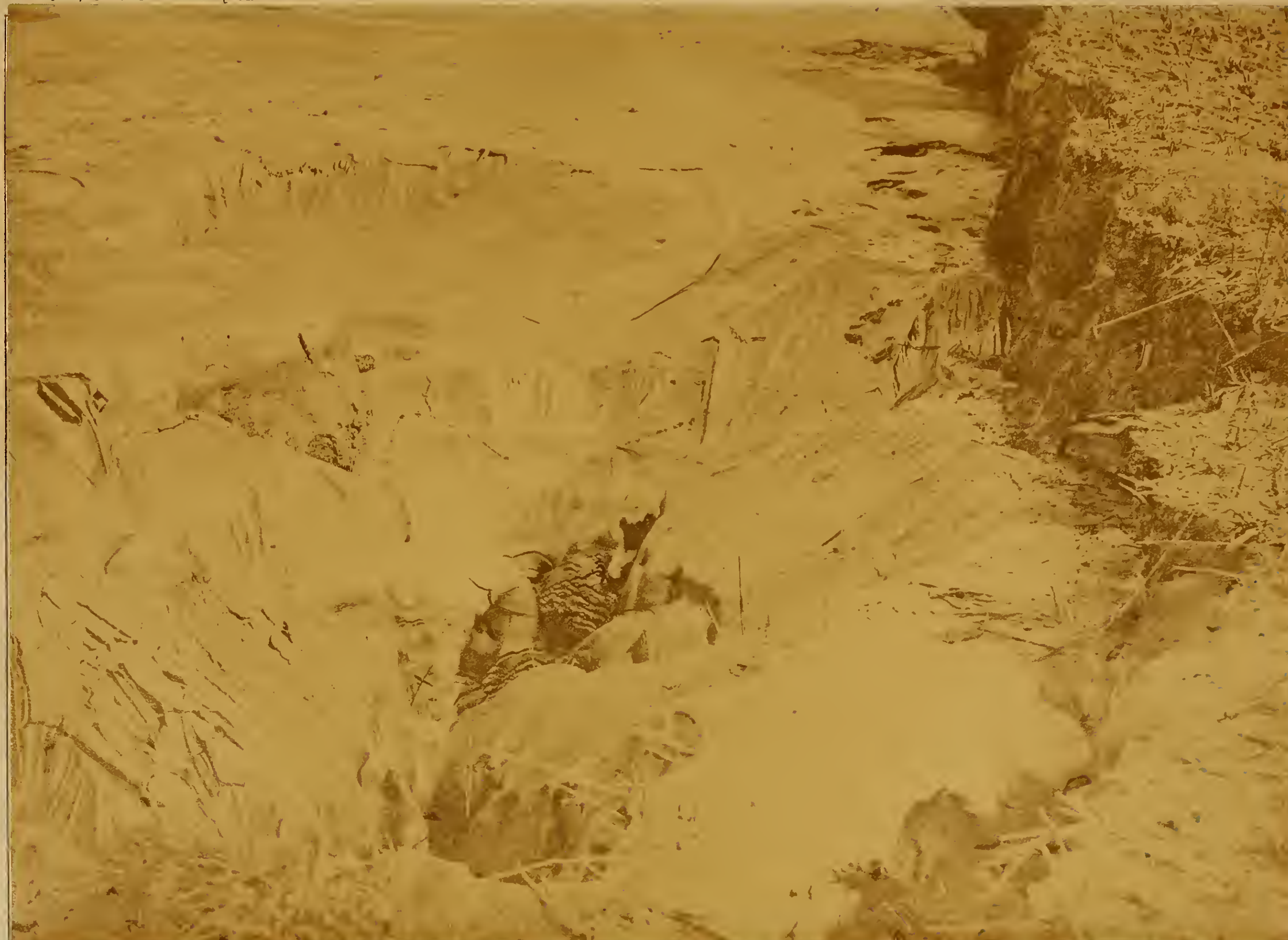
The height, 4·05 feet, is selected, as it is the height through which a body falls in one-half of a second; any other height would of course answer, but by taking this particular value, the subsequent calculations by which the observations are reduced are very much simplified.

It is evident that this would not be a suitable form of instrument to set up by itself, as the projection of the bullets to any particular distance might be due either to a high angle of emergence and a moderate velocity or to a low angle of emergence and a higher velocity of shock. If, however, the velocity of motion of the horizontal component of the shock be known, as would be the case approximately wherever a series of cylinders was established, this instrument will give a datum from which, by a simple calculation, the velocity of motion in the vertical component can be obtained.

From these two instruments, which are well within the constructive power of any native carpenter, results of very great value in the present state of seismology can be obtained, though there are doubtless many more perfect instruments than these; yet from their very perfection they are necessarily so expensive as to put them practically beyond the reach of private observers, while the expenditure is not one that could be recommended to Government; besides, while these instruments, to develope to the full their capacities, must be situated either at or in electrical connection with some astronomical observatory where the results would be automatically recorded on a chronograph, there is no astronomical observatory in India advantageously situated for seismological observations. It is otherwise with the two instruments above described, they would be inexpensive and could be attended to by any one able to read meteorological instruments.

The day may not yet be far off when every meteorological observatory throughout the earthquake-shaken districts of India may have attached to it these two instruments or some more perfect form of seismometer; and it is not too much to say that when such is the case, and these observations are communicated to a single centre, there to be compared and developed, five years will see more done towards learning the true cause of origin of earthquakes than has been effected by all the speculative theorizing of the past.

R. D. O.

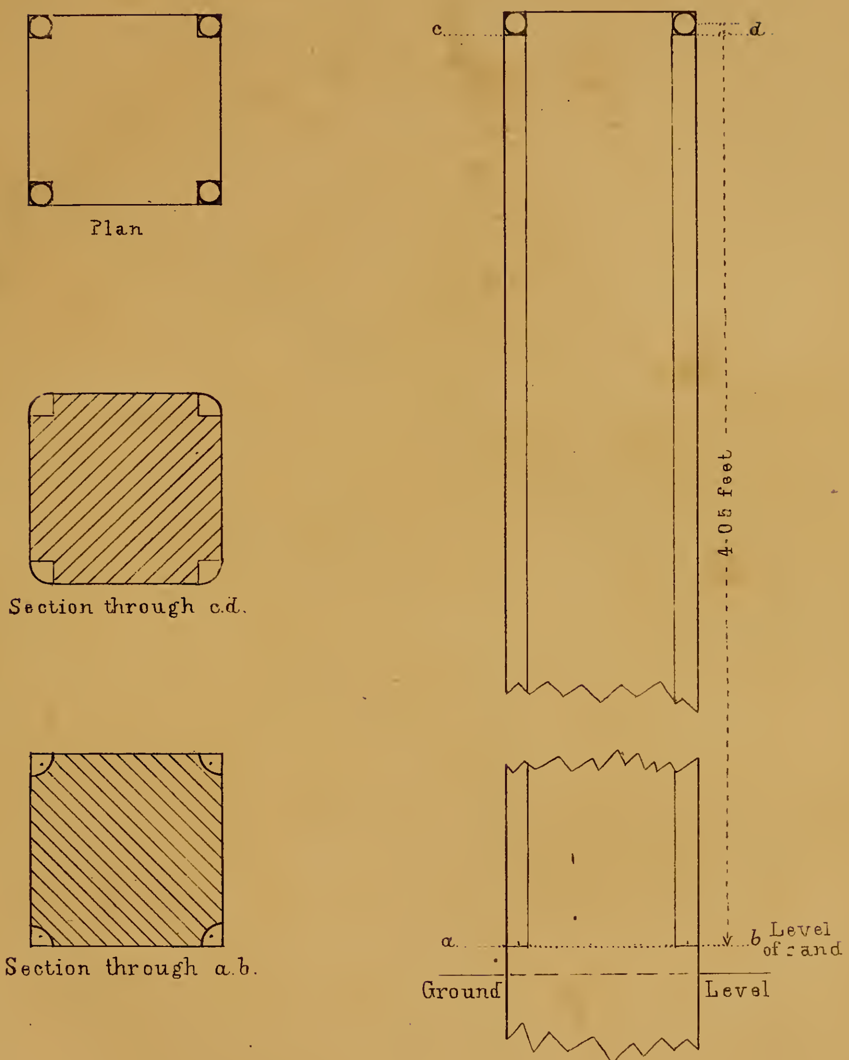


VENTS COALESCING INTO AN IRREGULAR FISSURE

VENTS COMBINED WITH EARTH FISSURES.

SEVERAL VENTS DEGRADED INTO ONE IRREGULAR CAVITY

Oldham: Memoirs. Vol. XIX 1. Pl. XIV.



FOUR-SPHERE SEISMOMETER.

Scale 1/6th

On Stone by Aminullah.


CIVIL STATION and CANTONMENT
OF
SILCHAR
DISTRICT CACHAR.
Scale 3" Inches = 1 Mile
Doodputli
Banks all broken up
Rocks
Rocks
Doodputli Bank
Much broken up
MODHOOHA N.
Great slips along here
Great slips along here
Much shaken and many slips.
BARAK RIVER
Many circular water holes
Mrs Sandeman's Bungalow
Messrs Begg Dunlop
Mr Broun's Bungalow
Hotel
Medical Hall
Planter's Retreat
Mr Barker's Bungalow
Old Burial Ground
Mr Shircore's Bungalow
B.I.T.Co
Dr Sconce
Mr Marshall's Bungalow
Nursing Dey Godown
E.T. Office
Mr Edgar's Bungalow
Kutchery
Church
Dr Davidson's Bungalow
Sepoy Lines
Hospital
Bells of Arms
Billiard room
Silchar rocks
Municipal Office
Mr Birkmyre's Bungalow
Post Office
Douglas Field
Gun Shed
Magazine
Magazine
Police Hospital
Mr Beckton's Bungalow
Police Lines
All broken up.
Jail

MEMOIRS

OF THE

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OF

INDIA.

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INDIA.

VOL. XIX, PT. 2.

PUBLISHED BY ORDER OF HIS EXCELLENCY THE GOVERNOR GENERAL OF INDIA IN COUNCIL.

CALCUTTA:

PRINTED FOR THE GOVERNMENT OF INDIA.

SOLD AT THE

GEOLOGICAL SURVEY OFFICE,

OFFICE OF SUPERINTENDENT OF GOVERNMENT PRINTING,

AND BY ALL BOOKSELLERS.

LONDON: TRÜBNER & CO.

MDCCCLXXXII.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING
1882.

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

The THERMAL SPRINGS OF INDIA, *by the late* T. OLDHAM, LL.D., F.R.S., &c., *Superintendent of Geological Survey of India. Edited by* R. D. OLDHAM, A.R.S.M., *Geological Survey of India.*

PREFACE.

THE hot springs of India have attracted the notice of many observers. In the majority of instances these remarkable outbursts of water, at a temperature considerably above that of the waters or even of the atmosphere in the neighbourhood, often charged with various gases and emitting strong odours, have been endowed by the superstitious and ignorant with wondrous virtues, or have been supposed to be the result of some miraculous interposition of divine energy. In this way the more remarkable of these springs have become widely known and spoken of, and travellers have frequently been induced to visit them and record the results of their examination. And thus for many of those recorded in the following pages, numerous references could be given. Others again are situated in out-of-the-way, distant, wild, and unfrequented localities, and the only record of their existence may be a single notice in the pages of some traveller, whom peculiar circumstances may have compelled to pass by that route.

The references given in the present list of these springs will show the varied sources from which information of their existence has been obtained. I should be sorry, however, that any one should imagine that this list is supposed to be complete, or even approximately complete.

Before we can venture to think that we have arrived at any such result, we must hope for the combined action of many in recording the existence and the phenomena of springs in their own vicinity which are only known locally and which may not have attracted general notice whether on account of the inaccessible localities in which they occur or from the absence of any very marked phenomena connected with them.

The earliest attempt at *mapping* these springs in India that I am acquainted with, was by Dr. G. Buist. On the map which accompanies his very interesting paper, 'On Volcanoes in India,' printed in the Transactions of the Bombay Geographical Society, Vol. X (published in 1852), he has marked the locality of thirty-seven hot springs, and he has given, printed on the map itself, brief details of each. All these will be found alluded to below. Several were repetitions of the same source under different names.

Newbold, in discussing the 'Temperature of the Springs, Hills, and Rivers of India and Egypt, &c.' (Philosophical Transactions, London, 1845, page 125; Edinburgh New Philosophical Journal, Vol. X, 1846, page 102), gives brief notices of many with which he was acquainted, and refers to others which had been quoted in a general way, but without any details. Thus he notes that Sykes had been informed of the existence of hot springs in Canara,—he had himself heard of them in the Raidrûg hills in the ceded districts, in the Koondahs on the Western Coast, &c. &c.

In the Indian 'Annals of Medical Science,' No. III, Calcutta, 1854, Dr. J. Macpherson gave a very full list of all the mineral springs then known to him, compiled partly from the records of the Medical Department, and largely also from other sources, both published and original. This list was subsequently issued separately. The point of view from which these springs were specially considered by Dr. Macpherson being their efficacy as therapeutic agents in the alleviation of disease and suffering, his list contained many other than simply thermal sources, but this paper was a very valuable contribution to the knowledge of these springs.

The most recent catalogue or record of the thermal springs of India with which I am acquainted, is that by Mr. Robert Schlagintweit, published in the Journal of the Asiatic Society of Bengal, Vol. XXXIII, page 49, 1864. In this a list of ninety hot springs in India and high Asia is given. Other notices of this list will be found further on.

In compiling the present list, we have of course taken advantage of all these sources of information, as well as of our own observations in several parts of the country, and the correspondence of friends, who have been good enough to give us the results of their experience also. And so far as we know at present, the following list contains all the thermal sources recorded up to this date as occurring within Indian limits, or closely adjoining to Indian boundaries. The special point of view from which these thermal springs became on the present occasion interesting being their connection with earthquake and volcanic or *quasi*-volcanic phenomena; the only fact considered in determining the admission of a spring to the present list has been the temperature of the water of the spring. When known, the actual composition of the water has generally been given, or the presence of peculiar elements stated; but the enumeration of any locality in the following list depends solely upon the fact that the water there thrown out is at a temperature above the mean temperature of the locality where the spring occurs, or at least above the mean temperature of the water of the locality.

There has been considerable difficulty in fixing on the names under which several of these springs should be entered in the list. Locally the springs are universally known by the name given to the spring itself, as Suraj Kund, the spring of the sun; Chandra Kund, the spring of the moon; Sita Kund, &c. &c.; or by descriptive names, as Garmab, hot water; Tatta or tapta pani, Jerria pani, &c.,—all different forms of the words expressing 'hot water;' or from the deities to whom they are supposed to be specially dedicated, or by whom they are said to have been produced, as Mahadeo, or Mahadeva, the great deity. As these names, however, are repeated again and again in different and far-distant districts, it is obvious that they become useless as distinctive names in any general list. Therefore, in almost all cases, the name of the nearest village or town where such exist has been taken as the name under which the hot spring is registered. This name, the geographical position of the place, the latitude and longitude, the elevation of the locality above the sea-level, and the temperature of the water at the spring, are then given, so far as these are known. And to these such further details are added as may be useful either to indicate the position more accurately, to give the composition of the water, or any other points of interest in connection with it.

The springs here noticed naturally divide themselves into geographical groups, as a simple inspection of the accompanying map will show; and in the descriptive notices we have taken them so far as possible in the order of these groups, commencing on the west coast of the peninsula and proceeding northwards, thence turning to the east, and finally terminating on the east coast.

At the end is given an alphabetical index, or list, in which all the names under which the springs have been described or noticed are given; the different spellings of these names, frequently scarcely recognizable, are also enumerated. The variety of these may be estimated from a comparison of the number of entries in this alphabetical list, with the number of separate springs alluded to or described. It is hoped that this list will prove useful to future enquirers.

This list having been prepared, so far as my own researches could carry it, was printed, and copies were circulated to the several local governments and authorities, with the expression of a hope that the various district officers would aid by giving us the benefit of their local knowledge of such facts. I desire to express my thanks for the assistance given, in several cases of considerable value. The additional details made known by these references have, so far as practicable, been embodied in the accompanying lists. I am quite aware that there is still much to be learned regarding the thermal springs of India, and I shall feel greatly indebted for any further information on the subject.

The following abbreviations have been used for brevity :—

M. G. S. I. and R. G. S. I. The Memoirs and Records of the Geological Survey of India.

J. A. S. B. Journal of the Asiatic Society of Bengal.

Q. J. G. S. L. Quarterly Journal of the Geological Society of London.

Buist, when no other reference is given, refers to the Transactions of the Bombay Geographical Society, Vol. X (1852).

Macpherson similarly refers to the Indian Annals of Medical Science, Vol. III (1854).

Schlagintweit to the Journal of the Asiatic Society of Bengal, Vol. XXXIII, pp. 49 *et seq.*

Other abbreviations used are self-explanatory.

Catalogue of the Hot Springs of India.

At intervals along the base of the great range of cliffs known as the Western Ghâts, which stretch almost continuously along the western coast of the peninsula from Surat, north of Bombay, to Belgaum, and are continued further to the south, though in a more broken range of high ground, a large number of copious hot springs rise in the comparatively flat ground, known as the Konkan or Kôkan, which forms a narrow belt between the Ghâts and the sea. Generally speaking, these springs lie about 20 miles (from 12 to 24) from the coast, and a little further from the hills which rise on the east. They occur both as single isolated springs, and in groups of springs, where several issue within a circle of small radius.

Of these the most southerly known to me is Rajapur. I say the most southerly known to me, because I find many marked far to the south of this on Greenough's sketch map of the Geology of India; but I have not succeeded in finding any description of these, while the general inaccuracy of the map prevents any confidence being placed in such references. I have not therefore noticed these.

N. B.—The latitudes given in the following list are all northern, and the longitudes are all east of Greenwich. The values given are generally taken from the sheets of the Atlas of India.

1. Rajapur .·. Lat. 16° 38′; Long. 73° 36′; Elev. ; Temp. 105°.
The spring is on the south side of the creek, or stream, on which the town of Rajapur is situated, between the village of Unali (or Oonali or Oonari) and this creek, on the face of a small hill opposite to Rajapur below the intermittent cold springs. There is only one hot spring. This is in the Viziadroog taluq, 20 miles from the Ghâts and 12 from the sea.—*Dr. Duncan,* Trans. Med. Phys. Soc., Bombay, Vol. I, 1838; India Jour. Med. Phys. Science, Calcutta, Vol. V, or Vol. III, new series, page 524. "Water issues from mouth of a stone cow into a small tank."—*Hazlewood,* Trans. Geog. Soc., Bombay, X, page xlii (1852). Rajpoor of *Buist.* Remarkable intermittent cold spring near. See *Giraud,* Bom. Med. Phys. Soc., V, 256.

2. MAT ... Lat. 16° 57′; Long. 73° 33′; Elev. ; Temp. 157°.

This is on slightly elevated ground, about 1 mile to the north of the river Kanjlee, which passes down from near the Ambaghat to Rutnagerriah: is about half-way between the Ghâts and the sea in Hatkumbi mehal. "People are said to be afraid to use the water of this spring on account of the increased consumption of grain and ghee it occasions by creating a voracious appetite."—*Duncan*, Trans. Med. Phys. Soc., Bombay, Vol. I.

3. SANGAMESHWAR ... Lat. 17° 11′; Long. 73° 39′; Elev. ; Temp. 105°.

Spring in bed of river about 1 mile to east of the town of Sangameshwar, south of the Shastri river which passes that place.—*Duncan*, Trans. Med. Phys. Soc., Bombay, I (1838). *Hazlewood* says the springs are 'in the middle of the river.' It is very probable that such slight differences as to exact locality are due entirely to the fact of the place having been visited by observers at different seasons of the year. Trans. Bomb. Geol. Soc., Vol. X, p. xlii, *Buist* gives SANGAMESHWAR and SANGAMNAIR, distant 14 and 16 miles from the Ghâts, 26 and 24 from the sea, respectively. Either these two are the same, or the latter is Arauli (No. 5); the distances do not agree with those laid down on the Atlas of India map.

4. RAJWARI ... Lat. 17° 15′; Long. 73° 37′; Elev. ; Temp. 110°.

Said to be so hot that the hand cannot be put in without being scalded.—*Hazlewood*, loc. cit. At Rajwari there are two thermal springs, removed from each other by the distance of a few feet. There is a great difference in their temperatures. The villages Tural or Toorul and Rajwari are at opposite (west and east) sides of feeder of the Shastri or Sangameshwar stream, and about half a mile from it. The principal hot spring lies between the two, close to the little stream; but there are several others. Water said to be "very hot—almost boiling." Both are in taluq Rutnagerriah.—*Duncan*, loc. cit. The temperature is that given by *Giraud*, who gives the flow of the spring as one and a half gallons per minute.—*Giraud*, loc. cit. These two springs are grouped together under the name of RAJWARREE TOORIL by *Buist*.

5. ARAULI ... Lat. 17° 19′; Long. 73° 36′; Elev. ; Temp. 105°.

Spring is close to the bank of the Garui, an affluent of the

Shastri stream. Arauli (Arowlee) is one mile and a half to the south. The town of Koondeuree lies about 4 miles to the west down the stream. Water strongly impregnated with sulphur. Is about 16 miles from the Ghâts and 24 from the sea, in Koondeuree mehal.—*Duncan,* loc. cit.: Flow of spring 1 gal. per minute. *Giraud,* loc. cit. On the Atlas sheet Garui and Arowlee are represented by Gurhnee and Arnole.

6. UNERI ... Lat. 17° 35′; Long. 73° 24′; Elev. ; Temp. 109°.

(Spelled OONHERE on the maps of the Atlas of India: UNARI by Schlagintweit, UNALI by others. Unari is the native term for warm water; and there are several places called by this name, as will be seen.)

This village is nearly 2 miles to the north of the Wasishtee river, in Havelee Jaffrabad. Several springs; one very hot —"so hot that rice is boiled in a few minutes;" others more moderate.—*Duncan,* loc. cit.: JAFFRABAD OONALE of *Buist.* OONARA FURRARA of *Giraud.* The temperature is that given by W. G. Salmon. Giraud gives it as 157°, but not on his own authority. The position is that of the village.

7. KHED ... Lat. 17° 43′; Long. 73° 27′; Elev. ; Temp. abt. 100°.

Is 16 miles south-east of Dapuli, about a mile from the town of Khed (Kher of Atlas sheets).—*Giraud,* loc. cit. The place is called Khed in the reports of the Collector of Ratnagiri, and this is probably the correct spelling.

8. WUDAOLI (UNERI) Lat. 17° 56′; Long. 73° 16′; Elev. ; Temp. .

In the course of the stream which flows into the sea at Kelsee. On the left bank of the stream, and about one quarter of a mile from it. Is nearly opposite to the village of Wudaoli, on the right bank. *Duncan* says this is in the Sewundroog taluqa; it is evidently the SEVERNDROOG OONALE of *Buist,* loc. cit.

9. SAVI ... Lat. 18° 6′; Long. 73° 24′; Elev. ; Temp. 109°.

In taluq Rajghur, between Mhar and Dasgaon, near the Savitri river. Referred to by *Sykes,* Geol. Trans. Lond., 2nd series, IV, 427, under the name of MAHR; "only known from report." SAO of *Giraud.* Bombay Med. Phys. Soc., V, 247.

10. PALI ... Lat. 18° 33′; Long. 73° 17′; Elev. ; Temp. .

On the right bank of the Amba river, nearly 2 miles north of Pali or Sarusgurh (on left bank). This has been referred to by Schlagintweit as another UNÀRI or UNÉRI. *Giraud* says the springs are a mile from Palee, in the Tanksee taluqa of the Tanna Collectorate. This, however, must be an error, as Pali is in the Colaba collectorate. The TANKSEE OONALE of *Buist* is evidently the same as this. *Dr. Duncan* says of all these springs that the water is insipid and sulphureous, but when allowed to stand and cool becomes good and pure (loc. cit.).

11. VIJRABHAI ... Lat. 19° 29′ 30″; Long. 73° 6′; Elev. ; Temp. 136°.

About 48 miles north of Bombay. Springs are in bed of river at each side of the hill on which the fort is—*Sykes*, Geol. Trans., London, 2nd series, IV, page 427. This name appears in several forms. Vijrabhai, Vizrabhaee Wujerabhaee, Wuzeerabhaee, Wuzirabhai, Wuzeerabhoy (on Atlas sheet Wujrabhy and Wujrabhye), are some among these. I am quite unable to decide which is the proper form; but, judging from the general history of the locality that it probably is *not* a Mahomedan town or fort, I have adopted the spelling which would be more consistent with a Hindu origin.—VIZERABHOY of *Buist*. Mr. Robertson, Collector of Tanna, mentions this under the name of AKLOWLE, and says the temperature of the different springs varies. Four more springs are situated on land at a short distance from the river, and near the temple of Rameshwar. This is probably the village called on the Atlas of India map AUNKLOWLE, whose position is given above.

12. NIMBOLI ... Lat. 19° 31′; Long. 73° 4′ 30″; Elev. ; Temp. .

This is called Nimbowle by the Collector of Tanna. The only village whose name resembles this is called Nunbolee on the map. The village is said to be situated on the Taunsa river, and the springs, which are hot and sulphureous, are one hundred and seventy-five paces from the village. Nunbolee is below Vijrabhai, and if my identification is correct, this will have been included by early authors with those at Aklauli under the general name of Vijrabhai.

3. GUNESHPURI ... Lat. ; Long. ; Elev. ; Temp. .

Given by the Collector of Tanna; said to be near Vijrabhai. The springs are either in or close to the Taunsa river.

14. GANDODI ... Lat. ; Long. ; Elev. ; Temp. .
Two springs in the bed of the river Taunsa, near the vi lage, which is in the Wada taluqa.—*Official Records.*

15. KULBHONE ... Lat. 19° 30′; Long. 73° 3′; Elev. ; Temp. .
A small hot spring in a field fifty paces from the Taunsa river; is 'in Sywon.—*Official Records.* This is KULMUN of the Atlas of India.

16. VEHLOLI ... Lat. 19° 30′; Long. 72° 55′; Elev. ; Temp. .
Near Dhysaur (Dysur), in the Bassein taluq of the Tanna collectorate.—*Giraud,* Med. Phys. Soc., Bombay, V., 260.

17. TUK MUK ... Lat. 19° 32′ ; Long. 73° 0″; Elev. ; Temp. hot.
In the Mahim taluq of the Tanna collectorate.—*Giraud, loc. cit.* TOOK MOOKH of Atlas of India.

18. HALOLI ... Lat. 19° 40′; Long. 72° 58′; Elev. ; Temp. .
The spring is fifty paces east of the Veyturna river; the water is hot and sulphureous.—*Official Records.*—This is written Hullolee on the Atlas of India sheet.

19. KOKNER ... Lat. 19° 42′; Long. 72° 54′; Elev. ; Temp. .
In the Mahim taluq of Tanna; there are several springs. which flow from the rocks in the steep bank of the Soorya (Sooreea) river into basins hewn for their reception. Water as hot as can well be borne by the hand.—*Giraud,* Trans. Med. Phys. Soc., Bombay, V., 246, called COAKNAIR on atlas sheets.

KOBINEERA ... Lat. ; Long. ; Elev. ; Temp. 130°.
Under the eastern face of the hill fort of Kaldroog. This is given as quite distinct from the preceding by Dr. Giraud, on the authority of Dr. Gibson. But I cannot help thinking that they are the same locality, the difference in the names being due to bad writing or printing.

20. SATIWALI ... Lat. app. 19° 45′ ; Long. 72° 51′ ; Elev. ; Temp. .
Is about 4 miles from Kokner.—*Giraud,* Med. Phys. Soc. Bombay, V., 247. The Collector of Tanna gives Satewli without any further details of geographical position; the springs are four in number.

21. GURGAON ... Lat. 19° 50′; Long. 72° 53′ 30″; Elev. ; Temp. .
About 800 paces from the village a spring rises through a rock in the bed of the river. The Collector of Tanna gives the name as Goregam, doubtless a slip of the pen—GOREGAUN being intended.

Besides the above, the Collector of Tanna gives another spring, whose position I am unable to trace.

22. PERIPLAS ... Lat. ; Long. ; Elev. ; Temp.
In the Wada taluqa, about one and a half miles from the village, two hot springs exist in the bed of the river, at the point of junction of the two rivers Pinali and Vuyburna. The water is as hot as can be borne by the hand.

N. B.—Although I am unable to state accurately the true elevation of any of the foregoing springs, it may be asserted that they are all low, none exceeding, say, 200 feet above the sea-level.

23. ANAVAL ... Lat. 20° 52′; Long. 73° 22′; Elev. ; Temp. 115°–120°.
About 2 miles from the village of Anavāl, which is at foot of hills south-east of Surat city, about 50 miles distant. The springs are commonly called UNEI (heat), or at full DEVAKI UNEI (the divine heat); in the Puranas, in Sanskrit, called USHNA UDAKI (warm water). Said to have been produced by an arrow shot by Rama, in order to supply 18,000 priests who had been miraculously transported there by Huniman, and had no water. A great fair is held here at the full moon of the month Chaitro, when the temperature of the water is said to be miraculously lowered, so as to allow of people bathing in it.—*White,* Trans. Roy. Asiat. Soc., III, pt. 2, 372, 1833. *Col. Sykes* refers to *White's* paper, but the name is, by a typographical error, converted into DEVAKLE UNEI. Dr. Drummond gives the name as DWREKEE OONAEE. Illust. of grammatical parts of Gujerattee, Mahratta, and English languages quoted, Trans. Roy. Asiat. Soc., III, pt. 2, 378. In *Giraud's* paper it appears as DEWKEE OOMAJEE and OONYE; the latter is spelt OONAI by the Resident at Baroda, and is probably identical with the former. In *Schlagintweit's* list it appears under two distinct numbers and names, ANAVAL and VEVAL: Veval is, according to *White,* a village 2 *coss* (4 miles) from the springs; it is Wegwul on Colonel Phayre's map of Gujerat and Wewul on Stanford's map of India.

This completes this group. There are one or two more isolated hot springs between these and the Indus, which may be noticed here.

24. TULSI-SHAM ... Lat. 21° 04′; Long. 71° 06′; Elev. abt. 800; Temp. 124°.
In the Gheer, Kattiwar, water received in a chain of

reservoirs ; so hot that persons cannot bathe in the first reservoir.—*Le Grand Jacob*, Bombay Geogr. Soc., Vol. VII, page 36. This is OONEE in *Macpherson's* list, Ind. Ann. Med. Ser. Calcutta, II, 208.

25 JALANDAR ... Lat. 23° 19′; Long. 71° 39′; Elev. abt. 100; Temp. .
In the Little Rann, near Jhinjhuwara, Top. Surv. of Kattywar.

Passing here to the westward, we find in Kutch—

26. MHURR ... Lat. 23° 20′; Long. 69° 00′; Elev. ; Temp. .
The spring is south of the dhurmsala, and 'on the line of the fault which runs along the northern base of the Mhurr hill.' 'Water warmish, saline.' Close by are several wells of pure sweet water, the nearest being only about nine paces from the warm spring. The water from this latter is used largely in the alum works in the vicinity. —*A. B. Wynne*, G. S. I. The spring is built round and forms a bathing tank; water probably much hotter at its source than in the tank; bubbles occasionally emitted.—*F. Fedden*, G. S. I.

We now come to a remarkable and well-defined group of thermal springs in Lower Scind. It is much to be regretted that our knowledge of many of these is so imperfect that we can say no more than that the spring exists.

27. MANGA-PIR ... Lat. 24° 59′; Long. 67° 06′; Elev. abt. 60; Temp. 127°.
There are three springs, whose temperatures are respectively 127°, 119°, and 99°. The last feeds the Alligator Tank. The water has a slight sulphureous smell, and leaves a blackish deposit on the stones in the vicinity. The above temperatures are the mean of several observations. The name is given as PEER MANGAL, MAGA or MANGEAR. —*Baker and Maclagan*, Jour. Asiat. Soc., Bengal, XVII, pt. ii, 230 (1848). *Carless* gives the temperature 133°.—Proc. Bomb. Geogr. Soc., II, February 1839, page 14. *Schlagintweit* calls it MÁGGAR-PIR, and records a temperature of 106°·2. *Giraud* gives the following names and temperatures for the springs (1854): Hajee Mouza 130°, Hajee Mouga 100°, and Lalshabag 107°. This is the MANGA-PEER of *Vicary*, who says, two springs are in a basin enclosed by hills, excepting to the north-west

and the valley through which there is an entrance from the south-east. Springs are in centre of basin, half a mile apart: water sweet. The northern spring is the hotter, 124°; the other, 99°. Both rise from partings of the strata, which crop out at angles of 50°.—Q. J. G. S., L., 1847, page 337. On the Atlas of India it figures as Muggur-pir. This, however, is incorrect spelling, as it derives its name not from the abundance of crocodiles, but from its being dedicated to Pir Haji Manga, a saint held in high veneration throughout Sind.

28. Jein Pir ... Lat. 25° 00′; Long. 68° 03′; Elev. ; Temp. .
Said by Giraud to be at the base of the Laki hills, 20 miles east of Jerruck (*sic. in orig.*). On the Atlas of India a small temple is marked near the Jhimpir station of the Scind, Punjab and Delhi Railway, 16 miles west of Jhirruk, whose position is that given above, being most probably the position of the spring.

29. Tong ... Lat. 25° 46′; Long. 67° 36′; Elev. ; Temp. .
Marked 'hot spring' in Atlas of India; no further information. See also Sind Revenue Survey, sheet 54.

30. Pokran ... Lat. 25° 48′; Long. 67° 48′; Elev. ; Temp. .
In Kohistan, on the Karachi and Sehwan hill roads.—*Official Records*. The position given is that of the village called Pokran Landee in the Atlas of India.

31. Rani-jo-kot ... Lat. 26° 07′; Long. 67° 58′; Elev. ; Temp. .
Sixteen miles west of Majanda; no further information.—*Official Records*.

32. Khosra-ka-wahi. Lat. 26° 08′; Long. 67° 70′ 30″; Elev. ; Temp. 120°.
In Khelat, shown on sheet 52 of the Revenue Survey of Sind; near the Hubb river, about 1 mile to the west.

33. Garm-ab ... Lat. 26° 13′; Long. 67° 42′; Elev. ; Temp. hot.
The next halting-place after Baluch Got, on the road to Karachi, is Garm-áb, so called from a hot spring in its neighbourhood.—*Masson*, Biluchistan, &c., II, 148. Biluch-Got is said to be within a day's march of Sehwan, and is probably identical with Gote Barocha of the Atlas of India. The position given is approximately that of the spring.

34. Khai ... Lat. 26° 15′; Long. 67° 42′; Elev. ; Temp. .
Three springs, 8 miles south-west of Janghar, on the Buddhro hill.—*Official Records*. In the Atlas of India a

ridge, called Buddhro hill, is marked south-west of Jhingarah. The position given is approximately that of the springs. It is very possibly the same as the preceding spring mentioned by Masson.

35. KANDHAR ... Lat. 26° 14′; Long. 67° 35′; Elev. ; Temp. .

Ten miles south of Naing.—*Official Records.* Kandhar is not marked in the Atlas of India; but a place called Kanda Shah is given, about 16 miles south of Gorandi, whose position is given above.

36. LAKHI ... Lat. 26° 16′; Long. 67° 55′; Elev. abt. 150; Temp. 105°.

About 15 miles from Sehwan, on road to Hydrabad (Sind). There are several springs, of which three are hot. The spot is sacred to Parbutti and Mahadeo. Two are called Surya and Chandra-kund (fountains of the sun and moon.) "If a patient plunges in without first confessing to the priest in attendance, he comes out covered with boils."—*Todd,* Rajasthan, II, 334. There are three springs close together, whose temperatures are 102°, 103°, and 105°; the stones in the stream flowing from them are covered with red, yellow, and white deposits.—*Baker and Maclagan,* J. A. S. B., XVII, ii, 230. Another hot spring in the hills west of the Indus river, a little below Sehwan; sulphur mines near. *Masson,* Beloochistan, &c., III, 148. Under the Dharun hill, issues from the centre of face of mountain, under a cliff of limestone, temp. 120°. Water like that of the Mugger-pir hill; said to have been tapped by Lal Shah Baz, a saint who stands to the Sindians in the same relation as Moses to the Hebrews. There are pucka tanks and a dhurmsala.—*Macdonald,* Surv. Rep., 1861-62, Appendix xxxii. Dr. Hunter, in the Medical History of the 2nd Queen's Regiment, gives the same temperature in 1840, 103°–104°.—Trans. Med. Phys. Soc., Bombay, III, 136.

Can the difference between these records of temperature and that of Major Macdonald be accounted for by difference in graduation of thermometers, or does it (105° up to 1840, 120° in 1860) point to an actual increase in the temperature of the water? See sheet 40 of Sind Revenue Survey.

37. PIR ARI ... Lat. 26° 18′; Long. 67° 47′; Elev. ; Temp. .
Flows from a hill named Lundo, 2 miles south of Jhangar (Jhingarah of Atlas of India).—*Official Records.*

38. NAING ... Lat. 26° 19′; Long. 67° 32′; Elev. ; Temp. .
Six springs 8 miles south-west of Gorandi; two rise from the same mountain as Pir Gazi, the other four from the Buddhro hill.—*Official Records.* There is no village of this name on the Atlas sheet, but a stream near this is called Neyig Jee Dhoree. The position given is approximate.

39. SEHWAN ... Lat. 26° 23′; Long. 67° 54′; Elev. ; Temp. .
Springs of sulphur and hot water about 3 miles to the south of the town of Sehwan.—*Sind Revenue Survey.*

40. PHADAK ... Lat. 26° 25′; Long. 67° 33′; Elev. ; Temp. .
Two miles south of Gorandi.—*Official Records.* Near the position defined is a village called FADUK in the Atlas of India, whose position is that given above.

41. GORANDI ... Lat. 26° 26′ 30″; Long. 67° 32′; Elev. ; Temp. .
Four miles west of Shah Hassan.—*Official Records.*

42. GAZIPIR ... Lat. 26° 27′; Long. 67° 30′; Elev. ; Temp. .
Is on a considerably elevated plateau on a hill called Bhil, above Gazee-pir, a saint's shrine, a few miles west of Shah Hassan. The water is too hot to hold the hand in it.—*Baker and Maclagan*, J. A. S. B., XVII, pt. ii, 230. This is probably the same as BEETH of *Vicary*, who says that about 650 yards from the head of a waterfall a hot spring rises from one of the numerous clefts which everywhere intersect the Hala mountains; the water is of a pale green colour, with a strong smell of sulphuretted hydrogen, and forms large deposits of tufa.—Q. J. G. S., L., III, 345 (1847). Bhil is a misprint for Bhit, the name given to the highest peak of the ridge in the Atlas of India, and a common term in Sind for any mound or hill. The position given is that of the shrine, about a mile and a half from the spring.

