EXTRACTS

FROM

NARRATIVE REPORTS

OF THE

Survey of India

FOR THE SEASON

1900-01

PREPARED UNDER THE DIRECTION OF

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SURVEYOR GENERAL OF INDIA.

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CALCUTTA:
OFFICE OF THE SUPERINTENDENT, GOVERNMENT PRINTING, INDIA.
1903.

CALCUTTA :
GOVERNMENT OF INDIA CENTRAL PRINTING OFFICE,
8, HASTINGS STREET.

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I

RECENT IMPROVEMENTS IN ZINCOGRAPHIC PROCESSES.

Extracted from the Narrative Report of Mr. T. A. Pope, Assistant Surveyor General, in charge Photographic and Lithographic Office, Calcutta. Season 1900-1901.

1. During the past two years considerable attention has been paid to improvements in the methods of map-reproduction in use in this office, and as this has led to important changes in the direction of both efficiency and economy, it seems desirable to record the objects of the changes introduced, and to describe as fully as possible the new methods now employed.

Of these there are two, both of which are in daily use. The first to be described, to which the name "Heliozincography" has been given, is a simple method of transferring a greasy image to a zinc plate from a reversed negative without the aid of paper transfers. The second, now known in the office as the "Vandyke" process, is a remarkably simple, speedy and inexpensive means of producing a direct image on zinc, without recourse to photography, from a drawing in black and white on thin paper or tracing cloth. Both processes are entirely novel in principle, and were invented and worked out by assistants in this office.

2. **Heliozincography.**—For many years past the process of photo-zincography by transfer, invented by Colonel Sir H. James, R.E., has been employed here with great success in the reproduction of the standard sheets and other large publications of the Department. As a means of producing, in the shortest possible time, perfectly accurate copies, either to scale or reduced, of our fair maps, the process has been of incalculable benefit. It has, however, certain inherent defects. Of these the chief is the liability to shrinkage and distortion to which the paper transfers forming the principal stage in the process are subject. Now that most of our maps are printed in at least two colours the difficulty of obtaining accurate registration, owing to this defect, has rendered it almost impossible to obtain good results with the old transfer method. While in England on furlough in 1901 I found that this method had been practically abandoned at the Ordnance Survey Office, Southampton, where all the larger publications are reproduced direct on zinc from reversed negatives, the zinc plate being rendered sensitive by a coating of bichromatized fish-glue. The same method has often been tried at this office, using gelatine instead of fish-glue, but never with great success, owing to the tendency of the gelatine coating to rot away under the influence of the damp heat of Calcutta. I was convinced, however, that this difficulty could be overcome, either by the use of fish-glue in place of gelatine or by employing bitumen as the sensitive coating. I therefore obtained sanction to have a camera made, large enough to take a standard sheet in one negative, with a suitable lens and prism for reversing the image. This camera is now in use and fulfils all our requirements perfectly. It was further essential that some better means of obtaining contact between the reversed negative and the thin zinc plate should be provided than is afforded by the old

pattern of printing frame. At Southampton I found that Sack's pneumatic printing frames were used with perfect success, and two of these, of suitable size for our large work, were also procured. In these frames, which are a recent invention, perfect contact is obtained, without the slightest risk of breakage, by exhausting the air inside the frame by means of a pump. The introduction of these frames has removed one of the chief difficulties in direct printing on large zinc plates, for which absolutely perfect contact between the zinc and the glass is essential.

3. On my return from furlough, the question of the best means of transferring the image from the reversed negative direct to zinc was at once taken up, and every effort was made to settle it satisfactorily before the arrival of the new camera, which was not expected for some months. In this matter I was very ably assisted by Mr. A. W. Turner, Photo-engraver, who had had considerable experience of both gelatine-bichromate and bitumen processes. The method finally adopted, and now in daily use, is entirely the result of his skill and industry. For the sake of convenience, and to distinguish it from the old method of photo-zincography by transfer, it has been called Heliozincography—the name applied to the similar process employed at Southampton. Though similar to the Southampton method in its results it is quite different in principle, and is, indeed, entirely novel. It will now be described in detail.

4. Hitherto, in all processes for direct printing on zinc from a negative (except in the bitumen or asphalt process, which is slow, uncertain and very difficult to work) the printing surface is supported on a substratum of gelatine or other colloid substance, intervening between the surface of the zinc and the greasy matter forming the printing surface. The objection to these processes, when worked in a climate like that of Calcutta, is that this colloid substratum, when mixed with bichromates to render it sensitive to light, and hardened by exposure, is liable to decomposition and does not stand the wear and tear of printing. In a dry climate, even though it be hot, this tendency is less pronounced. The new process which I am now describing is a decided improvement on the older ones, and might be substituted with advantage in any climate. In order to overcome the above difficulty, experiments were made in which the ink itself is made sensitive to light and ultimately forms the printing surface of the plate. The process is based on the fact that a colloid substance, such as gelatine, albumen, or fish-glue, can be intimately mixed with a fatty ink if the two substances are of similar consistency. This mixture, or emulsion as it really is, can then be made sensitive to light by combination with a bichromate. The idea is, as far as I know, an entirely new one, and is capable of very wide application.

5. The *modus operandi* is as follows:—Take one ounce of photo.-transfer ink and mix it with half an ounce of a ten per cent. solution of soap. Sunlight soap has been found to work well, but any good soap will do. The mixture must be well worked together with a palette knife. To this mixture add three ounces of a solution of one ounce of ammonium bichromate in four ounces of water, intimately incorporating the solution with the greasy ink with a muller or palette knife. Before mixing the bichromate solution with the ink three ounces of fish-glue is mixed with the bichromate. The mixture of ink and soap will keep indefinitely, but in this climate the solution of bichromate and fish-glue does not keep very well and in hot weather should be made up daily. To reduce the mixture of ink, soap, fish-glue and bichromate to the proper consistency, a sufficient quantity of a mixture of water and turpentine is added to it, the water and turps being emulsified by shaking immediately before use. Grained zinc plates

are used, and the coating of the above mixture is applied to them with a sponge, first up and down, then across, applying it perfectly evenly and leaving only the thinnest possible coating on the plate. The coating must be performed in a yellow light. When dry, the plate is exposed in contact with a reversed negative, taking care that perfect contact is obtained. In the pneumatic printing frames now used there is no difficulty whatever in this. In direct sunlight an exposure of from two to three minutes is sufficient. After removal from the frame the plate is covered with a thin coating of photo.-transfer ink thinned down with turpentine and applied evenly all over with a pad of soft cloth, rubbing it in hard until the coating dries. This application of a second coating of ink is not essential to the process, but was found to be an advantage in facilitating the subsequent rolling up of the plate, and to render it unnecessary to remove the original image, which thus remains embedded in the grain of the plate and gives more solid lines in printing. The plate is next washed in water, which removes all the sensitive inky surface unaffected by light, dried, and again exposed to light for a short time to harden the image. It is now immersed in a 5 per cent. solution of alum to which one per cent. of nitric acid is added, which has the effect of removing any traces of fish-glue and at the same time converts the soap into a fatty substance. The plate, when dry, is ready for the printer, who, after etching and cleaning with turpentine, proceeds with the printing in the ordinary way.

6. The novelty of the process lies in rendering greasy ink sensitive to light and thus avoiding the necessity for a colloid substratum intervening between the surface of the plate and the ink itself, a necessity which has hitherto rendered all efforts at direct zinc printing in this climate more or less futile.

7. At the present time, all or nearly all our standard maps are being reproduced in this way, with the great advantage that the results are sharper and better, and that no trouble is found in registering the hill-work now commonly printed in brown on the black outline plates. Not the least significant point in connection with the new method is that it finds favour with the staff engaged in working it. Ordinarily it is no easy matter to get one's assistants out of a groove in which they have been accustomed to work for years; but in this case all the men concerned, both in the negative and zinc printing sections, have thrown themselves heartily into the change. As was to be expected, now that the new method is in daily use and all difficulties have been overcome, it is greatly preferred by every one in the office to the old method with direct negatives and transfers. As soon as the change, now in course of introduction, in the method of reproducing our cadastral maps has been effected, and these are put down direct on zinc by the Vandyke process, the old transfer method will be practically a thing of the past.

8. **The Vandyke Process.**—This process, the object of which has already been stated, was described in the Appendix to the General Report for 1899-1900 (p. 26). Since that description was written, certain important modifications have been introduced, rendering the process more simple and easy of manipulation, and it is therefore desirable to give a further description of it, as it is being worked at the present time.

9. As it sometimes happens that subjects are received for reproduction by this method which are quite unsuitable, it is necessary at the outset to state the precise limitations of the process. In the first place it is only adapted to the reproduction of drawings to the same scale and drawn on a single sheet. Two or more sections cannot be joined together as in ordinary photo-zinco-

graphy. Tracing paper or cloth is the most suitable form of original. Failing this, any smooth-surfaced paper may be used, no matter how thick. Rough-surfaced drawing papers are unsuitable and should not be used. It is necessary that the work should be drawn in good, black, freshly prepared Indian ink, and with this proviso any drawing will reproduce satisfactorily, no matter how fine the lines may be. Colour should not be used. Nothing whatever should be pasted on either the back or front of the original. Slips of type or other matter pasted on the front will not reproduce, and consequently have to be drawn on the zinc afterwards. Nothing should be written on the back of the original. Headings, foot-notes and other type matter should be neatly printed on the original in their proper places. Lastly, original drawings should not be folded or creased if it can be avoided, but either left flat or rolled up when despatched.

10. The method by which the original drawing is reproduced upon zinc consists of five separate operations, *viz.*:—

1. Coating the zinc plate,
2. Exposure to light,
3. Development of a negative image,
4. Inking the plate, and
5. Development of a positive image.

After the fifth operation the plate is similar in all respects to one produced by the ordinary method of photo-zincography and can be printed from in the usual manner.

(1) *Coating the plate.*—The zinc plates (which should be grained in the usual way) are coated with a sensitising solution consisting of a bichromatized colloid substance, and the following is the formula adopted after many trials :—

Carpenter's glue	1 oz.
Hard Frankfort black	40 grains.
Bichromate of ammonia	30 „
Water	2½ oz.

The Frankfort black is well mixed with the glue and water with a muller or palette knife, and the bichromate is dissolved in the mixture afterwards. The plate is coated with a sponge; only the thinnest possible coating is required, and it should be applied as evenly as possible, all the superfluous solution being carefully sponged away. After coating, the plate is hung over a support in a drying box and dried by heat in the dark.

(2) *Exposure.*—The drawing is placed in an ordinary printing frame, face upwards, and the plate is placed in position upon it with the sensitive surface in contact with the face of the drawing. This must be done in a weak or yellow light. Perfect contact is essential. The exposure to light varies greatly according to the intensity of the light and the thickness of the original drawing. For a tracing, half a minute in bright sunlight may be sufficient; a drawing on thick paper may take five minutes or more.

(3) *Development of the negative image.*—The action of light through the drawing hardens the bichromatized glue and renders it insoluble in cold water. It is therefore possible, after exposure, to dissolve away by the action of water the unaltered glue which has been protected from light by the black lines of the drawing. This is effected by subjecting the plate, after removal from the frame, to the action of a stream of water, and by lightly rubbing with cotton wool to thoroughly clear the lines. When fully developed, the lines of the drawing should stand out sharp and distinct in clear zinc. It is then blotted off with blotting paper and dried. Any defect in the ground-work, caused by the acci-

dental removal of the glue, or by stains in the original drawing, can be removed at this stage by painting them over with gum, which will prevent them from appearing on the finished plate. A negative image of the original drawing in bare zinc on a background of glue has thus been obtained, and it is now necessary to convert this image into a positive one.