43. TANDRA RAHIM KHAN. Lat. 26° 30′; Long. 67° 30′; Elev. ; Temp. .
A hot well.—*Official Records.* *Vicary* says that 6 miles north of Peeth, at a place called SHAHDAD-KA-GOTE, a well

is bored through conglomerate 70 feet in depth, the water of which is tepid.—Q. J. G. S, III, 346 (1847).

44. WAHI PANDI ... Lat. 26° 41′; Long. 67° 16′; Elev. ; Temp. .
Twenty-four miles west of Johi.—*Official Records.*

North of this we come to a scattered series of springs extending up the Indus Valley as far as Peshawur.

45. LAKHA ... Lat. 28° 01′; Long. 67° 30′; Elev. ; Temp. .
About half way between Jannatar and Kichi is a stream of sulphureous water supplied from the neighbouring hot spring of Lakha.—*Masson,* Beloochistan, &c., II, 126. About this position a place called Lakha Peer is marked on the Atlas of India, whose position is that given above, as it is most probably the name is identical with Masson's Lakha.

46. UCH ... Lat. 28° 45′; Long. 68° 40′ (app.); Elev. ; Temp. .
In a valley about half a mile in breadth, and two and a half miles in length; curved in direction, at first tending towards the east, sometimes north-east, and north-north-east. Sandstone dips from the valley, on each side, at an angle of 15°, presenting abrupt faces inwards of about 200 feet in height. Central part of valley is highly saline, as are most of the springs. "I was told that a tepid spring existed in the centre of the valley.—*Vicary,* Q. J. G. S., II., 261 (1846); *Kirk,* Med. Top. of Upper Sind, Calcutta, 1827, page 90. This is Uch in Cutch Gondava, south of the Deyrah country, in Biluchistan, not that in the Punjab.

47. DOZA KHUSHTI ... Lat. ; Long. ; Elev. ; Temp. .
Spring comes up through a fissure in the limestone in the Deyrah valley.—*Vicary,* Q. J. G. S., London, 1846, 265; *Kirk,* Med. Top. of Upper Sind, page 90.

48. KISSUKER ... Lat. ; Long. ; Elev. ; Temp. 71°.
Near the foot of the Trukkee range; water warm.—*Vicary* loc. cit., page 265.

49. GARMO ... Lat. 29° 09′; Long. 69° 53′; Elev. ; Temp. .
Noted on the north-east quarter sheet No. 8 of the Atlas of India. 'Hot water.' It is on the Shoree nullah. No other information.

50. GARMAB ... Lat. 29° 33′; Long. 69° 54′; Elev. ; Temp. .
At the foot of the Mari hill, about 12 miles from Harrand,

the water is bitter with saltpetre and other similar salts.—*Official Records.*

51. Bindar Pir ... Lat. 30° 25′; Long. 70° 30′; Elev. ; Temp. .
Situated near the boundary of the Dera Ghazi Khan district, 6 or 8 miles up the Sodi (Shori?) pass, opposite Kala. Water clear and sweet, but too hot for a man to keep his hand in it.—*Official Records.*

52. Tausa ... Lat. 30° 42′; Long. 70° 37′; Elev. ; Temp. .
About 6 miles from the banks of the Indus river.

53. Bukkur ... Lat. 31° 37′; Long. 71° 07′; Elev. ; Temp. .
On east of Indus; not very far from the road from Dera Ismael Khan to Leia.

54. Sodhi ... Lat. 32° 35′; Long. 72° 19′; Elev. abt. 2,500; Temp. 75°.
About half a mile from the village of Sodhi, in a small deep ravine; the temperature of the stream close by was 64°, and deposits calcareous tufa.—*Official Records.*

55. Bukh Ravine ... Lat. 32° 40′; Long. 71° 51′; Elev. 700; Temp. 94°.
Water gives off sulphuretted hydrogen and deposits sulphur.—*Fleming,* J. A. S. B., XXII., 265. This is Musakhel (erroneously printed Musakhet), No. 53 of *Schlagintweit's* list.

56. Hossein Abdal ... Lat. 33° 50′; Long. 72° 45′; Elev. 1,200; Temp. tepid.
Very strong springs, rising from limestone (? nummulitic).—*Dr. C. J. Stewart,* MSS. corr.

57. Peshawur ... Lat. 34° 00′; Long. 71° 38′; Elev. ; Temp. .
"At a short distance from the cantonments, there are two (certainly one) springs of tepid water, rising from the ordinary alluvial soil."—*Dr. C. J. Stewart,* MSS. corr.

Besides the above, the following hot springs, which I have not been able to identify, are mentioned in the reports received from the Bombay and Punjab Governments :—

Wagodur ... Not far from Landi, in Southern Sind.

Sehaf ... In the Bughi country, far beyond the British border.

One in the western hills of the Shikarpur Collectorate; this is probably Lakha, No. 45.

To the west of the British boundaries, in the Afghan hills, several hot springs have been noticed.

58. DRU ... Lat. ; Long. ; Elev. ; Temp. .
This is between Bamian and Balkh. The springs are near a Therba village of this name.—*Gardiner*, J. A. S. B., XXII, 286.

59. GARM-AB ... Lat. 35° 30′ ; Long. 66° 40′; Elev. ; Temp. .

60. GARMAB ... Lat. 36° 08′ ; Long. 67° 25′; Elev. Temp. .
The above are marked on General Walker's map of Turkestan, and are most probably hot springs. DRU is in this neighbourhood, but is not identical with either.

61. KHORNUSHU ... Lat. ; Long. ; Elev. ; Temp. .
Several springs, all hot, at top of a narrow ledge of rock, 14 miles from the base of snowy range; also said to be a basin: cold in summer, hot in winter.—*Gardiner*, J. A. S. B., XXII, 287.

62. BISUT ... Lat. 33° 45′; Long. 68° 50′; Elev. ; Temp. .
Near valley of Shesh Burjeh, Bamian. The *Azdah* of Bisut is said to be the petrified remains of a dragon, from the back of whose head tepid sulphureous springs issue from a number of small cones of white friable sulphureous stone.—*Masson*, Beloochistan, &c., II, 357.

62*a*. KHAWAK ... Lat. 35° 40′; Long. 69° 40′; Elev. ; Temp. 108°–124°.
Twenty-three miles from Inderab, two thermal springs gush out from the side of a grassy hill.—*Wood, Journey to the source of the Oxus, 2nd edition, page 272.*

We come now to the springs situated in the North-West Himalayas, which will be divided, for convenience, into three series,—marginal, medial, and northern; the first situated on or near the southern margin of the hills; the second, among the peaks of the Himalayas; and the third, north of these, in Thibet.

63. TURNAWAI ... Lat. 34° 16′ 30″; Long. 73° 21′; Elev. 5,500; Temp. .
In Hazara proper, north from Abbotabad and east from Mansurah, rises from nummulitic limestone.—*Dr. C. J. Stewart*, MSS. corr. Turnawai (see Atlas of India, sheet 28) is about 9 miles north by east of Abbotabad, and about 7 south-east of Mansurah.

64. SAIRA ... Lat. 33° 37′; Long. 74° 02′; Elev. abt. 2,000; Temp. .
Hot spring on the left bank of stream running into the Mendola river, about 3 miles below the junction of the Mendola and Poonch Toi. See *Montgomerie's* map of Kashmir, north-west quarter. This is, I think, undoubtedly

that spring referred to by Schlagintweit as SOHORA, No. 78. They give Lat. 33° 40′, Long. 73° 49,′ and Elev. 2,200. They state that Sohora is in Rajaori, but this may be an error. Saira is not in Rajaori. I cannot trace any place called Sohora, where they locate it.

65. RAJAWAR ... Lat. 33° 18′; Long. 74° 25′; Elev. ; Temp. abt. 140°.
One day's march eastwards from Rajawar there is a hot spring (Tatapani); is sulphureous in taste. There is another 45 yards from it, and a cold spring between the two, colder in summer than in winter.—*Vigne*, Kashmir. &c., I, 232. The position given is approximately that of the spring.

66. AKNUR ... Lat. 32° 53′; Long. 74° 48′; Elev. 1,150; Temp. .
Water said to be cold for nine months in the year, but so hot during December, January, and parts of February, that it cannot be borne without pain. The water jerks out at intervals, and falls into a basin. The springs are on the right bank of the Chenab river, on the Trikota or Trikota Devi mountain, 27 miles from Jammú (?) AKNOOR of Atlas sheet.

67. LAUSAH ... Lat. 32° 23′; Long. 76° 05′; Elev. 1,380; Temp. 72°.
In the hills in the vicinity of the Chaki Nadí, north-east of Nurpur. Water contains in 1,000 parts,—hydrosulphate of soda 0·1596, chloride of sodium 0·7400, carbonate of soda 2·6000, carbonate of lime 0·0200, silica 0·0400.—*Marcadieu*, Ind. Ann. Med. Science, II, 536.

68. TEVA .. Lat. 32° 08′; Long. 76° 14′; Elev. 4,333; Temp. 108°.
Springs are about 10 miles from Dhurmsala, about 150 feet above the bed of the nala. The rocks around are covered with an efflorescence of common salt deposited by evaporation of the water. Water limpid, saline, slightly alkaline; 1,000 grs. of water evaporated gave of solid residue,—chloride of sodium 9·233, chloride of calcium 0·546, sulphate of lime 0·120, carbonate of lime 0·100. A subsequent examination of a larger quantity proved the presence of bromide of sodium 0·012.—*Marcadieu*, Ind. Ann. Med. Science, III, 532, and IX, 109. Is about 6 miles in a right line from Kangra to the north-west, opposite to the village of Silot on the River Guj, a feeder of the Beas, and is probably the spring referred to as FUTTIPANI in the Kohistan of the Jullundur Doab by *Parish*, J. A.

S. B., XVII, i, 285. *Schlagintweit's* (No. 85) elevation is given as 1,602 feet. If this be correct, there must be two distinct springs in the same neighbourhood.

69. TATWANI ... Lat. 32° 07′; Long. 76° 46′; Elev. abt. 7,000; Temp. 120°.
On the Lum, a tributary stream of the Birmi, which runs past Baijnath, north from Dewal, 3 miles beyond Bhand (Bhurrer Khoord of the Atlas of India). Water rises in various places among masses of blocks, which are of a gneissoid rock, with great felspathic masses in it. These blocks are profusely scattered over the glen, but I could not see whether this was the rock *in situ* at the springs, or a schistose rock which occurs a little further down. The Lum gets its name (Lon-salt) from a small spring which rises under the water in the stream. A slight metallic scum appears on the surface, and there is some ferruginous deposit on the stones, &c. Taste is most nauseous, and exceedingly adhesive; chiefly bitter, with a kind of metallic flavour.—*Dr. C. J. Stewart*, MSS. corr.

70. BHASRA ... Lat. 31° 14′; Long. 76° 47′; Elev. 6,683; Temp. .
Spring is near the village of Bhasra, and the source of the Lohand Khad, a stream flowing into the Sutlej from below the ridges on which the fort of Chamba is situated. Water is strongly saline in taste, and slightly aperient in action. Water is said to be very efficacious in cases of goitre, dropsy, and rheumatism.—*Wade*, J. A. S. B., VI, 153. This is quoted under the name of LAHAND KHAD by Dr. Macpherson.—*Schlagintweit's* BHATRA, No. 13.

71. SUNI ... Lat. 31° 14′ 30″. Long. 77° 11′; Elev. 2,000; Temp. 135°.
On the right bank of the Sutlej, opposite to the village of Suni. There are eight or ten springs at 2 or 3 feet from the stream. Strong sulphureous smell, and very disagreeable saltish taste; encrusts stones with a yellowish substance, probably sulphur.—*Gerard*, Kunawur, &c., 142. Contains common salt with a little alkaline sulphate. *Prinsep*, Glean. in Science, III, 17. *Schlagintweit's* No. 81.

72. SANSAODARAH ... Lat. 30° 25′; Long. 78° 11′; Elev. 2,800; Temp. 73°.
Near Rajpur; they issue from the limestone at the bottom of a small valley.—*R. D. Oldham; Jaquemount's Journals*, II, 21.

73. Bhaori ... Lat. 30° 05′; Long. 78° 28′; Elev. 3,500; Temp. 94°.
The water wells out of the ground in three or four slight streams. It is situated near the village of Amola, in Pargana Salan, British Gurhwal. This is the Vodri in Gurhwal, No. 98 *of Schlagintweit*, who gives the elevation 5,384 feet. The position is that of Mala on the Atlas of India.

74. Naini Tal ... Lat. 29° 23′; Long. 79° 31′; Elev. 6,200; Temp. .
At the eastern end of the lake; issues from beneath large rocks in the bed of the overflow channel; the water is very sulphureous and deposits a yellowish incrustation. There are said to be several other sulphureous springs in the bed of the lake.—*F. Fedden.*

Passing on to the medial series we find in the valley of Kashmir—

75. Theed ... Lat. 34° 5′; Long. 74° 55′; Elev. 6,000; Temp. .
"Taked, a village in the Pargana of Phak, Soobah of Kashmir. Here is also a spring, the water of which is in winter very hot, and in summer cold."—*Gladwin's* Ayeen Akbary, III, 89. This would appear to be the Theed of Montgomerie's map of Kashmir, and the Tushut, or Tas'hud, of *Thornton's Gazetteer*. Thornton says: it (Tushut) lies on the eastern shore of the lake or 'dal' of Sreenuggur. He gives position of Tushut as Lat. 34° 8′, Long. 74° 44′. Also spelled Tashest. Probably T'hed is the correct spelling.—*Blochmann*, MMS. corr.

76. Pampur ... Lat. 34° 1′ 30″; Long. 74° 59′; Elev. 5,200; Temp. 70°.
Water issues from contorted limestone rocks; sulphuretted hydrogen emitted.—*Vigne*, Kashmir, II, 34. *Hugel*, Kashmir, I, 260. *Schlagintweit's* No. 61. Is about 10 miles east from Srinagar, called Kohir Nag.—*Moorcroft*, Trav. Him. Prov., II, 243. *Schlagintweit's* No. 61.

77. Islamabad ... Lat. 33° 44′; Long. 75° 13′; Elev. ; Temp. .
In the valley of Kashmir; water is 10° higher than the temperature of springs in the neighbourhood. There are two springs, sulphureous.—*Adams*, 'Wanderings of a Naturalist in India,' 1867, page 200.

To the south-east, as far as is at present known, an isolated spring is found between these and the great group of springs in the North-West Himalayas proper.

78. Tatwani ... Lat. ; Long. ; Elev. 6,000; Temp. 140°.
Is on the left bank of the Chenab, not far from Ootoh and Chattargurh. Clay slate and gneiss are seen not far off.—*Dr. C. J. Stewart*, MSS. corr. This, doubtless, is Chatarguhh in Kishtvar, No. 17 of *Schlagintweit's* list, there given "from native information." The latitude is stated to be 33° 3′, and the longitude 76° 16′. I am quite unable to explain, for the author himself gives no clue to it, how in this and a good many other instances, where the very existence of the hot spring is stated to be dependent "on native information," and where the exact locality is therefore unknown, still the latitudes and longitudes are given with the same detail as those of the best known and most frequently visited springs. It surely cannot be intended to lead the reader to suppose that the "native information" was so accurate and detailed as to be acquainted with the geographic position of the locality. And yet, if this were not so, the giving of such detail is only a pretension to accuracy, which can have no other effect than to mislead. I cannot identify the position of this spring on the Atlas of India.

79. Bashisht ... Lat. 32° 16′; Long. 77° 13′; Elev. app. 6,600; Temp. 138°.
On the left bank of the Beas, in the large lateral valley of Kúlú. Ten thousand parts gave an evaporation 7·0 of salts, similar to those found in Manikarn water.—*Marcadieu*, J. A. S. B., XXIV, 198. *Not* sulphureous.—*Marcadieu*, Ind. Ann. Med. Sci., IX. Is a few miles down from the Rotang pass. Temp. 138°.—*Dr. C. J. Stewart*, MSS. *Schlagintweit* also gives the temperature 138°·6, while *Marcadieu* (loc. cit.) says 117°. Strong smell of sulphuretted hydrogen escapes with the vapour.—*Moorcroft*, Trav. in Himalayan Prov., I, 186. About 500 feet above the river; Temp. 123°·5.—*Dr. C. W. Culthrop* in Official Returns.—Bihist, No. 1506, *Schlagintweit's*.

80. Kelat ... Lat. 32° 12′; Long. 77° 12′; Elev. 5,700; Temp. 106°-110°.
A few (12–18) miles below Bishisht, Elev. about 6,000, rises probably from clay slate.—*Dr. C. J. Stewart*, MSS. On right bank of Beas; 10,000 parts gave 8 of solid salts; gives out an odour of animal matter; and the residue from evaporation has a peculiar shining appearance.—*Marcadieu*, J. A. S. B., XXIV, 200. Is 9 miles from

Dwara, and 5 from Monali (Manauli). The spring is called Sita Kund.—*Cuningham*, J. A. S. B., XVII, i, 209. *Gerard*, Kunawur, 142. *Schlagintweit's* KELAT, No. 37. It is called KELAT by *Marcadieu*, KULAT by *Gerard*, and KALAK by *Dr. C. W. Calthrop.*

81. DHARMAUR ... Lat. 31° 59'; Long. 77° 17'; Elev. 4,960; Temp.

At a village of same name on the left bank of the Parbatti, called HISSAOO TEERUTH in the Punjab Government Records. The springs are all under the water of the river, so that the temperature could not be measured.

82. KALUTH ... Lat. 32° 01'; Long. 77° 23'; Elev. 5,700; Temp. 100°-108°.

Several springs within a few hundred yards of the Kashole bridge over the Parbatti river, on the right bank of and close to the river.

BISHENAND is about 500 yards from the above.—*Punjab Government Returns.*

83. MANIKARN ... Lat. 32° 2'; Long. 77° 25'; Elev. 5,587; Temp. 202°.

These springs are in a transversal east and west valley about 20 miles from the lateral valley in which the Beas flows; they are of enormous volume. The hottest springs are close to the right bank of the Parbutty, near the village of Manikarn. They deposit a ferruginous travertine; 10,000 parts only contain 3·2 of saline substances, chloride of sodium, sulphate of soda, chloride of calcium, and carbonate of lime.—*Marcadieu*, Jour. Asiat. Soc., Bengal, XXIV, 198. *Moorcroft*, Travels, I, 177. Temperature, in 1864, 180°; hottest spring 202.°—*Dr. C. J. Stewart*, MSS. corr. The temperature of the principal springs was, in 1864, as follows:—

1. ... 160·5	6. ... 178°·3	11. ... 193°·5
2. ... 162·5	7. ... 185°·5	12. ... 199°·1
3. ... 168·5	8. ... 185°·4	13. ... 201°·2
4. ... 169·09	9. ... 187°·5	14. ... 202°·0
5. ... 174·6	10. ... 191°·5	

The boiling point of water at the level of the springs at the time the above temperatures were measured was 201°·85. The hottest springs, those above 180°, were in a state of ebulition, due, no doubt, in part to an escape of gas. Nos. 12 and 13 were violently so, and also No. 14, from which both water and steam were squirted forcibly through a small vent. On partially obstructing the opening with the ball of a thermometer, the temperature rose to 204°. The heat given off from the spring of largest volume is so great that one cannot approach within several feet. Nos. 12 and 13 are used by the natives for cooking, a vessel of water put over them boiling nearly as well as if heated by fire.—*F. R. Mallett*, MSS. notes, 1864.

84. KHIRGUNGA ... Lat. 31° 59′; Long. 77′ 32″; Elev. 6,800; Temp. 118°.
About 9 miles from Manikarn, opposite the village of Nakthan.—*Punjab Government Records*. *Schlagintweit's* NAKTHAN, No. 55.

85. BABUT ... Lat. 31′ 44″; Long. 77′ 17′; Elev. ; Temp. .
Near a village called Larfi, at the junction of a small stream, called Saving, with the Beas river.

86. JAORI ... Lat. 31° 32′; Long. 77° 50′; Elev. ; Temp. .
On left bank of Sutlej, in Busahir.—*Gerard*, Kunawur, 142. *Schlagintweit's* JAORI, No. 34. This is probably the same as that referred to under the name of ORUN, in communications received from the Punjab Government. It is said to be 3 miles from Serhan, in Busahir. Orun is not marked on the Atlas of India map. The same springs are called AUGOON KOOND in *Lloyd and Gerard's* Tours in the Himalayas, I, page 198: they are five in number. The water is clear and hot, with a saline taste but no smell; forms a ferruginous incrustation on the stones near.

87. NATPA ... Lat. 31° 35′; Long. 78° 02′; Elev. 3,580; Temp. 137°.
On right bank of Sutlej.—*Gerard*, Kunawur. *Schlagintweit*, NATSSA, No. 56. It is also called TATPA, which is probably the correct name. NATPA of Atlas of India.

88. RARANG ... Lat. 31° 31′; Long. 78° 20′; Elev. ; Temp. .
On the right bank of the Sutlej, in Pargana Shoungi.—*Punjab Government Returns*.

89. PUARI ... Lat. 31° 33′; Long. 78° 21′; Elev. 6,555; Temp. 125°.
Is on the left bank of the Sutlej, about 4 miles north-east from Chini, said to be BOKTI (?) of *Gerard's* Kunawur.—*Schlagintweit*.

90. PALIA ... Lat. 30° 54′; Long. 78° 23′; Elev. ; Temp. .
Commonly called ASARIGADH (WAZIRGURH of Atlas): at the bottom of the rocks on which the small fort is, and in the bed of the river several springs of hot water; water is beau-

tifully clear, of more than blood heat, strongly impregnated with sulphureous acid: cold springs close by. In the bed of the Jumna are many such springs of warm water.—*Fraser*, Journey to sources of Jumna. &c., Asiat. Res., XIII, 185. Is on the right bank of the Jumna.

91. BANASSA ... Lat. 30° 56′; Long. 78° 23′ Elev. 7,478; Temp. 160°.
Hot springs abundant; heat too great to bear the hand in the water; little if any taste. —*Hodgson*, Surv. of Rivers Ganges and Jumna, Asiat. Res., XIV, 141.—*Schlagintweit's* No. 8.

92. JUMNOTRI ... Lat. 31° 00′; Long. 78° 31′; Elev. 9,793; Temp. 192°·6.
At the source of the Jumna river, from quartzose laminar rocks, same as at Asarigurh. From one of the springs a column of water of considerable size issues. The water is much hotter than at Asarigurh, perfectly transparent and tasteless; a thin deposit of red (iron) earth on rocks. Springs numerous; all have special names, as Gauri-Kund, Terbet-Kund, &c., &c.—*Hodgson*, Surv. of Rivers Ganges and Jumna. Asiat. Res., XIV, 147. *Fraser*, Journey to sources of Jumna and Bhagirathi. Asiat. Res., XIII, 197. *Schlagintweit's*. No. 32.

93 KHARSALI ... Lat. 30° 57′; Long. 78° 31′; Elev. 8,653; Temp. 72°·1.
Springs are about one and a quarter miles from Kharsalli village, and about the same from Banas, on the left bank of Jumna.—*Schlagintweit's* No. 39.

94. HURI ... Lat. 30° 54′; Long. 78° 44′; Elev. abt. 6,100; Temp. 139°·8.
On the left bank of the Bhagirathi river, about quarter of a mile south of village. URI (No. 95) of *Schlagintweit* and Atlas of India, GANGOTRI of *Macpherson*.

95 GAURIKUND ... Lat. 30° 39; Long. 79° 04′; Elev. 6,417; Temp. 127°.
This is *Macpherson's* KEDARNATH; *Schlagintweit's* No. 25. It is on the road to Kedarnath. The water has no particular taste.—*Official Records*.
Another hot spring is reported below Gaurikand, on the bank of the Mandakni river.

96. BADRINATH ... Lat. 30° 45′; Long. 79° 22′; Elev. 10,214; Temp. 129°.—*Schlagintweit's* No. 6.

97. TAPOBAN ... Lat. 30° 29′; Long, 79° 40′; Elev. 6,300; Temp. 99°–127°.
There are four springs in two groups,—two about half a mile from the village, and two others about half a mile from the first. Those near the village have a temperature of

99° and 109°; the others, 123° and 127°. The water is clear and sparkling, but leaves a yellowish sediment.—*Official Returns*. *Schlagintweit's* No. 84.

98. BHAP KUND ... Lat. 30° 36′; Long. 79° 51′; Elev. ; Temp. 'hot'.
One and a half miles from the village of Jhelum, on the Niti road and on the banks of the Dhauli Ganga.—*Official Returns*. The position is that of Jelam of the G. T. Survey maps of Kumaon.

99. KULSARI ... Lat. ; Long. ; Elev. ; Temp. .
On the banks of the Pindar river, in Pindarwar.—*Official Returns*. I cannot find this place in the maps of Kumaon and Garhwal.

100. AGUR ... Lat. ; Long. ; Elev. ; Temp. .
On the bank of the Ramgunga, near the village of Seernan Mulla, Patti Lobha, Pargana Chandpur.—*Official Returns*.

Returning to the north-west, we begin the northern series with—

101. BULU ... Lat. abt. 35° 30′; Long. 74° 00′; Elev. ; Temp. .
North-east of Bulu and Jaákúr, south-west from Gilgit, are several salt and hot springs, one day's journey from Gilgit.—*Gardiner*, Jour. Asiat. Soc., Bengal, XXII, 301.

101 *a*. ISSAR ... Lat. 37° 05′; Long. 72° 50′; Elev. ; Temp. 116°.
Before entering Issar we passed a mineral spring, about 800 feet up the mountain on the right bank of the river; the ground over which it ran had a ferruginous appearance, but the water was tasteless.—*Wood*, Journey to the source of the Oxus, 2nd edition, page 216.

102. DUCHIN ... Lat. 35° 38′; Long. 74° 50′; Elev. abt. 7,000; Temp. 154°.
Two hot springs at the brink of the river, near the plain of Bonj. Taste sulphureous, and slightly chalybeate; sulphur deposited.—*Vigne*, Kashmir, &c., II, 302. On the map accompanying Vigne's Travels and in the Atlas of India this is spelt DASHKIN, and it is most probably the spring referred to in *Schlagintweit's* list (No. 54) as MUSH-KIN, given "on native information."

103. BISIL ... Lat. 35° 53′; Long. 75° 27′; Elev. ; Temp. abt. 160°
Called BEHITSIL by *Vigne*, Cashmere, &c., II, 285.

104. CHUTRUM ... Lat. 35° 42′; Long. 75° 28′; Elev. abt. 8,200; Temp. 16°0.
This is on the right bank of the Basha river, near a village called Hemasil. See Atlas sheet 28. The hot spring here

gives its name to the village, from *chu*, water ; and *iron*, hot. The water is clear as crystal, without taste or smell. Temperature 110°.—*Godwin-Austen*, Jour. Roy. Geol. Soc., London, XXXIV, 46.

105. TOSHA ... Lat. 35° 44′; Long. 75° 44′; Elev. abt. 8,000; Temp.
On the right bank of the Braldoh river, near the village of Tosha, in Mushim, Baltistan. See Atlas sheet 27a, S. E. quarter.

106. HOTO ... Lat. 35° 43′; Long. 75° 47′; Elev. ; Temp. 137°.
On the right bank of the Braldoh river. About 2 miles north-west of the hot springs at Chongo, there are three springs within a mile of each other; the temperatures are 137°, 122°, and 117°.—*Godwin-Austen* (loc. cit.), page 43.

107. CHONGO ... Lat. 35° 41′; Long. 75° 48′; Elev. 9,700; Temp. 169°.
On the Braldoh river, near the village of Chongo, in Baltistan. It issues from the summit of a conical mound of tufa, 30 feet high, deposited by the spring.—*Godwin-Austen* (loc. cit.), page 42. In all probability this spring is that referred to in Schlagintweit's list under the name of ASKOLI, No. 5. Askoli, or, as it is spelled on the Atlas of India, Askoley, is 5 miles east from the locality of the springs.

108. SNEURON ... Lat. 35° 16′; Long. 75° 42′; Elev. 7,700; Temp. 109°.
This is called TSUH TRON by *Vigne*, who says it is at the foot of the rock of Iskardo. Spring copious; water pure, apparently rises from limestone; forms a bath.—*Vigne*, Kashmir, II, 273. Sneuron is the spelling adopted on the Atlas of India.

109. KHORKUN ... Lat. 35° 20′; Long. 76° 50′; Elev. 9,000; Temp. 185°.
This is the name, as given on the survey sheets, of the nearest village. It is the same as the CHORKÓNDA, No. 19 of *Schlagintweit's* list, and the KOR CHONDUS of *Vigne*. This spring is in Balti, on the Kondus, a branch of the Saltoro valley. Water is sulphureous, depositing gypsum and sulphur.—*Vigne*, Kashmir, II, 388. *Schlagintweit* gives the elevation as 11,594.

110. PANAMIK ... Lat. 34° 47′; Long. 77° 34′; Elev. 10,500; Temp. 170°·5–172°.
On the Nubra, about 13 miles above the junction with the Shyok. Two springs rise from the rocks on hill side, about 400 yards from the edge of the plain, and about a mile from the village: water is faintly sulphureous, not

perceptibly saline: a thick calcareous incrustation on the rocks.—*Thomson*, W. Himal. and Thibet, page 407. *Moorcroft*. This is CHUSAN on the Charassa of *Moorcroft*, Trav. Himal. Prov., I, 406. PANGMIG, No. 62, *Schlagintweit's* list.

111. KNARUNG ... Lat. 33° 53′; Long. 77° 26′; Elev. ; Temp. 'tepid.' Water has a mawkish taste, but without any decided flavour.—*Moorcroft*, Trav. Himal. Prov., I, 416. In Ladák.

112. KISIK KIUL ... Lat. 35° 40′; Long. 78° 48′; Elev. 15,010; Temp. 120°. In Turkistan, near Kisik Kiul, there are fifty hot springs, chiefly containing common salt; the temperatures vary from 77° to 120°. They are situated below the lake of Kiuk Kiul, which is 18,000 feet above the sea.—*Schlagintweit*, J. A. S. B. XXVI, pp. 112 and 118. These are evidently the same as the 'hot spring' marked on General Walker's Map of Turkistan. Schlagintweit in his list gives the elevation as 15,010; Lat. 35° 40′; Long. 77° 56′.

113. GOKRA ... Lat. 34° 28′; Long. 79° 02′; Elev. abt. 16,500; Temp. abt. 150°. Eight miles from Gokra are several hot springs, one of which spouts up from a boulder-like mass of tufa to the height of a foot or more. The water is surcharged with carbonic acid gas and effervesces. There are numerous other hot springs in the neighbourhood having a temperature of about 90°. The elevation is approximate.—*Henderson*, Lahore to Yarkand.

114. KIUM ... Lat. 34° 18′; Long. 79° 02′; Elev. 14,000; Temp. 147°. In the Changchengmo valley, just south of the Changchengmo river, on the road to the Lamkang pass. See Kashmir map, section 16. This is the KYAM, No. 42 of *Schlagintweit's* list, and the elevation and temperature given above are on his authority. The latitude and longitude, which differ a good deal from that given by the Brothers Schlagintweit, are taken from the Trigonometrical Survey map.

115. CHIGAR ... Lat. 34° 05′; Long. 78° 06′; Elev. abt. 15,000; Temp. 70°·5. Hot spring is to north of the trigonometrical station or Chigar, on the Changla road from Chinni to Tankse, about 8 miles from the latter place. This is CHAGRAR in Pangkong, No. 16 of *Schlagintweit's* list.

116. SHUSHUL ... Lat. 33° 36′; Long. 78° 41′; Elev. 14,400; Temp. 96°. Water has neither taste nor smell.—*Moorcroft*, Trav. Himal.

Prov., I, 436. The CHUSHUL in Pangkong, No. 21 of *Schlagintweit's* list.

117. PUGHA ... Lat. 33° 13′ 30″; Long. 78° 22′; Elev. 15,269; Temp. 174°.
There are numerous hot springs in the course of the stream, both on the banks and under the water. Gas evolved smells strongly of sulphur, and taste is slightly sulphureous.—*Thomson,* W. Himal. and Thibet, page 164. *Cuningham,* Ladák, p. 240. Pugha yields a large supply of borax.

118. KURUCHUN ... Lat. 33° 5′; Long. 77° 35′; Elev. abt. 18,000; Temp. .
On the road from the Tsomoriri lake by the Pankpo-la to Shach. Atlas of India.

119. TSOMORIRI ... Lat. 32° 40′; Long. 78° 10′; Elev. 15,670; Temp. .
The southern end of the Tso-Moriri has several warm springs, which render the water of the lake quite tepid.—*F. R. Mallet,* MS. notes.

120. DAMCHOK ... Lat. 32° 40′; Long. 79° 29′; Elev. abt. 17,000; Temp. .
East of the district of Hanle, in Chinese Tartary. Atlas of India.

121. CHANGRIZANG ... Lat. 32° 03′; Long. 78 40′; Elev. 11,000; Temp. 117°·5.
On the south bank of the Para river, north-west of Changrizang, and a few miles from Shalkar. The water issues from 8 to 10 small vents, within a distance of about 20 yards, about 7 feet above the river into which it flows. The temperature of different vents varies from 116°·5 to 117°·5; the water from little pools through which bubbles apparently of sulphuretted hydrogen rise, and a disagreeably strong smell of this gas is perceptible in the immediate neighbourhood. The sides of the pools are covered with a saline incrustation, appearing from its taste to consist of common salt, with admixture. About 100 yards up the river are three or four similar vents.—*F. R. Mallet,* MSS. notes, August 1861. These springs are in great repute for their curative powers, each being considered specific for some special complaint,—the names of the different diseases, and directions for bathing and drinking, being engraved in the Tartar tongue upon large flat stones beside each.—*Gerard,* Koonawur, p. 142. These are the springs noticed under the name SHALKAR, No. 73, by *Schlagintweit;* ZUNGSUM, "4 miles north of Sheal-

khur, at meeting of the Spcetee and Parati rivers." of *Macpherson* and *Gerard*.

122. KIENLUNG ... Lat. 31° 02′; Long. 80° 33″; Elev. ; Temp. .
Opposite to the village of Kienlung, on the left bank of the Sutlej, about 12 miles below the Terthapuri springs.

123. TERTHAPURI ... Lat. 31° 06′; Long. 80° 44′; Elev. ; Temp. .
There are two springs about one-quarter of a mile to the west of the town. Stream issues from mouths or openings about the size of a man's finger, springing up about four inches above level of the orifice. Water is clear, and so hot that the hand cannot be held in it for two seconds. There is a deposit of calcareous matter from the water on cooling.—*Moorcroft*, Journey to Manasorawar lake in Undés, Asiat. Res. XII., 459. The name is spelled Teerutapooree on old maps, place not far from supposed position of the Rhawun Rhud lake. See Atlas, sheet No. 65.

Schlagintweit says that hot springs can be traced all along the southern part of the Kuenluen, from the origin of the Indus near the Mansarowar lake to the Western Kuenluen around Mustak. Some of these springs have a temperature from 90° to 92° cent. (195°–197° F.) at elevations of 11,000 to 12,000 feet above the sea. J. A. S. B., XXVI, 130.

Besides the above, a hot spring is mentioned in the returns from the Punjab Government as existing in Thibet beyond the fort of Salkhan in Bisahir.

We are now interrupted in our passage towards the east by the unknown and unexplored country of Nepal, in which, in all probability, numerous hot springs occur; but of these we have no information of any but two. In a letter from Colonel G. Ramsay, formerly resident at Katmandu, to the Medical Board at Calcutta, he gives a description of them, which I quote in full, as we have no other account of the hot springs of this tract of country.

124. SHEOPURI ... Lat. ; Long. ; Elev. ; Temp. .
The Sheopuri spring issues from the base of a high mountain the summit of which, at an estimated distance of 3 or 4 coss, is perpetually covered with snow. It is situated within a few yards of the eastern bank of the Buri Gandak river, and some 5 or 6 feet above the stream, about a mile from the village of Sheopuri, due north of Noa-

kote, and five days' journey in a northerly and somewhat westerly direction from Katmandu. Its water flows from a black-looking rock, and forms a clear pool 4 or 5 feet in diameter by 2 feet in depth. There are no weeds in it, but its sides and bottom are covered with the white substance of which I have sent a specimen. This spring is said to have a disagreeable smell and an unpleasant salty taste, and the people in its neighbourhood consider that invalids derive much benefit from bathing in it. It is said that it is sufficiently hot to cook rice in, and the persons who went to the spring to bottle the water told me that, although they put their hands into it, they could not bear to hold them in it for any length of time.

125. TATA PANI ... Lat. ; Long. ; Elev. ; Temp. .

The Tata Pani springs are five days' journey from Katmandu in the Listi direction, or nearly north-east of the capital, and issue from the base of a very precipitous mountain in the west bank of and close to the River Sunkusi. There are two or three small springs close together which unite and form a pool of 4 or 5 feet in diameter and one hand in depth. There is no crusty sediment in this pool, its bottom and sides being of a dark-coloured sand; the water is too hot to admit of the hand being suddenly plunged into it, and it is said to smell like gunpowder that has been exploded, and has a nauseous taste. Bubbles were seen rising from this spring, and its waters are considered to be very beneficial to invalids, particularly, I am told, to persons who have lost their strength or are suffering from the effects of protracted sickness, and many persons go from a considerable distance to bathe in them. I gave particular directions that I might be furnished with pieces of the rocks in the neighbourhood of these springs, but I have not succeeded in procuring any; and the persons who were sent to them for the water inform me that, in consequence of their being considered sacred, no persons would be allowed to fracture the rocks in their immediate vicinity.

In Eastern Nepal, Mr. B. H. Hodgeson of Darjiling has obtained, through native collectors, information of several mineral springs, of which, however, only two are hot.

126. HANGTHUWA ... Lat. ; Long. ; Elev. ; Temp. .
East of the Tamor river, and close to it, the water is hot and has a sulphureous smell.

127. NANGIN ... Lat. ; Long. ; Elev. ; Temp. .
In the zilla of Nangin, at a lofty place covered for half the year with snow, and at the spot where a small stream called the Trisul Sanga issues, the water is said to be very hot.

Still further east we come into the Sikkim and Darjiling territories, and here we find a small group of thermal sources, several of which are remarkable both for the great elevations above sea-level at which the springs emerge, and also for the very high temperature of the water.

4. SIKKIM GROUP.

128. MECHI ... Lat. 26° 50′; Long. 88° 30′; Elev. ; Temp. .
On the west bank of the River Mechi, about 6 miles above Mechi Gola, within the hills; deposits iron; is called Menchu by the Lepchas.—*Campbell*, quoted by Baird Smith, Jour. Asiat. Soc., Bengal, 1843, 1039. Position approximate.

129. PUKLAZ ... Lat. ; Long. ; Elev. ; Temp. .
On the Runjit river, about one day's journey from the monastery of Pemlong; is called Puklaz Sachu (*sachu* means hot spring). The water has a disagreeable smell and deposits a whitish substance; is used medicinally.—*Campbell*, quoted by Baird Smith, J. A. S. B., 1843, 1039.

130. PHUG ... Lat. 27° 11′; Long. 88° 24′; Elev. ; Temp. .
Phug Sachu is also on the east bank of the Runjit river, one day's journey from Rinchang-púng towards the east. Its deposit is also white, and the water fetid. This and Puklaz Sachu are both in Sikkim, three days' journey from Darjiling.—*Campbell*, quoted by Baird Smith, loc. cit. The position is approximate.

131. YEUMTONG ... Lat. 27° 46′; Long. 88° 43′; Elev. 11,920; Temp. 112°·5.
On the Lachong river, Sikkim. The springs are about a mile below the village; they are used as baths. Water slightly saline in taste; sulphuretted hydrogen in bubbles. A cold spring (42° Fahr.) close by. Water contains chlo-

ride of sodium and sulphate of soda. The rocks are granite (?), impregnated with sulphate of alumina.—*Hooker*, Himal. Jour., II, 116. Schlagintweit quotes the boiling point determination of the height given by Hooker, *viz.*, 11,730, but this was corrected subsequently.

132. MOMAI ... Lat. 27° 52′; Long. 88° 40′; Elev. 16,000; Temp. 110°-116°.
The springs are at the foot of the Kinchinjow glacier, only a mile below the end of the glacier. They are some four degrees hotter than Yeumtong, although 4,000 feet higher. Water contains 25 grs. per gallon of chloride of sodium, sulphate and carbonate of soda; reaction is strongly alkaline when concentrated.—*Hooker*, Himal. Journ., II, 181.

133. MANGPMU ... Lat. 26° 38′; Long. 88° 29′; Elev. abt. 1,300; Temp. .
About 600 feet above the Tista river there are two or three small clefts in the slate, the air in which feels warm and moist to the hand. There is probably a warm spring here, the water of which trickles away through the crevices of the rock.—*Mallet*, M. G. S. I., XI, 9.

North of Sikkim, in Thibet, a hot spring is known at—

134. CHANGRA ... Lat. 28° 45′; Long. 89° 30′; Elev. ; Temp. 88°.
Twelve miles from Changra and 11 from Salu; the spring is much frequented for medical purposes.—*Turner*, Embassy to the Court of the Teshoo Lama in Thibet, page 220.

In the returns from the Bengal Government a hot spring is said to exist at—

135. RAJSHAHYE ... Lat. ; Long. ; Elev. ; Temp. .
In the district of Dinagepur, between Burgunje and Titalya. —*Official Records.*

Returning now to the west, we find a small group of springs south of Delhi, in Northern Rajputana.

136. SUNAH ... Lat. 28° 13′; Long. 77° 06′; Elev. abt. 800; Temp. 108°.
The spring is about 35 miles south of Delhi, and about 15 from Gurgaon, on the eastern face of, and close under, the Murat hills, near to one of the most craggy and precipitous parts of the ridge. Water gives off a strong smell of sulphur: sulphuretted hydrogen is thrown out: no iron. The well or basin into which it rises has been cut out of the solid rock, 16 feet square and about 30 feet deep,

covered by a dome, and surrounded by apartments, with an open verandah, which are now occupied by Brahmins, said to have been constructed by a Brinjára.—*Ludlow* (1826), Trans. Med. Phys. Soc., Calcutta, III, 19. See also *Baird Smith*, Jour. Asiat. Soc., Bengal, XII, 270. *Jacquemont*, Jour., III, 337. The spring is said to have run cold after the earthquake of the 19th February 1842. The temperature is 125° according to C. E. Smith, M.D.—*Official Returns*. This spring is also noticed in the Ain-i-Akbari. Gladwin's Translation says: Near the town of SEHNAH is a spring of hot water upon a mountain; this certainly is occasioned by a mine of brimstone.—*Ayeen Akbary*, Vol. III, page 89. Given by *Buist* as two springs, under the two distinct names of SONAH and SONEEB, Delhi.

13 7. PAKUL ... Lat. 28° 21′; Long. 77° 17′; Elev. ; Temp. .

This is noticed in the Ain-i-Akbari as ISLAMABAD, which, Mr. Blochmann informs me, is another name for Pakul, near Pali, to the south of Delhi. I know nothing more of this spring than this notice. It is said that "on the mountains of Islamabad is a very deep spring of hot water; it is called Purbhuss, and is a great place of Hindu worship."—Gladwin's Translation, Vol. III, page 89. The true reading is *Prabhas kund*, *i. e.*, pilgrimage well.

138. KANWERY ... Lat. ; Long. ; Elev. ; Temp.

At the town of Kanwery are many cold and hot spriugs.—*Gladwin's* Ayeen Akbary, II, 39. This place is in the Narnoul district, of the Soobah of Agra; the name may read, according to Mr. Blochmann, Kanun, Kanon, Kaon, or Gaon. The only name in the Atlas of India at all resembling any of these is Goreer, in Lat. 28° 3′, Long. 75° 59′.

139. GANESAR ... Lat. 27° 40′; Long. 75° 53′; Elev. ; Temp.

A hot spring at Gunneshur, in the Taurawatti district.—*Official Returns*.

140. TALBRIK ... Lat. 27° 30′; Long. 76° 25′; Elev. ; Temp. 118°.

This is about 14½ miles from the city of Alwár to the west by south, and about 5 miles from Naraiupura to the east. Temperature unpleasantly warm.—*C. A. Hacket*, G. S. I. Water quite clear. Temp. 108° in 1870.—*Selec-*

tions, Government of India, XC, 78. This is evidently the hot spring, 15 miles west by south of ALWÁR, mentioned by *Bellew*, and quoted by *Macpherson*.

141. KOILESAR ... Lat. 27° 04′; Long. 75° 53′; Elev. ; Temp. .
A hot spring at Koleshur, in the district of Dowsah.—*Official Returns*.

142. MORA ... Lat. 26° 42′; Long. 76° 34′; Elev. abt. 1,000; Temp. 120°.
Water clear; leaves no deposit. Mora is about 60 miles south of Alwár.—*F. R. Mallet*, Geol. Surv., India. This is called MORLOH in the Official Returns.

Macpherson, quoting *Bellew*, mentions a spring in the Alwár country, "20 miles north-east of Jeypore." I have not been able to identify it; it does not seem to be any of the three noticed above. Schlagintweit quotes it in his list as JAIPUR, although it is distinctly stated to be in the Alwár country, and he gives (No. 31 of his list) the latitude, longitude, and elevation of Jaipur town as that of the spring.

We may here notice two thermal springs which lie at some distance from any others referred to; the first is in the great desert of Rajputana.

143. DEO CHANDESWAR MAHADEO. Lat. 26° 18′; Long. 69° 51′; Elev. ; Temp.
Forty *coss* from Suni, on the road from Jessulmeer to Sehwan, called by Mahomedans *Diu Bawah*. Spring itself is called Surajkund, fountain of the sun.—*Todd*, Rajasthan, II, 232.

144. GANGRA ... Lat. 25° 03′; Long. 74° 40′; Elev. 1,000; Temp. 80°.
This is 12 miles to the north-west of Chittore. Spring rises from sandstone slabs near the base of a hill.—*Hardie*, Sketch of Central India, As. Res., XVIII, pt. 2, page 53. This is the spring called CHITTUR by *Schlagintweit*, No. 18 of list. GANGAR of the Atlas of India.

Further south, in Baroda, we find a pair of thermal springs.

145. LAUSUNDRA ... Lat. 22° 55′; Long. 73° 11′; Elev. abt. 200; Temp. 124°.
Springs are about 18 miles to the west-north-west of Tui.—*Sykes*, Geol. Trans., London, 2nd series, Vol. IV, 427. This is the LUSSOONDRA of *Giraud*, Trans. Med. Phys. Soc., Bombay, new series, V, 249 (1859). In the Official Returns the place is called LASSINDRA; there are said to be six springs of various temperatures. The water is of an unpleasant taste, but not sulphureous.

146. TUI ... Lat. 22° 48′; Long. 73° 30′; Elev. ; Temp. .
Near Ruttunpur, on the Mahai or Mhye river.—*Sykes*, on authority of Cruikshank, Geol. Trans., London, 2nd series, Vol. IV, 427; TOWA of *Giraud*, Med. Phys. Soc., Bombay, V, 246 (?) The springs are quite close to one another, so much so that the earthen vessels with their bottoms knocked out, which are placed over each spring to the number of 150 to 200, actually south each other as they lie. The temperature of the jets varies from almost boiling (?) to extreme cold; very cold and very hot jets in some cases immediately adjoining. A rank sulphureous vapour is thrown off.—*Official Records*.

Passing to the south-east, we come to a series of thermal sources in Khandesh, lying at the foot of the Satpura hills.

147. KHAIR PARA ... Lat. 21° 44′; Long. 74° 30′; Elev. ; Temp. abt. 98°.
In the Achchrani (Akrani) Pargana of the Sultanpur taluqa.—*Giraud*, Trans. Med. Phys. Soc., Bombay, V, new series, 258 (1859). This is evidently the 'hot spring' marked on the Khandesh topographical survey maps in the position given above.

148. WADLA ... Lat. 21° 28′; Long. 75° 13′; Elev. ; Temp. abt. 90°.
About 2 miles north of the village of Wadla, in the Amba mehal, of the Shirpur taluqa; it is called by the natives Unabdeo, without any addition to distinguish it from that near Arawad.—*Official Records*. This is the OONAPDEO of Briggs (*Sykes*, Geol. Trans., series 2, IV, 247) mentioned above, and the UNAPDEO of *Schlagintweit*.

149. NAZARDEO ... Lat. 21° 18′; Long. 75° 25′; Elev. ; Temp. 100°.
Mr. Pollen says that Nijardeo is situated about a mile and a half to the north of the village of Wirwada, close to a deserted village lying at the foot of the Satpura range, called Magapur. The temperature of the water at noon was 103°.—*Official Records*.

150. SUNAFDEO ... Lat. ; Long. ; Elev. ; Temp. 85°.
Nizardew and Sunabdew are situated within a mile or two of each other, and about 7 and 8½ miles respectively from Unabdew.—*J. W. Grant*, Acting Collector of Khandesh. This may be the SUNAPDEO of *Schlagintweit*, and SOONOOPDEO of *Briggs*. The temperature was ascertained by J. Pollen, Assistant Collector of Khandesh, in 1875, and

was taken at dawn ; at noon it was 6° higher. This spring is not marked on the topographical survey map of Khandesh.

151. ARAWAD ... Lat. 21° 16′; Long. 75° 28′; Elev. ; Temp. 139°.
Is in the Chopra taluq of Khandesh. The spring is locally known as Unapdeo, and is much frequented as a place of pilgrimage.

From here a series of hot springs, or groups of springs, takes us in a north-easterly direction to near Allahabad.

152. DÁMARNI ... Lat. 21° 10′; Long. 75° 36′; Elev. ; Temp. .
"A populous town, in the vicinity of which is a reservoir, the water of which continually boils; the Hindus worship it."—*Gladwin's* Translation of the Ain-i-Akbari, Vol. III, p. 53. Damarni or Damerny, on our maps. Dumurni or Dumbarnee, or Damoree, is about 4 miles north of the River Taptee, in Khandesh. Dambhorni of the topographical survey map of Khandesh.

153. PILI ... Lat. 21° 30′; Long. 77° 19′; Elev. ; Temp. 91°.
In the Gawilghur hills. "The hot spring here is in the bed of the river. The thermometer rose from 85° to 87° when placed in the water." The water is of a brackish taste, and appears to have a slightly aperient effect when drunk. It is considered sacred, and, curious to say, "is frequented by birds and beasts regularly to drink the water."—MSS. letter from *Captain Douglas*, Deputy Conservator of Forests, East Berar, to Major Nembhard, Commissioner, East Berar. Temp. 91° at 6 A.M.—*Major Nembhard* in subsequent letter.

154. SALBALDI ... Lat. 21° 25′; Long. 78° 40′; Elev. ; Temp. 100°.
The water is clear, tasteless, and scentless. Spring rises actually from the metamorphic rocks, but quite close to the fault, which bounds them here.—*W. T. Blanford*, Mem. Geol. Surv. of India, Vol. VI, page 280.

155. ANHONI SAMONI, Lat. 22° 38′; Long. 78° 25′; Elev. abt. 1,000; Temp. 120°.

156. ANHONI ... Lat. 22° 36′; Long. 78° 40′; Elev. ; Temp. .
Two springs near villages of the same names, 17 miles apart, both within the Narbada coal basin near its northern boundary, in or at the edge of strong basaltic dykes, cutting through clays and sandstones of an upper group of the sedimentary series, both of the same charac-

ter, perfectly clear and leaving no deposit. A free discharge of gas occurs, which burns in a receiver with a steady blue flame, the smell being like that of hydrocarbons. The eastern spring is 8 miles from the boundary of the basin, a few feet above the bank of a small stream, where it cuts a gap through a strong east-and-west trap-dyke ; it seems to be in the line of the centre of the dyke, and has a copious discharge of water. The western spring is 1 mile from the boundary of the basin on the south side, and at the very edge of a strong run of trap. There is one principal spring with a small discharge of water barely cool enough to bathe in. Gas is more abundant than in the eastern spring. For more than quarter of a mile along the dyke, gas and water—some hot, some cold—ooze out at many spots.—*H. B. Medlicott*, G. S. I. ; compare also *Spilsbury*, Trans. Med. Phys. Soc., Calcutta, III, 450. Water smells of sulphur. All salts are in minute quantities, sulphates, muriated and carbonated alkalies.—*Prinsep*, Gleanings in Sci., III, 17. "The first word (*anhoni*) means to wash, and *samoni* to mix cold water with warm water ; hence *Anhoni Samoni*, 'lukewarm water washing-place,' would be a good name for hot springs."—*Blochmann*, MSS. letter. These are the HOSHUNGABAD No. 28 of *Schlagintweit's* list, but the latitude and longitude given are those of the town, which is several miles off. Names are spelled UNHONE and AMONI on the survey maps.

157. BUDI. ... Lat. 22° 37′; Long. 78° 47′ ; Elev. : Temp. .

Eight and a half miles east by north of the Western Anhoni ; temperature is tepid, but it gives off the same kind of gas as those at Anhoni.

158. BAHAIHA ... Lat. ; Long. ; Elev. ; Temp. .

A hot spring is said to exist in the bed of the Babaiha nala, in the Mandla district.—*Official Returns.*

159. DEORI ... Lat. 23° 33′ ; Long. 80° 36′ ; Elev. ; Temp. 82°.

Is a little to the west of the village of that name near the Mahanandi river; the temperature of the water of the river was 64°. The spring issues from the natural junction of the Bijawar and Jabalpur rocks ; the water is tasteless.—*C. A. Hacket*, Geol. Surv., India.

160. Bijeragogarh ... Lat. 24° 00′; Long. 80° 41′; Elev. ; Temp. .
A warm spring is said to exist about quarter of a mile east of the town.—*Official Records.*

161. Gupt Gudaoli ... Lat. 25° 05′; Long. 80° 50′; Elev. ; Temp. .
It is 2 or 5 miles south of Puldeo. In the Atlas of India it is marked as a village, but it is merely a spring, near which there may be a few huts for Brahmins, as it is a place of pilgrimage. It issues from a cave, which can be entered crouching, and is warm.—*J. P. Stralton in epist.*

162. Manikpur ... Lat. 25° 04′; Long. 81° 08′; Elev. ; Temp. .
Close to Manikpur, about half a mile in a jungle called Chururgar: water, though hot at first, soon cools down.—*Official Returns.*

163. Kandela ... Lat. 25° 05′; Long. 81° 16′; Elev. ; Temp. .
About 10 miles east and north from Manikpur, on the Rewah frontier, 7 miles south-west of the village of Kotha Kandela.—*Official Returns.*

164. Hurma ... Lat. 24° 31′; Long. 82° 33′; Elev. abt. 700; Temp. .
This spring is opposite to Hurma, a village on the north bank of the *Sone*, and between the villages of Chucki and Gangi, about 3 miles east of Khyra and 10 east of Burdhi. Water clear, has no taste, and leaves no deposit. The spring is on the south bank of the river near the stream, near the village of Gangur.—*F. R. Mallet,* Geol. Surv., India.

165. Ganduari ... Lat. 23° 36′; Long. 83° 18′: Elev. abt. 1,800; Temp. .
About 4 miles due east of Seersa hill, close to the road from Pertabpur to the north; much frequented by wild animals on account of the lick.—*V. Ball,* G. S. I.

166. Sirguja ... Lat. 23° 41′; Long. 83° 42′; Elev. 1,460; Temp. 186°.
In Sirguja, commonly called Tattapani (hot water), springs rise over a large space which is always covered with the vapour from the hot water.—*Breton,* Med. Top. of Ceded Provinces, 1826, page 4. These springs constitute by their number and copious outpourings a very remarkable and, in this part of India at least, a unique, display. They are all arranged, with one exception, on or in the immediate vicinity of a strong ridge of pseudomorphic quartz and breccia, which evidently marks a line of fracture. It is not easy to say how many distinct active springs there are at Tattapani; but these were seen by me certainly

not less than a score, besides which there are indications of many others whose action has been either temporarily or wholly suspended. The temperature of the springs varied from 130° to 190°.—*Ball,* M. G. S. I., XV, 21. By typographical error called "TATTAPARI in the Saryma or Saryuyur district" by *Buist.*

167. THATHA ... Lat. 23° 46′; Long. 84° 05′; Elev. ; Temp. 151°.
In the Hutar coal-field, near the village of Kokratra; the water is strongly sulphureous.—M. G. S. I., XV, page 21.

168. JARUM ... Lat. 23° 49′; Long. 84° 42′; Elev. ; Temp. 132°.
In the bed of the Tabaka river at Jarum; water gives off bubbles of sulphuretted hydrogen in considerable amount. —M. G. S. I., XV, 18.

169. KATKAMSANDI ... Lat. 24° 07′; Long. 85° 16′; Elev. 1,750; Temp. 110°.
Springs come up in a stream as big as a man's finger.—*Everest,* Gleanings in Sci., III, 134. Contains carbonic acid and sulphur, silica, alkaline muriates and sulphates, and iron.—*Prinsep,* Gleanings in Sci., III, 277. This spring is quoted by Schlagintweit as HAZARIBAGH. The cause of this change of name is not very obvious. Katkamsandi is 17 miles from Hazaribagh, and close to the old road from Calcutta to the north-west. The springs rise over a space of 50 yards in length; the water is brackish and gives off a good deal of sulphuretted hydrogen.—*Captain Samuells, in epist.* The name is printed in Newbold's list, Phil. Trans., London, 1845, page 138, as KUTKUMSANDY, and this becomes in the reprint of the paper in the Edin. New Phil. Jour., XL, 1846, page 112, KUTKUMSUANDY.

170. GANDWANI ... Lat. 23° 45′; Long. 85° 26′; Elev. ; Temp. 92°.
Is situated at the south end of the Sorunga ghât, close to the road leading from Burdwan to Ranigurh, on the left bank of the Sondurah nadi, and a mile to the north-west of the village of Kunkee.—*Captain Samuells.*

171. KOWA GANDWANI, Lat. 23° 43′; Long. 85° 26′; Elev. ; Temp. 92°.
Is about a mile south-west of the village of Kowdeh. The water leaves a white deposit on the rocks; it is almost tasteless, but smells of sulphuretted hydrogen.—*Captain Samuells.*

172. INDRA JURBA ... Lat. 23° 50′; Long. 85° 30′; Elev. ; Temp. 102°.
Sulphureous, forming slight deposits; only warm, discharge small; comes up on the faulted boundary of the gneiss and coal-measure rocks on west of Bakaro coal-field. No village very close; about 12 miles from Hazaribagh to the south.—G. S. I.

173. BELKAPI ... Lat. 24° 09′; Long. 85° 41′; Elev. abt. 1,219; Temp. 190°.
The springs are about 27 miles from the station of Hazaribagh, at base of table-land. Four springs, which vary considerably: water of one is at the ordinary temperature of the atmosphere, in another the temperature is 108°, and in the other two 170° and 190°. Sulphuretted hydrogen is thrown out, and a copious deposit, chiefly of muriate and sulphate of soda, with indications of sulphate of iron, is thrown down. The water is nearly tasteless: cattle are said to be very fond of it.—*H. H. Wilson*, Trans. Med. Phys. Soc., Calcutta, III, 450. The springs are commonly known under the name of Surajkund. There are four springs, the temperature of which is 169°, 170°, 173°, 190°; the hottest being in the middle of five—there being a cold spring close by, between two of the hot springs. The cold spring varies from 75° in the morning to 84° in the afternoon. The springs are close to the great trunk road in a small valley.—*Hooker*, Himal. Jour., I, 27.

174. KESODÉH ... Lat. 24° 11′; Long. 86° 04′; Elev. ; Temp. .
A sulphureous hot spring, about 2 miles south-west of Madurkal, not far from the Barakur river, to the north of it, near the road to Palgunj, Hazaribagh, and Kurrukdiha. Two and a half miles south of Bharkatta village.—*Captain Samuells.*

175. SHEOPUR ... Lat. 23° 40′; Long. 86° 37′; Elev. abt. 400; Temp. .
This is also a sulphureous spring. Is further up the Damudar river, and on the north or left bank. It is near the boundary of the Jherria coal-field. Like all others, it is frequented and reverenced.—G. S. I. These three springs are in Manbhum.

176. TANTOLYA ... Lat. 23° 41′; Long. 86° 48′; Elev. 320; Temp. 190°.
This is close to the bank of the Damudar river, a little west of the confluence of the Barakur, on the right or southern bank. Is sulphureous. These are the springs referred to as PACHET springs, the hill of Pachet being

6 miles to the south.—Jour. Asiat. Soc., Bengal, II, 46. The name is so spelled on the survey maps. It is the same word exactly as the Tautlui given below.

177. NUCHIBAD ... Lat. 23° 43′; Long. 86° 48′; Elev. ; Temp. .
This rises from the metamorphic rocks, close to the boundary fault of the coal-field, in the lands of Nuchibad village south of the colliery of Chanch: water good.—*T. Oldham*, G. S. I. JORYA BOOREE of Macpherson's list.

178. SUSINIA ... Lat. 23° 24′; Long. 87° 02′; Elev. ; Temp. .
At the south-western slope of this hill there is a warm spring, which can scarcely be called hot, but is of continuous temperature, quite above the cold-weather mean.—*V. Ball*, Geol. Surv., India.

179. AHMEDPUR ... Lat. 23° 48′; Long. 87° 13; Elev. ; Temp. .
Is in Shahalumpur in Birbhum, north of the Hingla nulla, a branch of the Adjai.—G. S. I.

180. TANTIPARA ... Lat. 23° 53′; Long. 87° 26′; Elev. 290; Temp. 162°.
A group of hot springs, of which five are surrounded by masonry tanks on the right bank of the small stream, the Buklesur, 1 mile south of Tantipara, about 12 miles to west of Sooree, in Birbhum. Sulphuretted hydrogen thrown out. Much frequented. The hottest spring has a temperature of 162°, the coldest 128°.—*Sherwill*, Rep. Stat. Geog. on Beerbhoom, page 14.

181. TAUTLUI ... Lat. 24° 03′; Long. 87° 22′; Elev. 350; Temp. 150°.
About 5 miles above the confluence of the Sidh nullah and the River More, on right bank of the Sidh; about 1 mile from Sadipur spring. In Birbhum.—*Sherwill*, Stat. Geog. Rep. on Birbhum, page 22.

182. HATBALIA ... Lat. 24° 11′; Long. 87° 09′; Elev. ; Temp. .
This is in a ravine about one-half of a mile west of Koomrabad, at Hatbullia. Is in Bhagulpur district, in Tuppeh Belputtah.—*Sherwill*, Rep. on Bhagulpur, 1854, page 25, given from native information.

183. NUNBHIL ... Lat. 24° 10′; Long. 87° 10′; Elev. ; Temp. .
Five coss west of Koomarabad; is the site of an annual fair —*Sherwill*, loc. cit.

184. BARA ... Lat. 24° 21′; Long. 87° 15′; Elev. ; Temp. 145°.
Exactly half way between Dumka and Noni Hat, three-quarters of a mile east of the road; the spring is known as

Tautlui—*W. Oldham, G. Ormsby.* This is the spring 4 *coss* south of Nooni Haut, in the Bhoorbury (Bhoorbooree, Atlas of India) nullah mentioned by *Sherwill.*—Top. Stat. Rep., Bhaugulpore. Temp. 145° in July 1882.—*R. D. Oldham.*

185. Jerwapani ... Lat. 24° 26′; Long. 87° 31′; Elev. ; Temp. 87°.
A very copious outbreak of warm water, which shows in several outlets, along the faulted boundary of the gneiss and coal measures, in the southern portion of the Rajmahal hills, near Gopikaudur.—G. S. I.

To the north of this series lies a small group of springs, all of which have a high temperature.

186. Monghyr ... Lat. 25° 22′; Long. 86° 36′; Elev. abt. 160; Temp. 140°.
The spring here noticed is well known in all the country as *Sitakund* (Seetacoond), but the name of the nearest town is given here to avoid confusion, as the name of the spring is common to many others. The spring is copious, and rises from the plain about 5 miles from Monghyr on the east. There is a slight odour of sulphuretted hydrogen, but the water is very pure, and keeps remarkably well; it is much used.—*Hooker,* Himalayan Journals, I, 88. "Sita was pursued by a giant, and seeing no other mode of escape, took refuge under ground;" hence the spring.—*Archer,* Tours in Upper India, Lond., 1833, II, 118.

187. Paharpur ... Lat. 25° 18′; Long. 86° 34′; Elev. 320; Temp. 104°.
In the Kewa-kol valley several springs rise from the eastern side of the hills, at temperatures varying from cold to 104°. Springs known as Kishi-kund.—*Sherwill,* Kurruckpur hills, Journal Asiatic Society, Bengal, XXI, 198. The springs are actually 5 miles from Paharpur; but this is the nearest village. Several hot springs under the eastern face of Kurruckpur hills flow from hornstone rock, and vary in temperature from 105° to cold; two close together.—*Sherwill,* Top. Stat. Rep., Bhagaulpur, 1854.

188. Bhimband ... Lat. 25° 04′; Long. 86° 27′; Elev. 450; Temp. 147°.
Spring rises from the base of a small rocky detached hornstone hill named Mahadeva; produces a fine stream. All rocks about encrusted with sinter, and appear partially decomposed. A few hundred yards further north, at the foot of a small hill called Dumduma, there is a region of hot springs, the principal of which has a temperature of

145°. On east side of the Kurruckpur hills.—*Sherwill*, J. A. S. B., XXI, 198.

189. BHARARI ... Lat. 25° 07′; Long. 86° 24′; Elev. ; Temp. 145°.
On the Anjun river, water passes out at 145° from two orifices in a heap of jaspideous hornstone rocks. A fine botryoidal silicious sinter deposited from the hot water covers all the rocks near. Springs are about one and a half miles from Babudin and Gurmaha.—*Sherwill*, Kurrukpur hills, J. A. S. B., 1852, XXI, 198. Springs are known by the name of JANUM KUND. Locality commonly called Bhúnd Bharárí.

190. SITAURA ... Lat. 25° 03′; Long. 85° 29′; Elev. ; Temp. 110°.
In the north-west part of Pargana Sumaie of Behar, near foot of the Rajghir hills. A great fair is held here.—*Sherwill*, Surv. Rep., Behar, page 3. Sittourah of the Atlas of India.

191. RAJGHIR ... Lat. 25° 01′; Long. 85° 29′; Elev. ; Temp. abt. 108°.
A group of hot springs, nineteen in number, with four cold springs, rise within a small space, close to the entrance of the gorge which leads into the centre of the Rajghir hills. They are all enclosed in temples, and the natural temperature at the point of issue from the rocks (hornstone quartz) cannot now be ascertained. But it is very high. Much resorted to by the natives.—G. S. I. *Sherwill*, Surv. Rep., Behar, p. 18. J. A. S., B., XV, 59.
There are also a few hot springs along the southern face of the Rajghir hills.—*Ibid*, page 18.

Passing down to Orissa, and thence westwards into the Berars, we come to the following springs :—

192. OTERI ... Lat. 20° 12′; Long. 85° 34′; Elev. 50; Temp. 112°.
Ten miles west of Khoorda.—*Official Records.* Dr. Brander, in a notice on the climate of Pooree, mentions a hot spring at Ooteer, which he evidently believed—for there is no mention of his having personally seen it—to be on the sea-shore. I cannot find any place of that name on the sea-shore, and most probably the above-mentioned spring is referred to. The distance from Pooree, 30 miles, agrees with that given by *Brander*. Trans. Med. Phys. Soc., Calcutta, IV, 382. It is called JAGGARNATH by *Schlagintweit*, and OOTEER by *Macpherson*.

193. Atmalik ... Lat. 20° 45′; Long. 84° 34′; Elev. ; Temp. .
In the native state of Atmalik, opposite the island of Kudergaon (Kudugant of Atlas of India), on the north bank of the Mahanadi.—*Official Records.*

194. Loagudi ... Lat. 19° 19′; Long. 84° 27′; Elev. 1,300; Temp. 110°.
The spring is called Tapta Pani; it is on the east face of the Girtrabadi hill, about 8 miles from the village of Puramari. The water is in ebullition round a rock in the centre of the well, and has a strong smell and taste of sulphur.—*Official Records.*

195. Kotgaon ... Lat. 20° 15′; Long. 82° 35′; Elev. ; Temp. .
The springs are at the foot of the Katpar hills, at the south-east end. They form a considerable stream; temperature that of a comfortable warm bath.—*Colonel Saxton*, Rep. Top. Surveys, Bengal, 1862-63, p. 22. Top. Surveys, 1863-64, App., page 6.

196. Mezka ... Lat. ; Long. ; Elev. ; Temp. .
A spring flows from a hill 25 feet from Mezka. The water is hot, and it has an acid taste with a smell like that of burning charcoal. The inhabitants of the village drink the water of the spring with impunity, as they are accustomed to it. But in the hot weather it proves injurious to new-comers.—*Official Records.*

197. Mandai Chota... Lat. ; Long. ; Elev. ; Temp. .
Between Mandai Chota and Bendra there exists a nala, in which water remains constantly. A spring broke out from this nala about November 1871, at a distance of 500 feet from the village to the north-east. The water of this spring is hot, clear, and sweet.—*Id.*

198. Dalli ... Lat. 20° 35′; Long. 81° 07′; Elev. ; Temp. .
Situated 200 feet from the village of Dalli; the water, which is hot, clear, and sweet, is used by the inhabitants.—*Id.*

199. Bhagatpur ... Lat. ; Long. ; Elev. ; Temp. .
On a hill one mile north-east of the village there is a spring, of which the water is hot, clear, and sweet.—*Id.*

200. Chuikadan ... Lat. 21° 32′; Long. 81° 04′; Elev. ; Temp. .
Near the village.—*Id.*

201. Unapdeo ... Lat. 19° 51′; Long. 78° 18′; Elev. abt. 950; Temp. 110°.
The hot spring is copious, while there is a small cold spring within two or three yards. This cold spring is inside a

small temple, the hot spring outside. Water used for drinking. Situated on the Right bank of the River Pem Gunga.—*W. T. Blanford.* Also known as OUNKDEO. It is in the Nizam's territory, but close to the boundary.—*Official Returns.*

202. GANERI ... Lat. 19° 51′; Long. 78° 26′; Elev. abt. 900; Temp. 101°. Rises from a fault in the lower Vindhyan limestone and shale. Water used for village drinking, and is taken in preference to the stream which runs past the place. Air in shade at time of observation, 86°. Spring lies in the bed of River Pem Gunga.—*W. T. Blanford.*

203. ARJUNA ... Lat. 19° 50′; Long. 78° 51′; Elev. abt. 800–900; Temp. 87°. A small spring issues from lower Vindhyan sandstone (limestone close by); air in shade at time of observation, 78·5° in East Berar.—*Malcolmson,* Geol. Trans., 2 series, V, 556. This is No. 4 of *Schlagintweit's* list.

204. KHAIR ... Lat. 19° 54; Long. 78° 57′; Elev. abt. 870; Temp. 87°. In East Berar, very copious; said to be most abundant and hottest in the hot weather, and to cease or nearly so in the rains. There are several springs; temperature of the smallest, about 200 yards off, is 85°. Air in shade at time of observation, 50°. The water is used for irrigation; is tasteless, scentless, pure, and also used for drinking. Spring rises from the lower Vindhyan limestone, or between the limestone and sandstone.—*Blanford,* Geol. Surv., India. This is the KAIS, a misprint for Kair of *Newbold's* list, Phil. Tran., 1845, 137. Edin. New Phil. Jour., XL, 1846, p. 112.

To the east in the lower Godavari valley are two springs.

205. GONDALA ... Lat. 17° 39′; Long. 81° 00′; Elev. 130; Temp. 140°. Rises in the sandy bed of the Godavari river, about 2 furlongs from its left bank, about 3 miles below the pagoda Bhadrachellum, close to rocks of granite and trap (hornblende rock) mixed in various ways. It is covered by the river in the rainy season. Temperature of air at sunrise, when recorded, 70°, of spring 139°, and of other adjoining 130°–120°. The odour of sulphuretted hydrogen sensible but slight; 2,880 grains evaporated left 6 grains of saline matter, consisting of sulphate of soda, common salt, and muriate of lime.—*Voysey,* J. A. S. B., II, 396. Tem-

perature 49° cent, certainly due to one of the great fissures of dislocation or faults which have accompanied the upheaval of the eastern ghâts, although in the immediate neighbourhood no peculiar alteration in the general features of the country is visible.—*Adol. Schlagintweit*, Reports of Magnetic Surv. of India, J. A. S. B., 1857, 103. 'Temp. 140°. Rises in sandy bed of Godavari; contains sulphuretted hydrogen, sulphate and muriate of soda and lime.'—*Malcolmson*, Geol. Trans., London, 2 series, V, 365. Spring emerges fully 12 feet below the sandy surface of the river bed. Temperature 140°, as nearly as I could take it; probably a degree higher a little deeper down. The spring is near the boundary of the metamorphics and sandstone, here a fault.—*W. T. Blanford*. This is *Schlagintweit's* BHADRACHELUM in Orissa, No. 12. Bhadrachellum is not in Orissa, nor is the spring at that place.

206. BUGA ... Lat. 17° 56′; Long. 80° 45′; Elev. ; Temp. 108°.

In a valley surrounded by sandstone rocks, 30 miles north-west of Gondala; a pool of water 40 feet long by 30 feet broad, and 5 feet deep; temperature in centre 110°, at the sides 100°. Water tasteless and pure, holds a small quantity of carbonate of lime in solution. The place is surrounded by blocks of black porous limestone.—*Voysey*, J. A. S. B., II, 396. The hot spring at Buga, 12 miles west by north of Dumagudem, flows in a valley into a small pool from which a trifling stream flows. The quantity of water is small. Temperature 108°. It is close to a boundary between the 'Kamthis' and 'Vindhyans,' but there does not seem to be a fault.—*W. T. Blanford*, Geol. Surv. of India, MSS. This is the BAIDRA (not in Berar, however) of Schlagintweit's list (No. 7), the BAIDRA or BYORA of *Malcolmson*, Geol. Trans., London, 2 series, V, 565. It is written BANGA by *Voysey, loc. cit.* This is probably a misprint for BAUGA. In the Phil. Trans., 1845, page 137, *Newbold* gives BAUGHA, reprinted in Edin. New Phil. Jour., XL, 1846, page 112. Schlagintweit had evidently sought for it in vain.

In the Nizam's Dominions, west of Hyderabad, there is a small group of thermal sources.

207. BEDER ... Lat. 17° 55′; Long. 77° 36′; Elev. ; Temp. .

On the Castle hill.—*R. Cole*.

208. KAULAGI ... Lat. 17° 21′; Long. 77° 12′; Elev. ; Temp. .
Springs are immediately south of the village, welling up in small tanks in pagoda buildings on each side of the stream; a large volume of water is thrown out and a stream of air-bubbles is always rising to the surface. The water is warm, very clear, and gives a pale-bluish tinge to litmus.—*W. King.*

209. RAMTEERUTH ... Lat. 16° 59′; Long. 77° 14′; Elev. ; Temp. .
Occurs in a fault near the village of Ramteeruth, in the Nizam's Dominions. The water is warm.—*W. King.*

210. ATMACOOR ... Lat. 15° 53′; Long. 78° 46′; Elev. ; Temp. 'tepid.'
Near the tank of Siddapur.—*W. King,* G. S. I., MSS.

211. CALWA ... Lat. 15° 36′; Long. 78° 16′; Elev. app. 1,000; Temp. 90°.
Springs are about 1½ miles southward from Calwa, a large and old village in Kurnool district. The first spring has a temperature of 89° Fahr., as has the second also; while the third, which is half a mile further up, is 90°. There is a temple dedicated to Iswara at the springs which gush from several fissures in the rocks into a handsome stone tank, about nine paces square. The water is beautifully transparent, tasteless, and odourless. The stream formed by the springs runs along the glen, from which a *calwa* or aqueduct (hence the name of the village) conveys the water to the lands around the village. Thick beds of calcareous tufa occur round the springs.—*Newbold,* Madras Jour. Lit. and Sci., XV, 160. These springs are on the east and west line of faults which pass through Gunnygull hill.—*W. King,* G. S. I., MSS.

212. VANKARUM ... Lat. 15° 33′; Long. 78° 41′; Elev. ; Temp. warm.
About 7 miles north of Mahanandi pagoda hill.—*W. King.*

213. LANJABANDA ... Lat. 15° 30′; Long. 78° 03′; Elev. 1,250; Temp. 85°–91°.
Several springs, about 1 mile to the east of the village, in a transverse jungly valley. The water silicifies, is tasteless, inodorous, slightly alkaline, with carbonate of lime and iron.—*Newbold,* Jour. Asiat. Soc., Bengal, XIII, 1313. Lanjabanda is in Kurnool district, not in the Dekkan, as stated by *Schlagintweit,* list No. 44. In *Macpherson's* list a typographical error has made this name SUNJABANDA.

214. MAHANANDI ... Lat. 15° 29′; Long. 78° 41′; Elev. app. 800; Temp. 88·7°.
The springs rise on the western side of the Nulla Mullay hills, which separate the districts of Kurnool and

Kuddapah. They are enclosed by a temple dedicated to the great bull, Mahanandi. The nearest village is Gaza. pilly, about 2 *coss* south. Water is very clear, with a faint aqua-marine hue. The supply is so abundant as to form at once a stream which constitutes a large portion of the supply of the great tank of Nandial, a town about 10. miles to the west of the springs. Water tasteless. Diamond. and lead mines occur in vicinity.—*Newbold*, Madras Jour Lit. Sci., XV, 160.

215. WUDDYRALLA ... Lat. 14° 58′; Long. 78° 18′; Elev. ; Temp.
In the Jamul Madugu hills of the Kadapah district; it flows out of nearly horizontal quartzites in a small stream abouo 1 mile from the village; the water is sensibly warm in the early mornings, but hardly distinguishable so later on in. the day.—*W. King*, Geol. Surv., India.