(4) *Inking the plate.*—For this purpose the plate is first covered all over with an ink prepared as follows:—

Lithographic chalk ink	6 oz.
Bitumen	6 ,,
Writing ink (Litho.)	2 sticks.
Burgundy pitch	3 oz.

This mixture is thinned down with turpentine and then well rubbed into the lines of the drawing with a pad. The lines are now covered with ink, and the background still remains covered with hardened glue, having a coating of ink over it.

(5) *Development of the positive image.*—The next operation is to get rid of this glue, leaving the ink-covered lines intact, and this is effected by immersing the plate in hot water until the glue can be removed with a sponge. Instead of hot water a very dilute solution of hydrochloric acid may be used, which, after a short immersion, softens the glue so that it may be easily rubbed away with a sponge or flannel pad. In this office, where about thirty plates are prepared daily, the whole number are, after being inked up, placed, one on top of another, in a hot water bath and left to soak for a short time. They are then taken out one by one and developed singly by light rubbing with a flannel pad under a steam of cold water. This rubbing does not affect the ink-covered lines in any way. It is necessary to remove the glue background very thoroughly, and to ensure this the plate is rubbed over, after development, with powdered carbonate of magnesia. After this it is dried, and it is then ready for printing.

11. The above process has been in daily use for the past 18 months for the reproduction of the sheets of the Bengal cadastral surveys, tracings of which are made on ordinary tracing paper, and sent in at the rate of thirty daily. This work is shortly to be transferred to the Bengal Drawing Office, where it will be undertaken by a staff trained in this office for the purpose. Arrangements are now in progress for the reproduction of the Burma cadastral surveys in the same manner, and as the actual cost is rather less than one-fourth of the cost of reproduction by photo-zincography, the change of method will effect a very large saving.

12. Mr. Vandyke, the inventor of the process, has obtained patents for it both in this country and in England, and has been paid a sum of R10,000 for the right to use it by the Government of India, and of £400 by the authorities in England for the use of it in that country.

T. A. POPE.

II

TRIANGULATION IN UPPER BURMA.

THE "GREAT SALWEEN" AND "MANIPUR MINOR MERIDIONAL" SERIES.

Extracted from the Narrative Reports of Captain H. H. Turner, R.E., and Lieutenant H. Wood, R.E., in charge of No. 24 Party, Survey of India.—Season 1900-1901.

NOTE.—The party worked in two separate sections, one under Captain Turner and the other under Lieutenant Wood.

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2. Captain Turner's work was to start a new principal series to be called the *Great Salween Series* emanating from the base, Ubyetaung H. S.—Katha H. S. of the Mandalay Meridional Series,—and proceeding eastward to the Salween River where it was to turn Southwards and follow that river.

* * * * * * *

A tetragon was found necessary for the first figure owing to a range of hills preventing intervisibility of the diagonals of a quadrilateral.

3. Messrs. Troughton and Simms' 12″ Theodolite No. 3 was used, the new tribrach being employed throughout the season. Observations were taken on 12 zeros with 4 intersections (two on each face); if the four values did not agree within 2″ an extra observation for every 1″ over was taken.

4. At the first station, Katha, the method adopted was to take one swing F. R. and change to F. L. for the return swing. The zero was then changed and the same operation continued. By this means two values were obtained on each zero, the remaining two values being obtained at some later time; if one set was to Lamps, the other set was taken to Heliotropes preferably.

This method was afterwards given up, as it was found that the continual changing from one face to the other was apt to lead to the intersection of the object on the wrong side of the central horizontal wire. In its place the method of obtaining four values for each zero (two on each face) at the same time was adopted.

To ensure quite different readings on the horizontal arc between the two successive observations on the same face, the micrometer head of the eye-piece was made to read about 10 divisions different for each swing of the telescope on the same face.

5. Owing to the delay caused at the beginning of the season by waiting for the building of the forward stations, and to the bad weather, only one figure was completed; but two angles each of two of the triangles of the next figure were also observed, and these observations have been used to get *preliminary values* of two more stations.

6.

Number of new stations fixed (principal)	3
Number of new figures completed	1
Length of Triangulation in miles	49
Area of Triangulation in square miles	1,730
Number of new stations fixed (approximately)	2
Average triangular error (four triangles)	0·57

7. An Azimuth was observed at Sin-pi-taung H. S. the difference between the Astronomical and Geodetic values being 6″·101.

8. At the end of the season the revolving tribrach was tested, by first observing a round of 4 angles on all zeros with the tribrach, and again re-observing them without it, (in the latter observations, owing to haze, etc., only three of the angles were observed). Below is a tabulated statement showing the seconds only of the angles measured with and without tribrach.

Angles between	Condition of Instrument.	R.-0-0. L180-0.	L15-1. R195-1.	R30-2. L210-2.	L45-3. R225-3.	R60-4. L240-4.	L75-5. R255-5.	R90-6. L270-6.	L105-7. R285-7.	R120-8. L300-8.	L135-9. R315-9.	R150-10. L330-10.	L165-11. R345-11.
Loi Lem / Pompi Bum.	With tribrach .	27·43	30·56	27·43	26·99	29·13	29·82	29·87	30·74	27·28	29·24	29·77	28·93
Pompi Bum	With tribrach .	41·14	41·00	42·52	40·59	38·82	41·27	38·30	37·99	42·20	41·18	39·29	39·95
Tangté .	Without tribrach	42·40	42·29	43·05	40·29	39·68	42·12	38·97	38·49	40·60	38·72	39·47	40·29
Tangté .	With tribrach .	22·16	21·45	21·37	22·22	24·07	22·53	24·46	24·01	22·44	22·35	23·21	21·94
Sin-pi-taung	Without tribrach	20·64	20·73	20·04	22·68	23·38	22·69	25·11	23·75	22·36	21·64	22·79	20·63
Sin pi-taung .	With tribrach .	29·26	28·08	28·62	29·77	27·24	26·89	26·75	26·32	28·09	29·22	27·51	30·55
Loi Lem .	Without tribrach	29·59	28·09	29·42	29·07	26·45	25·77	26·10	26·50	28·55	29·55	28·60	30·77

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11. Owing to the cloudy weather the heliotropes were in the early part of the season hardly ever visible during the middle of the day, so vertical angles were always taken at night.

The greatest care was taken in getting the reciprocal observations at as near the same hour and minute as possible.

Tabulated results of the heights obtained by observations to (1) Helio from one station only, (2) Reciprocal Helio, (3) Lamps from both stations, are given below:—

Station.	Heights obtained from observation to			Co-efficient of Refraction $\frac{r}{c}$.	
	Helio.	Reciprocal Helio.	Reciprocal Lamp	From Helio.	From Lamp.
Noepeji h. s. . . / Kyet-tayah-taung h. s.	...	3393·1	...	·071	...
Vownalumol h. s. . / Kyet-tayah-taung h. s.	...	3398·1	3395·0	·076	·077
Vownalumol h. s. . / Waibula h. s. . .	5952·8	...	5952·7	...	·070
Kyet-tayah-taung h. s. / Waibula h. s. . .	5955·2	...	5948·8	...	·087
Kyet-tayah-taung h. s. / Kyet-taung h. s. .	...	4304·8	4304·7	·073	·080
Waibula h. s. . . / Kyet-taung h. s. .	4281·9	...	4305·5	...	·089
Waibula h. s. . . / Wone-lone-taung h. s.	...	...	4925·5	...	·069
Kyet-taung h. s. . / Wone-lone-taung h. s.	...	...	4936·8	...	·091

Station.	Heights obtained from observation to			Co-efficient of Refraction $\frac{r}{c}$.	
	Helio.	Reciprocal Helio.	Reciprocal Lamp.	From Helio.	From Lamp.
Kyet-taung h. s. . . } Kyane-taung h. s. . . }	4465·0	4	4472·0	...	·092
Wone-lone-taung h. s. . } Kyane-taung h. s. . . }	4463·1	...	4469·5	...	·087
Wone-lone-taung h. s. . . } Kyauk-pyu-taung h. s. . . }	...	2591·0	2588·6	·069	·073
Kyane-taung h. s. . . } Kyauk-pyu-taung h. s. . }	...	2588·8	2587·0	·076	·081
Kyane-taung h. s. . . . } Hlaingmataung h. s. . . }	...	...	4283·4	...	·077
Kyauk-pyu-taung h. s. . } Hlaingmataung h. s. . . }	...	4285·6	4285·4	·079	·090
Kyauk-pyu-taung h. s. . } Pya-Nattaung h. s. . . }	...	1865·0	1865·9	·072	·094
Hlaingmataung h. s. . . } Pya-Nattaung h. s. . . }	1865·1	...	1860·8	...	·090
Kyauk-pyu-taung h. s. . } Khan-taung h. s. . . }	...	2655·0	2652·8	·066	·086
Pya-Nattaung h. s. . . } Khan-taung h. s. . . }	...	2653·5	2653·7	·074	·081
Pya-Nattaung h. s. . . } Ponya-taung h. s. . . }	...	3636·1	3638·3	·063	·074
Khan-taung h. s. . . } Ponya-taung h. s. . . }	...	3637·0	3634·1	·071	·086

From the close accordance of these results it would seem worth while to take daily and nightly observations from one station to another over some long period and also to test whether there is not some period of minimum refraction at night as well as by day.

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12. *Manipur Minor Meridional Series.*—The two final Stations Hlaingmataung h. s. and Pya-Nattaung h. s. of the Mandalay Minor Longitudinal Series were connected with the Manipur Minor Meridional Series. The elements of the stations as deduced by each series are given below :—

Series.	Station.	Latitude.	Longitude.	Azimuth.	Height in feet.
Mandalay .	Pya-Nattaung h. s.	22° 7′ 20″·562	94° 11′ 15″·162	205° 32′ 0″·934	1845·3
Manipur .	,,	20·576	15·193	4·540	1864·2
Mandalay .	Hlaingmataung h. s.	22° 21′ 4″·475	94° 18′ 18″·365	25° 34′ 41″·090	4263·4
Manipur .	,,	4·446	18·393	44·694	4284·46

Side Pya-Nattaung h. s.—Hlaingmataung h. s.	Log. feet.
Mandalay Series	4·9645195
Manipur Series	4·9645006

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Lieutenant Wood's Work.

13. *Manipur Minor Meridional Series.*—The country afforded no difficulty as there are two parallel ranges, one on each side of the Myittha River, running due North and South. The peaks on that to the East (known at different parts of it as Kyet-tayah-taung, Ponya-taung, Pongdaung) vary from about 2,000 feet to 4,000 feet, and from these a good view Eastwards over the Chindwin Valley and to the higher peaks in the Chin Hills is obtained.

Those to the West vary from 8,000 to 10,000 feet, but as these were from 40 to 50 miles from those on the range to the East, and as the series is a secondary one for topographical purposes, points on lower peaks giving sides of about 20 miles to the figures were selected.

A large number of the high peaks were fixed by rays from 3 or more stations. One of these rays was 95 miles long, while 27 were over 50 miles in length. From these Western Stations a good view is obtained to the North-East and South, but that to the West is restricted

14. No. II, Theodolite 12-inch, which had been sent back to the makers in 1899, was used. Considerable differences still appear between Zero means, thus giving much inferior weights to the measures as compared with those of No. III measured under same conditions, but the average triangular error (0″·78) compares favourably with that of last year's (0″·88), when No. III was used. It is only fair to add that usually more measures of each angle were taken this season especially during the earlier portion when the weather was most unfavourable, and it was not known what kind of error would be given with only 4 Zeros. During the middle portion of the season while the weather was favourable, the average error of 6 triangles was only 0″·48. As the instrument has now been regraduated three times, and with not much improvement in the accordance of the Zero means, it would appear as if the error were axial.