In reply to enquiries the Collector of Karnul has given a list of hot springs in his district without any further information. I give his list with a view to elicit further information rather than as a satisfactory account of these sources. I have endeavoured to ascertain, from the sheets of the Atlas of India, the geographical co-ordinates of the localities noted, but have failed to have many of them. They are all said to be hot, but are most probably only of constant, perhaps tepid, temperature; for it is hardly probable that such a remarkable group of springs, had they been really hot, would have failed to attract more attention.

216. CHINNA TEKUR Lat. 15° 43′; Long. 78° 03′; Elev. ; Temp.
217. BODAVANIPALLI Lat. 15° 40′; Long. 78° 06′; Elev. ; Temp. .
Bodanpilly of Atlas of India.
218. WULANDIKONDA Lat. 15° 38′; Long. 78° 02′; Elev. ; Temp. .
Oolendaconda of Atlas of India.
219. YEMBAYI Lat. 15° 34′; Long. 78° 11′; Elev. ; Temp. .
220. DHONE Lat. 15° 22′; Long. 77° 56′; Elev. ; Temp. .
221. MALAKAPURAM Lat. 15° 21′; Long. 78° 02′; Elev. ; Temp.
Mulkapoor of Atlas of India.
222. NARMUR Lat. ; Long. ; Elev. ; Temp. .
223. BRAHMAGUNDAM Lat. ; Long. ; Elev. ; Temp. .
224. PANEM Lat. 15° 32′; Long. 78° 23′; Elev. ; Temp. .
Two miles west of the village; Paneum of Atlas of India.

225. GADIGEREVALA... Lat. 15° 37'; Long. 78° 29'; Elev. ; Temp. .
Two springs, 1 and 2 miles south-west of the village respectively; Guddagarval of Atlas of India.

226. CHAMAKAPALLI ... Lat. ; Long. ; Elev. ; Temp. .
One mile north-east of the village.

227. RANGAPURAM ... Lat. ; Long. ; Elev. ; Temp. .
Eight springs near this, 1, 1½, and 3 miles, 1½, 2 and 3 miles S.W., 2 miles N., and 2 miles N.E., of the village respectively.

228. KOTAKAPALI ... Lat. ; Long. ; Elev. ; Temp. .
Two miles to north-east of village. There are several places marked on the Atlas of India maps, under the name of Kottapali or Cottapilli.

229. MUTTALUR ... Lat. 15° 12'; Long. 78° 38'; Elev. ; Temp. .
Half a mile north of the village.

230. ALAMUR ... Lat. 15° 09'; Long. 78° 39'; Elev. ; Temp. .
Three springs, half a mile north-east of the village.

231. RUDRAVARAM ... Lat. 15° 14'; Long. 78° 43'; Elev. ; Temp. .
Two and a half miles east of the village. Roodrar of the Atlas of India probably.

232. CHAGORLMARI ... Lat. ; Long. ; Elev. ; Temp. .
Two springs, one and a half mile east of the village.

233. SIRWELL ... Lat. 15° 20'; Long. 78° 36'; Elev. ; Temp. .
One mile north of the village, in the bungalow compound.

234. GAJJALABONDA... Lat. ; Long. ; Elev. ; Temp. .
Eight miles to the east of Markapuram.

235. GOPAVARAM ... Lat. 15° 26'; Long. 78° 40; Elev. ; Temp. .
Two miles east of the village.

236. BUKKAPURAM ... Lat. 15° 28'; Long. 78° 40'; Elev. ; Temp. .
Two springs, 2 miles east of the village and half a mile south of the Mahanandi road; probably the same as Mahanandi No. 214.

237. GAZULAPALI ... Lat. ; Long. ; Elev. ; Temp. .
Two miles north of the village.

238. KADMALA KALVA Lat. 15° 30'; Long. 78° 45'; Elev. ; Temp. .
Two miles south-east of village. Kuddamal Calwa of Atlas of India.

239. TINIMAPURAM ... Lat. ; Long. ; Elev. ; Temp. .

240. BHUGA ... Lat. 14° 25'; Long. 78° 53'; Elev. 560; Temp. 88°.
In the Puliconda hills, south of Cuddapah. Water perfectly pure and well tasted; rises from a fault in the subja-

cent strata. Water is made to come from the mouth of a sculptured cow or bull; five or six other springs close by; is in a sharply truncated hill top on banks of the Cuddapah river or stream.—*Newbold,* J. A. S. B., XIV, 505. BOOGGA, on Atlas maps.

241. SALEM ... Lat. 11° 37′; Long. 78° 13′; Elev. 2,000; Temp. 84°.—*Newbold,* Phil. Trans., London, 1845, page 129. Edin. New Phil. Jour., XI, 103.

242. IBADE ... Lat. 12° 43′; Long. 75° 13′; Elev. ; Temp. 99°—102°. Six miles from Pootoor; water pure and preferred by men and cattle to that of the river close by.—*Official Records.*

243. BOTHA ... Lat. 17° 47′; Long. 74° 26′; Elev. ; Temp. . The spring is called Lin Khal; the water is tepid; it rises from a hill near the village of Botha, in Sattara.—*Giraud*. Trans. Med. Phys. Soc., Bombay. New series, II, 58 (1859).

In the Assam hills, we have every reason to believe that there must be an extensive group of hot springs, but, with the exception of the two mentioned below, we have no particulars of any of them, though there can be but little doubt that, as soon as this district is more thoroughly explored, more will be discovered.

244 KOPILI ... Lat. 25° 31′; Long. 92° 40′; Elev. ; Temp. 122°. On the right bank of the Kopili, three days' journey from Silchar, one and a half day's journey from Jawai. The water is not saline but only hot.—*Official Returns.* Captain (now Lieut.-Col.) Godwin-Austen however, speaking of the spring in a private letter, says it is strongly saline.

245. NAMBA ... Lat. 26° 02′; Long. 93° 53′; Elev. ; Temp. . On the right bank of the Namba stream, close to where it joins the Dhunsiri river, 12 miles from Golaghat. There are several springs; gas, apparently slightly sulphuretted, is copiously given off; the discharge of water is copious and at a scalding temperature.—*H. B. Medlicott.*

The district of Nowgong is said to contain several mineral and hot springs, the waters of which are generally brackish, though those of a few sources of sulphuretted hydrogen.—*Robinson's* descriptive amount of Assam.

We meet near Chittagong, on the shores of the Bay of Bengal, or near to them, the large group of springs known generally under the name of Sita Kund (Seeta Koond). These are about 22 miles to the north of Chutgaon, or Chittagong.

246. SITAKUND, CHITTAGONG. Lat. 22° 98′; Long. 91° 43′; Elev. 100; Temp. .
These were visited in detail by Pogson in 1778, who describes them. There are many springs within a small radius. Babu Kund is at the end of a valley surrounded by hills; the water is always cold; springs covered by brick-work. Flames in successive flashes were playing on the surface of the water, which, though cold, had the appearance of being boiling, from the volume of perpetually rising bubbles of gas; water is brackish, sulphureous and chalybeate. There are seven other springs within a circle of 6 miles, called Nuolukka, Kooaree Dudhee, Burma, Sooruj, Chandur, and Seeta. Nuolukka is warm and saline; vapour ignites on the application of flame. Kooaree is hot, saline, sulphureous, and chalybeate; vapour ignites. Dudhee, water is cold, salt; vapour does not ignite. Burma (Brahma?), very hot and saltish, slightly chalybeate; vapour ignites. Chandra, or Chandur, is on a hill, salt and exceedingly hot ("said to have appeared within the last four months"). Seeta is pure, limpid water.—*Pogson*, quoted in Corbyn's Ind. Jour. Med. Phys. Sci., Vol. III or Vol. I, new series, page 156, &c.

In British Burma there is an exceedingly numerous series of springs, of the particulars of many of which we are unfortunately lamentably ignorant.

247. SANDOWAY RIVER Lat. 18° 06′; Long. 94° 54′; Elev. ; Temp. 110°.
Situated in a very secluded spot in the central Sandoway township, near the sources of the Sandoway river, three days' journey from the nearest river; the spring gushes with some vehemence from the rocky wall in some twenty places; the water is of a greenish colour.—*Captain Fryer.*

248. BÚ-LÉ ... Lat. 19° 15′; Long. 95° 16′; Elev. ; Temp. .
Close to the mouth of the Bú-lé stream, on the north bank —*W. Theobald.*

249. LEPAN-BEW-CHOUNG. Lat. 19° 16′; Long. 96° 36′; Elev. ; Temp. 100°–115°.
Two springs, situated in the valley of the Lepan-bew-Choung river, about 4 miles apart, on an E. N. E. and W. S. W. line.—*W. Theobald.*

250. KAYENG CHOUNG Lat. 19° 10′; Long. 96° 36′; Elev. ; Temp. abt. 110°
—*W. Theobald.*

251. CHOUNG-NA-NAY Lat. 18° 44′; Long. 96° 46′; Elev. ; Temp. 108°.
North of Khyouk-Thwa-Choung.—*W. Theobald.*

252. KAYLOO MYOUNG Lat. 15° 33′; Long. 96° 51′; Elev. ; Temp. 157°.
In the Hmoh valley; others exist higher up to the eastward.—*W. Theobald.*

In the Official Returns from the district of Shwe gyeen, the following hot springs are given with their geographical co-ordinates, but no further information :—

253. BIN-BYAI ... Lat. 18° 33′; Long. 96° 55′; Elev. ; Temp. .
254. MAI-POUK ... Lat. 18° 19′; Long. 96° 54′; Elev. ; Temp. .
255. SAIR-AO-KHAN ... Lat. 97° 04′; Long. 18° 04′; Elev. ; Temp. .
256. HTEEPAHTOH ... Lat. 17° 56′; Long. 97° 03′; Elev. ; Temp. .
257. VADAI CHOUNG Lat. 17° 56′; Long. 97° 12.′; Elev. ; Temp. .
258. KOON-PAI ... Lat. 17° 55′; Long. 97° 01.′; Elev. ; Temp. .
259. MAITINE ... Lat. 17° 53′; Long. 97° 04.′; Elev. ; Temp. .
260. KYOUNG CHOUNG Lat. 17° 35′; Long. 97° 02.′; Elev. ; Temp. .
261. GYO ... Lat. 17° 10′; Long. 97° 39.′; Elev. ; Temp. .
On the Gyo creek, 45 miles north of Moulmein Pagoda. *W. Theobald.*

262. NGA YAI KYOON JUIN. Lat. ; Long. ; Elev. ; Temp. .
Is in the Nga Yai Kyoon Juin, in Martaban; water salt to the taste.—*Official Returns.*

263. SIENLI ... Lat. ; Long. ; Elev. ; Temp. .
In Martaban; water sulphureous, with trace of sulphate of iron.—*Prinsep.* Gleanings in Sci. III, page 17.

264. KALINE AURIG ... Lat. ; Long. ; Elev. ; Temp. 108°.
This is the same as Eubien, in Martaban.—*Low,* Asiat, Res. XVIII, 128: called a 'hot well'.

265. POUNG YABOO ... Lat. ; Long. ; Elev. ; Temp. .
In the district of Salween Hlinebway; water saltish.—*Official Returns.* On the map issued by the Siam boundary survey, there are marked in the district of Hleingbway two places—one Phoung, in Lat. 17° 06′, Long. 98° 00′ and another, Yayboo, in Lat. 16° 81′, Long. 98° 02. One of these is perhaps the place referred to.

266. NOUNG-TYNE ... Lat. ; Long. ; Elev. ; Temp. .
Water salt to the taste.—*Official Returns.* The only names resembling this on the Siam boundary map are Nyoung-Zouk, and Noung-ta-bway, near the boundaries of the

Hleingbway and Houngdarun districts, 4 miles from each other; in about Lat. 16° 44′, Long 98° 12′.

267. Mai-palai ... Lat. ; Long. ; Elev. ; Temp. .
Water salt to the taste.—*Official Returns.* There is a stream, called May-play, flowing down near Maya-waddee, whose course is 35 miles long.

268. Mya-waddi ... Lat. 16° 43′; Long. 98° 32′; Elev. ; Temp. .
Water saltish.—*Official Returns.*

269. Thaphun ... Lat. ; Long. ; Elev. ; Temp. .
Water salt —*Official Returns.*

270. Poung ... Lat. 16° 9′; Long 98° 14′; Elev. ; Temp. .
Water salt.—*Official Returns.* Poung-ta-goo of Siam boundary map?

271. Ye-bu ... Lat. 16° 34′; Long. 98° 09′; Elev. ; Temp. .
Water salt to the taste.—*Official Returns.*

272. Damathat ... Lat. 16° 33′; Long. 97° 52′; Elev. ; Temp. .
The spring is situated on a hill near the village; water brackish. *Official Returns.*

273. Bonet ... Lat. 16° 27′; Long. 97° 37′; Elev. ; Temp. .
In Pya Gueen near Bonet village.—*Official Returns.*

274. Ahtaran ... Lat. 16° 06′; Long. 98° 02′; Elev. ; Temp. ab. 130°.
"There are ten hot springs, or rather hot-water ponds, of which I could only examine the nearest, as the access to the others was through deep water at 130°. A large quantity of carbonic acid gas is evolved."—*Mason.* Nat. Prod. of Burma, page 16, quoting Dr. Helfer. The same spring is described under the name of Attayen; it is said to be in active ebulition; there are three wells about 60 feet in diameter, and close by is a cold fetid spring evolving sulphuretted hydrogen gas.—*Faley,* J. A. S. B., V, 269. This is probably the spring said to be on the Athan river, which flows from the Athan hills.—*Piddington,* Gleanings in Sci., III, 24.

275. Myan Khoung Lat. 15° 13′; Long. 98° 07′; Elev. ; Temp. .
Water salt.—*Official Returns.*

276. Thalan Khoung Lat. 15° 10′; Long. 98° 03′; Elev. ; Temp. .
Water salt.—*Official Returns.*

277. Ingyee ... Lat. ; Long. ; Elev. ; Temp. .
In the Binhline circle of the Phagot township; water salt.—*Official Returns.* Neither of these names are given in the *Burma Gazetteer.*

278. Nat Gyi Zin ... Lat. 14° 55′; Long. 98° 00′; Elev. ; Temp. .
Situated at the foot of a hill called Shitka Doung, 500 feet from the mouth of a small stream, a tributary of Nat Gyee Zin (Nat-kyee-seng of map) to the south of it.—*Official Returns.*

279. Henzai ... Lat. ; Long. ; Elev. ; Temp. .
Lies near the mouth of a small tributary to the Henzai stream, distant about half a day's journey from where the stream flows into the Henzai basin.—*Official Returns.* On the Siam boundary map there are two streams, called Hseng-Hsway, flowing into the Hean-Zay basin.

280. Myitta ... Lat. 14° 13′; Long. 98° 33′; Elev. ; Temp. 119°.
At the foot of a hill north-east of Myitta, on the right bank of the Tenasserim river.—*Official Returns.* This is the spring 4 miles below Matah, at the forks of the Tenasserim river; very sulphureous and chalybeate.—*Mason,* Nat. Productions of Burma. Marked on pl. X of Calcutta Jour. Nat. Hist., Vol. II.

281. Paltha Kyoung Lat. ; Long. ; Elev. ; Temp. .

282. Mandoo ... Lat. ; Long. ; Elev. ; Temp. .
On the Bin stream, south of Myitta; water luke-warm —*Official Returns.*

283. Lankyen ... Lat. 14° 12′; Long. 98° 25′; Elev. ; Temp. 144°.
Is situated on some low lands near the source of a tributary to the Pagayai stream.—*Official Returns.* Water sulphureous, containing sulphate of lime.—Glean. in Science, III. 17. This is probably the spring nearly east of Tavoy mentioned by *Mason,* who gives its temperature—*Mason,* Nat. Productions of Burma, page 18.

284. Moung Magan Lat. 14° 9′; Long. 98° 9′; Elev. ; Temp. .
On low land in a mangrove swamp within reach of salt water.—*Official Returns.*

285. Toung Byouk ... Lat. 13° 33′; Long. 98° 40′; Elev. ; Temp. .
At the head waters of the east branch of the Toung-byouk stream, about 1 mile from the junction—*Official Returns.*

286. Pai ... Lat. 13°26′; Long. 98°33′; Elev. abt. 1,000; Temp. 198.°
Is about 65 miles south of Tavoy town in the Yéboo. Springs on side of hill, surrounded by granite rocks. A jet of stream rushes out of a hole nearly midway down a cascade, some 6 feet high, with such force as to drive

the water of the cascade out horizontally 4 to 5 feet
Iron, alumina, lime, potash, soda, silica, hydrochloric acid, sulphuric and hydrosulphuric acids, organic matter, nitrogenous.—Jour. Asiat. Soc., Bengal., XXXII, 383—*Stevenson.*

287. PALOUK ... Lat. 13° 13′; Long. 98° 40′; Elev. ; Temp. 196°.
One spring immediately on the right bank of the river, and another two or three minutes' walk inland to the north-east; there must be thirty or forty small springs bubbling up along a line of about 50 feet by 20 feet—*Major McLeod,* quoted by *Mason,* Nat. Productions of Burma, page 18.

TAVOY ... Lat. ; Long. ; Elev. ; Temp.
A 'hot water fountain.' A little sulphuretted hydrogen; principal ingredient, sulphate of lime, sp. gr. at 86°·6 = 1001·7.—*Prinsep,* Glean. in Sci. III, 17. This is probably one of those given above, but I cannot say which.

Though not within strictly Indian limits, the following hot springs may with advantage be noticed here.

288. BARREN ISLAND ... Lat. 12° 11′; Long. 93°· 54′; Elev. ; Temp. 130°.
Mentioned by *Mouat* and *Liebig,* the former of whom says the water was hot enough to boil eggs.—*Mouat,* Adv. in Andaman Islands, page 154. *Liebig,* Jour. Asiat. Soc., Bengal, XXIX, page 3. When seen by *Mr. V. Ball* in 1873, the temperature was 130° and therefore *not* hot enough to cook eggs.

In Ceylon the two following are known :—

289. KANNEA ... Lat. 8° 35′; Long. 81° 12′; Elev. ; Temp. 85°—115°.
There are several springs whose temperature is said to range from 85° to 115°, according to the season of the year.—*Tennant,* Ceylon, I, 242.

290. BATICALOA ... Lat. 7° 45′; Long. 81° 40′; Elev. ; Temp. 13°.
On plate XIII of the Trans. Roy. Asiat. Soc., London, is a plan of a hot spring at Baticaloa, in Ceylon; but there is no reference to it in the text.

In addition to those springs enumerated above, there are some others which I have not been fortunate to trace, and have therefore, in the absence of more definite knowledge, not classed with those of which we have more or less definite knowledge.

291. Panna ... Lat. ; Long. ; Elev. ; Temp. .
Both *Buist* and *Macpherson* mention a hot spring here on Captain Franklin's authority. I have not been able to trace this; it is not mentioned in Franklin's paper on the Geology of Bundelcund.—Trans. Geol. Soc.; London, 2nd series, III.

The following are given by Schlagintweit:—

292. Bargan, in Gilgit. Lat. 36° 00′; Long. 74° 10′; Elev. ; Temp. .

293. Chua, in Chamba. Lat. 32° 08′; Long. 76° 30′; Elev. ; Temp. 110° 5′.
No such place is shown on the atlas sheets of the Indian Survey at or near the latitude and longitude here given.

294. Devat, in Chamba. Lat. 32° 06′; Long. 76° 42′; Elev. 4,410; Temp. 132.°
The same remark applies here.

295. Imla, in Kumaon. Lat. 30° 02′; Long. 80° 02′; Elev. ; Temp. .
Said to be given "from native information." I have no other knowledge of it.

296. Janglung, in Nubra. Lat. 35° 00′; Long 77° 08′; Elev. 11,890; Temp. 165· 8°.

297. Mulbe, in Dras ... Lat. 34° 20′; Long. 76° 13′; Elev. 10,990; Temp. 78· 6°.
The latitude and longitude here given is not in Dras. Can this be Moolbekh of the Atlas of India in Lat. 34° 22′; Long. 76° 26′, on the north bank of the Wakka river?

298. Nilt, in Gilgit. ... Of which neither geographical position nor temperature are given; is inserted in the list "from native information".

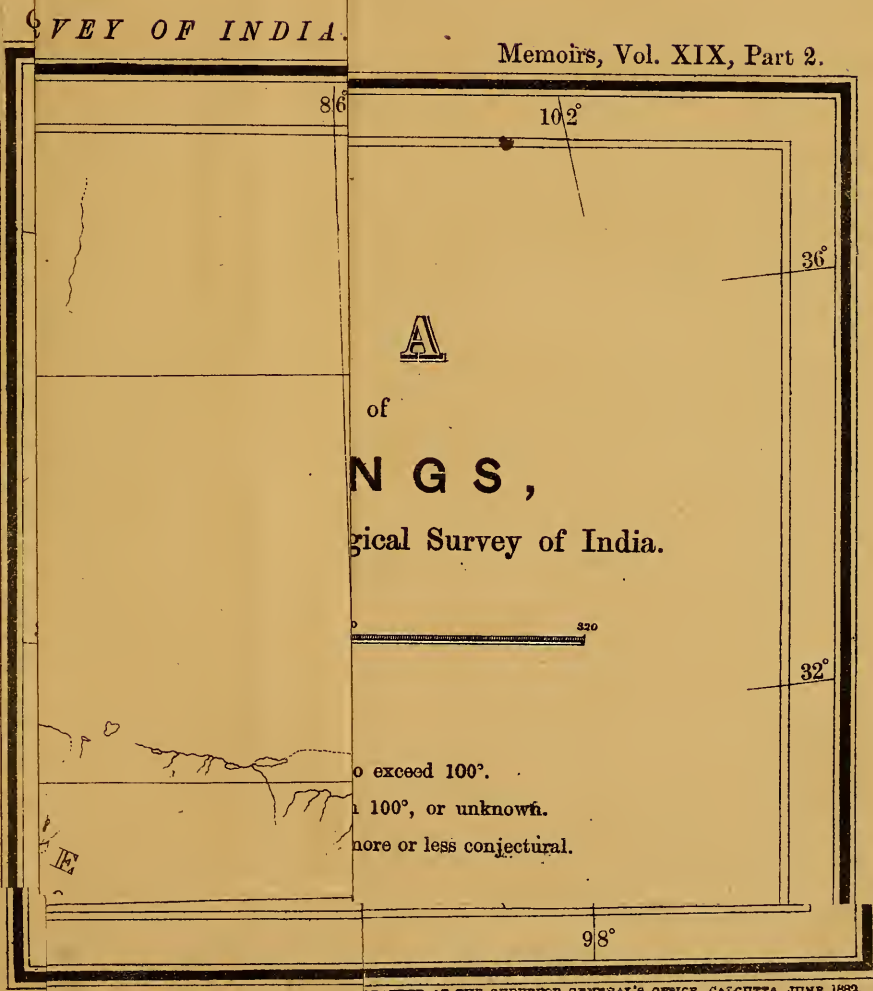
299. Pekar, in Gilgit ... Exactly in same way, "from native information."

300 Sheolor, in Kashmir. Lat. 34° 21′; Long. 74° 14′; Elev. ; Temp.
No such name is to be found on Montgomerie's beautiful map of Kashmir, at or near the position assigned to it, "from native information."

301. Shogore, in Chitral. Lat. 35° 08′; Long. 72° 04′; Elev. . Temp.
Also given from native information. I do not find any place of that name near the geographical position given.

INDEX.

Names in Roman type are those adopted in the catalogue; in Italics are synonyms or errors under which the spring has been described by previous authors: the numbers in all cases refer to paragraphs.


VEY OF INDIA.
86°
102°
36°
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A
of
N G S,
gical Survey of India.
320
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100°, or unknown.
nore or less conjectural.
E
GRAPHED AT THE SURVEYOR GENERAL'S OFFICE, CALCUTTA, JUNE 1882.


MAP OF
INDIA
shewing the distribution of
HOT SPRINGS,
By R. D. Oldham, A. R. S. M., Geological Survey of India.
1 Inch = 128 Miles.
INDEX to SIGNS.
Hot Spring, the temperature of which is known to exceed 100°.
Hot Spring, the temperature of which is less tha 100°, or unknown.
Hot Spring, the geographical position of which is more or less conjectural.
ARABIAN SEA
BAY OF BENGAL
TIBET
RAJPUTANA
CENTRAL INDIA
CENTRAL PROVINCES
CHOTA NAGPORE
BEHAR
NEPAL
BHUTAN
BURMAH
HYDERABAD
MYSORE
CEYLON
ANDAMAN ISLANDS
NICOBAR ISLANDS
MERGUI ARCHIPELAGO
MALACCA STRAITS
SUMATRA
BOMBAY
MADRAS
CALCUTTA
DELHI
HYDERABAD
KANDY
COLOMBO

MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

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OF

INDIA.

VOL. XIX, Pt. 3.

PUBLISHED BY ORDER OF HIS EXCELLENCY THE GOVERNOR GENERAL OF INDIA IN COUNCIL.

CALCUTTA:

PRINTED FOR THE GOVERNMENT OF INDIA.

SOLD AT THE

GEOLOGICAL SURVEY OFFICE,

OFFICE OF SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA,

AND BY ALL BOOKSELLERS.

LONDON: TRÜBNER & CO.

MDCCCLXXXIII.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA.
1883.

Compiled by J. & N. James

1882.

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

A CATALOGUE OF INDIAN EARTHQUAKES *from the earliest time to the end of A. D. 1869, by the late* THOMAS OLDHAM, LL.D., F.R.S., &c., *Superintendent of the Geological Survey of India.*

In the preparation of the following catalogue, the authorities which have been accessible to me were—'The Earthquake Catalogue of the British Association, by Robert and J. W. Mallet, London, 1858.' This catalogue only comes down to the close of 1842. For years subsequent to that date, the valuable series of catalogues published by Professor Perrey of Dijon, which appear in different numbers both of the 'Mémoires de I' Academie de Dijon,' and in the 'Bulletin,' and in the 'Mémoires Couronnées, de l' Acad. de Belgique,' have been consulted. The valuable papers of Baird Smith, in the Journal of the Asiatic Society of Bengal, on Indian Earthquakes have also been useful, but unfortunately do not come down later than 1843; also the papers of Dr. G. Buist in the 'Trans. Bombay Geog. Soc.' The files of the well-known weekly paper, *The Friend of India,* from 1843, for the use of which I am indebted to the courtesy of the Editor, G. Smith, LL.D., have been carefully gone over. The travels of Vigne, Moorcroft, Masson, Burnes, Thomson, Hooker and others, private communications as well as unpublished official records and the pages of the 'Asiatic Journal,' the 'Asiatic Annual Register,' and numerous other periodicals, have all contributed more or less to the list. In *all cases,* excepting when such is specially stated, the original papers or books in which the descriptions are given have been referred to.

Lithographed at the Surveyor General's Office, Calcutta, October 1882.

When completed in this way, a few copies were printed and distributed to several public offices and private individuals, more especially to the principal officers of the Public Works Department, with a request for any additional information which the records of their offices might afford. From a few, valuable additions were received, which have since been embodied in the catalogue.

While convinced that, if we desire to reap any harvest of accurate results from the cultivation of this difficult but promising portion of terrestrial physics, we must carry our investigations to a much more advanced stage than merely cataloguing the phenomena, I still think that much information can be gained from such lists. And as they have never before been attempted for the Indian Empire (with the exception of the admirable summary for 1842 by Baird Smith), I have devoted some time to the following catalogue. I am conscious of its deficiencies, notwithstanding the care given to its preparation. In fact, no such lists can be rendered satisfactory by individual efforts; they necessarily demand the co-operation of many. I would ask for aid from any who may have it in their power to contribute information. And with a view to a continuance of similar returns for future years, I will feel indebted to any one who will communicate to me the facts regarding any earthquake which they may experience within the limits of British India or its dependencies.

For the curious and valuable information regarding several of the earthquakes which occurred in the earlier centuries of our era, the pages of Al Macin and Abul Faraj have been consulted. But I am specially indebted to H. Blochmann, Esq., for his invaluable aid in tracing out the interesting histories of these striking phenomena. He has ever been most willing to give me the full benefit of his extensive reading and acquaintance with oriental literature, and I fear I have more than once been induced, by his own readiness to assist, to trespass on his valuable time more than I wished.

The catalogue is only brought up to the end of the year 1869.

Catalogue of Indian Earthquakes.

A. D.

893 ? 894. ... India.—Under the year 893, A.D., in the catalogues of earthquakes, a very severe shock is stated to have occurred in India. The capital is said to have been destroyed, and 180,000 men to have perished; preceded by an eclipse of the sun, &c., &c. And as authorities for this statement, Abul Faraj and Al Macin are quoted. I have, however, been unable to find any reference to this earthquake in the only edition of Abul Faraj to which I have access, (Pocock's Translation, Oxford, 1663); nor can I see any account of it in Al Macin (Erpenius' Translation, Leyden, 1625). But, on referring the question to my friend Mr. Blochmann, he furnished me with the following references: In the *Táríkhul Khulafá*, or History of the Caliphs, it is said: "And during this year (A. H. 280) a letter came from Daibul that there was an eclipse of the moon during the month of Shawwál, and that the next morning the world was in darkness, which continued till about 4 o'clock in the afternoon: and there blew a *black* wind, which lasted till a third of the night had passed away, and the wind was followed by a great earthquake which caused the whole town to disappear. The number of people which were dug out from the ruins was 150,000 men." Again, in '*Alkámil-fí-l Táríkh* by Ibn-ulathír (possibly the largest historical work of the Arabians), it is said: "And in the Shawwál of this year (A. H. 280) there was an eclipse of the moon, and the people of Dabíl and the whole world awoke in darkness. And the darkness lasted for a long time, and when it was 4 o'clock in the afternoon there blew a black wind,[1] which continued to a third part of the night. And when the third part of the night had come, there was an earthquake, and the town was destroyed, so that only about 100 houses remained, and after this the earth shook five times more

[1] This may have been a drifting shower of volcanic ashes.

A. D.

893 ? 894. ... and the total number of people that were found killed below the ruins amounted to 150,000."—(Tornberg's edition of Alkámil, Vol. VII., p. 323.)

There is here a perfect agreement as to date. Indeed it seems probable that both writers derived their information from the same source. The month of Shawwál, in the year of the Hijra 280, commenced 90 days before the 13th of March, 894, A. D., that is, on the 14th of December 893. Hence the earthquake must have been at the close of the year 893, or in the few first days of 894, A. D.

But these two authorities differ in the name of the large town said to have been destroyed, one calling it "Daibul," the other Dabíl. Now, Daibul, according to Yáqút's Geographical Dictionary (a famous Arabic work), lay "on the coast of the Indian Ocean. It is a famous town, and the waters of Láhor and Multán reach it, and flow into the Bahr-i-Hind" (Indian Ocean). This is the ancient town of *Daipul.* In all probability this was the town visited by this severe earthquake, still it is very strange that the narrators refer to no sea-wave having covered the land.

According to the same authority, Dabíl is, 1st, a town in Armenia, near Arrán[1] (between the Euphrates and Tigris); and 2nd, a sandy district in Arabia, between Yamámah and Yaman. This would render it probable that the earthquake was in Armenia, although there seems nothing to lead one to conclude that this Dabíl was a town of such importance or size as to contain more than 150,000 inhabitants.

1505. *July* *6th.*—In the catalogues this very severe earthquake is referred to, but without a date, 'about the middle of the year.' In Sultán Báber's memoirs also no date is given. And, again, in Firishtah (Dow's edition, II., 75), an earthquake is stated to have occurred at Agra on the 15th July, which it seemed probable was the same as that reported in Kábul, Afghanistan, &c. Elphinstone also (India, II, 586) notices the same earthquake as occurring at Delhi. Mr. Blochmann, at my request, has been able to trace out the history of this occurrence fully and to fix the date.

[1] Arrán, Harrán Harra, (Greek, αυρουιτμS), signifies volcanic region.

A. D.

1505. *July* *6th.*—In the *Mir-át-ul-'Álam*, a MS. in the library of the Asiatic Society of Bengal, it is stated—"In the beginning of this year (911) an immense earthquake happened in the confines of Kábul. The walls of the fortress and of most houses of the Bálá Hiçár and in the town fell down, and thirty-three times in one day did the earth tremble. For a whole month twice a day pieces of earth slipped down, and a large number of men was killed, and between Pimghán and Bekfaut (?), a piece of land about sixty cubits broad tore off and slipped down as far as you can shoot an arrow, when suddenly at the former place several springs appeared. And from Istargháb to the Maidán which is nearly six *farsangs*, the ground presented depressions and elevations as high as an elephant. And in the same year an earthquake was also felt in Hindústán."

In *Badáoní* (Bibliotheca Indica, Vol. 1, p. 319), we find it recorded: "On the third day of the month Çafar, 911, A. H., there was an immense earthquake in the whole of Hindústán, so much so that the mountains trembled, and high, firm, buildings came down. The earth broke open in several places, and immense fissures appeared. Villages and groves slipped from their places, and people thought the day of resurrection had come. But from the memoirs of Sultán Bábár it would seem that the earthquake was not confined to Hindústán, but was felt just as powerfully in Kábul and Persia. Since the creation of the world there never was so dreadful an earthquake."

In the memoirs of Báber (Erskine's edit., p. 170), it is said: "At this period (Muharram, 911), there was such an earthquake that many ramparts of fortresses, the summits of some hills and many houses both in the towns and villages, were violently shaken and levelled with the ground. Numbers of persons lost their lives by their houses and terraces falling on them. The whole houses of the village of Pemghán (or Peghmán, south or south-west of Kábul) fell down, and seventy or eighty respectable landholders were buried under the ruins. Between Pemghán and Bektob, a piece of ground about a stone's throw in breadth separated itself, and descended for the length of a bowshot, and springs burst out, and formed a well in the place which it had occupied. From Istarghaôb (north of

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1505. *July* *6th.* Kábul) to the plain, being a distance of about six or seven *farsangs,* the whole space was so rent and fractured, that in some places the ground was elevated to the height of an elephant above its old level, and in other places as much depressed; and in many places it was so split that a person might have hid himself in the gaps. During the time of the earthquake, a great cloud of dust rose from the tops of the mountains; many rising grounds were levelled. That same day there were thirty-three shocks, and for the space of a month, the earth shook two or three times every day and night."

Firishtah also (Lucknow edition, p. 183) mentions this earthquake as occurring at Agra during the reign of Sultán Sikandar Lodhí "on Sunday, the third day of Çafar."

These dates combined fix the occurrence very accurately, as having taken place on the 6th July. The year 911 of the Hijra commenced on the 4th June 1505, A. D. Muharram (1st month) has 30 days, Çafar (2nd month) has 3 days, or the 3rd of Çafar, 911, was the 33rd day from the 4th of June = the 6th July. Firishtah adds, "On Sunday." Now, according to Prinsep's Useful Tables (p. 198), the year 911, A. H. commenced on Wednesday, the 4th of June; therefore the 33rd day of the year coincides with Sunday, the 6th July, 1505, old style. Firishtah died soon after, 1600, A. D.

1552. Cashmir.—Mentioned in Prinsep's Tables; no particulars.

1618. *May* *26th.*—Bombay, &c.—Accompanied a severe hurricane; 2,000 lives and 60 vessels lost at Bombay.

1663. *February 7th* ?.—Lakhugar.—One day's journey from Gauhati; in the evening. *Jour. As. Soc. Beng.*, XLI., pt. 1, page 95.

1664. *date.* ?—Seven days' journey from Dacca.—Shocks recurred for 32 days —*Brit. Ass. Catal.*, 1852, 84, quoting *Collect. Academ.*

1668. *May* .—Samájí.—Delta of Indus. "At this time (between 1st and 10th Zi Hajjah, A. H., 1078) a report was received from the Soobah of Tattah that the town of Samáwání (or Samájí) which belongs to the Parganah of Láhori had sunk into the ground with 30,000 houses during an earthquake." *Maásir A'lamgiri, Edit. Bibl. Indica,* p. 74. This time corresponds to 2nd to 11th May, 1668.

A. D.

1669. *June* *4th.*—UPPER INDIA.—In the *Mir-át-ul-' Alam* (Mirror of the World) by Bakhtáwar Khán,—MS. never printed,—it is said: " A strong earthquake took place on the 14th Muharram of Aurangzib's 12th year, in the districts surrounding the fort of Mandrán. A chasm appeared in the ground about fifty cubits long and two yards broad. The inhabitants tied stoues to ropes five and six hundred yards long, in order to ascertain the depth. But the ropes were too short, and the depth was not ascertaiued. After four days the chasm closed without apparent cause." The 12th year of Aurangzib commenced on the 1st Ramazan, 1079, A. H., and the 1st Muharram (new year's day) of this 12th year falls on the 22nd May A. D. 1669. The 14th Muharram was, therefore, the 4th June 1869.[1]

22nd.—CASHMIR.—On the 3rd Çafar a very violent earthquake felt all over Cashmir, lasted all night.' *Maásir i' A'lamgiri.*

23rd.—ATOCK.—On 4th Çafar (1080, A. H.) an earthquake; a fissure 50 yards long was formed in the ground. *Maásir i A'lamgiri.* The 4th Çafar was the 33rd day of the year, and so corresponded to June 23rd.

1684. *date?*—SURATE.—(Surat?) in Further India.—*Brit. Ass. Catal.*, 1852, 96, quoting *Collection. Academ.*

1720. *July* *15th.*—DELHI.—" At this very time (*viz.*, 22nd Ramazan, 1132, *12—1 Noon.* A. H., Friday), whilst in most mosques of the Capital, (Delhi) the *Khutbah*" (Friday prayers for the reigning

[1] The same historical MS. mentions two remarkable meteoric phenomena during Aurangzib's reign, which may be quoted here. In the month of Ramazan of the eighth year of Aurangzib, a large star in the shape of a flame fell from the air into a tank near the fort of Kalyánígarh, which lies in the Soobah of Dakhin. The mere fall caused the waters to overflow "the banks, the water itself remained in motion for two pahars" (ta do pahar? six hours)!

The eighth year of Aurangzib was 1075, A.H., and the Ramazan of that year commenced on the 4th February and ended 5th March 1665, A.D.

Again, it is said: "In the ninth year (of Aurangzib) a flame appeared in the Parganah of Malkí (Bahár). "The flame was one imperial yard long (34 inches) and one yard broad. It passed along like a whirlwind for six *kos*, and burnt the trees, &c., which it met in its course."

The ninth year of Aurangzib—1076, A. H.—lasted from 22nd January, 1666, A. D., to 10th January 1667, A. D.

Both these events appear to have been undoubtable meteoric falls, although the description of the effects is decidedly highly coloured!

A. D.

1720. *July* *15th.* sovereign) "was being read" (between 12 and 1 o'clock mid-day) "and the people stood in lines ready for prayers, a dreadful earthquake took place. So people thought, judging from the roar below the ground, the shaking of the walls, and the cracking of the roofs of high buildings. During the day and the following night the houses shook nine or ten times, and the ground was going to and fro. It is well known that the walls of the fortress and many houses were destroyed, and innumerable people lost their lives both at Shábjahánábád" (New Delhi) "and at Old Delhi. The writer of this history, who had mounted a horse, saw with his own eyes that the bazaar road from the Kábuli gate in the north up to the Lal Derwáza in the south broke open in several places: the walls of the fortress were much injured, as also the Sháhrpanáh Derwáza, and the battlements of the Fathpur mosque tumbled down, and killed ten or twelve men, and wounded many more. It is also noticeable that for one month and ten days afterwards, the ground shook every day four or five times, and the houses trembled and the people got so afraid, they would no longer sleep in their houses. Though the shocks decreased after that period, the earth shook occasionally for the next four or five months."—*Kháfí Khán's Muntakhab ullubáb.* The exact date is thus arrived at: The year 1132, A. H., commenced on Tuesday, 3rd November 1719, old style: hence the 1st January 1720 is the 60th day, counting from November 3rd. But the 22nd Ramazan is the 257th day of the year, hence the date was the 197th (257—60) day of the year 1720, *i. e.*, 15th July. This was Friday. This earthquake is noticed in Elphinstone's India, Vol. II., page 586. The month is given, but no day; hence the testimony of the eye-witness Kháfí Khán becomes very interesting

1737. *October* *11th. Night.*—CALCUTTA, &c.—"In the night between the 11th and 12th October 1737, there happened a furious hurricane at the mouth of the Ganges, which reached 60 leagues up the river. There was at the same time a violent earthquake, which threw down a great many houses along the river side; in Golgotta (Calcutta) alone, a port belonging to the English, two hundred houses were thrown down, and the high and magnificent steeple of

A.D.

1737. *October* *11th.* the English Church sunk into the ground without breaking. It is computed that 20,000 ships, barques, sloops, boats, canoes, &c., have been cast away. Of nine English ships then in the Ganges, eight were lost, and most of the crews drowned. Barques of 60 tons were blown two leagues up the river; three were lost with their men and cargoes; 300,000 souls are said to have perished! The water rose 40 feet higher than usual in the Ganges."

The steeple of the church was described as being "lofty and magnificent," and as constituting before this period the chief ornament of the settlement.[1]—*Gentleman's Magazine,* 1738-39.

This most destructive earthquake and hurricane has not been recorded in the principal Earthquake Catalogues.

1762. *April* *2nd.*—Bengal, Arracan, and Burmah.—A very destructive and violent earthquake felt all over Bengal, Arracan, &c., chiefly or most severely in the north part of the east coast of the Bay of Bengal. In Calcutta, water in tanks rose 6 feet; direction said to have been north and south; lasted ten minutes. At Ghirotty (Gorhatty), 18 miles above Calcutta, river rose more than 6 feet perpendicularly. At Dacca, water rose so suddenly as to carry up hundreds of boats, and many lives were lost. Islamabad (Chittagong) suffered very severely; great explosions heard at first; openings in the earth were formed 10 to 12 cubits in length, and chasms were filled with water. Water was spouted out like a fountain and fine sand or mud; earth continued to sink day by day little and little. Sixty square miles said to have been per-

5 P.M.

[1] To the description of this hurricane in the *Gentleman's Magazine* there is a very amusing addition, which I will quote in the exact words of the original: "A French ship was drove on shore and bulged; after the Wind and Waters abated, they opened their Hatches and took out several Bales of Merchandise, &c., but the Man who was in the Hold to sling the Bales suddenly ceased working, nor by calling to him could they get any Reply; on which they sent down another, but heard nothing of him, which very much added to their Fear; so that for some time no one would venture down. At length one more hardy than the rest went down, and became silent and inactive as the two former, to the Astonishment of all. They then agreed by Lights to look down into the Hold, which had a great Quantity of Water in it, and to their great Surprise they saw a huge Alligator staring as expecting more Prey. It had come in through a Hole in the Ship's side, and 'twas with Difficulty they killed it, when they found the three Men in the Creature's Belly!! *Gentleman's Magazine* 1738, *June; Historical Chronicle, p.* 321.

A. D.

1762. April 2nd.—*contd.* —manently submerged. At DoHazari houses fell; cavity opened 200 cubits in length and filled with water. Two volcanoes (?) said to have opened on the Seeta Kunda Hills. At Nahar Charcak (Bakar Tschurak) the island clove as under and was swallowed up by the waters.—*Phil. Trans., 1763, vol.* viii, 251; *Asiatic Annual Register, vol.* vi, *p.* 60. Minor shocks continued up to 19th.

To this severe earthquake is attributed an elevation of the coast of Arracan, stated to extend over more than 100 miles in length, with varying amount. Captain Halsted, who was engaged in a survey of that coast in the *Childers,* gives the results for the area he examined "from the Terribles, off the north coast of Ramree, to Foul Island." The general direction of the shoals, and coast here, is north-west by north to south-east by south. The elevation was greatest about the centre. At the Terribles it was 13 feet; at various points of the north-west of Cheduba 22 feet, diminishing to 9 feet at Foul Island at south. Men were living at the time of Captain Halsted's visit who had fished over the then dry land. A third elevated beach was traced also on the west coast of Cheduba half way down and on Flat Island. Oysters were found adhering to a pinnacle of rock, about 40 feet high, on a line about 13 feet above the second line of beach (that produced in 1766), which was itself marked in a similar way.—*Jour. Asiat. Soc., Beng.,* x, 433, &c.

With the exception of the extremely vague story of men being 'alive who had fished over the then dry land,' it is entirely a matter of assumption to attribute this elevation to the earthquake now just described. Captain Halsted's visit was in 1841.

1762. *July* 13th. 2-30 P.M.—CALCUTTA.—Not severe; two or three shocks.—*Phil. Trans.,* viii, 251.

1764. *June* 4th.—BANKS OF GANGES.—Several violent shocks; many houses overthrown, and large numbers of men and cattle killed.—*Asiat. Ann. Reg.* viii, 98.

1780. ? CASHMIR.—Date unknown; severe.—*Jour. Asiat. Soc., Beng.,* xii, 1044.

1800. *October* 19th. 4-10 A.M.—ONGOLE.—Severe; lasted nearly a minute: occurred during a violent cyclone.—*Asiat. Ann. Reg.,* 1801, iii, *chronicle,* 43.

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1803. *May* 22*nd*.—UPPER GANGES.—Lasted six or seven seconds; rumbling
3-7 P.M. noise like distant thunder.—*Raper, Asiat. Res.*, xi, 511.

1803. *September* 1*st*.—MATURA (MUTTRA).—Very violent; lasted several minutes.
0.30 *Midnight.* Many pucka buildings thrown down: very extensive fissures in fields, through which water rose with considerable violence, and in quantity sufficient to be used by cultivators. Principal mosques, erected by Ghási Khán, destroyed, and a considerable part of the dome was swallowed up during the opening of the earth. Several slighter shocks followed.[1]—*Asiat. Ann. Reg.*, 1803, vi, *chronicle*, 58.

1-35.—CALCUTTA, &c.—The same was felt at Calcutta and neighbourhood; river much agitated; water, with many fish, thrown out of tanks; church clock stopped at 1-35 night.—*Ibid.*, vi, 35.

—KUMAON.?—The earthquake, given as occurring in this year without date in Kumaon, where many buildings were ruined, was most probably the same.—*Brit. Ass. Catal.*, 1854, *p.* 54.

UPPER VALLEYS OF GANGES, SIRMOOR, AND GURHWAL.—Very violent; 200-300 people destroyed at Barahal. Badrinath also suffered severely; several villages swallowed up.—*Raper, Asiat. Res.*, xi, 509; *Gleanings in Science*, ii, 50; *Asiat. Res.*, xiv, 139; *Jour. Asiat. Soc., Beng.*, xii, 1031.

Elphinstone (India, Vol. II) states that the Qutb Minar at Delhi was deprived of its upper portion by an earthquake. No authority is given, and I have searched in vain for any detailed record. I have been able, by the friendly aid of Maulavi Kabiruddin, to find in a modern work entitled Asár-u-Sanádíd, by Sewad-ud-dowlah, printed at Delhi in 1847, a passing notice of this fact. But this merely records that Sultán Sikandar, son of Beloli, had the upper portion of the Qutb renewed after it had been injured by lightning, and that "subsequently it was again injured by lightning and *an earthquake*," after which it was repaired by the English. No date is given, or interval after the repairs by Sikandar. General Cuningham states that this injury to the Qutb Minar happened on

[1] This is the earthquake referred to in Mallet's Catalogue under 1803 on the banks of the Upper Ganges, but without date; given under the month of July.

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1803. *September 1st. —contd.* the 1st August 1803, but he gives no authority. There can be little doubt that it was the result of the earthquake here noticed. And the authorities quoted are clear as to its having been on the 1st September, not August.—*Archl. Rept. Jour. Asiat. Soc., Beng.*, 1864, xxxiii, *App. lix.*

1807. *December 10th.*—MADRAS.—Three distinct shocks occurred in middle of a *Between* 12 *and* 1 *Night.* terrible cyclone, and accompanied by very heavy sea-waves. —*Asiat. Ann. Reg.*, x, 1808.

1808. *April 13th.*—CALCUTTA.—Not very violent: rumbling noise succeeded.
2 A. M. CHANDERNAGORE, &c.—House walls rent, a "northern room most considerably."—*Asiat. Ann. Reg.*, 1808, x, 60.

„ *June 4th.*—BANDA.—Two smart shocks; felt also at Secrora.
2-40 P. M. DINAGEPORE.—Here said to be from south-west to north-east.—*Asiat. Ann. Reg.* 1808, x, 67.

1809. GURHWAL.—Falconer states that the Bishnoo Gunga River, one of the great branches of the Ganges, was blocked up below Gosheenath by landslip caused by an earthquake, and that the water rose 40 feet above its usual level.—*Jour. Asiat. Soc. Beng.*, x, 618; no date or authority is given.

1810. *April 1st.*—CALCUTTA.—Just after cessation of a north-wester: two 7-25 P. M. shocks, very distinct, quick: appeared first to be from north-east to south-west, and then the opposite; duration 6 seconds and 30 seconds. Felt very distinctly at Garden Reach, close to Calcutta, by three persons sitting at one corner of a table and by the three sitting at the opposite corner, but not by the remainder of the party (11). Noise accompanied shock, said to be 'like muffled bells.'[1]
Felt also at Dum-Dum, Barrackpore, Moorshedabad, Ramnuggur, &c.—*Asiat. Ann. Reg.*, 1811, xii, 10, 463.

„ *May 13th.*—CALCUTTA.—Said to be perpendicular: three successive 9-45 P. M. shocks, and then undulatory motion lasting 8 to 10 seconds, and finished with a loud rumbling noise. Felt also in all the vicinity.—*Ibid.*, xii, 464.

1811. *February 1st.*—CALCUTTA.—Severe; continued for about 30 seconds.—*Asiat.* 2-20 P. M. *Ann. Reg.*, 1811, xii, 69.

[1] This is evidently the earthquake quoted in published catalogues as occurring on April 8th; according to the authority given it was on the 1st.

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1816. *May* *1st.*—PENANG.—Very smart, passed to north-west: chiefly confined to the northern and central parts of island; lasted 15 to 20 seconds; felt at sea also.—*Asiat. Jour.*, iii, 66.

„ *September 12th. to 15th.*—RUNGPUR.—Several shocks felt; last day severe.—*Ibid.*, 498.

„ *September 16th.* 4 A.M.—MADRAS.—Sharp; made every one sick: buildings struck with lightning.—*Ibid.*, 498.

„ *May 26th.* *Between* 10 *and* 11 P.M.—GUNGOOTRI—*Upper Valley of Ganges.*—Two shocks. Rocks hurled in every direction from the peaks. Smartly felt in all parts of the mountains, as well as in the plains of North-Western Provinces.—*Herbert, Asiat. Res.*, xiv, 98.

„ *May 27th & 28th.*—Slight shocks recurred frequently. Huge landslips resulted; one said to extend for half a mile, and to reach to summits of hills 4,000 feet high.—*Ibid.*

„ *July* *11th.*—CALCUTTA, &c.—Slight shocks.—*Garnier, Meteorol.*, 118, quoted in *Br. Ass. Catal.*

„ *August* .—MADRAS.—*Ibid.*

1819. *June* *16th.* 6-45-50 P.M.—CUTCH.—And over a large portion of Northern India.—This was one of the most severe and destructive earthquakes on record in India. The main focus of disturbance must have been near Cutch, where the damage done was terrific. Bhooj, the chief town, was reduced to ruins, 2,000 people perishing; shock lasted from 2 to 3 minutes with a heavy appalling noise. At Ahmedabad, a city famous for its noble architectural remains, spires of great mosque of Sultán Ahmed were overthrown; other mosques also destroyed; 500 people assembled for a wedding feast, all perished in ruins. At Surat, motion heavy, but destruction of buildings slight. At Broach, motion very heavy. At Poonah, only slightly felt. The shock extended right over the north of India; was felt sharply at Sultanpur in Oudh, Jaunpore, Chunar and Mirzapur, and at Calcutta.

In Cutch, first shock at few minutes before 7 P.M. of 16th: shocks continued of lesser intensity until 20th, when, it is stated, the 'volcano called Denodur burst into action, and the shocks ceased.' (Denodur, however, is *not* a volcano). In the western portion, the town of Sindree and adjoining country were inundated by a tremendous rush from the ocean, and all submerged, the ground sinking apparently about 14 feet. While to the north of

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1819. *June 16th.—contd.*—this tract, about 5 miles, a long low ridge or swell of perhaps 15 miles in width, was *said to* have been raised and to extend 50 miles east and west. It passed immediately across the channel of the Indus. The natives called this the Allah Bund, or Mound of God. The elevation was nowhere more than 10 feet. It was afterwards cut through by the Indus, and was found to be composed of clay with imbedded shells. In the Runn of Cutch, numerous jets of blackish, muddy water were thrown out from fissures, and cones of sand, 6 and 8 feet high, were thrown up.—*Trans. Lit. Soc., Bombay*, iii, 90; *Burnes' Travels*, vol. i; *Lyell's Principles of Geology*.

The details of this earthquake have been so often quoted, and with such exaggeration of statement, that I would advise those who desire to investigate the facts to resort to the original authorities.

1819. *June 17th, 18th, 19th.* Shocks continued to be felt at intervals, but none serious.

„ *June 20th.*—On this day the hill Denodur is said to have burst into volcanic action, and the shocks immediately ceased. (Recent examination could find no trace of volcanic action in this hill.—See *Mem. Geol. Survey, India*, vi, 25.)

The shock of 16th is stated to have been felt very sharply also at Pondicherry, Pulicat, Coimbatore, but this is most probably a different earthquake.—*MacMurdo, Trans. Lit. Soc., Bombay*. Also sensibly felt in Nepal, and Khatmandu, &c.—*Asiat. Jour.*, ix.

„ *August 3rd.*—TIRHOOT.—Felt in different parts, not severe.—*Ibid.*, ix, 384 (1820).

1820. *January 27th.*—BHOOJ.—Accompanied by a loud noise like thunder.—CUTCH. *Trans. Lit. Soc., Bombay*, iii, 90.

„ *November 13th.*—BHOOJ.—Several slight shocks.—*Asiat. Jour.*, xi, 628, (1821.)

„ *December 31st.* 9-26 P.M.—NELLORE.—First shock at times stated, then undulatory motion followed by a second shock, more violent than the first, and longer: duration altogether about 3½ minutes; supposed to be from north to south, from the swinging of pictures on the walls.—*Asiat. Jour.*, xii, 88, (1821).

„ *December 31st.*—NOAKALLY.—Felt also here.—*Ibid.*

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1821. *January* *10th.*—TRAVANCORE.—Slight shocks, less than a minute; noise like the passage of a heavy carriage over a drawbridge, *Ibid.*, xii, 193.

„ *August* *13th.*—KAIRA.—Lasted about a minute, said to be east and west.
3 P.M. DAMAUN.—Felt also at Damaun, and in Bombay Presidency.
2-45 P.M. AHMEDABAD.—Slight and tremulous; lamps, &c., set in motion.—*Asiat. Jour.*, xiii, 293, (1822).

1822. *January* *29th.*—MADRAS, CHITTORE, VELLORE, &C.—Several shocks: very
1 P.M. heavy rumbling noise; broke up roofs, &c., said to be from south-east by south to north-west by north.—*Ibid.* xiv, 370.

„ *April* *3rd.*—BENGAL.—Several shocks felt generally over Bengal, Cal-
10 P.M. cutta, Jessore (three distinct shocks, loud noise); Berhampore (lasted 2 minutes, said to be north-north-west to south-south-east); Comillah (said to be east and west, people could not stand); Bhaugulpore, Gya (apparently from north).—*Ibid.*, xiv, 493.

„ *August* *16th.*—CALCUTTA.—Commenced with a rushing noise like a whirl-
6-30 P.M. wind; walls of houses began to move from north to south; became more violent; two shocks, second most severe, whole lasting about 30 seconds.—*Ibid.*, xv. 293, (1823).

1823. *February* *9th.*—CEYLON.—Felt at Kandy, Colombo, Rutnapura, Negumbo,
1-15 P.M. &c., accompanied by subterranean noise like a cannonade. Felt also severely at sea by Ships *Winchilsea* and *Orpheus*. The latter felt a second shock at 2-5, and a third about 3 P. M., very slight.—*Edinb. Jour. Science*, iv, 261, 264; *Quar. Jour. Roy. Inst.*, xvi, 174.

MADRAS.—The same earthquake, just noticed at Ceylon, was felt at Madras, where it lasted only a few seconds; also at the Nilghiri hills, Nagercoil, south Travancore, &c.; appeared to travel southwards, with a rumbling noise. At Kotagherry (Nilghiri hills) there were two distinct shocks with an interval of about two minutes.—*Asiat. Jour.*, xvi, 376, 482, (1823.)

[*N. B.*—This shock is erroneously quoted in the Brit. Ass. Catalogue (1854, p. 148), as occurring on March 9th, and as occurring in North Eastern India.]

„ *March* *2nd*—MADRAS AND CEYLON.—Severe shocks felt at Travancore 20 minutes later than at Madras.—*Arch. d. Découv.*, 1824, 210, quoted in *Brit. Ass. Catal.*

„ „ *9th.*—See above, February 9th.

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1823.	*April* 10 P.M.	*3rd.*—CALCUTTA.—Shocks from north to south, and *vice versâ*, up to 10 o'clock.—*Garnier, Meteorol., p.* 137, in *Brit. Ass., Catal.*
,,	*April* 5-3 A.M.	*22nd.*—PENANG.—Two shocks.—*Asiat. Jour.* xvii, p. 137, (1824).
,,	*November* 12-10 *Noon.*	*26th.*—CALCUTTA.—A shock, rather sharp, accompanied by subterranean noises.—*Ibid.*, p. 518.
1825	*January* *12 Noon.*	*3rd.*—GOWHATTY.—From eastward.—*Ibid.*, xx, 88, (1825).
,,	*January* 7 P.M.	*5th.*—MYMENSING.—Two shocks: first at 7 P.M., second at midnight.—*Ibid.*
,,	*January*	*8th.*—MYMENSING.—Gentle at first, severe afterwards: apparently from the north.—*Ibid.*
,,	,, 6-50 P.M.	*8th.*—COMILLAH.—Four shocks, last rather severe: apparently from the north-east.—*Ibid.*, xix, 839.
,,	6-46 P.M.	LUCKNOW.—Shock felt at 6-46 P.M.
,,	*March* 12-35 P.M.	*22nd.*—DELHI.—Sharp, with loud rumbling noise; appeared to go towards the south-west.—*Ibid.*, xx, 452.
1826.	*October* 2 A.M.	*29th.*—NEPAL, &c.—First great shock followed by eight minor vibrations; first vertical; others came from south to north. In Katmandu several houses fell, also temple near city. At Patun fourteen houses fell. Smaller shocks succeeded.—*Ibid.*, xxiii, 672, (1827.)
1827.	*January* 5 P.M.	*6th.*—VIZAGAPATAM.—Sharp shocks, apparently from the sea; shocks lasted only a few seconds, but the undulation continued for some time.—*Ibid.*, xxiii, 864, (1827.)
,,	*January* 11-22-19.	*19th.*—CALCUTTA.—Said to be west-south-west and east-north-east; felt also at Burdwan.—*Ibid.*, xxiii, 855.
,,	*Middle of month.*	—CALCUTTA.—An earthquake.—*Brit. Ass. Catal.*, 1854, 179. Probably the same as the last mentioned.
,,	*April*	*17th.*—KÁBUL.—Slight.—*Masson, Beloochistan, &c.*, iii, 8.
,,	,,	*19th.*—KÁBUL—Very smart. "It is considered correct and deferential to the will of Heaven to sit tranquil during their occurrence."—*Ibid.*
,,	*September, before the 26th.*	—LAHORE, &c.—Fort Kolitaran, near city, destroyed; about 1,000 perished in ruins. A hill shaken down, which falling into river Rowée (? Ravee) produced an inundation of 100 coss of lands.—*Brit. Ass. Catal.*, 1854, 183, *quoting Madras Gazette.*—? *Asiat. Jour.*, xxv, 377, (1828.)

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1828. *June 6th.*—CASHMIR.—Very severe; shook down many houses, and killed many people—perhaps 1,000 people and 1,200 houses. Earth opened in many places about the city, and fœtid water, rather warm, rose rapidly from the clefts and then subsided. Clefts soon closed and left no traces. Just before sunrise another shock, accompanied by terrific explosion louder than a cannon; twenty such shocks on that day, each with an explosion; river sometimes appeared to stand still and then to rush forward. For the two months succeeding there never were less than 100, often 200 shocks in the day, each accompanied by an explosion. Number then decreased to about 10 in the 24 hours, and shocks gradually ceased. One bad shock on 15th, and three of the explosions out of whole number were very bad.—*Vigne's Travels, Kashmir*, i, 281.
10-30 P.M.
June 15th,
3 P.M.

„ *July 8th.*—CALCUTTA.—Three shocks; lasted two minutes; appeared to be from east to west.—*Asiat. Jour.*, xxvii, 88, (1829.)
2 P.M.

2 P.M. MYMENSINGH.—Three shocks, apparently from north to south; the last shock most severe. Another shock 12 minutes afterwards.—*Ibid.*

„ 2—14—4 P.M. SYLHET.—Sharp; lasted one minute: *mean* time given.—*Ibid.*

„ *July 20th.*—BHOOJ.—Nearly emptied water out of a tumbler which was half full. East to west; violent.—*Asiat. Jour.*, xxvii, 227, (1829); *L. and B. Jahrb.*, 1833, 125.
1 P.M.

„ *Aug. 22nd.*—MALABAR COAST.—Smart shock felt all along Coast. At Vingorla, bungalows violently shaken; lasted quarter of a minute, with loud rumbling noise.—*Asiat. Jour.*, xxv, 377, (1828.)

„ *September 18th.*—CALCUTTA.—Smart double shock; vertical.—*Ibid*, 370; *L. and B. Jahrb.*, 1833, 125.
7-15 A.M.

„ *October 8th.*—DACCA AND VICINITY.—Four distinct shocks in succession; lasted about quarter of a minute; appeared to be from south to north.—*Asiat. Jour.*, 1828, xxv, 509.
5 P.M.

„ *October 29th.*—NEPAL.—Von Hoff quotes no authority for the statement he gives of this earthquake, but from his accounts, which correspond in all particulars with that given in the Asiatic Journal for the earthquake of October 1826, in Nepal, it is evident that the same event is referred to.—*Brit. Ass. Catal.*, 1854, 197.
2 A.M.

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1829. *No date.*—KÁBUL.—Very severe.—*Burnes quoted by Baird Smith.—Jour. Asiat. Soc., Bengal*, xii, 1041.

„ *March 12th.* 8-10 P.M.—BANGALORE.—Lasted only few seconds: houses much shaken noise like a rushing wind.—*Asiat. Jour.*, xxviii, 479, 1829.)

„ *September 18th.*—CALCUTTA.—Very strong, said to be vertical.—*Jour. Asiat. Soc., Beng.*, 1843, p. 1042.

1830. *July 17th.* 1-15 A.M.—DELHI.—Smart: undulations from east to west; "the last of three earthquakes felt during four months."—*Asiat. Jour., new ser.* v, 199, (1831.)

„ *December 15th.* 4-50 P.M.—CHITTAGONG.—Three rapidly succeeding severe shocks: loud; noise from southwards.—*Ibid.*, 64.

„ *December 16th.* 10 A.M. 11 P.M.—CHITTAGONG.—Two other shocks at the hours mentioned.—*Ibid.*

„ *December 31st.* 2 A.M.—CHITTAGONG.—Very violent, more so than any of the others; ten shocks felt since 15th; houses all seriously cracked.—*Asiat. Jour.*, v, 64, (1831).

1831. *date ?.*—PESHAWUR AND VALLEY OF INDUS.—Severe; extended from Peshawur to Dera Ghazee Khan: felt most at Derabund; men and camels unable to stand; rocks fell in many places: water forced from crevices in the plain.—*Vigne's Afghanistan*, i, 58.

„ *October 24th.* 12-30 *Noon.*—DELHI, &c.—Apparently perpendicular, or from north to south; lasted one minute; trees appeared violently agitated; difficult to stand: nausea general. (Recorded at N. lat. 28° 34′, E. long. 78° 4′ 26,″ or west of Delhi). Scarcely felt to the north of this, but more severely to south and south-west.—*Gleanings in Science*, iii, 388.

„ *December 25th.* 9 P.M.—LOHUGHAT IN KUMAON.—Undulatory motion from north-west to south-east, lasting seven seconds.—*Brit. Ass. Catal.*, 1854, 130; *McClelland's Kumaon*, p. 207.

1832. *January 22nd.* 11 P.M.—NEAR LAHORE.—Violent: people all rushed out of houses.—*Asiat. Jour.* 1832, viii, 146. This was only on the outskirts of this severe shock which appears to have had its centre near the valley of the Oxus.—*Burnes' Travels in Bokhara*, ii, 15, *2nd edit.*, 1835.

„ *February 21st.*—LAHORE, VALLEY OF BADAKSHAN, N. W. INDIA.—Huge masses of rock were thrown from the cliffs in many places,

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1832. *February 21st —contd.* choking up valleys. Great part of population o Badakshan destroyed.—*Trans. Geol. Soc., Lond.*, 2 *ser.*, iii, 492.

1832. *July 2nd.* 11 P.M.—LOHUGHAT.—Earth shook for twelve seconds, accompanied by a sound like that of rushing water, which lasted three seconds before the shocks and as many after.—*Brit. Ass. Catal.*, 1854, 233; *McClelland's Kumaon*, p. 207.

„ *August 18th.* 7 A.M.—LOHUGHAT.—Another vibratory shock, lasting five seconds; weather sultry.—*Ibid.*, *p.* 208.

„ *September 23rd.* 10 P.M.—LOHUGHAT.—Another shock, as on 2nd July.—*Ibid.*

1833. *May 30th.* 12 P.M.—LOHUGHAT—Earth shook rather violently for about twelve seconds; noise like rushing water.—*McClelland's Kumaon*, p. 208.

„ *August 26th.* 5-30 P.M., 11 „, 12 „, &c.—NÉPAL, AND ALL OVER THE CENTRE AND EAST OF NORTHERN INDIA.—At Katmandu, accompanied (11 P.M.) by a loud subterranean noise, compared with the noise produced by the discharge of 100 pieces of artillery. More than 100; houses were levelled in a moment, and equal or worse destruction in other places. Trees and even the smallest shrubs rocked from their very roots. At Chupra, a chasm of considerable size was said to have been formed in the earth. In Tirhoot, water thrown out of tanks, 4 feet deep, the water of which was 3 feet below the edge. Birds thrown right out of their nests. Men could not keep their feet. At Buxar, shocks said to have been felt violently at one side of river and not at the other. Preceded by very hot close weather, and in many places succeeded by stormy winds and heavy rain.

The direction of the motion is very variously stated. At Tirhoot, said to have been from east to west: at Buxar, from north to south: at Patna, apparently east and west: at Calcutta, north-east to south-west: at Katmandu, apparently east to west: all shocks came from east or north-east! Each of the shocks lasted only three or four seconds generally, but some are stated to have lasted one minute. At Lucknow, four shocks are reported; at Calcutta, three; at Purneah, three. In all places, several shocks of greater violence, besides numerous slighter ones. At most of the places, the earth was in almost continuous agitation for 24 hours.

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1833 *August 26th*—*contd.*—So far as can be ascertained, the time of the principal and most violent shock, the second, was (reduced to Calcutta time) as follows at the several places:—

	h.	m.	s.
Calcutta	11	34	48
Monghyr	11	34	0
Rotas Hills	11	30	0
Arrah	11	29	0
Goruckpur	11	39	0
Allahabad	11	28	0
Rungpur	11	18	0
Katmandu	10	57	0

But these are only approximately accurate. See *Jour. Asiat. Soc., Beng.*, ii, 439 and 564, xii, 1049, &c.

„ *August 27th.*—KATMANDU.—Three shocks, 4-53 A.M., 5-20 A.M., 5-26 A.M. *Ibid.*

„ „ *28th.*—Ditto.—Two shocks, 7-15 A.M., 4-55 P.M.—*Ibid.*

„ „ *30th.*—Ditto.—Four shocks, one at 9 A.M.—*Ibid.*

„ „ *31st.*—Ditto.—Two slight shocks during the night.—*Ibid.*

„ *Sep. 1st to 11th.*—Ditto.—Ten shocks, all slight.—*Ibid.*

„ *September 20th. Night.*—MEERUT.—Lasted about 15 seconds; not felt in Calcutta—*Asiat. Jour.*, xiii, 158, (1834).

„ *October 4th.* 7-3 A.M.—KATMANDU, MONGHYR, ALLAHABAD.—Lasted half a minute; violent; as bad as that of 26th August.—*Jour. Asiat. Soc., Beng.*, xii, 1053.

„ *October 4th.*—JAUNPUR.—Sudden and smart.—*Asiat. Jour.*, 1834, xiii, 24.

„ „ *18th.* 4-40 A. M.—KATMANDU, GORUCKPUR, ALLAHABAD.—Lasted nearly a minute; violent; apparently from east to west.—*Ibid; Jour. Asiat. Soc., Beng.*, xii, 1053.

, *October 24th.* 8-35 P.M.—SINGAPORE.—A slight shock, succeeded by a tremulous motion, which lasted about a minute; and then two other shocks, slighter than the first.—*Asiat. Jour.*, xiv, 21, (1835).

October 26th.—KATMANDU.—Slight; 10-37 A.M.—*Jour. Asiat. Soc., Beng.*, xii, 1053.

November 8th.—KATMANDU.—Slight; 3-55 A. M.—*Ibid.*

November 16th.—KATMANDU.—Severe; about midnight.—*Ibid.*

„ *26th.*—KATMANDU.—Of the up and down kind; 11-45 P. M..—*Ibid.*

1834. *July 8th.*
„ *July 21st.*—RUNGPUR.—Two shocks: fissures formed in ground, from which smoke and flames were thrown out; and then fissures closed!—*Asiat. Jour.*, xiii, 91, (1834).

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1835. *January* 4*th.*—Lohughat.—Slight; lasted 15 to 20 seconds; seemed to be
7 a.m. north and south.—*McClelland's Kumaon*, p. 208.

„ *January* 14*th.*—Lohughat.—More violent; appeared to be from north-
1-30 a.m. west; noise like distant thunder; motion tremulous, and in crossing the strata seemed to affect one at a time.—*Ibid.*

„ *August* 26*th.*—Singapore.—Slight; only a few seconds.—*Asiat. Jour.*, xix, 128, (1836.)

„ „ —Penang.—No date—*Jour. Asiat. Soc., Beng.*, xiv, 607.

1836. *January* 24*th.*—Chandernagore, Sook Sagur, &c.—Plaster shaken off houses, &c.—*Asiat. Jour.*, xx, 187.

„ Kábul.—Both Vigne and Masson state that shocks occurred frequently at Kábul; no particulars.—*Vigne's Travels*, p. 812; *Masson*, iii, 8.

1837. *June* 15*th.*—Ganjam.—A severe shock.—*Henderson's Chronological Tables.*

„ *September* —Penang.—Shocks continued seven days. Volcanic eruptions
End of month. near Acheen.—*Asiat. Jour.*, xxv, 232; *Jour. Asiat. Soc., Beng.*, xiv, 607.

„ *December* 14*th*—Kábul.—Three shocks felt at night.—*Burnes' Travels.*
Night.

1839. *January* 14*th.*—Suddya, U. Assam.—Preceded by rain and heavy snow:
9 p. m. motion apparently from south-west to north-east.—*Hannay, Jour. Asiat. Soc., Beng.*, xii, 907.

„ *March* 23*rd.*—Burmah.—During my visit to Amarapoora in company with Colonel A. Phayre, and the mission to the Court of Burmah in 1855, I had the opportunity of seeing the abundant evidences of the fearful destruction caused by this earthquake, which were even then very marked although sixteen years after its occurrence. In the wonderfully truthful and interesting narrative of that mission, published by Colonel Yule, R.E. (London, Smith, Elder and Co., 1858), most remarkable illustrations of this destruction will be found. And in the appendix (page 349) a detailed account is given by myself from the notes of Mr. Spears, who was in Amarapoora at the time of the occurrence. I was, unfortunately, not then aware of the importance of such careful measurements of bearings and angles as would now be sought for. And I allowed the splendid opportunity to pass, which the study of the

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1839. *March 23rd —contd.* stupendous mass of brick-work in the temple of Mengoon would have afforded to determine the direction and probably the velocity of the shocks. This, "doubtless one of the hugest masses of solid brick-work in the world" (Yule, *loc. cit.*, p. 160), has been rent and shattered in the most wondrous way, and yet was just in the condition favourable for such investigations. I still have hopes of obtaining careful measurements of it. Mr. Spears, in reply to queries, asking his experience during the shock, and directing his attention specially to certain points, favoured me with the following brief narrative, which I give here in full, as illustrative of one of the most destructive earthquakes within Burmese limits. The same account has been already given in the appendix to Yule's Narrative (page 349). Mr. Spears says:—

"On Saturday morning, 23rd March 1839, at about 4 o'clock A.M., Amarapoora was visited by an earthquake that surprised the oldest inhabitants by its strength. Burman history mentions nothing of the kind having taken place before. I was in bed and asleep at the time, but was soon awoke by a tremendous roar, and the tiles from the roof of the house coming down about my ears; the motion so great that I had some difficulty in finding the door, but whether vertical or horizontal, I had not presence of mind sufficient to judge at the time. I did not even know it was an earthquake until it was finished. The shock may have taken up about 30 seconds in all.

"When I did get into the open air, I found the heavens without a cloud, and although there was not a breath of wind, the trees shook as if it were blowing a gale. The dust rising all round from the destroyed houses gave the sky a peculiar appearance, not easily to be forgotten.

"From the appearance the ruins presented in the morning, I have little doubt the motion was from north to south. The river did rise a little, as if its bed had been obstructed, but did no damage to the boats, even to those that were deeply laden. I never heard of a wave, but the banks of the river between Amarapoora and Ava were rent in many places, presenting chasms of from 5 to 20 feet in width, from which large quantities of water and sand of a

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1839. *March* *23rd* blackish appearance had been ejected. The earthquake
—contd. was not accompanied by any perceptible smell.

"Judging from the appearance the city walls of Amarapoora and Ava presented the next morning after the great shock, I am decidedly of opinion that it must have been felt stronger in the latter than in the former city.

"At Tsagaing, I will not say that it was not stronger than at Ava, either on the hill tops or on the river side. My reason for supposing this is, that the pagodas on both sides of the river presented the same appearance; that is, they were all deprived of their 'htees', and the same quantity of brick-work from the top.

"This earthquake was felt at Bamo and Rangoon; in fact, all over the Burman territory. In Rangoon, the time observed was very nearly the same as here; it did no damage, but was strong enough to ring pagoda and some house bells, and alarm the inhabitants.

"From all I have been able to learn, I think Ava must have been about the centre.

"After the great quake, we had strong shocks all day every five or twenty minutes, but none coming up to the first in violence. They were, almost invariably, preceded a second or two by a sound resembling a cannon fired at a distance; or, at other times, as if a number of carriages were passing over a rough bridge under ground. There were two distinct kinds of earthquakes: that preceded by the cannon-like sound had little or no rolling motion, but more resembled some one thumping up from below, as it were: it made the houses 'dirrl' and set the slates and glasses a dancing. The other came like the wave of the sea, with a motion generally from east to west; at least that was my impression at the time.

"The under-ground sounds seemed to come always from the eastwards.

"For four or five days we had nothing but earthquakes every fifteen to thirty minutes; and for six months after, scarcely a day passed without one. In fact, it is only the last three years that we have been tolerably free from them.

"The impression left on the people was, that it was very unsafe to live in brick buildings, unless a wooden frame

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1839. *March* *23rd* *—contd.* work is put up inside of them, which is always done now by any Burman wishing to have a pucka house.

"There never was a correct list of the number of people killed; but there must have been from three to four hundred. Ava suffered most from having some brick Kyoungs, where a great number of Poongyis were destroyed."—*Amarapoora, 24th September, 1855.*

In a MS. Journal of Captain McLeod, in the Foreign Office, Calcutta, there is a brief and very uncircumstantial notice of the same earthquake.

"At about half-past one this morning, we were suddenly roused from our sleep by two terrible shocks of an earthquake. Though numerous concussions continued to take place, none were so severe as the two first. In the morning, not a pagoda was to be seen standing whole. Every brick building in the town had either been thrown down burying in their ruins numbers of people, or rent and damaged so as to render their being taken down necessary.

"The pagodas crowning the height of Tsagaing shared the fate of those at Amarapoora. In the neighbourhood of the Residency, extensive and deep fissures had spread out from which large quantities of water had been discharged, and the earth in many places hove up with water springing up from the centre. The wells were choked up and dry."—*MS. Journal of Captain McLeod for 1839.*

Again he notices a shock of earthquake which occurred on March 25th, during his visit to the King.

He states that "the King of Burmah informed him that their religious treatises told him that earthquakes occurred every twenty or thirty years, and were severer on the seacoast than inland. The Burmese attributed earthquakes to the movement of some animal in the earth, but that foreigners maintained that they proceeded from the sudden union of certain matters in the bowels of the earth, and as a proof of this hypothesis, that they buried certain preparations in the earth, which after a few days would cause the same sensation as an earthquake, and throw open the earth, &c. That during earthquakes eyesight grew dim, and an oppression in the chest was also felt."

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1839. *March 23rd. —contd.* I do not find further notices of any earthquakes in Burmah, although, probably, the form in which phenomena attending the death of kings are stated by Padre San Germano to be recorded in the Royal Chronicle, may be taken as proof of their not unfrequent occurrence.[1]

The large lake called Endan-gyi, west of Mogoung, is said to cover the site of a large Shan town called Tumansye. The Natives affirm that it was destroyed by an earthquake.[2]—*Yule's Narrative, App.*, p. 349.

Ava, Burmah, Amarapoora, &c.—Two very severe shocks at the hour mentioned, succeeded by a series of minor ones up to 8 o'clock, and almost daily shocks afterwards for many months. Scarcely a brick building in the town was left standing. The current of the Irawadi was reversed at a time. In several places great earth-fissures were produced 10 to 20 feet wide, from which large quantities of water and grey earth were thrown out, emitting a sulphureous smell. Ava and Tsagain were destroyed, 200 to 300 persons killed, not a temple left. Felt also at Moulmein and for more than 1,000 miles north and south. The direction of shocks said to be from north to south.—*Asiat. Jour.*, xxx, 194; xxxii, 118 (1839.)