From an examination of the observations taken this year, angles measured on that part of the limb between 340° and 70° appear to be too small, and those between 70° and 160° to be too large, but as all the angles were measured on only 4 Zeros no very critical examination is possible.

The value of one division of the level on the vertical limb was found, when tested on return from the field, to have increased from 1″·8 to 5″·1. The Superintendent, Trigonometrical Surveys, ordered a value of 2″ to be used for level correction in the computations. With this correction the heights came out very well.

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15. Number of stations newly fixed (secondary)	10
Number of hill peaks, etc., fixed by intersections	63
Number of figures completed	10
Length of triangulation in miles	96
Area of triangulation in square miles	1,850
Average triangular error (10 triangles)	0″·78

At the close of triangulation work, Mr. Hunter remained behind in Burma, inspecting the following localities for sites for base lines to be measured with the Jäderin Apparatus :—

(1) The Mansi district between the parallels of 24° 30′ and 24° 50′ and along meridian 95° 45′.
(2) The Upper Chindwin between latitude 24° 30′ and 25° 0′ and longitude 95° 25′ and 95° 37′.
(3) The Mèza valley in the Katha district.
(4) The Kyauksè district.
(5) The Sittaung valley in the Toungoo district.

He found sites in the two last named districts which would probably be suitable, but owing to the lateness of the season the haze prevented any distant view, and thus the feasibility of connecting the ends with Principal Stations remained undecided.

The country round Mansi, Mèza and the portion explored in the Upper Chindwin was quite unsuitable.

H. WOOD, Lieut., R.E.

III

LATITUDE OPERATIONS FOR THE YEAR 1900-1901.

Extracted from the Narrative Report of Lieutenant H. McC. Cowie, R.E., in charge of No. 22 Party, Survey of India.

1. During the season 1900-1901 this party was employed on the determination of the latitudes of the undermentioned stations of the Karachi Longitudinal Series:—

Khankharia.	Rojhra.
Didáwa.	Chánga.
Virária.	Khori.
Lúnki.	Alamkhán.

Károthol.

In addition to the above, observations were taken at
Akbar of the Jogi-Tíla Meridional Series,
Ranjítgarh of the Gurhágarh Meridional Series.

2. The object of these latter observations was to obtain more information regarding certain anomalies in the deflection of the plumb-line, revealed by latitude observations taken in the Central Punjab. The instrument used was Troughton and Simms' Zenith Telescope No. 1 fitted with two spirit levels.

MICROMETER VALUE.

3. The value in seconds of arc of a revolution of the micrometer screw was determined from measurements of the differences of the declinations of couples of stars, close to one another in point of right ascension, and differing in declination by not more than 50′; this latter condition being imposed by the working length of the micrometer screw.

By equating this difference of declination, measured in revolutions of the screw, to that deduced from the data of the Star Catalogue, the value in seconds of arc of a revolution was determined.

Sixty-eight values, obtained from such observations taken during the season, gave the result:—

One Revolution of the Screw = 69″·1198 ±0″·0027.

4. The following abstract shows the values determined in previous years:—

TABLE I.

YEAR.	Adopted Value in seconds of one Revolution of the Micrometer Screw.	REMARKS.
	″	
1890-91 . .	69·345	Determined from consideration of latitude results, the value given by observation of a Circumpolar Star at elongation being 69″·349.
1891-92 . .	,,	
1892-93 . .	,,	
1893-94 . .	69·355	Determined from a consideration of latitude results.
1896-97 . .	,,	
1898-99 . .	69·197	Determined from observations of star couples.
1899-1900 . .	69·126	
1900-1901 . .	69·120	

It will be seen that between the seasons 1896-97 and 1898-99, the value of the screw underwent a change of —0″·2 approximately per revolution. In the case of the Zenith Telescope, this change corresponds to an increase of about $\frac{1}{10}$th inch in the distance from the centre of the objective to the diaphragm. Between 1896-97 and 1898-99 the objective was re-polished. This process seems to have somewhat altered the shape of the lens, causing this increase of 0·1 inch in its focal length.

This value, 69″·1198, was adopted and used in the latitude computations.

5. By comparing the mean Colatitude resulting from such observations as give a positive micrometer correction, with that obtained from observations giving negative corrections, the amount by which this value of the screw is *apparently* in error can be determined.

I find that the observations at the several stations give the following results :—

TABLE II.

Name of Station.	By results given by positive Micrometer corrections.		By results given by negative Micrometer corrections.		Difference of Colatitudes.	Sum of Micrometer Corrections.	Apparent Error in the adopted Value of Micrometer Screw.
	Mean Micrometer Correction.	Seconds of Colatitude.	Mean Micrometer Correction.	Seconds of Colatitude.			VI. / VII.
I.	II.	III.	IV.	V.	VI.	VII.	VIII.
	Revolutions.		Revolutions.		″	Revolutions.	Per revolution. ″
Khankharia	8·945	1·41	9·655	2·06	−0·65	18·60	−0·0349
Didáwa	13·680	42·68	11·080	42·66	+0·02	24·76	+0·0008
Virária	10·035	27·26	10·425	27·41	−0·15	20·46	−0·0073
Lúnki	11·165	41·14	11·505	41·31	−0·17	22·67	−0·0075
Rojhra	10·395	33·81	11·885	33·95	−0·14	22·28	−0·0063
Chánga	10·195	12·67	12·545	12·80	−0·13	22·74	−0·0057
Khori	9·365	29·21	12·665	29·50	−0·29	22·03	−0·0132
Alamkhán	11·660	29·41	11·120	29·59	−0·18	22·78	−0·0079
Károthol	10·070	15·13	11·140	15·30	−0·17	21·21	−0·0080
Akbar	13·695	21·28	11·135	21·58	−0·30	24·83	−0·0121
Ranjítgarh	16·280	53·25	16·34	53·64	−0·39	32·62	−0·0119
				Mean (omitting the first) value.			−0·0081

It will be seen that the result given by the observations at the first station, Khankharia, is much larger than that at any other station. This is due to the focal setting of the telescope having been different at this place to what it was at all the others. In deducing a value for the mean apparent error during the season, the first result has consequently been excluded.

The figures of this table, then, *apparently* show that the adopted value of a revolution of the micrometer screw was too small by 0″·0081 and instead of

69″·1198 as determined from the observations of couples of stars, the correct value would seem to be 69″·1279.

6. It is probable that the value of the micrometer, deduced from the observations for latitude, is more liable to errors due to irregularities of atmospheric refraction than is the value obtained from observations of star couples.

In the latitude observations, of each pair of stars, one is south of the zenith and the other to the north. It is quite possible that on occasions the refraction co-efficient for the heavens of northern aspect may differ sensibly from that for the southern heavens. In such cases, errors would be introduced into the latitude computed from the star observations.

In the observations of star couples, both stars are selected in the same part of the heavens and close together in point of declination. Uncertainty in the co-efficient of refraction would affect the observation on each star equally and in the differences of these observed zenith distances, such errors would be eliminated.

7. In the second place, it so happens that in the majority of cases, one star of a pair is intersected with the horizontal wire A and the other with wire C. Now the micrometer reading recorded is always that of wire B.

In computing the micrometer correction, the difference of the two readings of B is calculated, and to this is applied the known value of the interval A—C. Hence the micrometer corrections are usually dependent on the quantity, $B_1 - B_2 + \overset{\text{Interval}}{A - C}$, so that into the colatitude, resulting from observations which give a positive micrometer correction, the quantity $\overset{\text{Interval}}{A - C}$, enters as a positive correction.

Similarly this quantity is applied as a negative correction in cases where the micrometer correction is negative.

8. Hence though the mean colatitude, resulting from positive micrometer measurements, differs from that obtained from negative measurements, the discrepancy may not be due to error in the adopted value of the micrometer, but simply to an incorrect value assumed for the interval A—C.

9. If we assume that the discrepancy between the mean colatitudes given by positive and negative micrometer corrections, is due to an incorrect value for the interval A—C, we find the following results from the observations at each station :—

TABLE III.

STATION.	Apparent Error in adopted Value for the Interval A—C.	REMARKS.
	Micrometer Divn.	
Didáwa	+0·001	The value of the interval A—C is approximately 2,000 divisions of the micrometer.
Virária	−0·016	
Lúnki	−0·032	
Rojhra	−0·014	
Chánga	−0·013	
Khori	−0·027	
Alamkhán	−0·019	
Károthol	−0·020	
Akbar	−0·062	
Ranjítgarh	−0·139	
Mean	−0·034	

10. These investigations into the apparent error in adopted values, whether of micrometer or of interval, point to one conclusion—the desirability of equalizing the sums of positive and negative micrometer corrections, and besides, of contriving, if possible, to introduce into observations, the A—C interval correction as often with the positive sign as with the negative.

This procedure will tend to eliminate from the final value for the colatitude, errors due to either of the sources just considered.

THE LEVELS.

11. The instrument is furnished with two of Holmes' levels, No. 6 and No. 9.

The values of the divisions of the scales attached to the tubes, were determined by me in October 1900 and again in April 1901 at Dehra, by means of Bubble Tester No. 1.

The resulting mean values for one division of the scales were

In October 1900.

For level No. 6	0″·94118
„ No. 9	0″·91220

In April 1901.

For level No. 6	0″·89128
„ No. 9	0″·89670

The means of these values have been used in the season's computations. These are

For level No. 6	0″·91623
„ No. 9	0″·90445

12. In order to minimise the effects of errors in these adopted values, I kept the dislevelment of the instrument, while observing, as small as I could.

The following table gives the numbers and average magnitude of the corrections found in the observations at each station:—

TABLE IV.

STATION.	NUMBER OF CORRECTIONS.			AVERAGE MAGNITUDE OF CORRECTIONS.		
	Under 0″·5.	Over 0″·5 and under 1″·0.	Over 1″·0.	Under 0″·5.	Over 0″·5 and under 1″·0.	Over 1″·0.
Khankharia . .	64	20	8	0″·19	0″·68	6″·08
Didáwa . . .	97	9	4	0·19	0·67	9·59
Virária . . .	95	2	4	0·20	0·66	3·62
Lúnki . . .	33	3	2	0·24	0·68	1·73
Rojhra . . .	119	3	3	0·18	0·65	1·82
Chánga . . .	102	4	3	0·14	0·69	3·04
Khori . . .	102	11	5	0·21	0·61	1·52
Alamkhán . .	91	12	6	0·20	0·73	3·17
Károthol . . .	86	7	1	0·18	0·67	1·05
Akbar . . .	44	3	2	0·17	0·72	1·48
Ranjítgarh . .	26	1	...	0·15	0·62	...

STAR CATALOGUES.

13. In drawing up the programmes of observations two catalogues were used—the Catalogue of Fundamental Stars for the epoch 1900·0 by S. Newcomb and the Greenwich Ten-year Catalogue for 1880·0—the former being used in preference to the latter. For it was considered that the reduction of Stars' mean places from the epoch 1880 to that of 1900 might introduce error and was undesirable.

14. The following table shows to what extent each catalogue was used at the several stations :—

TABLE V.

STATION.	Number of Stars taken from Newcomb's Catalogue.	Number of Stars taken from Greenwich Catalogue.	Total Number of Stars.	
Khankharia	78	14	92	
Didáwa	77	39	116	
Virária	60	35	95	
Lúnki	49	20	69	
Rojhra	78	35	113	
Chánga	77	28	105	
Khori	78	20	98	
Alamkhán	81	20	101	
Károthol	74	16	90	
Akbar	38	7	45	
Ranjítgarh	26	1	27	

15. To determine how far the results, as given by the use of the two catalogues, differed, I have computed the colatitudes of eight of the stations, from a certain number of observations, using

(i) the N. P. D.'s as derived from Newcomb's Catalogue.