A letter from the Revd. E. Kincaid, Baptist Missionary in Burmah, published in Silliman's Journal, gives a forcible account of this violent and destructive earthquake. He says the earth reeled "from east to west. Everything built of brick, houses, monasteries, temples, pagodas, and city walls, all crumbled down." Letters up to the 11th of April stated, that "the noise has not yet ceased, and that shocks of considerable force were felt day and night, with seldom so much as an hour's intermission. Prome to south of Ava and Bamo to the north are said to have been entirely overthrown."—*Silliman's Jour.*, xxxviii, 385.

At Kyouk Phyoo a smart shock of an earthquake, immediately followed by a magnificent burst of fire from the range of volcanic hills to the south-west of the station,

[1] "When there is an earthquake in Pegu," Valentyn says, "they think that the King will die, or will lose his throne, or will oppress them, or that there will be a famine, or something else."—! !

[2] Journal, Asiatic Society, Bengal, vol. VI, page 274.

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1839. *March* *23rd* *—concld.* which continued to rise and fall in huge jets for half an hour, accompanied by reports resembling discharge of distant artillery.—*Asiat. Jour.*, 1837, xxix, 289.

1839. *May* *11th.*—JAMALPUR,—Direction at Jamalpur, Mymensing, said to 9-30 A.M. COMERCOLLY. have been, west to east, or from north-west 9-50 A.M. SYLHET. to south-east.—*Asiat. Jour.*, xxx, 15. 9-55 A.M.

„ *June* *3rd.*—SUDDIYA, (U. ASSAM).—Season unusually wet from March. —*Hannay, Jour., Asiat. Soc., Beng.*, xii, 907.

1840. *January 14th.*—UPPER ASSAM.—Two shocks; felt by Mr. Masters at Nazera.—*Ibid*, 1055. 6 A.M.

„ *January 26th.*—KABUL.—Sharp; lasted several minutes; preceded and followed by slighter shocks; several houses down.—*Asiat. Jour.*, xxxii, 104 (1840.)

„ *February 3rd.*—UPPER ASSAM.—Shock felt by Mr. Masters at Nazera.—*Hannay, Jour. Asiat. Soc., Beng.*, xii, 1056.

„ *March* *4th.*—SUDDIYA (U. ASSAM).—Apparently from south. A second 1 P.M. after interval of ten minutes. A total eclipse of sun about an hour before, during which the air was unusually cold and disagreeable.—*Ibid.*

„ *March* *23rd.*—Under this date a violent earthquake is recorded as having occurred in Burmah in the Edinburgh New Phil. Jour. xxxvi, 234, and is so quoted in Brit. Ass. Catal., 1854, 294. But this is obviously the same as noticed above on same day and month in the previous year, 1839.

1841. *February* *9th.*—GOWHATTY.—Sharp and stunning, as if a blow had been struck under the jaw; a low rumbling noise.—*Jour. Asiat. Soc., Beng.*, xii, 907.

September 15th.—TRAVANCORE.—General Cullen records a shock.—*Trans. Bomb. Geol. Soc.*, xiii, *App. C, p.* 9.

October *12th.*—UPPER ASSAM.—Slight shock felt by Mr. Masters at 6 A.M. Nazera.—*Hannay, Jour. Asiat. Soc., Beng.*, xii, 907.

1842. *January* *2nd.*—DELHI.—Slight shocks.

„ „ *4th.*—SEEBSAGUR.—Weather cold and gloomy. A smart shock; 7-30 P.M. undulatory.—*Hannay, Jour. Asiat. Soc., Beng.*, xii, 907.

„ *January* *4th.*—UPPER ASSAM.—Slight.—*Jour. Asiat. Soc., Beng.*, xii, 260, DELHI, ARAVULLI MNS. 1026.

„ „ *16th.*—NORTH-WEST PROVINCES.—Muttra lasted 30 to 40 seconds 7 to 8 P.M. between 7 and 8 o'clock; at Mainpuri slight and seemed to come from west; at Chunar and Mirzapur, felt

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1842. *June* *16th.* about 8 o'clock, at Chunar accompanied by a noise like that occasioned by the rapid flight of birds; Jaunpur at half past 8, three distinct vibrations were felt which passed from west to east, but were unaccompanied by any noise; at Sultanpur, in Oudh, it was felt at 8-17 p. m., and the soldiers' huts were much damaged.—*Official Records.*
—contd.

„ *February 4th.*—UPPER ASSAM.—Recorded by Mr. Masters at Nazera.—*Official Records*; *Jour. Asiat. Soc., Beng.*, xii, 907.
8. A.M.

„ *February 19th.*—KÁBUL, JELLALABAD, PESHAWUR, N.-W. INDIA.—At Kábul said to have lasted three minutes; several shocks; rocked the fort in a frightful manner. At Jellalabad, at midday lasting about a minute and a half, every one thrown down; bastions of fort, and walls and houses overthrown; one-third of town destroyed; fully one hundred shocks within one month. At Peshawur very destructive; "earth trembled like an aspen leaf;" several killed. At Ferozpur severe; at Ludiana said to have been north to south; at Delhi not severe, appeared to consist of several distinct undulations. The hot springs of Sonah, the temperature of which is usually from 104°—110° Faht., became on the date of the earthquake as cold as the ordinary wells of the country; the amount of water diminished greatly, and at times the springs were completely dry. These appearances continued for 25 days, when the wells had resumed their usual state.

The shock was scarcely felt at Saharunpoor; was felt slightly at Mussoori, and also at Shalkar on the border of Little Thibet. Superficial area affected was at least 216,000 square miles; general course from west to east (erroneously given as east to west.—*Jour. Asiat. Soc., Beng.*, xii, 273), modified by local conditions.

Jellalabad was, so far as known, nearest the focus, and the times reduced to Jellalabad time, at which the shock reached other places noted, appear to have been as follows:—

	Period of shock.			Interval of time.			Approximate distance in degrees of Long.	
	h.	m.	s.	h.	m.	s.	°	'
Jellalabad . . .	11	40	0	......			......	
Peshawur . . .	11	41	12	0	1	12	1	12
Ferozpur . . .	11	48	40	0	8	40	4	0·5
Delhi . . .	11	53	56	0	13	56	6	46

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1842. *February 19th.*—Scarcely felt in Sind; at Quettah inconsiderable.—*Asiat. Jour.* All instruments disturbed violently, but mean positions unaltered, at Simla Observatory.—*Boileau, Brit. Ass. Rep.*, 1845, 4.
—*contd.*

Shocks continued frequent until the 24th.

For full detail, *see Baird Smith, Jour. Asiat. Soc., Beng.*, xii, 260, *&c.*, 1843; *see also Sale's Jellalabad; Edinb. New. Phil. Jour.*, xxxiv, 107; *Brit. Ass. Rep.*, 1845, 4; *Asiat. Jour.*, xxxviii, pt. 2, 120.

" *March* *3rd.*—Kábul.—Severe shocks continued every day. *Vincent Eyre*: Military operations before Kábul, quoted by *Baird Smith—Jour. Asiat. Soc., Beng.*, xii, 1043.

" " *5th.*—Mussooree, Simla, N.-W. Provinces.—Very sharp and sudden; a 'magnified' jarr.' Felt almost simultaneously at Simla, Mussooree, Deyrah, Saharunpoor, &c. Houses at Landour and Deyrah injured; motion from north to south.—*Jour. Asiat. Soc., Beng.*, xii, 275; *Asiat. Jour.*, xxxviii, 17.
9-10 P.M.

" *April* *20th.*—Kábul.—A severe shock. *Vincent Eyre*, &c.

" *May* *21st.*—Bengal, &c.—Slight motion from south-west to north-east. Felt at Patna, Gya, Jaunpur, Darjiling; at latter place at 9-10 P.M.—*Jour. Asiat. Soc., Beng.*, xii, 277.
Between 8 *and* 9 P.M.

" *May* *23rd.*—Bengal, &c.—Another shock.—*Ibid.*

" *June* *4th.*—Kábul.—A severe shock.—*Vincent Eyre*, &c.

" " *10th.*—Kábul.—A smart shock during the night.—*Ibid.*

" " *29th.*—Kábul.—A shock of earthquake.—*Ibid.*

" *July* *4th.*—Near Delhi.—A violent trembling, accompanied by a rumbling noise; motion appeared to be from west to east.—*Jour. Asiat. Soc., Beng.*, xii, 280.
2-50 P. M.

" *July* *21st.*—Jellalabad.— Severe shock.—*Ibid.*
9 P.M.

" *July* *25th.*—Delhi.—Smart, with loud rumbling noise.—*Ibid.* 281.
3-45 A.M.

" *September* *7th.*—Mussooree.—Slight; vertical; or from west to east; lasted five seconds; occurred during a severe storm.—*Ibid.*, 282.
1-58 P.M.

" *September 18th.*—Darjiling,—Smart; apparently from north-west to south-east.—*Ibid.*, 282.
4-30 A.M.

" *September 26th.*—Delhi.—Smart; accompanied by a tremendous rumbling; lasted two minutes; from west to east.—*Ibid.*, 283.
9 A.M.

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1842. *September 27th.*—DELHI.—Another slight shock in same direction.—*Jour. Asiat. Soc., Beng.*, xii, 283.

" *October 9th.*—BARODA.—Smart.—*Asiat. Jour.*, xxxix, pt. 2, 409.

" " *23rd.*—CHITTAGONG.—Motion east to west; stopped clocks' vibrating north and south.—*Jour. Asiat. Soc., Beng.*, xii, 284.

" " *23rd.*—GOWHATTY, &c.—Motion tremulous; lasted about half a minute.—*Ibid.*, 284.

" " *25th.*—JELLALABAD.—Severe; local.—*Ibid.*, 284.
1-30 A. M.

" *October 29th.*—GOWHATTY.—Motion appeared to be from north to south.
7-30 P. M. Gentle and repeated after half a minute.—*Ibid.*, 908.

" *November 6th.*—DELHI.—Slight; local.—*Ibid.*, 285.
1-30 P. M.

" *November 11th.*—CALCUTTA, DARJILING, GOWHATTY, CHITTAGONG, MON-
9-38 P. M. GHYR, &c.—Direction east-north-east to west-south-west. "Two or three vertical shakes or heaves of the earth, with a noise like the rumbling of a passing carriage, and one strong horizontal shake from east to west, or from north-east to south-west. The whole took place within about a minute of time." Three shocks felt at Botanic Gardens, near Calcutta; river much agitated. A remarkable luminous appearance observed in part of the river, which passed, and on its closing the ship, a general and severe tremor felt throughout.—(Ship *Southampton*). Felt severely at Serampore; at Darjiling not severe, motion apparently south to north. Felt also at Pubna; severe, south-west to north-east; at Burrisaul ground heaved; river greatly agitated; loud rumbling noise. At Gowhatty, slight, tremulous. At Chittagong, more severe, north to south. At Monghyr, part of fort wall overthrown. Felt also sharply at sea by the *Agincourt*, about 50 miles south-east of floating light ship,—*Jour. Asiat. Soc., Beng.*, xii, 285; *Asiat. Jour.*, 1843, xl, pt. 2, 25.

1843. *January 4th.*—SINGAPORE. MALACCA. Two shocks near midnight.—*Perrey*; *Mem. Cour., Bruxelles*, viii.

" *January 6th.*—PENANG, SINGAPORE.—Slight but extremely severe at Pulo
0-30 A.M. Nias, off the coast of Sumatra, where there were two shocks accompanied by a sea-wave.—*Jour. Asiat. Soc., Beng.*, xiv, 605.

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1843. *January* *8th.*—PENANG, SINGAPORE, &c.—At night; very slight. Said t
2-30 P. M. be from east to west at Singapore; from north to south at Penang.—*Jour. Asiat. Soc., Beng.*, xiv, 605.

" *February* *6th.*—KHYOUK-PHYOO.—Magnificent eruption and slight quaking
11 P.M. at Ramree; lasted till 1 in the morning; said to occur once in ten years.— *Ibid.*

" *February* *8th.*—AHMEDABAD.—Four shocks within eight minutes; from
2 A.M. north-east to south-west; slight and local.—*Ibid.*

" *Before March 12th.* DECCAN.—A shock over the Deccan.—*Ibid.*

" *April* *1st.*—DECCAN.—Widely extended: at Sholapur, preceded by a
4-30 A. M. noise, which seemed to come from south-east and lasted two minutes. Walls and towns thrown down. At Maktal at 4h. 45m. a simple trembling, with a dead noise. At Singroorgurh motion very strong, and at Shorapur; does not appear to have extended to Hyderabad. At Bellary, 4h. 45m. a noise resembling escape of steam, increasing to that of moderate thunder, with an undulatory movement from south-east to north-west, shook the whole cantonment. At Karnool, a shock of some seconds, at near 5h.; noise like distant artillery from north-east; felt also at Belgaum. Hurryhur was the most southerly point at which it was felt. Bellary was nearest to centre.—*Ibid.*

" *April* *6th.*—UPPER ASSAM.—At Jeypur, at 8 or 9 in the evening, a strong
8 P.M. shock, followed four or five minutes afterwards by another much more violent, lasting two minutes; appeared to be from east to west. At Sibságur, about 8h. 30m., several strong shocks during five minutes. At Dibrooghur at 8, a strong shock from west or south-west.—*Ibid.*

" *April* *7th.*—UPPER ASSAM.—Another shock at Jeypur and at Dibroo-
Midnight. ghur. At 1h. 15m. another shock at Sibságur.—*Ibid.*

" *April* *11th.*—LANDOUR.—Very sharp from north to south; lasted 30
8-5 *Morning.* seconds; extended to Hurdwar; and also to neighbourhood of Delhi and Meerut.—*Ibid.*

" *May* *12th.*—PENANG.—A succession of waves, north-west to south-east;
1 P. M. lasted five or six seconds.—*Ibid.*

" *June* *3rd.*—TITALYAH.—Foot of Sikkim Himalaya; slight shock; three seconds: from north-east to south-west.—*Ibid.*

" " *15th.*—SIBSÁGUR.—Strong and vertical.—*Ibid.*
11 A. M.

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1843. *June* *16th.*—JEYPUR.—(Upper Assam).—One of the most violent felt in Assam. At Sibságur 8-45 evening, another violent shock. —*Jour. Asiat. Soc., Beng.*, xiv, 605.

" " *17th.*—SIBSÁGUR.—Very sharp shock; movement slight and undulatory, followed by a violent blow; seems to have come from south-west or west.—*Ibid.*
8 P.M.

" " *17th.*—Baird Smith, in his Register of Earthquakes for 1843 (Jour. Asiat. Soc., Beng., xiv., 605, *et. seq.*) gives, on the authority of Mr. Masters and an anonymous correspondent, an earthquake on the evening of the 16th of June, which is said to have been the most severe noticed in Assam by the observer. As it is impossible to suppose that Captain Harvey could have failed to observe this, we must conclude that either Captain Harvey or Mr. Masters and the anonymous correspondent have made an error in the date.

" " *19th.*—COLOMBO (Ceylon). Three slight shocks half an hour after midnight, in space of a minute and a half.—*Ibid.*
0*h.* 30*m.*

" *August* *10th.*—DARJILING.—A horizontal movement, lasting 20 seconds from north-west to south-east. Felt also at Patna and in Tirhoot.—*Ibid.*
4-30 P.M.

" *September 2nd.*—ASSAM.—A strong shock at night.—*Ibid.*, p. 908.

" " *3rd.*—ASSAM.—Another, coming from the south, preceded by loud noise in the air.—*Perry, Mem. Cour., Bruxelles*, viii.
7·30 P.M.

" *October* *30th.*—SANDOWAY.—Violent shock from north to south, lasted two minutes; felt at Ramree, but slightly; more strongly in Cheduba; scarcely sensible in the Yoma range, but very sharp at Gukiong, on sea, 90 miles to south.—*Jour. Asiat. Soc., Beng.*, xiv., 605.
7-45 A.M.

" *November 14th.*—GOWHATTY.—A single shock.— *Ibid.*
Between 1-3 A.M.

" *December 18th.*—GOWHATTY.—Violent, with dead sound from south to north.—*Ibid.*
4-20 P.M.

1845. *April 19th to 25th.*—LUKPUT (Cutch).—Sixty-six shocks, some of which were destructive.—*Perry, Mem. Cour. Brux.*, viii.

A shock is stated to have been felt at Jogee, in Assam, which appeared to come from the Cossia hills; but without date, except the year.—*Ibid.*

" *July* *24th*—SERAMPORE, CALCUTTA.—Smart shock, succeeded by two less severe shocks.—*Friend of India.*
4-30 A. M.

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1845. *July 26th.*—SERAMPORE.—Another shock; motion appeared to be from
2 A.M. north.—*Friend of India.*

„ *August 6th.*—SERAMPORE.—A pretty smart shock.—*Ibid.*

11-30 P.M. SYLHET.—Same shock felt severely at Sylhet; several houses injured; also portico, &c., of church.—*Ibid.*

GOWHATTY.—Ten or twelve shocks had been felt during the preceding 48 hours (date, August 8th), one of them so severe as to have knocked down the new church spire.—*Ibid.*

MIDNAPORE.—A letter states that the earthquake of the 16th (? 6th) was immediately followed by an inundation of the Cossye, more severe than had previously been known. (The connexion of the two phenomena is not established.)—*Ibid.*

GOWHATTY.—Shocks very frequent; some very severe; 18 felt in one week; rumblings of earth incessant. For last week these commotions have proceeded from the south.—*Ibid.*

„ *August 22nd.*—GOWHATTY.—Severe; lasted about half a minute; motion
12-30 *Noon.* tremulous; no undulations; day hot; no rain; rumbling sound, as of distant thunder.—*Ibid.*

„ 3-5 P. M. —GOWHATTY.—Another shock: slight.—*Ibid.*

„ *August 24th.*—GOWHATTY.—Smart shock: earth said to have opened and
6. A.M. thrown up water near the hills. The direction of all these shocks is said to have been from west-north-west to east-south-east; some said north to south.—*Ibid.*

„ *October 28th.*—SYLHET.—A smart shock; lasted 20 seconds.—*Ibid.*

1846. *May 27th.*—NERBUDDA.—At foot of a hill called Dhumoh-pahari, a tremendous noise and rumbling in hill; in morning, hill found to have opened and engulphed trees of immense size, supposed to have been a landship, but found not to be so. Dhumoh-pahari (smoking mountain) is 500 feet above level of plain. No traditions of previous eruption; hill rent for ¾ths of a mile.—*Jour. Asiat. Soc., Bengal,* xvi, 380.

„ *October 17th to 19th.*—MYMENSINGH.—Torrents of rain during previous week. From the morning of the 16th to 10 A. M. of 19th, no less than 15 shocks, with five or six more occurring at night.

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1846. *October 18th.*—The most severe was that at. 2h. 15m. on Sunday, the 18th;
2-15 P.M. every house in the station suffered. The Collector had to live in a boat, the Magistrate to move into a tent; lasted a minute, and was followed about an hour later by another. Frightful loud rumbling noise.

CALCUTTA, SERAMPORE, &c.—Same shock as did so much damage at Mymensingh was felt also at Calcutta and in the vicinity; a smart shock lasting eight to ten seconds. Also felt at Dacca, more severely; "earth actually heaved;" houses all in motion; all masonry buildings cracked in every direction.—*Friend of India.*

" *December 10th.*—ASSAM.—Severe shock; loose sandbanks along the Burrampootra fell in several places: the Debroo was agitated as by a high wind. The Jansie, a small river in the Seebsaugor district, observed next morning to have risen 6 inches; and water of the Dakkho, which rises near the other, had sunk proportionately.—*Friend of India, January 14th, 1847.*

1847. *March 30th.*—PUNJAB.—A shock causing more fright than injury.—*Perrey.*

" *May 5th.*—CALCUTTA, &c.—Very different from ordinary shocks.—
5 P. M. None of the usual rumbling sound and undulatory motion; was "as if a chimney had suddenly fallen down on the roof of the house with a crash, which shook it to its foundation." Said to have been very sharp.—*Friend of India.*

" *October 31st.*—NICOBARS.—Continuous shocks, producing great landslips.
to Fire said to have been seen on the top of one of the moun-
December 5th. tains of Great Nicobar.—*Junghuhn's Java; Hochstetter, Novara Reise; Geol. Th.* ii, p. 93.

ASSAM, NOWGONG.—Public buildings destroyed, &c.—*Thornton's Gazetteer* under Assam. No date given.

1848. *February 20th.*—CALCUTTA, &c.—A smart shock, felt elsewhere also.—*Friend*
5 P. M. *of India.*

" *April 26th.*—MOUNT ABOO.—First shock at 11 P. M. on 26th, preceded by
11 P. M. a heavy rumbling noise coming up from the south-west; bungalows all cracked; things thrown from tables, &c.; temple of Dilwara much injured. Slight shocks continued up to 2 A. M. of the 27th, when another occurred, so sharp as to compel every one to "hold on;" shocks continued during day.—*Ibid*; also *Perry.*

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1848. *April 26th.*—Felt also at Deesa, Ahmedabad, Cambay, Mundlaisir, Sehore, Bhopal, Pahlunpur, &c.

„ *January 3rd.*—Khyouk-Phyoo.—Severe shock: damaged civil magazine and also sluice of salt golah.—*Friend of India; also Perry.*

„ *November 30th.*—Calcutta.—Shock said to have been vertical; not felt at *12-2 Midnight.* Serampore.—*Ibid.*

1849. *January 22nd.*—Calcutta.—Slight shock.—*Ibid.*

8-15 A. M. Gowhatty District.—Sharp shock. At Jogee lasted nearly one minute. At Burpettah (8 o'clock) the movement commenced by a slight undulation of the soil, accompanied by a dead sound, which continued for a minute, and terminated by a violent shock from north to south; followed by a second which caused the bells to ring; lasted altogether 1 to 1½ minute.—*Perry; Mem. Dijon Acad., 2 Ser., Tom.* 1, p. 15, *&c., Jour. Asiat. Soc., Beng.,* xviii., 172.

„ *January 23rd.*—Jogee, Burpettah.—Another strong shock from south-east

9 P. M. to north-west. At Burpettah did not occur until 11 o'clock and seemed to come from north (? a different shock) from Himalaya and not from the Cossia hills.—*Jour. Asiat. Soc., Beng.*, xviii, 172.

„ *January 26th.*—Jogee.—Sharp; long and in same direction as preceding;

5 A. M. the noise resembled that of heavy artillery.—*Ibid.*

6 A. M. Burpettah.—Two slight shocks. At Gowhatty, they were preceded for two or three seconds by a sound which continued for about the same time after the ground ceased to undulate.—*Friend of India.*

„ *February 27th.*—Darjiling.—Very sharp; many well-built walls cracked.—

9-10 P. M. *Hooker's Jour.*, i, 276.

„ *February 28th.*—Titalya.—Three sharp jerking shocks from the south, with

9-8 P. M. hollow rumbling sound: felt at Darjiling at 9h. 10m.—*Ibid.* i, 276.

„ *April 24th.*—East Indies?—*Perry, loc. cit.*

„ *November 23rd.*—Travancore.—From west-north-west to east-south-east.—*Trans. Bombay Geogr. Soc.*, xiii, *App.* c, 9.

„ *December 26th.*—Bombay.—Very slight.—*Perry, Bull. Acad. Belg.*, xvii, i, 225.

1850. *May 7th.*—Calcutta, &c.—A hot blast of wind, said to have been accompanied by an earthquake, and subsidence of a tract

A. D.

1850. *May* *7th* of land near Oolabariah: no shock felt at Serampore.—*Friend of India.*

1851. *January* *8th.*—CHITTAGONG, &c.—Sharp, preceded by a dull thumping sound; lasted about twenty seconds; motion apparently from south; felt also at Mymensing, Dacca, and Calcutta. —*Hooker's Jour.*, ii, 349.

" " *17th.*—LAHORE AND ALL PUNJAB.—Widely extended, but not severe shocks.—*Perrey, Bull. Acad. Belg.*, xix, i, 355.

" " *21st.*—LAHORE AND ALL PUNJAB.—Similar, but stronger.—*Ibid.*

" *February 2nd.*—SEHWAN.—Phooljee, near Sehwan; sharp.—*Bomb. Geogr. Soc.*, x, 284.

" " *4th.*—LAHORE.—Appears to have extended all over Punjab.—*Perry, loc. cit.*

" " *6th.*—PUNJAB.—Appears to have extended all over Punjab.—*Ibid.*

" " *9th.*—CALCUTTA.—Tremulous motion, not undulatory; preceded by an explosion like the blowing up of a powder magazine; lamps swung, chiefly from east-north-east to west-south-west.—*Ibid.*, page 356; *Friend of India.*

" " *14th.*—NAINI TAL.—Shock accompanied by storm with lightning and thunder; at same time immense inundations; barometer on 12th at minimum height in Bombay and Calcutta.—*Perry, l. c.*, p. 356.

Locality spelled Narnee Jal by mistake in Perry's Catalogue.

" " *17th.*—LAHORE, MOOLTAN, CALCUTTA.—Not severe.—*Ibid.*

" *April* *19th.*—GWADUR.—Three shocks; several houses destroyed.—*Bomb.*
5 P. M. *Geogr. Soc.*, x, 284; *Perry, loc. cit., page* 21.

" *April* *22nd,* OOTHUL IN BEILA.—*Ibid.*

" " *27th.*

" *October* *15th.*—CHERRA POONJI.—Motion distinct from south and east;
3-12 P. M. a second shock at 3h. 35m.—*Oldham. Khasi Hills. App. P.*, xiii.

" *July* *4th.*—CHERRA POONJI.—Slight.—*Ibid.*

" *October* *9th.*—NUNGKLOW.—Wave from south-east. Rumbling noise last-
3 P. M. ed thirty-five seconds.

" *October* *15th.*—CHEERA POONJI.—Motion distinct from south and east; a
3-12 P. M. second shock at 3h. 35m.—*Ibid.*

1851. *December 13th.*—BELUCHISTAN. CUTCHEE AT FOOT OF MURREE HILLS.—Noticed.—*Bom. Geogr. Soc.*, iii, *Buist.* x, 284, *Perrey, Mem. Dijon Acad.*, 2 *Ser.*, ii, 64.

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1852. *January 24th.*—UPPER SIND. MURREE HILLS.—Duration brief, but was
3-45 A. M. severe, causing death to a large number, especially in the Murree hills; fort of Kahun destroyed, and people with herds taking shelter in a cave in the hills buried; 350 people destroyed. Direction east to west.—*Trans. Geogr. Soc., Bombay,* x, 284; *Perry Bull. Brussells Acad.,* 1853, xx, 40.

" *February 9th.*—CALCUTTA, SERAMPORE, &c.—Slight shock.—*Friend of*
1-55 P. M. *India.*

" *March 31st.*—N.-W. PROVINCES, MEERUT.—Severe shock; felt strongly at Meerut; clocks and watches (?) stopped; panes of glass smashed to pieces.—*Friend of India; Perry, loc. cit.*

" *May* .—DARJILING, &c.—Threw down several thousand square yards of south-western face of Kunchinjinga.—*Sherwill, Jour. Asiat. Soc., Beng.,* xxii, 540.

" *August 9th.*—DACCA.—Preceded by a dead sound; shock strong; oscilla-
4-37 A. M. tion lasted fifteen seconds; strong all that time. Abbé Kuch says:—"I was in bed at the time, the bed lying south to north; shocks appeared to come from north-west; some said from north-west, some south."—*Perry, loc. cit.*

1854. *November?* —BOMBAY.—Slight shocks before 1st December.—*Perry.*

1855. *August 26th.*—SINGAPORE.—Not severe.—*Asiat. Jour.*

" *September 18th.*—AMARAPOORA.—Slight.—*Yule's Narrative, App.,* 349.

" *October 5th.*—AMARAPOORA.—Slight.—*Ibid.*

1856. *March 17th.*—MADURA.—Near midnight; noise seemed to come from east to west.—*Bomb. Geogr. Soc.,* xiii.

" *April 7th.*—KANGRA, SIMLA, KOTGHUR.—Four shocks at Kangra, one rather sharp; slight at Simla. At Kotghur, walls cracked and chimneys injured.—*Friend of India.*

" *August 11th.*—TREVANDRUM.—Low rumbling sound from south and east,
5-51 P. M. about three seconds before the shock; shock and noise twenty seconds.

" *August 25th.*—TREVANDRUM.—Another at 4-25-10; one or two more in
4-25 P. M. the month.—*Broun, Brit. Ass. Rep.,* 1860; *Trans.,* 74.

" *September 1st.*—TRAVANCORE.—North-west by north to south-east by
0-25 *Noon.* south; pendulum 17 feet long swung for four minutes.—*Broun, Trans. Geogr. Soc., Bombay,* xiii, *App. C.*

1857. *August 16th.*—CEYLON.—(? 14th). None said to have occurred since February 1848.—*Friend of India.*

1858. *March 16th.*—BALASORE.—A short pounding from the south, with usual
7-8 A. M. rumbling noise.—*Trans. Bomb. Geogr. Soc.*

A. D.

1858. *August* *11th.*—SIMLA.—Two shocks, first slight, between 5 and 6 P. M.; lasted 4 seconds; walls cracked, &c.—*Friend of India; Trans., Bombay Geogr. Soc.* Extended to Madras: (?) not felt at Bombay.—*Perry, Mem. Cour. Belg.*, xii, 54.

„ „ *13th.*—MALABAR.—Houses shaken 'for an hour.'—*Offl. Records.*

7-0 A. M.

„ *August* *22nd.*—TEZPUR.—*Ibid.*

8 A. M.

„ „ *23rd.*—LAHORE.—Slight; 6-30 P. M.—*Ibid.*

„ „ „ .—JACOBABAD.—Almost imperceptible.—*Ibid.*

2 A. M.

„ „ „ .—MALABAR.—Shocks for about an hour; shook all houses.—

7 A. M. *Ibid.*

„ *August* *24th.*—WALTAIR.—Slight shock in forenoon.—*Ibid.*

„ „ „ —BRITISH BURMAH.—A very severe and destructive earthquake in many parts of Burmah. The shock was most severely felt in the north of British Burmah, about Thayet Myo and Prome, but was experienced at all stations, the intensity decreasing from the north southwards: general direction appears to have been from east-north-east to west-south-west, being the mean of directions as noticed by different persons. The time is given as 3-38 P.M. at Thayet Myo; 3-45 A.M. at Rangoon: at Rangoon or Moulmein no damage appears to have been done. At Henzada tops of pagodas were knocked down or canted over. At Prome, about 3-38, lasted about a minute, sharp and severe. The Shue-the-thlap pagoda much injured; the only three pucca houses in the station uninjured, especially those on the bank of the river. Captain Ardagh, Deputy Commissioner, says, he felt his house rattle very much as if a horse or other animal had got under it and was knocking against it. But the motion was too great for this, and he was going out to see what was the cause, when he felt the floor wave beneath him, and just then heard the crash of a number of bottles, &c. Dr. McQueen says, he distinctly saw the east end of the house raised first and then the west.

THAYET MYO.—"Lasted about 45 seconds; three distinct undulations or waves, preceded by a rocking or tremulous motion of very short duration. Some persons who were in

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1858. *August* *24th* *—contd.* the open air experienced a current of hot air and a rushing sound as of a large flight of birds immediately preceding the shock. The rumbling and clattering noise was instantaneously followed by a tremulous vibratory movement, which in its turn was almost immediately replaced by the passage of the first earth-wave which threatened every house with destruction. The houses rocked distinctly. Most of the pagodas greatly injured; the tops of these fell to the south-west, and more than one was reduced to ruins, breaking down the south-west corner of their enclosures. These buildings had, I believe, their stability shaken by the first wave and fell by the second. Lighter bodies like bottles, &c., fell towards the north-east, as if they had fallen with the first wave. Mess table in mess house of XVth Regiment, Madras Native Infantry thrown out of its position and canted. At pagoda, near Assistant Commissioner's house, north wall looks as if upheaved, and is separated from the body of the structure by a wide chasm. In Major Cooper's pucca house north wall has bulged aud partly fallen outwards, and portico has separated from main wall of building in same direction. The *Diana* steamer lying at the ghât in 9½ fathoms felt "as if driving in a ga le of wind." She swung completely with her head down stream, and remained so till midnight, when the course of the river which had been reversed and ran with a current of three miles an hour was restored to its natural direction. Mud was brought up to surface of water and to north of cantonment, where the river is shallow; the bed of the river was distinctly seen to rise out of the water. It resumed its old level after the shock had passed. Partial eclipse of moon same evening. "Past season has been an unusual one, the rainfall has been far below the average; barometer gave no indication of any change" (Dr. Ranking's private letter, September 7th, 1858). Lieutenant Falconer, Executive Engineer, says:—"North and south walls injured much more than east and west; quoins suffered more than any other portion of buildings; all terraced roofs cracked, principally at corners near base of parapet; cracks from parapet to parapet cutting off triangular pieces over the corners of the buildings."

A. D.

1858. *August 24th —contd.* Allan Myo.—"Vibrations violent, rapid, upheaving jerks from east to west in rapid succession; crisis of earthquake about sixteen seconds after commencement; feeling was as if the convex side of an immense circle was passing with great impetus under your feet. Vibrations had a rolling feeling, as if the waves violently jerked, were passed rapidly under you in a different direction to the feeling caused by the crisis of the shock."—*G. Barr, Collector of Customs, Thayet Myo, 13th September 1858.*

Ava and Pagan Myo, &c.—Shock was felt at Ava, but slightly; some slight injury done to the old temples at Pagan.

Toungoo—First shock produced effect of heavy weight suddenly let fall, or of a man stamping violently. Three seconds after this earth-wave came and lasted three or four seconds; vibration similar to that felt on wooden bridge when a heavy train passes.

Akyab.—Motion said to be from south to north; lasted about a minute and half; unusually severe; dislodged bricks out of masonry walls of Collector's office and shook down some plaster.

Khyouk-Phyoo.—Assistant Commissioner's house rocked so that he and others were thrown down, and with difficulty got out of the house. Masonry buildings injured; water welled up in several places in various parts of town.

Ramree.—The Principal Assistant at Ramree reported the entire disappearance of False Island, situated south-east of the island of Cheduba, Lat. 18° 38′ N., Long. 93° 55½′ E., no trace of it having been seen after the 24th August; and he thinks the disappearance of it may be attributed to this earthquake. (March 16th, 1859).

In the *Madras* Presidency a slight shock is said to have been felt on the 24th August from north to south, and at the Adyar, close to Madras, also very slight at 4 or 4¼ P.M. The magnetic instruments at Madras Observatory were distinctly disturbed, not the meteorological.

In *Bombay*.—A very slight shock is said to have been felt at Carinjah Island, opposite Bombay, between 4 and 5 P.M. This, however, could scarcely have been from the same centre.

A. D.

1858. *August 24th —contd.* In *Punjab.*—On enquiry being made, it was reported that the shock was felt, but so slightly as not to have excited any notice. At Paneeput, Rhotuk, Jullunder, Umritsur, Lahore, Jhelum, Jhung, Rawul Pindee, Peshawur, the time is differently stated from 2 o'clock to 6 o'clock P.M. At Hissar said to have been felt at 9 A.M. I think from all this we may safely conclude that the shocks of the afternoon of 24th August were not felt in the Punjab.

In the North-West Provinces it was not felt; the only place where any shock is stated to have been felt about same time is Mozuffernuggur, where a very slight shock is reported about 4 o'clock P.M.; said to have been from north-east to south-west.

BENGAL.—It would serve no really useful end to give in detail the various statements sent in by district and local officers from all parts of Bengal. To take extreme localities, I may mention that the shock was just felt at Darjiling. At Hazareebagh, it was felt as two distinct waves; duration less than half a minute, and apparently from east to west. At Chota Nagpore, it was felt so slightly that no notes were taken. At Singhbhum, Cuttack, Balasore, not felt. At Cachar, not noticed. At Sylhet, 3-30 P.M. lasted thirty seconds. An earthslip, 20 feet long by 4 feet broad, fell from one of the teelahs. In Assam, seems not to have been felt. In Cossia hills (Cherra) only slight, about 3-45 P.M. At Tavoy, on Tenasserim Coast, it was so slight as to be scarcely perceptible, and was not felt at Mergui to south.

CHITTAGONG.—3h. 40m. P.M.—Three distinct shocks, first preceding others by eight or ten seconds, second and third being one continuous roll; more severe than any shock since 1852; motion apparently east-north-east to west-south-west; clocks stopped in several houses.

These observations enable us to mark out with tolerable accuracy the limits of the seismic area affected by this severe shock. And although, unfortunately, but little is on record of any accurate measurement of the direction, still by grouping the observations, we can arrive at a satisfactory conclusion, I think, that the seismic focus of the 24th August 1858 must have been under the ranges of hills lying between the Irawadi and the Bay of Bengal, in or

A. D.

1858. *August 24th.* about the parallels of Prome and Thayet Myo 4 A.M. *Official Records.*

" *August 25th.*—JACOBABAD.—Said to be very slight.—*Friend of India.* 2 A.M.

" *August 26th.*—PROME, &c.—A second shock, slight; lasted four seconds.— 8-30 A.M. *Ibid.*

" *August 26th.*—TEZPUR.—*Official Records.* 4 A.M.

" *August 27th.*—THAYET MYO.—Slight.—*Ibid.* 9 A.M.

" *August 29th.*—LAHORE.—Sharp shock.—*Ibid.* 6-30 P.M.

" *October 3rd.*—GANJAM.—Slight.—*Ibid.* 3-30 P.M.

" *October 12th.*—CHICACOLE.—Sharp.—*Ibid.* 4-30 P.M.

" *December 30th.*—In the three talooks of Kistnaghery, Tengoricottah, and 7 A.M. Tripatur, in the Salem district.—*Ibid.*

" *December 31st.*—KHANDEISH.—Slight.—*Ibid.*

In December 1858 and January 1859, several earthquakes occurred in Salem, Coimbatore, and North Arcot districts, Madras; general motion from south to north.

Shocks are also said to have been felt "during three days in the middle of August 1858 at 2 P.M., 10 A.M., and in the evening," on the Malabar Coast.—*Ibid.*

End of Augvst.—MANDALAY.—Daily shocks.—*Perrey. Mem. Cour.*, xxi, 17. *Beg. of Sep.*

1859. *January 3rd.*—NORTH ARCOT.—In the Pooloor Taluk tiles were displaced, about 8 A.M. and a rumbling noise continued for twenty minutes. Also felt in the Wallowanad Taluk of Malabar and the Coimbatore district.—*Official Records.*

" *February 5th.?*—TRIPATUR.—Accompanied by a subterranean roar, like that 5 A M. of a fast carriage.—*Ibid.*

" *July 21st.*—GUNTOOR.—Sharp; felt at Comalpand; large stones said to 4 A.M. have been rolled into the plains: loud rumbling noise: also felt at Condaveed.—*Mad. Jour. Lit. Sci.*, xxi, 165.