(ii) the N. P. D.'s as derived from the Greenwich Catalogue.

In order to make an exact comparison, only such observations as had been taken to pairs of stars, both of which were to be found in both catalogues, have been considered.

The number of such observations is small; still these are sufficient to give fairly trustworthy results. These are tabulated below.

TABLE VI.

STATIONS.	Number of pairs of Stars used in this investigation.	Colatitudes resulting from use of N. P. D.'s taken from Newcomb's Catalogue = N.	Probable Error.	Colatitudes resulting from use of N. P. D.'s taken from the Greenwich Catalogue = G.	Probable Error.	Differences N − G.
		° ′ ″	″	° ′ ″	″	″
Didáwa . .	22	65 8 42·70	±0·049	65 8 42·99	±0·063	−0·29
Virária . .	16	65 3 27·34	±0·072	65 3 27·65	±0·067	−0·31
Lúnki . .	13	65 1 41·03	±0·096	65 1 41·34	±0·089	−0·31
Rojhra . .	25	65 2 33·83	±0·031	65 2 34·06	±0·047	−0·26
Chánga . .	23	65 1 12·61	±0·034	65 1 12·86	±0·047	−0·25
Khori . .	23	64 59 29·41	±0·038	64 59 29·59	±0·045	−0·18
Alamkhán .	24	65 10 29·49	±0·039	65 10 29·70	±0·050	−0·21
Károthol . .	25	65 6 15·23	±0·034	65 6 15·40	±0·045	−0·17

16. From this it will be seen that, in every case, the colatitude given by the Greenwich Catalogue N. P. D.'s is larger than that given by the N. P. D.'s of the Newcomb Catalogue.

At the same time, the probable errors for each catalogue are very much the same, showing that the accordance of the individual results *inter se* is of nearly the same degree for both catalogues.

17. As yet no investigation has been made into the causes of the N—G difference—a difference, which, by reason of its consistency of magnitude and sign, is worthy of consideration.

Probable Errors.

18. From the observations at eight stations, have been computed the probable errors of observation and of declination in the result obtained from one pair of stars.

19. It may be remarked here that probable error of observation is truly one of observation, depending on the intersection of each star and on the reading of the micrometer and the level. As the dislevelment of the instrument was kept very small during the observations, a small error in the adopted value of the level scale has no appreciable effect on the level connection introduced into the computations. So that the discrepancies between the two or more results given by repeated observations of the same pair of stars are due to purely accidental errors.

20. But the so-called probable error of declination is dependent not only on the declinations of the stars, but also on the value adopted for one revolution of the micrometer screw, and hence the theory of errors is not strictly applicable.

The value of the micrometer may often be in error by an appreciable amount.

Consequently in the residual differences between the mean result given by each pair of stars and the general mean are included errors of a systematic nature, and the probable error deduced from these residuals is not a true one. Though called, as has been customary, a probable error of declination, in the following table, it must be remembered that the residuals from which it is deduced are made up of true errors of declination entangled with errors due to the micrometer value, and therefore it can be taken as no indication of the consistency *inter se* of the catalogued declinations.

21. The results given by the observations at eight stations are tabulated below:—

TABLE VII.

Station.	Probable Error of Observation.	Probable Error of Declination.	
Khankharia	±0″·47	±0″·44	
Didáwa	±0·32	±0·16	
Viráría	±0·18	±0·22	
Rojhra	±0·30	±0·12	
Chánga	±0·28	±0·20	
Khori	±0·32	±0·08	
Alamkhán	±0·28	±0·18	
Károthol	±0·26	±0·07	
Means (omitting the first values)	±0·28	±0·15	

THE SYSTEM OF WEIGHTING.

22. This season, as in previous ones, it has frequently happened that certain pairs have been observed only once, while other pairs have been observed twice, others again three or even more times. In the deduction of a general mean, the mean results from each of these various pairs should not, then, have the same weight.

23. Again, there have been frequent instances of three stars being found in the catalogue, from which two pairs could be conveniently formed, the observation on one of the stars entering into the computations for each pair. It is evident that the mean result from two such pairs should not be given the same weight as the mean result from two entirely independent pairs.

24. This season, in combining the results given by the different pairs, a system of weighting has been utilized. The relative weight attaching to the result from any pair has been made dependent on the relative accuracies of the catalogued declinations of the stars and of the observed difference of zenith distances, as well as on the number of times the pair has been observed.

This relative weight is given by the expression

$$w = \left\{ e_\delta^2 + \frac{e^2}{n} \right\}^{-1}$$

where

e_δ is the probable error of the mean of the declinations of two stars,
e the probable error of the observed difference of the zenith distances of two stars,
n the number of times the pair has been observed,
w the weight to be assigned to the result.

25. In the case of three stars forming two involved pairs, to the result given by each component has been allotted a weight equal to two-thirds of that given to the result from an independent pair.

This results from the following investigation. If a_1 and a_2 be the declinations *plus* the measured zenith distances of two stars south of the zenith, and a_3 the declination *minus* the measured zenith distance of the third star north of the zenith, and if the probable errors of these quantities be e_1, e_2, e_3, then, computing the latitude from each component pair and taking the mean, the result obtained is

$$\tfrac{1}{2}\left\{ \frac{a_1+a_3}{2} + \frac{a_2+a_3}{2} \right\}$$

$$= \frac{a_1}{4} + \frac{a_2}{4} + \frac{a_3}{2},$$

and the square of its probable error is

$$\left(\frac{e_1}{4}\right)^2 + \left(\frac{e_2}{4}\right)^2 + \left(\frac{e_3}{2}\right)^2;$$

assuming $e_1 = e_2 = e_3$, this becomes $\frac{3}{8} e_1^2$.

Similarly the square of the probable error of the result from a single independent pair can be found to be

$$= \tfrac{1}{2} e_1^2.$$

26. The weights to be assigned to the results from the combined pairs and from the independent pair should be in the ratio of

$$(\tfrac{3}{8}e_1^2)^{-1} \text{ to } (\tfrac{1}{2}e_1^2)^{-1}$$

or as $\frac{4}{3}$ to 1.

Hence to the result from each component pair given by three stars, should be given a weight $\frac{2}{3}$ of that of an independent pair.

27. If we now take the mean values from Table VII, that is, putting

e_δ = probable error of declination = ± 0″·20 (accepting this as due to errors of declination only),

e = probable error of observation = ± 0″·30,

and consider the mean result given by one pair of stars, observed twice, to have a weight of unity, we find, when a pair is observed

once, the weight to be assigned to the result = 0·7
twice, „ „ „ mean „ = 1·0
three times „ „ „ „ „ = 1·2
four times „ „ „ „ „ = 1·3

and the weights to be given to the results from each component of a "doublet" from three stars should be $\frac{2}{3}$ that for the result from a similarly observed independent pair.

MISCELLANEOUS.

28. The following investigations have also been made:—

(i) The mean value for the colatitude given by the observations of each separate night, have been computed and considered with reference to the mean readings of the Barometer and of the Thermometer. No law of change is apparent. This would seem to indicate that no systematic errors have been introduced into the corrections for atmospheric refraction.

(ii) During the season, I drew up my programmes of observation, limiting the zenith distances of stars to 25°, though, in a few instances, for experimental purposes, stars of 27° and 29° zenith distance were observed. The pairs of stars observed have been grouped together in order of their zenith distances and the residuals given by these pairs abstracted and a mean residual obtained for each degree of zenith distance.

An examination of the results shows that the residual is no function of the zenith distance.

The average residual for each zenith distance differs very little from the general mean, 0″·297, except in four cases out of the twenty-seven, in which the data is very weak.

This indicates that the use of zenith distances up to 30° does not tend to introduce errors into the results.

(iii) The following table shows a comparison of the results, given when the telescope is swung, during the observation of a pair of stars, from E. to W. with those when the swing has been from W. to E.:—

TABLE VIII.

STATION.	Value of Colatitude with Swing E.—W.	Value of Colatitude with Swing W.—E.	Difference (E.—W.)—(W.—E.)
	Seconds of Colatitude.	Seconds of Colatitude.	″
Khankharia	1·69	1·90	− 0·21
Didáwa	42·65	42·70	− 0·05
Virária	27·33	27·33	0·00
Lúnki	41·38	41·12	+ 0·26
Rojhra	33·93	33·88	+ 0·05
Chánga	12·70	12·79	− 0·09
Khori	29·44	29·40	+ 0·04
Alamkhán	29·53	29·50	+ 0·03
Károthol	15·25	15·17	+ 0·08
Akbar	21·29	21·53	− 0·24
Ranjítghar	53·49	53·33	+ 0·16

The size of the differences (E.—W.)—(W.—E.) at Lúnki, Akbar and Ranjítgarh is probably due to the comparative paucity of observations at these stations.

At Khankharia the observations themselves were not of the same degree of accuracy as at other stations—the probable error of a result of unit weight being ±0·533 against an average probable error of ±0·239 for the same quantity at the other stations. The observations at these, when the accordance of individual results was good, give a small value to the difference (E.—W.)—(W.—E.). It will be seen that there is no tendency for the sign to be either positive or negative. This would seem to show that this difference is due purely to accidental errors, and is not the result of instrumental peculiarities.

Results.

29. The following table gives the final values for the latitudes and the apparent deflection of the plumb-line at each station :—

TABLE IX.

No.	Station.	Number of Stars observed.	Astronomical Latitude = O.	Probable Error.	Geodetic Latitude = C.	Apparent Deflection of Plumb-line = O − C.	Probable Error of a Result of Unit Weight.
1	Khankharia	92	24° 36′ 58″·17	±0″·082	24° 36′ 56″·19	+ 1″·98	±0″·533
2	Didáwa .	116	24 51 17 ·32	±0 ·036	24 51 19 ·36	− 2 ·04	±0 ·259
3	Virária .	95	24 56 32 ·76	±0 ·035	24 56 36 ·25	− 3 ·49	±0 ·235
4	Lúnki .	69	24 58 18 ·74	±0 ·053	24 58 23 ·16	− 4 ·42	±0 ·239
5	Rojhra .	113	24 57 26 ·08	±0 ·032	24 57 26 ·28	− 0 ·20	±0 ·234
6	Chánga .	105	24 58 47 ·25	±0 ·036	24 58 47 ·00	+ 0 ·25	±0 ·252
7	Khori .	98	25 0 30 ·60	±0 ·032	25 0 31 ·53	− 0 ·93	±0 ·221
8	Alamkhán .	101	24 49 30 ·50	±0 ·034	24 49 31 ·23	− 0 ·73	±0 ·235
9	Károthol .	90	24 53 44 ·78	±0 ·028	24 53 46 ·69	− 1 ·91	±0 ·185
10	Akbar .	45	30 53 38 ·52	±0 ·073	30 53 43 ·26	− 4 ·74	±0 ·343
11	Ranjítgarh .	27	32 35 6 ·51	±0 ·053	32 35 12 ·10	− 5 ·59	±0 ·186

The first and the sixth stations show an apparent deflection to the south. But it must be remembered that these quantities O—C are merely the differences between the absolute deflections at each place and that at the station of origin—Kaliánpur. So that, although the results at Khankharia and Chánga give +1″·98 and +0″·25, it does not necessarily follow that there are southerly deflections of the plumb-line. All that can be inferred is that at these stations the deflections to the north are less than at Kaliánpur by 1″·98 and 0″·25 respectively.

The last column gives the probable error of a latitude result of unit weight—that is, of the result from one pair of stars observed twice. It will be seen that, except in the case of the first station, this quantity is fairly consistent in magnitude.