CONDAVEED, in Guntoor.—The sound of an earthquake is said to have been heard on the 2nd, 3rd, 4th, 5th, 7th, 8th, 12th, 27th, 29th, 30th, and several other days in this month, but no shock is reported as having been felt but this one.—*Official Records.*

A. D.

1859. *August 2nd.*—GUNTOOR.—*Official Records.*

„ „ *9th.*—GUNTOOR.—*Ibid.*

„ *December 17th.* 5-6 A.M.—TRIPATUR, in Salem.—Single shock, rumbling noise, lasted 30 seconds; similar noise heard on 30th November, 5 P.M.—*Mad. Jour. Lit. Sci.*, xxi, 340.

„ *December 17th. Night.*—SALEM.—Three shocks, first at 10 P.M., the second at 12 P.M., and the third at 4 A.M., on 18th.—*Ibid.*

1860. *January 17th. Night.*—SHEVAROYS.—Two shocks, not severe.—*Mad. Jour. Lit. Sci.*, xxii, 140.—*Official Records.*

„ *January 20th.* 7 A.M.—SHEVAROYS.—Slight.—*Ibid.*

„ *February 2nd.* 5 P.M.—TRIPATI, in Madras Presidency.—Lasted for a minute; was from east to west, with loud rumbling noise; felt also at Chandragiri, and in vicinity.—*Official Records*; *Mad. Jour. Lit. Sci.*, xxi, 341.

„ *February 25th. Between 11 & 12* P.M.—BERHAMPORE, in Ganjam.—Vibration from west to east, accompanied by a loud rumbling noise, which lasted for some seconds.—*Official Records.*

„ *July 9th. Sunset.*—DHURMSALA, FEROZPUR, &c.—Vibrations said to be from east to west! (The great fall of ærolites at Dhurmsala took place on the 2nd of this month).—*Friend of India.*

1861. *February 16th.* 7-30 P.M.—PENANG, MALACCA, SINGAPORE.—Sufficient to throw crockery off shelves, stop clocks, &c. There were three shocks, each lasting about thirty seconds; motion from north to south. Five minutes before the shock, there was an unusual commotion in the sea. Sky clear, and no wind.—*Friend of India.*

„ *February 16th.*—CALCUTTA, &c.—Water in tanks at 7 P.M. rose about one foot above its level on one side of tanks, and sank as much on the other. Sides of tanks on which it rose and sank were east and west sides. The same facts were observed at Ballygunge, also at Kishnaghur, Nuddea, Madhubpur, near Cutwa, Birbhum, Gorai, to the north of Calcutta, and at Balasore to the south.—*Friend of India; Jour. Asiat. Soc., Bengal.*

„ *March 4th.*—SHEVAROYS.—Slight shock: the cook's son explained the facts by saying "it was too much hot, and the earth had got headache like from too much quinine."—*Friend of India.* Felt throughout the Salem District.—*Official Records.*

A. D.

1861. *April* 18*th.*—CALCUTTA.—Slight shock.—*Friend of India.*
12-5 *Midnight.*

„ *July* 24*th.*—KISTNA DISTRICT.—Supposed to be from south-west to north-east, accompanied by a noise similar to the report of a cannon.—*Official Records.*

1862. *January* 13*th.*—KISTNA DISTRICT.—Undulatory movements, and low rumbling noise; lasted about ten seconds.—*Ibid.*
12-25 *noon.*

„ *June* 18*th.*—DARJILING.—At night: severe.—*Col. Crommelin:* Another slight, on the morning of the 19th June.—*Official Records.*

1863. *March* 29*th.*—DARJILING.—Very severe: day had been very windy and hot.—*Col. Crommelin.*
10 P.M.

„ *July* 8*th.*—DARJILING.—Severe: another shock at 8-50 P.M.—*Ibid.*
8-15 P.M.

„ *August* 11*th.*—DARJILING.—Moderately sharp.—*Ibid.*
2-15 P.M.

„ *August* 21*st.*—DARJILING.—Slight.—*Ibid.*
5-15 P.M.

„ *October* 17*th.*—DARJILING.—Between 10 and 11 P.M.: slight.—*Ibid.*

„ *November* 18*th.*—NIMAR AND BURWANI COUNTRY.—Accompanied by a loud noise like the trampling of a multitude of horses. In the Burwani country walls fell: shocks from north-west to south-east. Felt south of Nerbudda river, from Burwani in west to Poonassa in east; and north of the river, from Manpoor to Burwani: not noticed to south of the Satpoora range, as at Burhanpur: weather very sultry; heavy rain for two or three days after.—*Jour. Asiat. Soc., Beng.*, 1863, xxxii., 66.
7-30 P.M.

1864. *January* 5*th.*—TRICHINOPOLY.—Appeared to be from south to north, about six seconds. Noise like a number of heavy artillery waggons.—*Official Records.*
3-50 A.M.

„ *January* 5*th.*—DACCA, &c.—Said to be east and west (south-west to east). Sharp; people thought houses were coming down; one gentleman, sleeping east and west on a couch with castors, was suddenly driven, couch and all, against the western wall, when concussion sent him back again in the opposite direction. Motion near the river severe, felt at Narainganj: felt also at Salem.—*Friend of India.*
Night.

„ *April* 29*th.*—AHMEDABAD, SURAT, &c.—Several persons thrown down; some felt sick. Shocks from the north-west: felt also

A. D.

1864 *April* *29th.* in Surat, Kaira, Kattywar, Mount Aboo.—*Trans. Geog. Soc., Bombay*, xvii, 288, *et seq.*

" *July* *23rd.*—RANGOON.—Two shocks; doors rattled, &c., but no damage done. Felt slightly at Thayet Myo.—*Friend of India.*

" " *25th.*—At Gwadur and Mekran, sharp; portions of mountain said to have fallen with a great crash. (This is not strictly within Indian limits, but is noticed here merely to record the facts).—*Ibid.*

" *August* *30th.*—PATNA.—Slight from north-west to south-east; lasted 13 seconds.—*Ibid.*

" " *30th.*—LUCKNOW.—Two smart shocks.—*Ibid.*

" " *30th.*—DARJILING.—Slight.—*Col. Crommelin.*
11 P.M.

1865. *April* *11th.*—SIMLA.—Beds rocked; roofs cracked.—*Friend of India.*
4 A.M. MUSSOOREE.—Lasted a minute and a half; noise like thunder.—*Ibid.*

NAINI TAL.—Felt slightly.—*Ibid.*

" *August* *2nd.*—PALAR HILLS.—Appeared to travel north-west.—*Official Records.*
4 P.M.

" *September* *9th.*—DARJILING.—Slight.—*Col. Crommelin.*
9 A.M.

" *November* *16th.*—DARJILING.—Slight.—*Ibid.*
7-8 A.M.

" *November* *17th.*—JESSORE.—*Official Records.*

" *December* *4th.*—LAHORE.—Two smart shocks.—*Friend of India.*

" " *4th.*—DHURMSALA—Four severe shocks; large rocks detached from hills.—*Ibid.*

" " *4th.*—CHAMBA.—Houses rolled like a ship passing over a succession of waves; much damage done.—*Ibid.*

" " *12th.*—SHILLONG.—Slight.
8 P.M.

" *December* *16th.*—DARJILING.—Slight, but lasted for some time.—*Col. Crommelin.*
10 P.M.

" *December* *19th*—CHITTAGONG AND BENGAL GENERALLY.—At Chittagong a severe shock, which cracked most of the buildings of the station: five shocks were felt between 7-30 and 10-30 P.M. The first was severe, and lasting about 2½ minutes, and accompanied by a noise like that of a coming nor'wester; the other four were slight, lasting only 5 or 6 seconds. Most of the buildings in the station were badly cracked.
7-30 P. M.

A. D.

1865. *December 19th.—contd.* At Comillah the verandah of the school-house alone was cracked. At Diamond Harbour and Contai the shock was slight; at the latter place said to have been accompanied by a rustling noise like the flight of birds. Felt also at Balasore, Midnapore, Shergotty, Bhaugulpore, Jalpaiguri, Dinajpur, Sylhet and Cachar, besides other places needless to enumerate; everywhere said to have been slight. The seismic vertical was probably situated somewhere in hills between Chittagong and Burmah.

„ *December 20th.* 9 P.M.—RAMPORE BAULEAH.—Not so severe as that of the 16th; also felt at Dinajpore, Julpigoree, Serajgunge, Pubna, and Malda.—*Official Records.*

„ *December 25th.* *Between 4 & 5* A.M.—KISHNAGUR.—Rather severe shock, accompanied by a loud explosion.—*Ibid.*

„ *December 27th.* 7-15 P.M.—BARASOLE.—*Ibid.*

1866. *January 6th.*—CHITTAGONG.—Another slight shock.—*Friend of India.*

„ „ *23rd.* *Noon.*—MOULMEIN.—Slight.—*Friend of India.*

„ *January 23rd.* 8-10 P.M.—CONTAI.—Slight, but accompanied by a loud rumbling sound, like the passage of artillery over a metalled road.—*Official Records.*

„ *May 23rd.*—BENGAL, &c.—In Calcutta shocks were slight. At Monghyr one house destroyed; at Darjiling two or three shocks felt, of which one was severe; at Jubbulpore some houses fell.—*Friend of India.*

„ „ *23rd.*—KHATMANDOO, NEPAL.—A terrible shock; destroyed a large portion of the town.—*Ibid.*

„ *September*—KHATMANDOO.—A letter, under date September 20th, mentions a severe shock of earthquake *lately.*—*Ibid.*

„ *December 19th.* *Night.*—CEYLON.—Very general over Ceylon; slight.—*Ibid.*

1867. *January 3rd.* 9 P.M.—KENNALAPUD.—In the Kistna District,—slight.—*Official Records.*

„ *January 6th.*—VINUKONDA, Kistna District, slight shocks are said to be common.—*Ibid.*

1868. *June 29th.*—CACHAR.—Slight shocks in evening and at 3 next morning.

„ „ *30th.*—SYLHET.—A few minutes after 12 midnight, three waves, rather abrupt; second shook all furniture: duration about

A.D.

1868. *June* *30th* half a minute: tremulous motion for half a minute more, from west-south-west to east-north-east (?)

DINAJPUR.—Slight; three distinct shocks, lasted about a minute: felt slightly at Rampore Bauleah, Malda, Nattore, Bograh, Pubna, and Rungpore.—*Proc. Asiat. Soc., Beng.*, 1868, 256.

JULPIGOOREE.—Sharp, seemed to come from the south; roof, of lock-up shifted slightly towards the south.—*MSS. Corr.* Also felt at Darjiling and Cooch Behar.

" *July* *31st.*—HAZAREEBAGH.—Lasted ten seconds; appears to have come from the north or north-east. Felt slightly at Ranigunj, at Gobindpore; very perceptible at Bugodhur, preceded by a loud noise.—*Proc. Asiat. Soc., Bengal,* 1868, p. 257.

" *August* —PESHAWAR.—Portion of fort shaken down.—*Official Records.*

" *September 30th.*—MANBHUM.—Lasted one minute; direction apparently from east to west.—*Friend of India.*

DAMUDAH.—Loud rumbling noise; lasted five seconds; travelled from south-west by south to north-east by north. —*Ibid.*

HAZAREEBAGH.—Three distinct undulations, lasting forty-five seconds, with loud rumbling noise.—*Ibid.*

BIRBHUM.—In Birbhum slight.—*Ibid.*

" *November 10th.*—MURWUT, BANNOO.— Said to have caused moisture in the soil to rise from 2 feet below to within 6 inches of the surface, so that the villagers were able to sow their crops. Mr. R. E. Egerton, Financial Commissioner of the Punjab, reports that the crops were sown, although no rain had fallen, as the time for sowing was very nearly past, and the villagers were afraid of losing them altogether. This is a very probable explanation, and shows clearly how many of the extraordinary stories current regarding the effects of earthquake may have arisen.—*Official Records.*

1869. *January 10th.*—ASSAM, BENGAL, DARJILING.—*Vide* pp. 1-98.

" *March 21st.*—DARJILING—Slight; only one shock which resembled a 9-30 P. M. concussion.—*Official Records.*

" *March 23rd.*—DARJILING.—Slight; three shocks in a few minutes.— 2-15 A. M. *Official Records.*

" *March 24th.*—JHELUM.—Said to have been severe.—*Ibid.* *Night.*

A. D.

1869. *March 4. A. M.* *25th.*—PESHAWUR, KOHAT and adjoining country.—*Official Records.*

„ *March* *25th.*—DUGSHAI.—Two shocks. Said to be at 5-45 P. M.; also felt at Mussooree.—*Englishman.*

„ *April* *17th.*—SHILLONG.—Rather sharp, but of short duration.—*P. E. Carnegy in epist.*

„ *April* ? .—PESHAWUR.—Part of fort destroyed.—*Ibid. Official Records.*

„ *June 3-15 P. M.* *9th.*—CALCUTTA.—Not serious; quick; during a cyclone; another slight shock at 3-37, and a third at 4-7.—*T. O.*

„ *June 6-30 P. M.* *9th.*—DARJILING.—Slight, lasted about 3 seconds.—*Englishman.*

„ *July Midnight.* *4th.*—NASSICK. CHANDORE.—Slight shocks, lasting ten minutes; appeared to move from east to west.—*Bombay Gazette.*

„ *July* *7th.*—NEPAL.—Perrey gives a tremendous shock at Katmandoo, which he says was nearly entirely destroyed, a large portion of the population being buried in ruins.—*Mem. Cour.*, XXI, 89.

„ *July 11-45 P. M.* *12th.*—DHOOLIA—Slight, accompanied by a peculiar noise.—*Ibid.*

„ *July Morning.* *25th.*—NAINI TAL.—Two smart shocks.—*Englishman.*

„ *August Evening.* *9th.*—DARJILING.—Slight, followed by a much more severe shock on morning of 10th, at 8 A. M.—*Ibid.*

„ *September 7-30 P. M.* *1st.*—NELLORE.—Said to be from west to east; walls and posts of houses shaken.—*Ibid.*

„ *September 7-0 A. M.* *2nd.*—NELLORE.—A slighter shock.—*Ibid.*

„ *October 3-13 P. M.* *5th.*—SIMLA.—Two slight shocks during a thunderstorm.—*Ibid.*

„ *December 11 A. M.* *19th.*—COCONADA.—Two shocks.—*Ibid.*

„ *December 7 A. M.* *20th.*—RAWUL PINDI.—Shock said to have lasted about half a minute; cracked walls and caused all people to run out of houses.—*Ibid.*

ATTOCK.—A series of shocks at intervals of about twenty minutes.

LAWRENCEPUR.—First shock fifteen seconds; others at five minutes interval.

A. D.

1869. *December 20th.*—CAMPBELLPUR.—For half an hour: building much damaged.
TALLAGUNJ.—Not felt.—*Official Records.*

" *December 24th.*—RAWUL PINDI, MURREE, &c.—Some very heavy claps of thunder preceded. (Is this the same as that of 20th ?).—*Englishman.*
6-30-7 A. M.

" *December 24th.*—OOSSOOR.—Said to have lasted forty seconds.—*Ibid.*
10 A. M.

Catalogue of Earthquakes, chiefly Eastern, although not Indian, which appear to have escaped notice in the preparation of published lists.

In addition to the earthquakes noticed in the fullest catalogue yet published (Mallet's British Association Reports, 1852, 1853, 1854), I have during my present researches met with the following, which it may be desirable to place on record here :—

A. D.

343. Abul Faraj (*ed. cit.*, page 87) says: In the sixth year of the Emperors Constantine, Constantius, and Constans, were great tremors at Antioch and many earthquakes, nor did the earth cease to tremble for a whole year, but nevertheless so that nothiug perished.

375. *July 21st.*—In the reign of Valentinian, a great fall like small stones happened at Constantinople, and tremblings and earthquakes and gaps in the ground in many places: also the city of Nicia was engulphed (absorptus est).—*Abul Faraj, l. c.*, page 89); *Gibbon*, iii, 136.

441. In the twentieth year of the reign of Theodosius, junior, a great earthquake at Constantinople, such that all the people fled outside the city, and many places fell.—*Abul Faraj, l. c.*, page 91); also noticed in *Gibbon's Roman Empire*, iii, p. 560.

457 ? In the year Leo Cæsar came to the throne, which was the 879th (?) year of Alexander, a great earthquake in the city of Antioch; many places sank iu the earth. Same year a great famine in the east, and hosts of locusts.—*Abul Faraj*, (*l. c.*, page 92).

551. *July 9th.*—In second year of the reign of Justinian the 3rd, a flame of fire, appeared in the sky near the arctic pole which remained the whole year, and darkness covered the earth from the ninth hour of the day till night, such that no one could see anything, and something like dust and ashes fell from the heavens. And in the third year of his reign the rains failed and winter was like summer, and a great earthquake occurred and serious pestilence.—*Abul Faraj, l. c.*, page 95); also *Gibbon*, iv, 549.

634-5. PALESTINE.—Al Macin (Erpenius, edit., page 22,) records an earthquake in Palestine in the year 13 A. H., which was from March 7th, 634, A. D., to February 24th, 635.

A. D.

713.? *July 9th.* ANTIOCH, SYRIA.—An earthquake, which lasted 40 days at Antioch, is recorded by Al Macin in the year of the Hijra 94. This year extended from 7th October 712, A. D., to 25th September 713, A. D. This is very probably the same disturbance which is quoted in Brit. Ass. Catal., 1852, page 11, on the authority of Theophanes and Anastasius, as occurring on the 28th February 713 in Syria.—(*Al Macin, edit. cit.*, page 86).

738. *January 16th.*—The date of this is stated by Al Macin (page 99, Erpenius' edition, Leyden, 1625) to have been the 21st day of Túba in the year 120, A. H. This is a mixture of Mahomedan and Christian eras. The month of Túba, in the "era of the Martyrs," lasts annually from the 27th December to the 26th January; and as the year 120, A. H., extended from the 29th December, A. D. 737, to 17th December, 738, the earthquake occurred (21st of Túba) on the 16th of January 738, A. D. Al Macin's account is: 'In the night a great earthquake destroyed many cities, the inhabitants perishing in the ruins, and many ships were sunk at sea. They say also that this earthquake was universal over all regions to the extreme east, and that 600 cities in the east were destroyed in that night, and men and animals innumerable.'—(*Al Macin, edit. cit.*, page 99.)

856. *December.* —'In the same year (A. H. 242), in the month Sha'bán, terrible earthquakes happened in Corinth and its towns, so that 45,000 people perished under the ruins.' * * * In Persia, also Khorasán and Syria, 'earthquakes occurred this year, and unusual sounds, and in Alamana, with great destruction.' —(*Al Macin, edit. cit.*, page 189). The year 242 of Hijra was from 10th May 856 to 29th April 857. The first day of the month Sha'bán was the 28th day of the year; hence counting 208 days from the 10th of May 856, we find that this earthquake happened between the 3rd day of December 856 and the 1st of January 857, A. D. Quoted in Mallet's Catalogue, but not at Corinth, as Al Macin states.

Abul Faraj (Pocock's translation, Oxoniæ, 1663) describes this same earthquake, and attributes to it (page 170) the upturning of the mountain Akrao (Akraios), near Laodicea; whereas Al Macin (p. 190) says this occurred in 245, A. H. = 859, A. D.

A. D.

859 or 860. —Al Macin says: 'The cities of the West were shaken by an earthquake, so that castles, houses, and bridges, fell [1]. It was felt also at Bagdad, Damascus, Tarsus, and the shores of Syria and at Laodicea. In the same year the springs at Mecca failed, so that a skin of water was sold for 100 statera. Same year also great earthquake at Antioch, which destroyed many people. Fifteen hundred houses said to have fallen, and more than 90 of the turrets of the wall fell. Terrible and tremendous sounds were heard from the ruins, and the people fled to the fields. The mountain Akraios was torn up and thrown into the sea, whence this was disturbed, and from it came a black, thick and foul-smelling smoke.—(*Al Macin, edit. cit.*, page 190). Abul Faraj (Pocock's edit., Oxford, 1663, page 170) mixes up this last event and the earthquake of 856 in the month of Sha'bán at Corinth, noticed above.

The year 245, A. H., which Al Macin gives for these events, commenced on the 8th April 859, and extended to the 27th March 860, A. D.

899. *November 14th.*—A great earthquake is recorded by Al Macin as occurring in Egypt 'from the middle of the night to the morning.' The date is given as the seventh day of Zulqa'dah (translated Dulkiad in Erpenius), A. H., 286. The month Zulqa'dah is the 11th month of the year, and the 7th of Zulqa'dah is the 54th day from the last day of the year. Now, 286 of the Hijra (a bis-sextile Mahomedan year) ends on the 6th January, A. D. 900; therefore the date of the earthquake was the 14th November, A. D. 899—(*Al Macin, edit. cit.*, p. 227).

941. *August 6th.*—A violent earthquake in Egypt. The date as given in Al Macin is 11th Zulqu'dah 329, A. H. This day is the fiftieth day from the last day of the year. Now, 329 (a bis-sextile year) ended on the 15th September, A.D. 942; therefore the earthquake occurred on the 6th of August 941, A.D.—(*Al Macin, edit. cit.*, page 260.)

989. 990. A. H. 379 = 11th April 989, to 30th March 990, fourteenth year of Basileus the Emperor. One third part of Sta. Sophia fell and many buildings destroyed; also in Nicomédia (*l. c.*, page 314).[2]

[1] Al Macin says, he quotes from Tabari '*qui fide est dignus.*'

[2] Gibbon (viii, 10) states that the church of Santa Sophia in Constantinople was destroyed by earthquake in 1346 A.D.

A. D.

991. *5th April to 1st May* 'On the 17th Muharram, great earthquakes at Damascus; 1,000 houses fell, and many perished under the ruins. The shocks did not cease before (*diem Veneris*) the 14th Çafar.' (*Al Macin, edit. cit.*, page 316). The year 381, A. H., under which this is recorded, commenced 20th March, A. D. 991, and the 17th Muharram, therefore, was the 5th April, A. D. 991, and the 14th Çafar (the forty-fourth day of the year), was 1st May, A.D. 992. This severe earthquake is quoted (Brit. Ass. Catal., 1852, 17) as occurring in August 992 on authority of Vattier's French edition of LeMacin (Al Macin). I have not had access to this edition, but the date is clearly given in Al Macin.—(*Al Macin, edit. cit.*, page 316.)

1111. *September 1st*—A great earthquake in Egypt recorded by Al Macin at the third hour of the day, *die Veneris*, Friday, on the 3rd day of Tút, 828. This is 828 of the era of the Martyrs, which commenced 29th August, A. D. 284 (the accession of Dioclesian). Tút is the first month of the year; therefore the 3rd of Tút was the 1st of September. And, adding 283 to 828, the year was 1111, A. D. (Al Macin says distinctly, *die Veneris*, Friday, which we have shown above, was the 1st September, 1111 A. D. Comparing this with J. Prinsep's tables, we find the 10th July of this year was Monday; therefore the 1st of August was Tuesday, so also 29, therefore the 31st August was Thursday, and the 1st September, Friday, as before; an important and independent confirmation of the date given.—(*Al Macin, edit. cit.*, page 369.)

1285. In the east; said to have been widely extended. In the Brit. Ass. Catal., 1852, 35, this earthquake is quoted on the authority of Abul Faraj. But I can find no mention of it in that author; indeed, as this treatise ends with 1284, it is not possible he could have noticed it. I have been unable to find other evidence of its occurrence.

1549. In 956 A. H. (=A.D. 1549), an immense earthquake at Qáyin, in Khorásán (east of Persia) and killed 3,000 inhabitants. —*'Álam Árái Sikandarí*, a work on the History of Persia.

1619. "In 1028 A. H. (=9th December 1611 to 27th November 1619), a terrible earthquake took place at Dúghábád in Khorásán. At several other places, throughout the whole year, there had been earthquakes, but especially in Khora-

A. D.

san. The town of Dúghábád, after the earthquake, looked to be an immense heap of bricks. From 700 to 800 dead bodies were dug out from the debris. In one house alone about 70 corpses were found: there had been a bridal party, and, curious to relate, the bride alone was saved. She attempted to jump out of the window, when the house tumbled down; but the wood of the window frame did not break, and she was saved."—*Ibid.*

MEMOIRS

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VOL. XIX, Pt. 4.

PUBLISHED BY ORDER OF HIS EXCELLENCY THE GOVERNOR GENERAL OF INDIA
IN COUNCIL.

CALCUTTA:
PRINTED FOR THE GOVERNMENT OF INDIA.
SOLD AT THE
GEOLOGICAL SURVEY OFFICE,
AND BY ALL BOOKSELLERS.
LONDON: TRÜBNER & CO.

MDCCCLXXXIII.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA.
1883.

PREFACE.

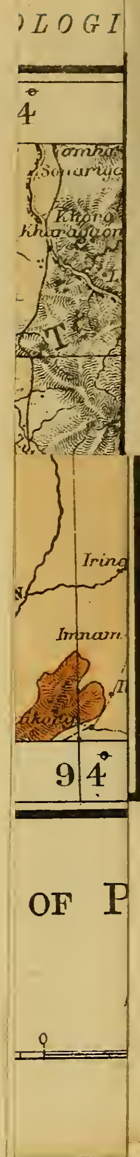
In extenuation of the incompleteness of the following Report, I would wish my readers to bear in mind the circumstances under which the observations on which it is based were made. Not only is the country so densely covered with vegetation, that for whole days one may march without seeing a single rock; not only is vegetation so dense that it is impossible for the most part to leave the narrow foot-path; not only is the structure of the country complicated and without any beds of marked individuality by which this structure could be unravelled, but my movements had necessarily to be guided by political exigencies rather than by geological necessities.

In a country partly depopulated and for the rest inhabited by savages of doubtful temperament, and where one's presence is decided by the accidental and temporary presence of an armed force brought there for objects among which geology, if regarded at all, is considered last of all, one cannot enjoy the same freedom and ease of movement as in the more quiet and settled districts of British India.

To Colonel J. Johnstone, Political Agent at Manipur, and to Mr. R. B. McCabe, C.S., Deputy Commissioner of the Naga Hills, I owe my sincerest thanks for the assistance I received at their hands.

R. D. OLDHAM.

Geological Survey Office;
Calcutta, 31st July 1882.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GEOLOGICAL SURVEY OF INDIA.

Report on the Geology of parts of Manipur and the Naga Hills, by R. D. OLDHAM, A.R.S.M., *Geological Survey of India.*

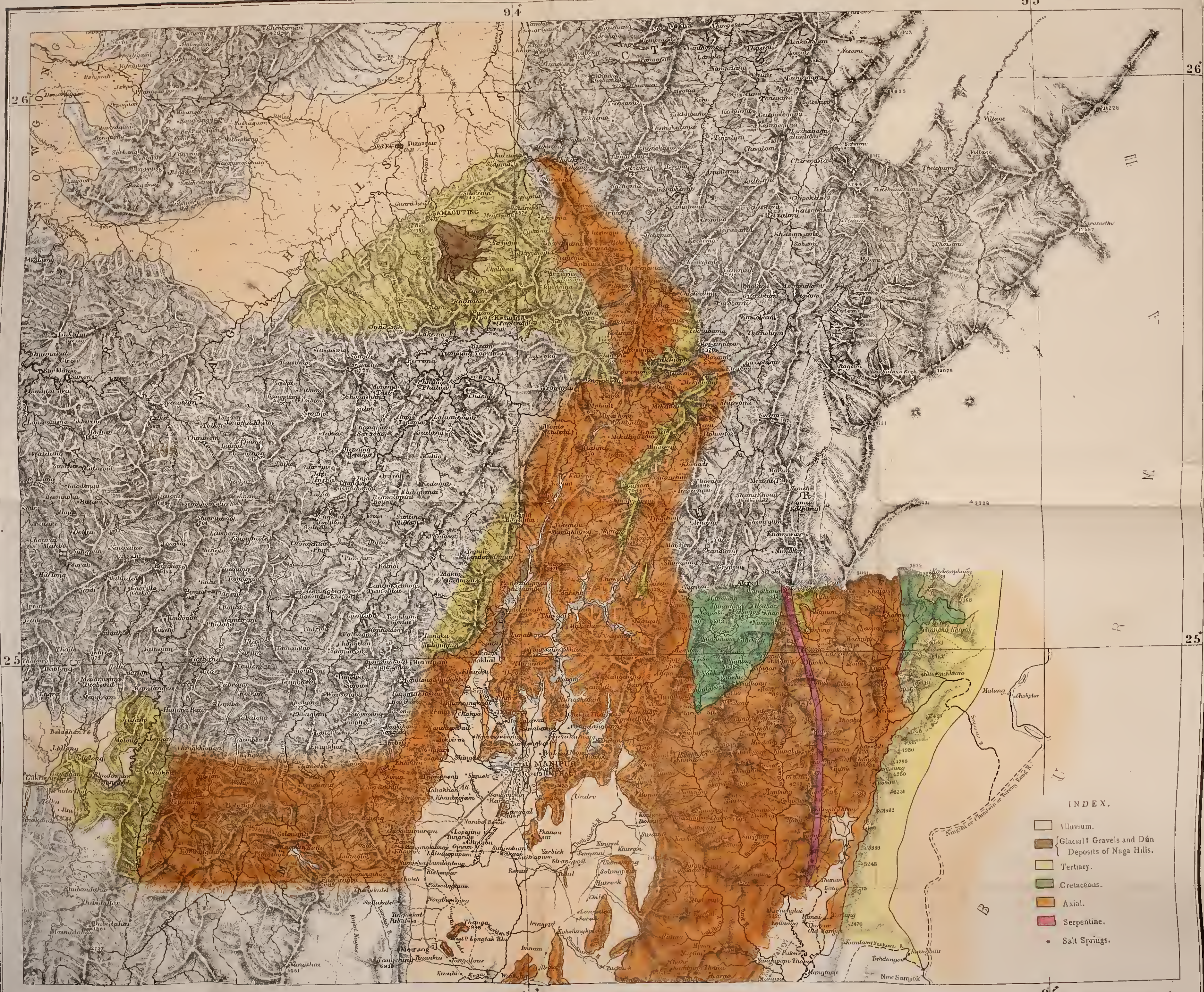
Previous information.

Of the geology of the country described in the following pages, comprising an area of some 1,800 square miles situated partly in the Tangkul-Naga hills, to the east of Manipur, the northern portion of the valley of Manipur and the hills inhabited by the Angami Nagas, together with the routes connecting those areas with each other, and the alluvial valleys of Cachar and Assam respectively, it may almost be said that previous to last November nothing was known.

R. B. Pemberton.
H. H. Godwin-Austen.

2. In the 'Report on the Eastern Frontier,' by Captain R. Boileau Pemberton, published in 1835, there are a few remarks on the economic minerals of Manipur, but it was not till Major (now Lieutenant-Colonel) Godwin-Austen visited this tract in charge of a survey party during season 1872-73 that any information of scientific value was obtained. The geological observations made by him were published partly in the official report on the Topographical Surveys for 1872-73, and partly in a paper on the evidence of past glacial action in the Naga Hills, published in the Journal of the Asiatic Society of Bengal, volume XLIV, pages 209—213. Besides these published observations, he noted on a map, by shades of colour, the rocks found in various localities of these hills; this map, deposited in the Office of the Geological Survey, though fragmentary and

Memoirs of the Geological Survey of India, Vol. XIX, Pt. 4.



GEOLOGICAL SKETCH OF PARTS OF MANIPUR AND THE NAGA HILLS.

Scale 1 Inch = 8 Miles.

incomplete in itself, has, taken in conjunction with and explained by my own work during the past season, enabled me to colour in a large area I should otherwise have been compelled to leave blank.

Method of description adopted.

3. In the following description I shall proceed in order of the various formations seen, commencing with the oldest; as the method of description by localities, while more convenient in the case of traverses would be very inconvenient when describing the connecting surveys I was able to make.

Older series.

4. I will therefore commence with a series of slates, sandstones and quartzites, which occupies the greater part of the area visited, and which I will provisionally call the 'older series,' deferring for the present the consideration of its age or title to a separate designation.

General description.

5. These beds were met with for the first time shortly after passing the Mukru river, on the road from Cachar to Manipur, where, two miles after crossing the river, the steady north-10°-east strike of the upper tertiaries suddenly ceased, and rocks, not at first very distinctly different in appearance, came in with a dip constantly changing in direction and amount, but settling down on the crest of the Kala Naga ridge to a south-easterly dip, which near the crest is 60° but as the road sinks down into the Barak valley is seen, while continuing steady in direction, to gradually decrease till in the bed of the Barak the strata are quite horizontal; this horizontality continues up the eastern slope of the Barak valley for some 1,000 feet, and here the series contains some beds of almost pure pipeclay. Beyond the village of Ballung (Bolongdoay) the dip again becomes south-east at 20°, and from here to the bed of the Irang the dip is constant to either south-east or east-10°-south, and generally about 20°. In the Irang the rocks are once more horizontal and continue so about half-way up the eastern slopes, whence they have a low dip to the west, all the way up to the crest of the ridge. After leaving the valley of Mapum the strike, though at first north and south, soon turns round to north-east and south-west, which, with local irregularities, continues with

a south-easterly dip to the bed of the Laimatak. On the ascent from the Laimatak there is a series of grey slates too decomposed for the dip to be distinguishable, but towards the crest sandstones come in at an E. N. E. dip, which continues as far as the alluvium of the valley of Manipur.

General description continued.

6. To the east of the valley, I found a great series of slates and quartzites with an easterly dip, generally with some north in it, which continued till the village of Tusom was reached. Near Tusom there appears to be a fault with an upthrow to the east, and here the dip suddenly changes to west and west-north-west, which dips continue to the great serpentine intrusion west of Kungal thanna, to the east of which there is a strip of the slates which have a generally westerly dip. In the whole of this section which, though apparently an ascending one throughout by far the greater part must have several repetitions, whether by faults or folding, I have not been able to detect any separation of the beds into more than a single formation.

General description continued.

7. On the Chatik ridge quartzose beds are not uncommon and on the crest there are one or two exposures of indurated pipeclay. Under the scarp of the Kasom range, there are numerous exposures of green (chloritic) schists, probably metamorphosed by the intrusive dykes which are here not uncommon; in some of the streams tufa was abundant, but in only one place, close to the Kasom village, was limestone found *in situ*; the rock was a highly metamorphosed dark marble with white veinings. Below the village of Chamu Khuno in the bed of the Nelay Khong, there was an exposure of fine-grained red slates; in the country lying between Chamu Khuno, Kachao, and the Kachao phung, the rocks are peculiar, a hard red coloured porcelanous rock, probably a more metamorphosed form of the red slate seen under Chamu Khuno, and structureless grey siliceous beds often passing into pure chert were the prevailing types, besides these grey and whitish slates and impure steatitic beds were seen. Near the deserted village of Kachao, there is a considerable amount of interbedded volcanic

ash exposed, which has a dip to the south-west. Westwards from Chamu Kulel to Chingsao the rocks are for the most part grey slate with a westerly dip, a band of white slate with the joint-planes stained red, being exposed below Chamu, while on the opposite side of the valley some fragments of steatitic schist were found. From here to Khangoi, except where interrupted by the trap or newer overlying rocks, slates and quartzites of this same 'older series' continue.

General description continued.
Limestone near Kongui.

8. Below Khangoi village I found for the first time some beds which were distinguishable from the great mass of grey slates and sandstones with which they are interbedded. These were a series of red and green slates, perhaps 200 feet in thickness, in which there was a solitary band of calcareous nodules, succeeded by grey and arenaceous slaty shales. Between Khangoi and Kampui (Lambui of map), about a mile beyond the former, there is another exposure of limestone which is well seen on the spur above Khangoi thanna; there is a thickness of about 150 feet, in all of a fine grained brittle limestone breaking with an imperfect conchoidal fracture, the lower portion is pinkish, while the upper and thicker portion is a pure pale-grey weathering somewhat yellowish; where seen *in situ* the beds were vertical with a north-north-west and south-south-east strike, though in the cliff above the grey limestone seemed horizontal probably from some freak of weathering; this, however, is a purely local variation of strike. The limestone is followed by slates and sandstones, but on the Hungdung spur, it crops out again with a north-north-east and south-south-west strike, or even nearer north, the exact bearing could not be distinguished. In the bed of the Nung-shang-khong the slates and quartzites had a north by east and south by west strike. Beyond Kampui red and green slaty shales once more cropped out with a single band of limestone nodules, and beyond this to Susukameng the rocks were of the usual grey slate and quartzite type.

Synclinal or anticlinal.

9. We have here evidently the only indication I have been able to find of the structure of the country, for this repetition could only be due to either a synclinal or an

anticlinal fold of the rocks, and though from my own observations alone it would be impossible to decide which, we have fortunately the observations of Major Godwin-Austen who found exposures of limestone, evidently a continuation of the Hungdung exposure, along the Rapfo ridge and as he does not mention any limestone to the east of this we may conclude that the corresponding exposure is separated by a greater intervening distance than is the case in the Nung-shong-khong valley. To the south, again, on the Susukameng-Kungal section no trace of the limestone was seen, and, unless some red coloured slaty rocks exposed under Tangkul Hungdung represent them, the red and green shales were equally absent. We have then the two outcrops diverging towards the north; this might be due either to an anticlinal whose axis had been elevated on the north, or a synclinal whose axis had been elevated towards the south. But, as I shall have occasion to point out when treating of the distribution of the upper tertiaries, there are very strong reasons for assigning an elevation to the country to the south rather than the north of the Nung-shong-khong. We may adopt the latter hypothesis, which would place the limestones above the red shales. Corroborative of this conclusion we have the section under the Kasom range here, where as far as appearances go we have an ascending section from west to east, limestone was found immediately beneath the escarpment of the upper tertiaries, while to the west, and therefore below it, red slates were found; if, and I see little reason for doubting the conclusion, these beds are identified with those in the Nung-shong-khong, it is another proof of the superposition of the limestone on the red and green shales.

Two series or one.

10. But it still remains to discuss whether these limestones and coloured shales should be considered as belonging to the great series below them or should be separated, and if so, where the line of separation should be drawn. Now, if the pipeclay of Chatik and that in the Barak valley be on the same horizon, and if the identification of the limestone at Khangoi and Hungdung with that below the Kasom escarpment be correct, and the weight of probabi-

lity in favour of these suppositions is greater than that against them, we have a most decided case of overlap. Further, on the western slope of the hill on which Chamu Kulel is situated, and again both north and south of the Kayeng village, white shales are found; I am not prepared to identify these for certain with the indurated pipeclay of Chatik, but they are very possibly the same; if so, their occurrence in these positions is still further proof of overlap.

Indirect evidence. Volcanic ash.