30. The results of this season complete a chain of latitudes observed close along the 24° parallel between 67° E. longitude and 87° E. longitude.

The following table gives the apparent deflection of the plumb-line in the plane of the meridian at each of the stations of observation :—

TABLE X.

Stations.	Latitude N.	Longitude E.	Apparent Deflection of Plumb-line = O—C.
	° ′	° ′	
Karachi	24 50	67 4	— 0″·11
Rámbágh. . . .	24 51	67 3	— 0 ·86
Károthol	24 54	67 56	— 1 ·91
Alamkhán . . .	24 50	68 46	— 0 ·73
Khori	25 1	69 6	— 0 ·93
Chánga	24 59	69 54	+ 0 ·25
Rojhra	24 57	70 17	— 0 ·20
Lúnki	24 58	70 42	— 4 ·42
Virária	24 57	71 5	— 3 ·49
Didáwa	24 51	71 21	— 2 ·04
Khankharia . . .	24 37	71 56	+ 1 ·98
Gúru Sikkar . . .	24 39	72 49	— 3 ·16
Aramlia	24 25	75 2	— 4 ·61
Gurária	24 26	76 7	— 0 ·48
Kaliánpur . . .	24 7	77 42	......
Pahárgarh . . .	24 56	77 44	— 0 ·45
Rangír	24 0	79 28	— 1 ·09
Potenda	24 37	81 0	+ 1 ·67
Karára	24 5	81 18	+ 0 ·19
Gurwáni	24 1	82 20	+ 3 ·22
Hurîláong . . .	24 2	84 24	+ 10 ·75
Chendwár . . .	23 57	85 29	+ 3 ·07
Malúncha. . . .	23 54	87 8	+ 0 ·62

This abstract shows at once the peculiar fact that east of 80° Longitude all the deflections are less than at Kaliánpur, while except in two cases only, those west of 80° Longitude are all more.

31. It has already been pointed out (*see* general report of the Survey of India for 1893-94) that such a result might be due to error in the initial azimuth at Kaliánpur, but this seems to me exceedingly improbable.

RESULTS OF THE WORK OF SEASON 1898-99 and 1899-1900.

32. During the past season the observations of the years 1898-99 and 1899-1900 have been recomputed and the final latitudes determined.

These final values are abstracted below:—

TABLE XI.

No.	Stations.	Number of Stars observed.	Astronomical Latitude =O	Probable Error.	Geodetic Latitude =C.	Apparent Deflection of Plumb-line=O−C.	Probable Error of a Result of Unit Weight.
	Season 1898-99.						
1	Vizagapatam .	100	18° 0′ 56″·66	±0″·065	18° 1′ 2″·91	− 6″·25	± 0″·453
2	Ráwal . .	86	18 32 4 ·72	±0 ·075	18 32 9 ·22	− 4 ·50	± 0 ·480
3	Mal . .	93	18 47 6 ·75	±0 ·071	18 47 16 ·97	−10 ·22	± 0 ·469
4	Khundábolo .	95	19 51 7 ·02	±0 ·063	19 51 12 ·90	− 5 ·88	± 0 ·429
5	Cuttack. .	109	20 28 52 ·05	±0 ·046	20 29 0 ·68	− 8 ·63	± 0 ·336
6	Chandípur .	86	21 26 34 ·03	±0 ·061	21 26 36 ·99	− 2 ·96	± 0 ·395
7	Patna . .	89	21 47 17 ·28	±0 ·047	21 47 20 ·83	− 3 ·55	± 0 ·315
8	Dariápur .	94	21 47 29 ·01	±0 ·059	21 47 27 ·95	+ 1 ·06	± 0 ·399
	Season 1899-1900.						
1	Karía . .	113	19° 12′ 2″·66	±0″·053	19° 12′ 5″·98	− 3″·32	± 0″·361
2	Háthbena .	68	19 51 42 ·60	±0 ·078	19 51 42 ·34	+ 0 ·26	± 0 ·434
3	Ramai . .	55	20 56 50 ·31	±0 ·076	20 56 51 ·47	− 0 ·16	± 0 ·372
4	Patháídi .	62	21 48 43 ·08	±0 ·063	21 48 45 ·97	− 2 ·89	± 0 ·336
5	Dalea . .	53	22 19 30 ·25	±0 ·071	22 19 33 ·62	− 1 ·37	± 0 ·341
6	Amúa . .	102	23 59 57 ·02	±0 ·052	23 59 56 ·24	+ 3 ·78	± 0 ·358

H. McC. COWIE, LIEUT., *R.E.*

IV

RESULTS OF THE EXPERIMENTAL MEASUREMENT OF THE DEHRA DUN BASE LINE, WITH THE JÄDERIN APPARATUS.

Extracted from the Narrative Report of Captain G. P. Lenox Conyngham, R.E., in charge of No. 23 Party, Survey of India.

1. Besides the reduction of the observations taken for measuring the expansions of the wires belonging to the Jäderin apparatus which has been discussed in Professional Paper No. 2 of 1902, Serial No. VI, the party took up the re-computation of the length of the Dehra Dun Base as measured with that apparatus in April 1900. The results are shown in the following table:—

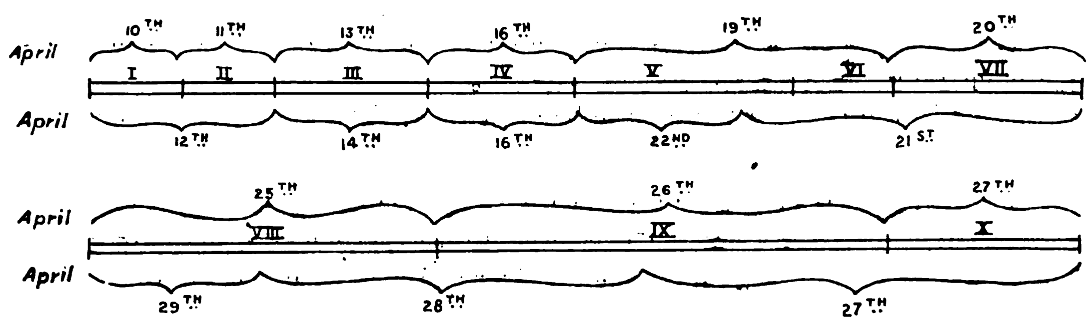
Abstract of the Results of the measurements showing discrepancies.

Section.	Length by Forward measurement.	Length by Back measurement.	Difference Forward—Back.	Difference as fraction of length.
	feet.	feet.	feet.	
I and II	2,648·608	2,648·704	—0·096	$\frac{1}{27,500}$
III	2,640·154	2,640·134	+0·020	$\frac{1}{132,000}$
IV	2,639·088	2,639·080	+0·008	$\frac{1}{330,000}$
V and VI	5,997·375	5,997·231	+0·144	$\frac{1}{42,000}$
VII	5,035·637	5,035·649	—0·012	$\frac{1}{420,000}$
VIII	7,920·595	7,920·902	—0·307	$\frac{1}{26,000}$
IX	10,243·046	10,243·046	0·000	$\frac{1}{\infty}$
X	2,062·667	2,062·627	+0·040	$\frac{1}{52,000}$
TOTAL	39,187·171	39,187·373	—0·202	$\frac{1}{194,000}$

	feet.
Mean result	39,187·272
Length by measurement with Colby Bars .	39,187·462
Difference	0·190

2. The discrepancy between the totals of the two measurements, *viz.*, 0·202ft. or $\frac{1}{194,000}$ of the length, is as small as could be expected, and if it could be taken to be a true indication of the precision attained in the measurement it would be very satisfactory. As a matter of fact, a glance at the discrepancies between the two values of the individual sections will show that there has been a considerable amount of fortuitous cancelment, and that the work is not so accurate as the good agreement between the totals would lead one to suppose. There is, however, this to be said, that the arrangements for marking the ends of the sections were not satisfactory, and it is not impossible that error may have crept in either through some movement in the register pins between the two measurements, or even by a blunder being made in replacing the head and the plug. Errors of this sort would cause discrepancies between individual sections without

affecting the total length, they would in fact cancel, but in a way which it would not be correct to call fortuitous. This at least would be the case if the forward measurement had been made right through from one end to the other, and the back measurement in the same way; but this was not done; the following diagram indicates the order in which the sections were taken up :—



It will be seen that if between the morning of the 25th and the afternoon of the 29th a movement took place in the register pin separating Sections VII and VIII, or if the head were by mistake placed differently on the wire on these two occasions, the error produced in Section VIII would affect the total length also. The same applies to several other pins, but this one is taken as an example because the discrepancy between the two measurements of Section VIII is by far the most serious, and because it is clearly the most important element in the difference between the totals, if it were possible to reduce it to about —0·08, which would be about $\frac{1}{104,000}$ of the length, the discrepancy between the two totals would almost disappear.

3. It is not to be expected that the errors in sections should bear as small a proportion to their lengths as in the case of the total length, for errors accumulate as the square root of the length measured, so that to compute what the error found in any particular case would have amounted to, if the length had been n times as great, the denominator of the fraction error over length must be multiplied by $\sqrt{n}$.

On this principle let us see what the fractions for the different sections would become if the length be increased to that of the whole Base Line :—

Section.	n.	$\sqrt{n}$	Denominator × $\sqrt{n}$.
I and II	15	3·9	107,000
III	15	3·9	515,000
IV	15	3·9	1,187,000
V and VI	6·5	2·5	105,000
VII	8	2·8	1,176,000
VIII	5	2·2	57,000
IX	—	—	Infinity.
X	19	4·4	229,000

This shows that the discrepancy in Section VIII is the only one that is really serious.

4. The next time that a measurement has to be made, the marking off of the sections must be done with much greater care. If the plan is adopted of measuring each section forward and back before proceeding to the next, the marks must be of a semi-permanent character and should be aligned and built as part of the preparation of the line. If it is decided to measure from one end to the other and then back it may be sufficient to use the register pins, but in this case each pin should undoubtedly have its own head and plug and these should not be removed, but left in position, suitably protected, until the close of the operations.

5. In the computation of the length of wire G on each occasion on which it was used, the length of the spans against which it was compared is computed using the mean length of wire A for the day; this is not rigorously correct, the temperature of A at the moment at which these particular spans were measured should have been determined and a special length deduced, the difference however is so small that the simpler procedure which has been adopted is quite justifiable. An examination of the field book and of the table in which the mean temperature on each day is deduced, will show that the greatest difference between the value of (S—B) during the measurement of spans for a comparison of G and the mean value of the day is $\overset{mm}{0{\cdot}7}$, this corresponds to $\frac{\cdot 7}{\cdot 250}$ degrees of temperature, or somewhat less than 3°.

6. The expansion of A per degree is $\overset{mm}{0{\cdot}0054}$, therefore the greatest error in the value of A employed is less than $\overset{mm}{0{\cdot}016}$, and therefore the greatest error in the deduced length of G is less than $\overset{mm}{0{\cdot}032}$; 5 spans of G is the greatest number in any section, therefore the largest error introduced into a section by the use of the mean daily value of A must be less than $\overset{mm}{0{\cdot}16}$, which is altogether negligible. Nevertheless if on any occasion the difference in the actual value of (S—B), at a time when G was compared, should happen to be widely different from the mean of the day, the possible effect should be scrutinized and, if necessary, a special computation should be made.

7. The use of the 160 feet wires has been found by experience to be a source of delay, and the fact that the comparisons cannot be made so satisfactorily with them as with the 80 feet wires makes it desirable to employ them as little as possible. In a well chosen base line it is to be presumed that there will be very few obstacles which an 80 feet wire cannot bridge over, but it may easily happen that a very small obstacle will necessitate the use of the long wire equipment as it stands at present; for if an obstacle, however small, happens to coincide with the position which should be occupied by one of the tripods, so that it cannot be set up, there is nothing for it but to get out the long wires. What is required is some means of stopping short, so to speak, so as to avoid the coincidence. For this purpose I would recommend that one of the steel wires (I do not think it would be worth while to make a brass one also) be cut up so as to provide one wire of 40 feet and one of 20 feet of the same pattern as the 80 feet ones. They would be used but seldom, and probably it would be sufficient to compare them once at the beginning and once at the end of the operations, for which purpose special measurements of lengths of 40 and 20 feet respectively could be made with Bar A, or it might be sufficient to deduce their lengths from measurements made with them of an 80 feet span. In any case the comparisons could be made under more satisfactory conditions than in the case of 160 feet wires.

8. These short wires could be of use in another way also. Measurements, except of very short distances, made with the steel tape are unsatisfactory; it is

difficult to stretch, there are no means of comparing it against the standard and we do not know anything about its expansion, nor of its temperature when in use. So long, however, as the 80 feet wire is the shortest we have, there is always a liability of having to measure a length of 40 feet with this tape; if, however, we had a 40 feet and a 20 feet wire we should never be obliged to leave more than 10 feet to be measured with the tape.

9. With regard to the remainder of the apparatus I have the following recommendations to make:—

(i) The number of tripods should be increased from 10 to 30. This would allow of the aligner and leveller getting a good start of the measurers, so that any temporary check in their rate of progress would not be felt all down the wire. These tripods might very well be made up in Calcutta. The pattern is simple and I think satisfactory, but the washers between the thumb screws and the legs should be much more substantial and the legs should not have iron points like those that came from Stockholm. Such points may do very well on European turf, but are not satisfactory in India. The point of the leg of an ordinary theodolite stand would be better. For tightening up the legs after the line has been obtained, a key of some sort would be useful. The screws have to be made very tight and the fingers soon become tired and sore.

(ii) The aligning telescope should be a little better, and should certainly have a cross level and some simple means of levelling, and also means of collimating the vertical wire.

(iii) The suggestions contained in Captain Crosthwait's memorandum* on the levelling should certainly be carried out, except that the levelling staves should not be graduated to feet and hundredths but to metres and millimetres as at present. As the scales on the wires are graduated to millimetres it has been found more convenient to keep all the minor corrections—for level, temperature, etc.,—in the same unit. It is a very convenient unit.

There should be two staves and two levels. It would be a considerable advantage if some satisfactory way could be devised of hanging the staff from some point above its base, as the present method of standing the staff on the tripod greatly confines the amount of rise that can be read off, the greatest possible amount being the difference between the height of the level-stand and that of the tripod, instead of the whole height of the stand, as it might be if the foot of the staff were on the ground.

(iv) A sufficient number of register pins of various lengths should be supplied (there are probably enough belonging to the old Base Line Apparatus), and each must be lettered distinctly and must have its own head, lettered to correspond, and with numbered holes, and moveable plug. (Traversing screws will not be necessary as the holes admit of the alignment being made correct within $\frac{1}{4}$ inch which is quite sufficient, and it is not necessary to set the plug to any particular point of the line as its position in the direction is read off by the scale on the wire). The heads must, of course, be removeable to allow of the pins being driven into the ground.

* *Vide* end of this report.

A 15-mile base would probably be divided into 10 sections of 1½ miles each; the ends of sections should be marked in a semi-permanent way, either by register pins built up in masonry or by a regular masonry mark, and there should be enough pins to allow of one being used on each section, though it is unlikely that so many would be required. Twenty pins would be an ample supply, probably 12 would suffice.

(v) For marking the ends of sections I would suggest the following method— it has not been tried and very possibly something better may be thought of later, in the meantime it would probably do. Having selected a suitable place, probably the highest point crossed by the line at about the required distance, mark the line to within an inch or two, and set up a theodolite over the spot; with it lay out a line at right angles to the Base and drive pegs, one on each side, to mark it, the pegs to stand about 1 foot 9 inches out of the ground, define this cross line more exactly by pencil marks or small nails. Then at the point selected build a small pillar,—foundation about 1 foot deep, and height above ground about 1 foot 6 inches and about 1½ brick square. In this pillar a flat stone to be carefully built. The stone to be 1 foot 3 inches long, 6 inches wide and about 1 inch thick. Its length to be vertical, its width lying across the Base, and to project 3 inches above the upper surface of the pillar. It should be carefully placed so that the centre line of its exposed end coincides with a thread stretched across the two pegs. When the stone has been fixed in place a thread should again be stretched across the pegs and a fine line drawn along the upper surface of the stone to coincide with it, then the final alignment might be done and a line made across the upper surface of the stone to mark the exact spot where the line cuts it.

It should be easy to measure direct to a section mark of the above pattern with the wires, if by good fortune the mark falls within the compass of the scale, and in any case the use of the tape will be greatly facilitated by setting up the last tripod, from which the measurement to the mark will have to be made with the tape, so that its top is nearly at the same level as the mark. This sort of mark should not, of course, be used for the ends of the Base, which should be founded so as to remain for all time, but merely for the ends of sections which are not required after the measurement is complete.

If marks of this sort are built not more than 10 register pins could possibly be required on a 10 section Base, and probably half the number would suffice.

10. The means of measuring a standard length of 80 feet, and of comparing the wires against it must now be considered. The comparing microscopes G and H are very satisfactory for determining the ends of the standard; but the existing moveable microscopes used in its measurement are very much the reverse. A new pair should be obtained, for which a design has been sent in. With a pair of microscopes of this or similar design the measurement of the standard should not be a very long business. The pillars for G and H

must be of solid construction, those for the moveable microscopes need not be so massive. The pillars built in the Trigonometrical Branch Office compound were found satisfactory and might be copied, but the stone caps on the intermediate pillars will not be necessary for the new microscopes, as they will be able to project much further from their bases than the old ones could.

11. I am decidedly of opinion, in spite of M. Jäderin's remark (*vide* page 29 of Professional Paper No. 2) that the comparison of the wires against the standard should not be made by hand but by means of the adjustable tripods, the scales of the wires being read by means of microscopes G and H. I consider this in every way better, and do not understand why M. Jäderin took the opposite view. It is worthy of remark that he did not, it would appear, follow his own advice, the reason being, he says, that the use of mechanical means saves time; in our experience, however, quite the reverse is the case; it takes much longer to adjust a wire to the proper strain and position with the tripods than by hand. The objections to making the comparison by hand are—

(i) That they cannot be made with the requisite precision in this way.

(ii) That it is very difficult to devise marks so rigid as to be immoveable when the wire is held to them in a hand comparison and at the same time so adjustable that they can be set to the foci of the microscopes, removed, and brought back again when necessary. Material objects are used to mark the ends of the 80 feet length, they must be removed before the Standard bar A can be introduced for a re-measurement and must then be brought back again for the next comparison; whereas when the external foci of the microscopes are the ends of the standard, the scales of the wires or the dots on Bar A can be brought into position without disturbing anything — it need not be pointed out that it would be impossible to employ the foci in this way except with mechanical means of stretching the wire, it could not be held nearly steady enough by hand.

12. The determination of the temperature of the wires at the time of comparison is a very difficult and doubtful matter. I think it is desirable that some sort of shelter be afforded to the wire and the thermometers, besides that of the tents or shed in which the comparing apparatus is erected. A sort of long trough 8 inches wide by 1 foot deep would do. This might be made of ordinary country blanket with a light framework of wood or bamboo. The wire and the thermometers should be allowed to hang side by side for about 5 minutes before a reading is taken.

13. For the measurement of the 80 feet standard, bar A should always be used. The thermometers α and β should be carefully compared against the standard thermometers before and after the measurement of a Base Line, the spare pair α and β, seem to be of poor quality and should not be used, and a new pair should be obtained, so as to have something to fall back upon in case of accident to α or β. For making a measurement very great attention must be paid to the aligning and levelling of Bar A, not so much on account of the danger of error creeping in (for appreciable errors are easily avoided) as because, when a re-measurement is being made, unless great care has been taken about these matters, it will be found that the forward dot of the bar, when the end is reached, will not be in focus, or even not in the field of H microscope.

If between measurements of the 80-feet standard the temperature has changed much, it may be found that the expansion of the bar has carried the forward dot right out of the field of H microscope. This is a very awkward business and there seems to be no remedy, except that of trying to select times at which the temperature is much the same, thus if the cold weather prevails at the first measurement, let it be done between 2 and 4 P.M., and later if it becomes warmer use the morning hours. A new 10-feet standard made of the alloy of nickel and steel would obviate this difficulty, but the discarding of Bar A as the Indian standard is a step which should not be taken lightly.

14. I think a shed of thatch and matting gives a better protection to the comparing apparatus than the Base Line tents; and it is much more convenient for the observers, especially if they are at all long limbed. Moreover, the tents are very heavy and probably the cost of transporting them to Burma would be greater than that of the erection of many sheds. It will be found convenient to let the length of the comparator lie east and west, for, in that case, it will be sufficient to erect a south wall, the north side remaining open, or with temporary means of closing it only.

15. On a 15-mile base, divided up into 10 sections of 1½ miles each, probably two comparators would be sufficient, one for five sections; these if placed opposite the middle of their divisions would be within 4 miles of the furthest point to which the wires would have to be carried after being compared. Of course if good and convenient roads exist so that the officers can drive to and from their work, the Khalasie's camp moving on as the measurement proceeds, one comparator would suffice, for a 7½-mile drive morning and evening would be no very serious matter, this, however, will but seldom be the case, and if the whole party has to walk to and from work, 4 miles to the furthest point should not be greatly exceeded.

16. Captain Crosthwait's memorandum on the levelling to which allusion has been made, is attached.

G. P. LENOX CONYNGHAM, CAPTAIN, *R.E.*

MEMO. BY CAPTAIN H. L. CROSTHWAIT, R.E., ON LEVELLING DURING RE-MEASUREMENT OF DEHRA DUN BASE WITH JÄDERIN'S APPARATUS.

17. The spirit levelling, in order to ascertain the difference in height between the top of the cylinder (carrying the mark) of each tripod, was carried on in front of the party measuring the base. On fairly level ground it was found possible to keep ahead of the measuring party, that is to say when there were no checks to the levelling, such as having to take an intermediate point, etc. The instrument was set up at equal distances from each tripod, either in the line joining them, or at the apex of an isosceles triangle, according to the nature of the ground, but always at equal distances from the tripods. These distances were measured by a party going just in advance of the leveller, with a 100 feet chain, the spot being marked where the level was to stand.

At first an ordinary "Dumpy" level by Cook & Sons, was used; subsequently, however, the level supplied by Jäderin was employed and the greater portion of the work was done with this instrument.

Only one staff being available, it was held successively on the "back" and "forward" tripod. In order to protect the mark engraved on the top of the tripod cylinder, a brass cap was used on which the base of the staff rested. This was carried by the staff man and put on top of the cylinder each time.

18. The following establishment is recommended for rapid working:—

1 Leveller	.	With the level.
2 Recorders	.	
1 Umbrella man	.	
2 Staff men	.	
1 Spare man	.	
1 Chain man forward end	.	Chaining party.
1 „ „ back end	.	
1 „ „ centre	.	
1 Peg man	.	

I found it desirable to have two recorders, one to actually record and the other to check his results. The small distance between two successive settings up of the instrument does not allow of the results being checked by the leveller himself (as is usually done) without causing considerable delay, for it is as much as he can do to walk the distance and set up the instrument, if he wishes to keep ahead of the measuring party. Therefore a second recorder is recommended so that the leveller can devote his whole attention to levelling alone. Jäderin's level is so light that it can easily be carried by the leveller himself.