11. Besides this more or less direct evidence, there is the indirect evidence of the contemporaneous volcanic deposits near Kachao, which being from their nature and composition probably derived from the same source as the great trappean intrusion of the neighbourhood would naturally be of later date than the rocks in which the latter was intrusive, thus pointing to the presence of rocks belonging to at least two series. Unfortunately this argument is somewhat double-edged, for of all the rocks that I saw few were more metamorphosed than those immediately under the Kasom range, which I have conjecturally identified with the limestone and coloured shales of Kongui. This fact is explicable on the hypothesis that the beds among which the volcanic ash was found interstratified are but higher beds of the same series in which the limestone is near the base; and bearing in mind the jungly nature of the country, the disturbed condition of the rocks, the paucity of exposures, and the fact that I had not that complete command over my own movements necessary for the proper elucidation of a country having such a complicated structure as that under consideration, I am not able either to refute or substantiate such a conjecture.

Possibility of a third series.

12. The facts noticed in the above paragraph may point to a third series of rocks existing in this neighbourhood contemporaneous with the serpentine intrusions, and newer than either of the other two above noticed.

Demarcation of series, obscure.

13. Having thus, as I believe, proved that the older should be divided into at least two distinct series, there remains the important problem of where to draw the line between them, and to this I regret to say I see no hope of a solution; but

bearing in mind that the rocks of the Chatik ridge almost certainly belong to the older series, the line of demarcation between the two must in this neighbourhood be drawn not far below the limestone.

Ages of the two series.

14. We now come to the very important question of the age of these two series respectively, and here we are balked at the outset by the entire absence of any trace of fossils, but notwithstanding this we can, I think, make a very good guess at the truth. The most important clue we have is the limestone of the Nung-shong-kong valley; this limestone is of a very peculiar character, and is absolutely identical in appearance and structure with a greyish limestone, which in Pegu has been classed by Mr. Theobald as of cretaceous age. If this identification be correct, the older of the two series would fall into its place with the 'axials' of the Arracan Yoma with which they agree in general characters, and be of triassic age. The only other clue we have to the age of these rocks is the presence of brine springs among them, which would point to a nummulitic age for the series; but seeing that, as I shall presently show, both are as may be inferred from the great unconformity at the junction vastly older than other rocks of miocene age, and as the brine springs occur in the older and not the newer of the two series, *viz.*, among the 'axials,' which under any circumstances could not be of nummulitic age, no great weight can be attached to this fact. But though these rocks cannot possibly be of nummulitic age, it is not improbable that other rocks of that age do exist in this district, for, as was pointed out in paragraph 11, there is possibly a third series which, lying between the cretaceous and miocene, would fall into its place among the rocks of eocene age.

Cretaceous?

Axials?

Not nummulitic.

Possible presence of nummulitics.

Axials of North Manipur and the Naga hills.

15. I must now pass on briefly to describe the older rocks north of Manipur and in the Naga hills. The road from Manipur to Kohima lying almost along the strike of the rocks, little but grey and black slates with a north and south

strike and a high, generally vertical dip are seen. The ridge to the west of the Tiki valley, which culminates in the peak of Koupru, is capped by sandstones dipping to the west at about 40°; I was unfortunately unable to cross this ridge and examine the rocks, and therefore cannot of my own observation declare that these do not belong to the same series as the slates below, but have good grounds for separating them, and shall recur to this subject further on. In the Angami Naga country quartzites are found not unabundantly interbedded with jet black and grey slates; the strike of these is subject to occasional variations, but the irregularity of strike mentioned by Major Godwin-Austen is mostly superficial and due to the action of gravity on rocks whose joint planes have been loosened by weathering, for wherever the rock is exposed in a deep gully or valley, the strike is almost invariably north and south and the dip generally vertical. These rocks I refer without exception to the axial group of the Tangkul country.

Tipam group and axials.

16. This will be a favourable opportunity for a short digression to consider the relations of these rocks with those to the north in the Assam coal-fields. Here as described by Mr. Mallet, we have a series, the Tipam group, older than the coal-bearing rocks, the latter being of presumably nummulitic age; the former in general characters agree very fairly well with what I have classed as 'axials,' and are very possibly identifiable with them; this would be further proof, if proof were necessary, that the 'axials' are not of nummulitic age, and further assign a triassic age to the Tipam rocks.

Serpentine intrusions.

17. The trappean intrusions are confined to the eastern portion of the Tangkul country, and, if we except variations in texture, due to unequal rates of cooling, substantially all of but one kind. In describing these the words used in the Manual of the Geology of India when treating of the serpentine rocks of British Burma, may be transcribed almost verbally; the rock which occurs in dykes of varying sizes, the main axis of the intrusion forming a band some mile or two in breadth which runs throughout the whole

of the district examined in a general north and south direction, is a "characteristic dark-coloured serpentine; it frequently becomes a gabbro and contains bronzite, and is intersected by veins of gold-coloured chrysotile, or sometimes carbonate of magnesia;" the former was not found by me in Manipur. "The hills formed of serpentine may be distinguished at a distance by their barrenness; they appear to support little except grass and a few bushes." "In the neighbourhood of some of the larger masses of serpentine, the sandstones and shales are converted into greenstone and chloritic schist; but the effect varies, and in some instances the neighbouring rocks appear almost unaltered." All this is as true, word for word, of the serpentine of Manipur as of that in Pegu, and suffices to show the close similarity, if not identity, of the two which in hand-specimens are undistinguishable—a specimen brought from Burma by Mr. Theobald might, so far as appearance goes, have been broken off the same block as one brought by me from Manipur. It is further worthy of note that the mode of occurrence of this serpentine is the same as in Pegu, namely, that the serpentine outburst is confined not merely to east of the main range, but to the neighbourhood of the eastern limit of the hill rocks.

Date of outburst.

18. The date of this intrusion is, as I have already mentioned, posterior to that of the rocks to which I have assigned a triassic age, possibly also to those to which a cretaceous age has been attributed, and it is worthy of notice as an additional evidence that these rocks in which it is intrusive are not of nummulitic age that in Pegu the trap is nowhere found intrusive in rocks of undoubtably nummulitic age, and is hence probably of pre-nummulitic age.

Upper tertiaries.

19. The upper tertiaries are almost entirely confined to the borders of the region under consideration; the tract of them crossed on the road from Cachar to Manipur consists of argillaceous sandstones, sandstones and shales with a north-10°-east and south-10°-west strike; after leaving this band I did not again see the upper tertiaries to the east till the Angoching and Kasom ranges were reached.

Kasom escarpment.

The former I had no opportunity of examining, but as the two form one continuous escarpment broken through by the gorge of the Napunga whatever remarks I shall have to make as to the one will be equally applicable to the other. The Kasom ridge is composed of regularly bedded sandstones with, in the part accessible to observation, but few argillaceous beds; the thickness actually examined amounted to 1,500 feet, and in the hills on the Burma side of the crest there must be at least as much again, making a total thickness of over 3,000 feet. The sandstones have a moderate dip to the east, averaging about 20°, and in them plant remains and patches of coaly matter, which have given rise to the rumours of coal in the Angoching hills noticed by more than one of the Political Agents stationed at Manipur, are not infrequent; there is however but little hope of finding workable coal, the beds corresponding to the Nahan band of the Sub-Himalayas in which similar fragments of lignite have but too often raised false hopes of mineral wealth. To the north of the Kasom escarpment there is a low gap over which the sandstones have been denuded, and the crest of the ridge is occupied by rocks of (probably) cretaceous age; to the north of this gap rises the Kachaophung, which is structurally on the continuation of the Kasom ridge; here the rocks were similar to those of the Kasom, but in addition to abundant, though imperfect, plant remains, fragments of fossil resin were found in one of the beds, pointing to a probably contemporaneous origin for the amber dug in Upper Burma.

No coal.

Fossil resin.

Probable extension of upper tertiaries to the north.

20. Looking northwards from the Kachaophung the general appearance of the country is very different from that to the south, the hills being much barer and the southern faces often precipitous, the beds, too, looking from the south, seemed to have a gentle dip to the northwards. It would seem from this that the boundary of the upper tertiaries here trends westward, and that instead of merely occupying a narrow strip between the older rocks and the alluvium of the Ningthi valley, they

here spread out and occupy a broad tract of hilly country—a conclusion that is supported by the fact of upper tertiary sandstones capping the spurs on which Mapum and Poshing are situated, and by the fact of their coming in so far westwards as the Kopamedza range in the Angami Naga country.

Koupru ridge and hills north of Manipur.

21. I have already mentioned, paragraph 16, that the rocks capping the ridge to the west of the Tiki valley, appeared to rest unconformably on the slates below, and I find that Major Godwin-Austen identified them as tertiaries, and as he discovered marine bivalve fossils at Yemi and coaly matter in the sandstones of Laisen, both high ridges to the east, I have accepted his identification as almost certainly correct, and have coloured the map accordingly.

Patkai.

22. In the Naga hills district the same rocks are found, here somewhat more indurated, forming the culminating peaks of the Patkai range; the sandstones, which, where unweathered, might almost be called quartzites, and of which some beds weather with a beautifully rose-coloured surface contain numerous plant remains which, beyond the mere fact of their belonging for the most part to dicotyledonous plants are unfortunately undeterminable. Between Mao and Kohima the boundary runs in a straight line, too nearly north and south to be that of a natural escarpment of rocks whose prevailing dip is south-west, or even in some places south-south-west; from Kohima the boundary trends to the westward passing under Jotsoma, it curves round by Sachema and Karuphima whence it was not followed to the north.

Kopamedza.

23. To the east the upper tertiaries come in again within the boundary of British territory, the Kopamedza range being composed of sandstones with intercalated slaty rocks which have a rolling dip trending away to the east.

Fossils.

24. In only one position was I able to find any fossils other than plant remains, *viz.*, in the gorge of the Diphupani, where a broad road has just been cut, for the most part out of solid rock, and in two places beds containing numer-

ous specimens of a species of *Venus* were exposed. These shells, as well as the matrix in which they are imbedded, are undistinguishable from the fossils discovered by Mr. Theobald in the miocene beds of Prome, and are also very similar to the fossils found by Mr. Mallet in the Sub-Himalayan (Nahan ?) beds under Darjeeling.

Sub-recent.

25. I now pass on to the consideration of various local deposits of doubtful age, which I will class together as sub-recent, though it is not impossible that some at least may be of late pliocene age; they are (1) the 'Dun' deposits east of Samaguting; (2) the high level gravels, so-called morraines, of the Naga hills; and (3) certain high level gravels in Manipur territory. These I shall describe in the order above mentioned.

Samaguting duns.

26. Between the outermost ridge, that on which the station of Samaguting is situated, and the higher hills to the south-east, there are large tracts of comparatively low-lying gravel deposits, not unlike those of the duns of the Himalayas. One of these is traversed by the road to Kohima between Pherima and the Diphupani gorge; here there is exposed, in the deeper sections, a thickness of over 200 feet of sand and shingle of various degrees of coarseness forming terraces through which the streams have cut their present channels. These seem to be river deposits caused by a check in the gradient due to the elevation of the Samaguting ridge, deposition ceasing afterwards as the river cut down its bed in the Diphupani gorge.

High level deposits of the Naga hills.

27. In the valleys draining from the high peaks round Japvo, there are old high level river deposits which, from their composition, being a medley of blocks of stone of all sizes and, near the heads of the valleys at any rate, for the most part sub-angular, have been mistaken by Major Godwin-Austen for morraines.

Physical features of the country.

28. But before proceeding to a description of the deposits themselves, it will be well to devote a few words to a description of the more marked physical features of the hills among which they lie. If a straight line be drawn from Kohima

to Mao, we have, east of this line, a series of comparatively straight-crested spurs with rounded summits stretching eastwards at a height of four to five thousand feet till they drop into the valley of the Zullo, while to the west the spurs suddenly rise to some 7,000 feet whence sharp crested ridges run towards the west till they unite and culminate in the peak of Japvo at a height of 9,872 feet above the sea; thus we must limit the catchment areas of any glaciers which may have existed in these valleys to the comparatively small drainage to the west of the upper tertiary boundary.

Deposit in the Mizir valley.

29. Extending up the Mizir valley for about a mile beyond the line laid down in the last paragraph and ending abruptly in its vicinity, is a roughly triangular patch of gently and evenly sloping ground, through which the stream has cut a channel about 200 feet deep with steep and regularly sloping sides, on which is exposed a section of boulders, generally sub-angular, mixed with debris of every degree of fineness; as far as texture goes, it is just such a collection as might naturally be called a morraine; and if, as described by Major Godwin-Austen, the deposit really did come to an end just opposite Kigwema at a distance of four miles from its source, it is not impossible that a glacier flowing from a catchment area of about three square miles at most could have formed it.

Further extension.

30. But though this particular patch ends abruptly opposite Kigwema as correctly described, it is by no means the original limit of the deposit, whose further extension I will endeavour to describe with the assistance of the map. To the north of the villages of Kigwema and Mima, there is a long straight valley at the bottom of which is a broad gently sloping floor of from a quarter to half a mile in width, extending right up to the extreme head of the valley whence there is a sudden drop into the Mizir valley. This surface, which slopes about 200 feet per mile, would, if continued, coincide with that of the first-mentioned terrace at the head of the Mizir valley; and if any further proof of the original continuity of the two is required, it can be found in the small terraces which are to be seen under Kigwema, and

whose surfaces lie in the same continuous slope with that of the two larger remnants already described. From here the deposit continues to the junction of the stream flowing north of Mima with the Zullo, where it forms a broad flat surface that ends by sinking abruptly into the bed of the Zullo river; but even this is by no means its original limit, for, stretching down the valley as far as the eye can reach, a distance of at least four miles, there is a terrace evidently the remains of an old detrital deposit once continuous with that I have traced from the head of the Mizir valley, thus giving it an original extension of at least twelve miles, the greater part of which has been derived from an area of about three square miles; for on whatever theory we account for its origin, it is improbable that any great proportion was derived from the spurs to the east of the upper tertiary boundary, which, too, it is impossible to conceive as having served as collectors of snow from which so large a glacier could have been fed.

Evidence of non-glacial origin.

31. This extent of the deposit is in itself sufficient to preclude a glacial origin for it, but there are not wanting other facts equally if not more cogent, and all pointing in the same direction. Thus we have deposits precisely similar to those already described, and to which we must attribute the same cause of origin which are found, *e.g.*, in the Zumha valley, at a height of about 2,500 feet above the sea; and though some may be willing to believe that glaciers have descended to a level of 5,000 feet in these latitudes, there are, I fancy, very few capable of such an effort of faith as to accept the possibility of glaciers having descended to within 2,500 feet of the sea level within three degrees of the tropics, at any rate as long as any other explanation is possible. Nor do the gorges by which the drainage from the hills round Japvo escapes show any signs of glacial action; in that of the Mizir, which is the most open, so much so that the word gorge is hardly applicable, we have near its termination a low sharp-crested spur of solid rock, which from its shape can never have been subjected to the grinding of a glacier, running across the valley right up to the present bed of the stream; those of the other streams, *e.g.*, the Gaziarur (Kerhur-

MA

Axial. Tertiary. High level gravels. Low level gravels.

MAP OF PART OF THE NAGA HILLS SHEWING THE DISTRIBUTION OF OLD RIVER GRAVELS.

Lithographed at the Surveyor General's Office, Calcutta, August 1882.

rur), which flows to the south of Jakhama, are vertical-sided gorges of aqueous erosion without the least signs of glacial action.

Cause of origin.

32. But though I have, as I believe, shown the non-morrainal nature of these deposits, it is equally certain that they were not formed under existing circumstances for at present the streams are everywhere cutting into them, nor will any mere alteration of the levels causing a check in the gradients of the valleys account for the texture of the older deposits which differs markedly from those at present being formed lower down in the same valleys; but were the temperature decreased so as to kill off or largely diminish the amount of the forest on the slopes of Japvo, the rock would be disintegrated to a much greater extent than at present, and, if at the same time the rainfall increased, the greater rush of water carrying with it large quantities of detritus, would be able to carry with it the largest of the transported blocks now seen some miles from their original position; when this torrent debouched from its gorge into the more open valley below, the velocity being checked deposition would immediately commence, and gradually a long slope of boulders of every size mixed with gravel and sand begin to extend itself down the valley, its ultimate extent depending on the relative slopes of its surface and that of the valley, the former again depending on the relative proportions of water and debris forming the stream; nor need the fact that the larger biocks as seen near the head of the valley are sub-angular stand in the way of this explanation, for the masses of hard sandstone, originally angular, and which had not been subjected to the weathering that has softened the blocks now found lying on the surface, would need to travel some little distance before they became thoroughly water-worn; and it is a noticeable fact that as one travels down the slope of these deposits the larger boulders get more and more water-worn and at the same time smaller in size till few are left larger than what may be found at the present day washed down by existing streams.

33. This increased cold which I postulate, may of course be considered

as much evidence of a past glacial epoch as the actual existence of glaciers, but this concurrence of increased cold and increased precipitation could be produced under existing circumstances by an increased elevation of the Patkai, which I shall presently show, there is strong reason for believing was the case in geologically recent times. This increased elevation of course reduces the difficulties of explaining the possibility of glaciers having existed here, but the independent proof of the non-glacial origin of the deposits are so strong that it is unnecessary to enter into this question.

Glacial epoch *v.* increased elevation.

34. Between Viswema and Jakhama is another patch of similar deposits where we can plainly see the cause of the peculiar disposition of those near Kigwema. Here we have to the north of the Jakhama spur a small stream whose drainage area, for all practical purposes, lies entirely outside the upper tertiary boundary, and in which there are consequently no high-level deposits. To the south of the same spur is a stream which flows from the slopes of Japvo, and which, with another to the south, has formed a broad triangular surface now cut into by the same streams which originally formed it; but close to the village of Jakhama the deposit has been raised to within thirty feet of the crest of the spur as is shown in the outline sketch, Pl. 1, fig. 1, taken from Major Godwin-Austen's paper.

Jakhama deposits.

35. We have here an illustration of the history of the Kigwema deposits which are in a more advanced stage than those near Jakhama. There can be no doubt that originally the Mizir flowed along the foot of the spur on which Mima and Kigwema now stand; but that having raised the level of its bed to that of the saddle in the spur to the north, it poured over the rapid slope at the head of the small valley, and cutting down its channel established itself in its present course. From the small amount of deposit in the present Mizir valley and the low level at which it lies, I conclude that the conditions under which these deposits were formed must have passed away shortly after this catastrophe. The same

Alteration of drainage.

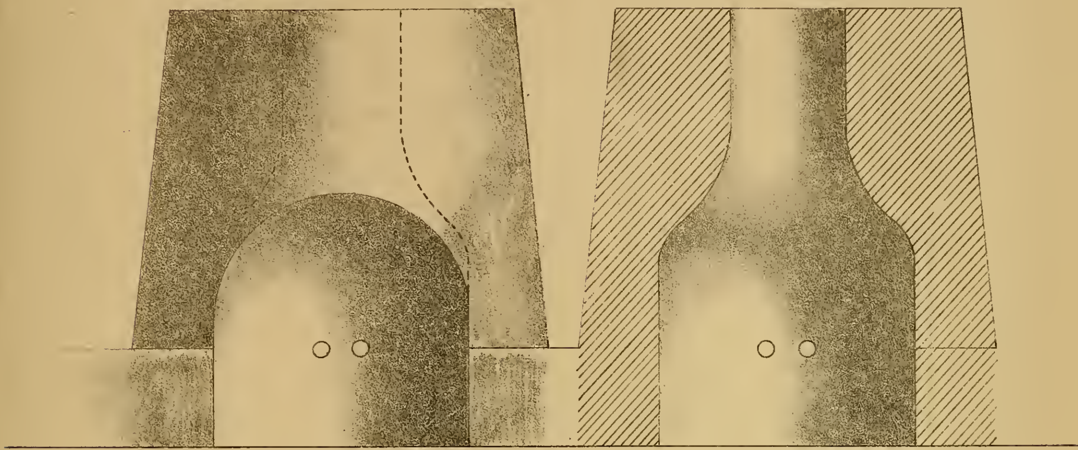


FIG. 2. MANIPUR IRON FORNACE

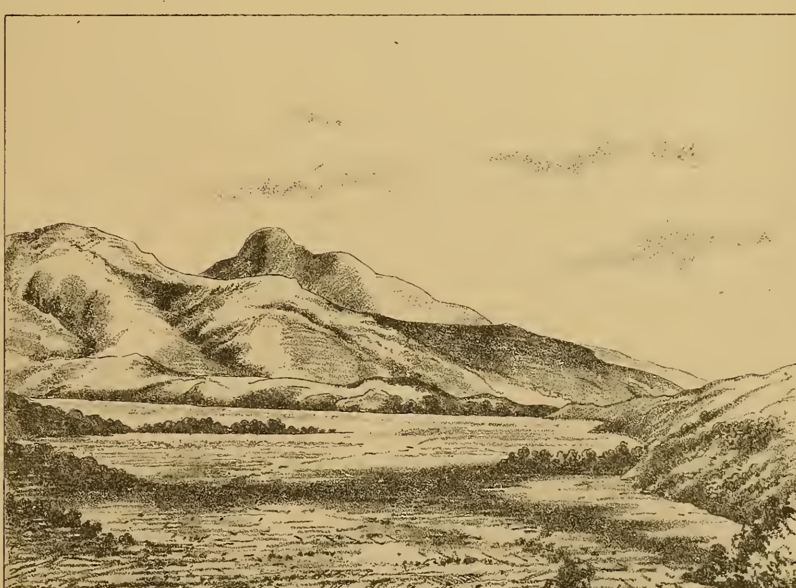


FIG:1. HIGH-LEVEL GRAVELS AT JAKHUMA.

thing would have taken place had the Gaziarur raised its deposits another thirty feet, and instead of flowing to the south of Jakhama it would have turned off to the northwards, where, through the ingenuity of the Nagas, a portion of its waters at present flow.

Other localities.

36. Deposits similar to the above described are also found below Khonoma, near Karuphima, and in Manipur territory they are to be seen in the valley up which the road to Kohima runs; but here, owing probably to the narrowness of the valley, they have been so much eroded that but little of their original sloping surface remains; here indeed it would be more difficult to prove that they were not morrainal, but the natural tendency to attribute their origin to similar causes to those of the others, added to the improbability of glaciers having ever descended to so low a level in these latitudes, is strengthened by the occurrence of small patches of almost level ground, gently sloping down the valley, which seem to have escaped the denudation that has elsewhere, in this valley, served somewhat to conceal the true nature of the deposit.

Tiki valley.

37. Entering the Tiki valley from Sengmai the road at first runs over the level alluvial surface of the Manipur valley; but before three miles have been traversed it passes into rolling stony ground sparsely covered with stunted trees and profusely scattered with boulders of slate and sandstone of all sizes and for the most part more or less sub-angular over which the road is carried till it makes a sudden drop to the level of the Tiki river; here the true nature of the tract just crossed is seen, for to the right is a narrow stretch of almost level ground through which the river meanders from side to side, while to the left abruptly rises a steep slope 100 feet in height, from the top of which the surface slopes gently upwards to the foot of the hills. It is on the north-east corner of this terrace that the thanna of Kaithamabi is situated. North of the thanna the terrace terminates, and a broad stretch of low land intersected by several streams slopes down to the Tiki; to the north of this, though no actual terrace can be detected there are remnants of an old high-level deposit which for the most part,

seem too elevated to have formed a continuous terrace with that to the south of the thanna.

Not lacustrine high level deposits.

38. This terrace might not unnaturally be taken as marking an old high-level littoral deposit of a lake, once filling the valley of Manipur, but not only is its texture not such as would be expected in lacustrine deposit, being not unlike that of the so-called 'morraines' of the Naga hills, and not only does it show in places near its very base evident signs of rivial action in its stratification and false bedding, but, were this explanation admissible, corresponding terraces should be found in all the other valleys draining into the same basin; so far from this being the case, I have seen no other similar terrace, in the valley of the Laimakhong there is no such feature, nor so far as could be detected in a distant view from Thunion is there any in the Iril valley; in both of these, as in all the small ravines flowing from the hills round the Manipur valley, the alluvium extends right up to the foot of the hills which descend in an even slope without any trace of a terrace. The only apparent exception that I can trace is in the Khongba valley; this I did not see myself, but a sketch is given by Major Godwin-Austen in which a most marked terrace is shown on the east of the valley; but from the appearance of the sketch and from the descriptive remarks in the text, I cannot but believe that Khongba is here a clerical error for Tiki.

Cause of origin.

39. Since then this feature is not general no general explanation is possible, but we must look to a local cause, which I take to be the same as that of the high level deposits of the Naga hills, that in past times in consequence of a colder climate, whether due to elevation or actual climatic change, the amount of debris brought down from the Koupru ridge was vastly greater than at present and choked up the whole valley, a subsequent rise of temperature causing an increase of vegetation and decrease of denudation enabling the Tiki once more to cut down the level of its bed. The open tract of low land north of Kaithamabi, which Major Godwin-Austen regarded as a filled-up lake, I take to be due to the almost

PART OF MANIPUR TO ILLUSTRATE THE ALTERATION OF DRAINAGE.

Blue lines indicate original courses of drainage.

Scale 1 Inch = 4 Miles.

5 4 3 2 1 0 5 10 Miles

complete removal of the talus by the streams flowing over it, which, as may be seen on the map, are much larger than those to the south. The numerous minor irregularities of the surface better accord with this theory than with the alternative one of its being an old lake gradually silted up.

Probable past extension of the Tiki valley.

40. But though the Tiki would probably have cut its bed down, as it actually has done, if the supply of water had decreased together with that of the debris, yet I hope to be able to show that it is not improbable that the stream may not only not have decreased, but may actually be greater now than at the time the high level terrace was formed. At the watershed between the Tiki and the Ngordai the road crosses over a low gap, hardly rising perceptibly, and passes over a fan brought down from the west by the stream marked on the map (opposite) as forming the head-waters of the Tiki, part of the drainage from which, if not part of the actual waters of the stream, flows into the Ngordai and part into the Tiki. This can only have originated by one of the streams having extended its valley at the expense of the other, nor is there much difficulty in determining which it is, for not only does the fan bear the appearance of having been formed by a stream originally flowing away to the north but the level of the Ngordai at four miles from this place is 400 feet higher than that of the Tiki at a similar distance from the same point, thus giving a more rapid fall and hence a more rapid erosion towards the south.

Bearing on theory of conversion of lateral into longitudinal drainage.

41. This has an important bearing on the much vexed question of the conversion of transverse into longitudinal drainage, for we have here one valley extending itself at the expense of and in opposition to another; and were the action to continue till the Tiki valley reached the junction of the Ngordai and the Barak, and consequently effaced the existence of the former, no inconceivable result, for the Barak is here 500 feet higher than the valley of Manipur, the waters of the Barak would be directed to flow along the Tiki valley to the south, and so transverse would be converted into longitudinal drainage.

42. Though I am not able to lay down the limit of the Tiki valley during the formation of the high-level deposits in either valley, I am inclined to place it, as marked on the map not far north of the low ground at Kaithamabi, for the high-level gravels there seem to be considerably higher, and more probably continuous with those of the Ngordai valley, than those to the south.

Limit of Tiki valley during the formation of the high-level terrace.

43. In the Ngordai valley there is, extending from almost its very head to within a few miles of the Barak river, an alluvial flat but little raised above the level of the stream, and above this fringing the valley, more especially on its western side, the remains of an old high-level deposit. About three miles from the Barak the stream begins to cut into the alluvium, and at the junction there is an alluvial flat some hundred feet or more below the terrace, on which the Karong thanna is situated, and which seems to be a continuation of the alluvium higher up the valley showing that, owing to a lowering of its outlet in the Barak the Ngordai has within times, geologically recent, begun to cut into its old deposits; in its lower part this erosive action has now ceased, and it is again forming an alluvial plain at a lower level than its old one.

Deposits of the Ngordai valley.

44. The only other valley in which I saw any high-level gravels was that of the Thobal Turel, where there are terraces raised 80 or 90 feet above the central plain of the valley, which is itself raised well out of reach of floods, being at present cut into by the river. In this same valley I saw, what is probably the oldest of all the high-level grounds of this district, a small patch on the very summit of the Hungdung spur, and over 2,000 feet above the level of the river.

High-level gravels of the Thobal Turel.

45. The idea of the origin of the valley of Manipur common to all previous observers, who have ventured to speculate on its origin, is that it is an old lake basin filled or dried up; indeed, when seen from the summit of one of the surrounding hills nothing could be more natural, the broad flat plain dotted with

Alluvium of the Manipur valley.

innumerable sheets of water and the low hills rising island-like from its surface all suggest the simile of a lake. Had this been the past history of Manipur, the present plains must either have originally formed the lake bottom, or have been produced by the gradual silting up of the lake and approximately mark the old water level. Major Godwin-Austen, the only one of previous observers who can be said to have had any knowledge of geology, rightly rejects the former, but adopts the latter supposition, in which I must differ from him, for it is impossible that, during the ages necessary for the gradual filling up of so large a lake, no terraces should have been formed by the inevitable cutting down of the outlet; but as has been mentioned no such terraces are to be seen, and consequently I am obliged to reject a lacustrine origin, for at least the upper beds of the Manipur alluvium. The Longtak lake, which has been appealed to as evidence of past lacustrine conditions in the Manipur valley, has no bearing on the question, as, in the absence of any information about its depth, it may be due to mere inequality in the rate of deposition of the alluvium.

Peculiarities of drainage.

46. A very marked peculiarity of the rivers flowing over the alluvium, and which is further proof of its rivial, rather than lacustrine, origin, is the manner in which many of them flow through gaps in the ridges which rise above the plain instead of round them as might have been expected; this feature is especially marked in the streams flowing into the north-west corner of the valley which all pass through the ridge that runs northwards from the town of Manipur. There can be but little doubt that this is due to the greater deposit of alluvium in the old valley of the Tiki, having risen to the level of the gaps in the ridge to the east, when the streams naturally flowed through these gaps into the lower level of the alluvium of the Imphal; so, too, the Iril having raised its alluvium till it found an easier outlet through a gap in the hills to the west, deserted its old course to adopt the one in which it now flows.

Similar deposits.

47. Alluvial plains surrounded by hills are not uncommon in this region. Besides that of Manipur and the small one in which the Kaopum thanna is situated, there are

the Kubo valley and the alluvial plains of the Ningti; it is evident, too, that Griffiths, in his tour from Assam to Bhamo, passed through several similar valleys, though he does not take any particular notice of the fact. The Kubo valley may not impossibly be a filled-up lake, for not only are there pretty distinct traces of an elevated terrace at its northern end, but in one of the small streams, not far from the northern limit of the alluvium, I discovered a bed of fine clay, almost pipeclay, which could hardly have been deposited by a stream flowing over an alluvial plain.

Kubo valley.

48. The alluvium of the Dunseri valley, though it has probably shut out for ever the possibility of tracing the connection between the cretaceous and nummulitic rocks of the hills to the west and the coal-bearing rocks to the north-east, is not without interest of its own. That the valley of the Dunseri is a longitudinal valley, which has extended itself along not merely the strike of the rocks but along the line of weakness separating the two contrasting areas of the Mikir and Naga hills, there can be but little doubt, for the large open valleys through which the Jamuna and the now insignificant stream of the Langpher flow, carrying part of the drainage from the Dunseri alluvium into the Diyung, could not have been formed except by rivers draining from a much larger area to the east than they now do. But after the Dunseri had thus diverted the drainage from the east into its own channel, a subsidence of the land took place, causing the formation of the Dunseri alluvium. Though this subsidence was probably divided into several stages, some of them perhaps dating from pliocene times, we have indications that the last stage of all must have been of geologically recent date, for some eight miles below Mohendijua the Jamuna river falls over a barrier of gneiss; now until by subsidence of the land the alluvium of the Dunseri had been raised to the level of this barrier, all the drainage that now falls into the Jamuna to the east of or above it must have flowed into the Dunseri, but a river depositing alluvium always raises its banks and the surface of its waters above the level of the surrounding country so that after

Dunseri valley.

the alluvium lying immediately to the east of what is now the barrier, and was formerly the water-shed of the Jamuna, was raised to its level, the first flood breaking through the banks of any of the affluents of the Dunseri naturally found an exit through the gap, and so struck out a new course for itself which it retained, and by a continuation of the same process, combined with an actual wearing away of the barrier, gathered to itself the waters of the other streams flowing down in its neighbourhood, and so part of the original drainage of the Jamuna, of which it had been robbed by the Dunseri, now flows once more in its original course. The large area of the Dunseri alluvium drained by the Jamuna is due partly to the well-known law by which alluvial plains slope from the banks of the depositing river, and partly to the cutting down of the barrier, thus enabling the streams to cut back their head-waters and divert to themselves more and more of the drainage of the Dunseri; this latter has, however, not yet occurred to any great extent, as may be seen by the very small depth of the channels in which the streams flow, and it is owing to this evidently very slight erosion of the barrier that I attribute a recent date to the escape of the present stream of the Jamuna in that direction, and it is not improbable that the subsidence which has caused this change in the drainage here was the same as that which put an end to the conditions under which the high-level deposits of the Naga hills were formed.

Mineral resources.

49. The region under description is very poor in minerals of economic importance, but iron, copper, gold, salt, lime, and edible earth are found in small quantities.

Iron.

50. Iron is found in more than one locality in the valley of Manipur; but so far as I know is confined to the swampy alluvial bays, where it is found in the shape of small pisolitic nodules of hydrated oxide of iron (bog iron ore) intermixed with clayey matter. The bed in which the ore is found is never at the surface, but covered with alluvium to the depth of two to five feet, and is itself from three to twelve inches thick. To procure it pits are dug, the barren soil above is thrown aside, and the band containing

the ore carefully collected and washed to separate the ore from the useless clay; the ore is then carried to the iron-maker's villages and there pounded in wooden mortars previous to reduction in the furnace.

Titaniferous iron ore (?).

51. Captain Pemberton in his report says that in the streams to the south of Thobal titaniferous iron ore is extracted, and that the exact locality of the deposit is discovered by thrusting a spear into the sand and examining the blade for particles of ore adhering to it. I cannot, however, but think that he was misinformed as to this, or misunderstood the process. He explains it by supposing the spear, which is always kept stuck upright into the ground, had acquired magnetic properties; this, however, could only be the case to a very slight degree, nor does it seem possible to me that, even if strongly magnetic, the fragments of ore could adhere to the blade while it was being extracted from the sand. I myself did not hear of any such process of discovering the ore, but it is possible that it may be followed, and that the yellowish-red streak of the ore on the spear blade betrays its presence.

Manipur iron furnace.

52. The furnace used in Manipur for the reduction of the ore differs not much in appearance, but greatly in principle, from those used in other parts of India. Externally it is a truncated cone, 18 inches high, about the same in diameter at the top and a few inches more at the base, perched on the edge of a terrace of earth four to six inches in height. The hearth varies somewhat, being larger in old furnaces than in new ones, but in the latter case is about 9 inches in diameter and the same in height; the tuyeres are inserted at the back at the level of the terrace on which the furnace stands and point downwards, while opposite to them is a roughly semi-circular aperture 9 inches broad and the same in height. Above the hearth the walls are thickened, and the central aperture is reduced to 6 inches in diameter: this structure will be easily understood from the sketch elevation and section in Pl. I, fig. 2, (page 16). When at work the blast from the tuyeres impinges on the hearth and passes out with all the products of combustion through the aperture in

front; the chimney above being kept full of charcoal and ore insures that the fire is continuously fed, but otherwise takes no part in the operation. From the above description it will be seen that the ore is practically reduced on an open hearth, and the Manipuri furnace would seem to show one of the first steps in the transition between the original method of reducing the ore in an open fire and its reduction in a scientifically-constructed blast furnace. Doubtless the Indian furnace is the descendant of such a structure, some inventive genius experimentally inclined tried the experiment of closing the aperture opposite the tuyeres and forcing the products of combustion to escape upwards through the chimney, and finding his experiment a success, inaugurated a new era in the reduction of iron.

Copper.

53. Copper is worked in the south-eastern corner of Manipur territory, the ore being obtained from the hills bordering the Kubo valley. I was not able to visit this locality, but was shown a specimen of malachite and copper pyrites mixed, said to have come from the Maku hill. I expect however that it really came from the first-mentioned locality, as I could get no exact information as to what part of Maku the ore was extracted from.

Gold.

54. Gold is washed in the sands of the Ningthi river, but not, so far as I was able to discover, to any great extent it is not found in Manipur territory.

Lime.

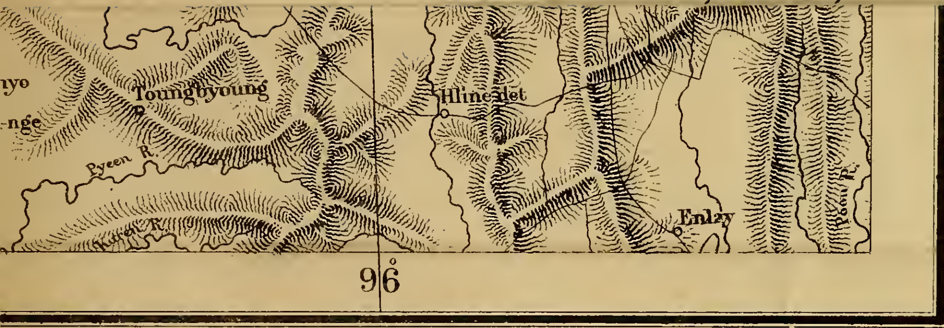
55. The supply of lime is very deficient. Manipur is supplied by the produce of the beds mentioned in paragraphs 7 (*et seq.*) which has to be carried three days' journey; here as elsewhere in India the solid limestone is not burnt, tufa being preferred. In the Naga hills no limestone has been discovered, nor do I consider it likely that any will be discovered at any rate within a reasonable distance of Kohima.

Edible earth.

56. In the valley of Manipur in a small tila to the left of the main road leading northwards from the city, there is exposed an unctuous clayey rock, which is dug out and sold in the bazaar, being esteemed a delicacy to which medicinal virtues are also attributed.

Salt.

57. Salt is in Manipur territory tolerably abundant; it is derived from brine wells. In evaporating the brine two distinct methods are followed, each spring being evaporated on the principle which has been found to be best suited. In some cases the brine is merely boiled down in open vessels and the resulting crystals wrapped up in small parcels in leaves; this form of salt appears to be deliquescent; but most of the Manipuri salt is treated in a very different manner; the brine is first concentrated in large earthenware vessels standing four feet or more in height and with sides over an inch in thickness but the final desiccation is performed in shallow metal dishes over a quick fire; the dishes are lined with green leaves and the brine poured on to them, as it solidifies more is added till a cake of half to three-quarters of an inch in thickness is formed, the brine is then dried off completely and the salt turned out in a meniscus shaped cake about nine inches in diameter and three-quarters of an inch thick. The salt prepared in this shape is not deliquescent, and the reason that this process is not uniformly followed seems to lie in the fact that the salt of some of the springs is deliquescent, in which case it could not retain its shape if formed into cakes.



Boundary of Meizoseismic area........ —.—.—.—.—.—

Outer Isoseismal line..................... —..—..—..—..—

MAP of the SEISMIC AREA of the EARTHQUAKE of 10th January 1869.

PRINTED AT THE SURVEYOR GENERAL'S OFFICE, CALCUTTA, NOVEMBER 1881.

Boundary of Meioseismic area

Outer Isoseismal line

XIX 2