19. As already mentioned, a "Dumpy" level was at first used. It is much heavier than Jäderin's, and requires an extra man to carry it. Subsequently Jäderin's level was employed with success, and I think it more suitable for this kind of work than the ordinary pattern level. Being carried by the leveller himself, a certain amount of time is saved in its not being handled by an extra person.

Slight alterations are recommended. (i) A better and longer bubble. An accurately ground but not very sensitive bubble tube is what is required. (ii) The adjusting screws are not quite fine enough. The present ones are 42 threads to the inch, I think this should be increased to 55 or 60 threads. (iii) The socket of the spherical joint used for rough adjustment should be more carefully turned, the present one does not bear evenly.

With these few alterations the instrument would I think do very well for further operations. It would be desirable to have one level in reserve in case of an accident which might delay the whole work.

20. Two light staves made of the same, or similar, wood to Jäderin's should be made, graduated similarly to the new proposed staves for the levelling detachment. The staves should be about 8 feet long; if longer than this they would be too heavy for the tripods. Some difficulty was experienced in holding the staff steady in a wind, but it seems probable that a wind which interferes with levelling would also interfere with the measuring, so that all work would have to stop.

21. Special recording forms were used. They seem to have answered their purpose well. Conversion tables are also necessary to convert values of one face of the staff to feet in order to ascertain whether the two values agree.

H. L. CROSTHWAIT, CAPTAIN, *R.E.*

V

THE MAGNETIC SURVEY OF INDIA

DURING THE YEAR

1900-1901.

Extracted from the Narrative Report of Captain H. A. D. Fraser, R.E., Survey of India.

MAGNETIC OPERATIONS.

1. **The base stations.**—The three new temporary Observatories (*a*) at Dehra Dún, (*b*) at Kŏdaikánal, and (*c*) at Rangoon will be dealt with separately.

2. **The Dehra Dún Observatory.**—The plans for this observatory were finished and work had been commenced before I arrived in India. The design was made by the Public Works Department from a sketch submitted to them by the Surveyor General, and the Observatory is situated in the compound of the Trigonometrical Branch Office at Dehra Dún. The building consists of a domed room, 15 feet square, entirely underground and surrounded by an all-round passage. During the previous rains an experimental excavation had been made on the site chosen for the building, and this pit remained dry throughout the rains. The building was to be made water-tight, and it was considered that any moisture that might percolate or filter through the walls could readily be swabbed out of the passage should it accumulate.

The roof of the building being only just below ground level was covered with 5 feet of made earth surmounted by a thatched roof to keep off the rain and sun.

3. The building was practically completed about the end of April, and early in May the first set of self-recording Magnetographs (made by Mr. W. Watson, Assistant Professor of Physics at the Royal College of Science, South Kensington) were temporarily erected. It was intended to use them during the total eclipse of the 17th May, in conjunction with eye observations to be taken with the absolute instruments in accordance with the appeal made and programme laid down by Dr. L. A. Bauer in the December 1900 issue of Terrestrial Magnetism. With the assistance of Lieutenant Tillard, R.E., I succeeded in erecting the instruments in time, and after determining their scale values and taking a few preliminary photographic traces, they were successfully used on the day of the eclipse. The results, together with the records of the eye observations taken every minute from the commencement to the end of the eclipse, were forwarded to Dr. Bauer, but the results of his investigation have not yet been published.

4. The eye observations when plotted and compared with the photographic traces showed that the two curves representing the Declination, thus obtained, were in close agreement: in the case of the Horizontal Force curves, the

Surveyor General's Office,
No. 13, Wood Street.

Calcutta, 7th Septr. 1903.

Colonel St. G. C. Gore, C.S.I., R.E., Surveyor General of India, has the honour to present The Director of the United States Geological Survey Washington.

with 4 copies of the Extracts from Narrative Reports of the Survey of India during 1900-01, and requests the favour of an acknowledgment of the receipt of the same.

agreement, though very fair, was not quite so good, but the eye observations for force being taken with a Unifilar Magnetometer did not give direct results, and the actual force had to be computed from the observed deflections at a fixed distance by correcting for temperature and for change of declination, when by assuming an approximate value for " m " the moment of the deflecting magnet, and "r" the distance between the deflecting and deflected magnets, the changes in the Horizontal Force were computed out.

The object of taking these eye readings for Horizontal Force was to check the results shown by the photographic trace, and they at all events served to show that the latter worked satisfactorily throughout the period of the eclipse.

After the conclusion of these observations the foot-screws of the bed plate carrying the recording mechanism and of the Declination and Horizontal Force instruments, respectively, were fixed into holes in the stone caps of the pillars; in the case of the latter instrument they were leaded in, but the other two were fixed by cement only. As this latter plan is not satisfactory, lead will shortly be substituted for the cement.

It was then decided that the final erection and adjustment of the instruments would be effected after the rains had set in and about the middle of July I returned to Dehra for this purpose.

It was then found that the atmosphere in the underground room was saturated with moisture, which was also deposited on the walls and on every part of the instruments; the mirrors after being cleaned soon again became dimmed with moisture and it was plain that the first thing necessary was to devise some means of overcoming this difficulty before proceeding with the erection of the instruments. It was not at first clear whether this moisture was due to the moisture in the walls or to the moisture deposited from the damp air from outside as it cooled down to the lower temperature of the underground room. For some weeks previously quicklime in trays had been placed in the room and round the passage, and this kept the place from running with moisture, though the walls were still always damp. However, as there was no natural draught through the room (as no lamps or stoves were burning at this time), it was at first thought that this moisture was chiefly due to the damp state of the masonry. An attempt was therefore made to dry the walls of the inner room by heat and the two brass stoves, which had been made for the purpose of artificially raising the temperature of the room for the determination of the temperature coefficient of the quartz suspension, were untilized for this purpose. These stoves were designed to hold an oil stove commercially known as the "Primus" stove, but when first lighted in the room (using oil), it was found that they speedily went out of their own accord. Fearing that the intake ventilation arrangements were at fault, two ordinary oil lamps were then lighted in the room and kept burning near the floor continuously for several days. After the second day they would hardly burn, owing to a deficiency of oxygen and to the accumulation of carbonic acid gas near the floor: in fact, the air had become noticeably foul. They were then removed and the trays of quicklime which were again put in place had the effect of absorbing the carbonic acid gas, so that two days later the air was again pure enough to permit of a lamp burning brightly. On the first occasion of lighting the lamps the mistake had been made of allowing the products of combustion to remain in the room, instead of burning the lamps directly under the outtakes; for it was thought that the hot burnt air would find its way through the ventilator in the dome, which was kept open for this purpose. As a matter of fact it got cooled to the temperature of the room before reaching the ventilator and then fell back and accumulated near the floor, causing the lamps to burn very faintly. On the second occasion, therefore, the cause of the previous failure being suspected, the lamps were placed with their chimneys well up the outtake pipes. At first they went out repeatedly, but as soon as a draught was established up the full length of the outtake pipes they continued to burn brightly, the failure at first being due to their inability to at once raise the long column of cold air in the outtake pipes. The failure of the Primus stoves to burn continuously was therefore evidently due to the stoves themselves, and not to the failure of the intake pipe to provide fresh air, and this was proved by further experiments with these stoves in the open air which showed that in the absence of constant attention they would not remain alight for long.

5. One of the stoves was then connected up to its outtake pipe in the north-western corner of the room and, the Primus stove being removed, an ordinary charcoal fire was lighted in it, which burnt well and created a considerable draught. The temperature of the room was easily raised some 10° to 15°F. and it was thought that under the influence of this temperature the walls would get dry in the course of a few days or weeks.

As a matter of fact a contrary result was produced, for, except in the immediate neighbourhood of the stove, the walls which before were merely damp, soon began to stream with water. This result, which might perhaps have been anticipated, was due to the warm damp air from outside (which had no time to deposit much of its moisture in the cool intake pipe) coming into contact with the cold walls which acted as condensers for its moisture, though it was certainly strange that this should continue day after day without growing less, as one would naturally have expected the walls to gradually pick up the temperature of the room. As, however, no improvement took place, the fire was stopped after a week or ten days and the accumulated moisture was again slowly absorbed by quicklime. It might here be mentioned that a small drying box filled with quicklime had been improvised and fixed to the intake pipe, but, owing to the velocity of the air passing through it, it proved quite inadequate to dry the air appreciably. After discussing the results of the previous experiments, it was now decided to take the following steps:—

(i) To make air-tight boxes for the instruments themselves and to provide trays of quicklime in these boxes to keep the air round the instruments dry. Also to provide a similar means of drying the air in the brass tubes connecting the instruments to the recording mechanism on the central pillar.

(ii) To connect up the small instrument lamps with the outtake ventilator and thus insure that all products of combustion should be carried clear of the room.

(iii) To construct a drying box, through which all fresh air from outside must pass before entering the room.

(iv) To use the outer passage as a condenser, in which air from outside would pick up the temperature of the passage and deposit all its excess moisture before passing through the drying box.

(v) To provide a duplex lamp with reservoir to burn for 26 hours and burn this lamp continuously near floor level under the outtake in the north-western corner of the room with the object of (1) maintaining a light and continuous draught of fresh air, and (2) removing such impure air as might accumulate and would from its nature be found near the floor level.

It was intended to thoroughly test each of the above arrangements before erecting the instruments and Lieutenant Tillard, who was looking after their construction during my absence at Mussooree, succeeded in proving the efficiency of the drying box and was about to try the effect of (4) above, when a misfortune occurred which put an end to all further work.

6. After an exceptionally heavy fall of rain during August, amounting to about 16 inches in four consecutive days, the underground room suddenly began to leak and in the course of two days the water rose a foot or more in spite of efforts to bale it out.

The water was then baled out completely, but continued to come in through the walls to such an extent that it accumulated to a depth of several inches in the course of a night. Two main leaks were discovered—one in the outer passage wall to the south, and the other at the re-entering angle, where the entrance passage joins the main outer wall at the foot of the stairs. The matter having been duly reported, the Superintendent, Trigonometrical Surveys, now put the matter into the hands of the Public Works Department, who submitted certain proposals to him and have commenced work on the repairs and alterations. The immediate result of this accident has been (1) to prevent the formation of definite conclusions as to the best method of overcoming the damp during the rains, for the experimental arrangements before detailed could not be thoroughly tested, and (2) to cause the postponement for some months of the erection of the magnetographs, which cannot now be available during the first part of the coming field season.

7. **The Kŏdaikánal Observatory.**—Early in February I visited Kŏdaikánal, and in conjunction with Mr. Michie Smith, the Director, and Mr. Keeling, the Executive Engineer, a site for the new observatory was selected close to the Director's house. Dip observations taken in the vicinity showed the natural rock to be distinctly magnetic and the Dip varied very considerably at places not widely separated. For this reason, and also on account of the convenience in designing the observatory, it was decided to place the absolute instrument pillars on the roof of the underground room, thereby insuring that the absolute instruments should be removed as far as possible from the magnetic rock of which the whole hill is composed. It was also decided, with the consent of the Meteorological Reporter, to build the lower room 15′×20′ instead of 15′×15′ as at Dehra, in order to leave sufficient room for the installation of a vertical force instrument at a future date, if so desired.

The Executive Engineer reports that the building will be ready early in January 1902.

8. **The Rangoon Observatory.**—After leaving Kŏdaikánal I met Mr. Eliot at Rangoon to select a site for the observatory. A suitable site was found on some rising ground near the cholera camp, about five miles from the the shore and about three miles away from the Shwe Dagôn Pagoda. It was necessary to build at this distance from the latter, as it will probably be the terminus of the electric tramway system which will be in working order in a few years. The building will consist of a room 15′×20′, partly underground and partly covered with made earth, surmounted by a teak house of the same dimensions containing the pillars for the absolute instruments. Tests made on the spot with a dip circle showed that the site is free from local attraction.

This building, together with quarters for the observer and a dark room, has now been completed.

9. **The Calcutta Observatory.**—On returning from Rangoon I took the opportunity of visiting Mr. Küchler, the Director of the Alipore Observatory at Calcutta, who was then engaged in erecting the magnetographs which are of the Kew pattern. Soon afterwards, however, it was decided by Mr. Eliot that a new observatory would have to be made out of reach of all electric traction schemes, as it was certain that the Alipore Observatory would be quite useless as a base station for survey purposes owing to its proximity to the electric tramway system. Arrangements have now, I believe, been made to build a new observatory at Madhupur near Ásansol, and it is hoped that the instruments will be installed during 1902.

10. **The training of observers for the base stations.**—The Kódaikánal observer, Mr. Theodore, was selected by Mr. Eliot and was sent to me for training partly in Mussooree and partly in Dehra Dún. He is now expert in the use of the absolute instruments, but owing to the failure to erect the magnetographs no training in this branch has yet been possible.

Two other observers, one for Dehra Dún and one for Rangoon, have been trained at the Colába Observatory in all branches of their duties.

An observer for the Calcutta Observatory was also sent to me at Mussooree for training but he got ill almost at once and absconded.

11. **Instructions for observers, etc.**—Full instructions have been drawn up for the guidance of observers in the use of the new absolute instruments and in the methods of work to be adopted in the field, but at present no instructions have been issued with regard to the routine work at the base stations. All instructions are at present in manuscript form, as it was not considered advisable to print them till some actual experience had been gained in the field.

New and somewhat modified computation forms have also been prepared and printed.

Comparison of the Kew and Colába Standards.

12. Before leaving England I had completed a somewhat extended set of observations with No. 1 Unifilar Magnetometer, by Cooke and Sons, at Kew. As soon as this instrument reached India, about the 20th January 1901, I proceeded to Bombay and made a careful set of observations at the Colába Observatory, in which I was much assisted by the Director, Mr. Moos. These two sets of observations allow of a comparison being made between the Kew and Colába instruments. The appended tables show the results obtained, from which it appears that the two standards are in close agreement.

10. The comparisons have at each place been made through the magnetograph records standardized by observations taken with the standard instruments and both at Kew and Colába these results have been furnished by the kindness of the authorities in charge. At Kew the deflection observations with the standard are always taken at distances of 1 and 1·3 feet, whilst at Colába the distances adopted are 0·8 and 1·0 foot. The Cooke instrument was, however, used with distances of 30, 35 and 40 cm. at each place. The value of "P," the distribution term, was found from each of the three groups of distances 30 and 35, 35 and 40 and 30 and 40 cm. and the mean of the three taken. This procedure is not correct, as the value derived from the last group has a much higher weight than either of the others, but tables VII and VIII show that no material difference in the results would be produced by using the third group only, which is, I think, the proper procedure.

14. The value of $\frac{M}{H}$ from the deflection experiments (used for finding M and H by combining it with the values of M H from the vibration experiments) was taken as the mean of the three values of $\frac{M}{H}$ appertaining to the three distances used. Probably it would be more correct to use only that value of $\frac{M}{H}$ which is derived from the shortest of the three distances or to assign weights to the different values proportional to the deflection angles obtained at each distance, but tables V and VI show that in this case also the final value would not be appreciably altered by adopting this procedure.

15. The accuracy of the comparison between the Kew and Colába instruments obviously depends chiefly on the consideration as to whether the instrument, Cooke No. 1, changed in any way during the interval between the two comparisons. The mean values of "M" and "P" derived from the two sets of observations agree so closely as to furnish strong evidence that no appreciable change took place, and I believe therefore that the final results obtained, may be accepted with some confidence.

16. With regard to the difference between Cooke No. 1 and either of the standards, it is known that this is largely due to an erroneous value of the quantity π^2k used in the computations. This value was found at Kew using an inertia bar subsequently found to be seriously lacking in uniformity of density: since then a new inertia bar has been received, but the correct value of π^2k has not yet been computed, though a considerable series of experiments is being made in order to obtain an accurate result. It seems certain, however, that the erroneous value used in the comparison cannot affect the comparison of the two standards, though it makes Cooke No. 1 differ from both of them much more largely than is really the case.

17. I am of opinion that it would be well to repeat this comparison under similar conditions, and if possible with the same instrument at the close of the fundamental survey of India, and to thus obtain reliable data for referring the absolute values of the Indian survey to those of the English and other European magnetic surveys.

ARRANGEMENTS FOR THE FIRST FIELD SEASON.

18. It was early recognized that it would not be possible to get the self-recording instruments at each of the five base stations into working order in time for the field season, and it was therefore decided early in the year by the Superintendent, Trigonometrical Surveys, that the field of operations would have to be confined to the area west of a line joining Dehra Dún and Bombay, and that three field detachments would suffice for the first season. Two of these detachments will work along railway lines and the third will work in the desert. As I considered that the efficiency of the Railway Parties would be much increased by providing them with carriages especially reserved for their use, enquiries were made of all the leading Railway Companies in India as to terms, etc., which showed that the necessary facilities would be forthcoming, if required, at a certain increase of cost. As, however, the increase of efficiency hoped for from this arrangement was largely a matter of speculation, it was finally decided by the Superintendent, Trigonometrical Surveys, that it would be wiser to do without special arrangements during the first season.

The correspondence with the Railway Companies is now, however, in such a state that special arrangements can be made for the following season with comparatively little trouble if considered desirable.

MISCELLANEOUS.

19. When taking observations at Colába, I found that the practice there in the deflection experiment is to observe at distances of 0·8 and 1·0 foot, in place of the Kew distances 1·0 and 1·3 feet, in consequence of the smallness of the deflections produced when using the latter distance.

20. I, therefore, with the consent of the Superintendent, Trigonometrical Surveys, at once wrote to Messrs. Cooke and Sons, requesting them to fit the remaining instruments with a set of holes for taking deflections at 22·5 and 26·25 cm. in addition to those already existing at 30, 35 and 40 cm. It will be seen that the relation of the distances in the first group of three to one another is the same as in the second group and that the ratio $\frac{22 \cdot 5}{30}$ and $\frac{30}{40}$ corresponds very closely to the ratio found by Airy, *viz.*, $\frac{1}{1 \cdot 32}$, as being the best for the determination of the distribution term "P." The intermediate distances 26·25 and 35 cm. in each group are to be used with the object of finding the value of the next term in the distribution factor which may be written $\left\{1 - \frac{P}{r^2} - \frac{Q}{r^4} -, \text{etc.}\right\}$, *i.e.*, the value of Q.

21. The deflection bars of the first two instruments were similarly altered at the Mathematical Instrument Office and the distances apart of the new groups of holes were determined by me at Dehra using base line microscopes G and H and the standard foot.

This was a laborious matter, as it involved making each measure in two parts and the determination of the values of the parts of the last divided inch of the standard foot which were not previously known.

22. Subsequently, a series of deflections have been taken with each of instruments, Cooke 1 to 4, with the object of investigating the subject of the best group of distances to adopt for the Indian survey and a discussion of the matter with Mr. Eliot and Mr. Moos has commenced. Owing, however, to pressure of other work, the reduction of the experimental deflections has not yet been completed and no final decision has yet been reached.*

23. A simultaneous comparison of unifilars Nos. 3 and 4 has also been commenced and a comparison of the Declinations points to the fact that the result obtained in the new and old absolute houses differ considerably, though the instruments seem to be in close agreement with one another in Declination. This seems to point to the fact that one or both of the houses is not entirely devoid of magnetic material and, until this important question has been investigated, the comparison of the field instruments with one another has been postponed.

24. It may here be mentioned that the new absolute magnetic house has been built a short distance north of the old house, both being on the true meridian and practically similar to one another.

25. *Instruments.*—Of the instruments ordered for the Magnetic Survey, all have been received at the date of writing, except—

(1) No. 5 Unifilar Magnetometer by Cooke.
(2) No. 7 „ „ „ for Colába.
(3) Three old magnetometers by Elliott Brothers, sent to Messrs. Cooke for alteration and repair.

Of these (1) has been tested at Kew and is now presumably on its way to

* Since this was written it has been decided to use the three distances 22·5, 30 and 40 cms.

India, whilst the others have been completed and are at Kew awaiting testing.

26. When all have been received, the magnetic instruments will be distributed as follows:—

(*a*) *For field use.*—Magnetometers Nos. 2, 3, 4, 5, 6, by Cooke and Sons. Dip Circles Nos. 35, 36, 37, 38, 40, by Dover.

(*b*) *For the use of the officer in charge when making comparisons at base stations.*—Magnetometer No. 1, by Cooke and Sons. Dip Circle No. 39, by Dover.

(*c*) *For the Dehra Dún Base Station.*—The first set of Watson's magnetographs. One of the old Elliott magnetometers, repaired by Cooke and Sons. One of the three old Dip Circles, repaired by Dover (now numbered 44, 45, 46).

(*d*) *For Kŏdaikánal Base Station.*—One of the last two sets of Watson's magnetographs. A repaired magnetometer and dip circle as above.

(*e*) *For Rangoon Base Station.*—As for Kŏdaikánal.

(*f*) *For Colába Observatory.*—A new magnetometer (No. 7), by Cooke and Sons.

(*g*) *For Alipore Observatory.*—A new set of magnets, by Cooke and Sons, for use in their own magnetometer, by Elliott Brothers.

The instruments under (*b*) above are those which have been compared with the Kew standard instruments.

27. In addition to the above there are at Dehra one old magnetometer, No. M 4, by Elliott Brothers, and one old Dip Circle, No. 43, by Barrow. These instruments have been used for taking the monthly magnetic observations which were discontinued from May 1901.

TABLE 1.

Comparison of Cooke Unifilar No. 1 with the Kew Standard Instrument.

Kew Observations.

DATE.	H. From Kew curves.*	H. Observed.	Kew-Cooke.	M. Observed.	REMARKS.
	C. G. S.	C. G. S.	10−5		
1st October 1900 .	·18434	·18400	+ 34	1001·6	The figures given in column 2 are the final values as supplied by the Kew authorities. They are taken from the magnetograph curves standardized by the standard magnetometer and are corrected for temperature.
2nd ditto .	418	382	36	1001·9	
2nd ditto .	430	397	33	1001·8	
2nd ditto .	433	396	37	1001·8	
3rd ditto .	423	395	28	1002·4	
3rd ditto .	425	387	38	1001·9	
4th ditto .	427	395	32	1001·8	
4th ditto .	429	392	37	1001·7	
4th ditto .	443	406	37	1001·6	
4th ditto .	447	409	38	1001·8	
5th ditto .	414	380	34	1001·9	
5th ditto .	434	398	36	1002·0	
5th ditto .	432	390	42	1001·5	
6th ditto .	429	391	38	1001·7	
6th ditto .	432	396	36	1002·0	
8th ditto .	428	394	34	1001·9	
8th ditto .	433	399	34	1002·2	
8th ditto .	440	401	39	1001·8	
8th ditto .	442	402	40	1001·9	
MEANS		·18395	35·9	1001·853	

* Corrected for temperature.

TABLE 8.

Comparison of Cooke Unifilar No. 1 with the Colába Standard Instrument.

Colaba Observations.

DATE.	H From Colába curves.*	H Observed.	Colába-Cooke.	M Observed.	REMARKS.
	C. G. S.	C. G. S.	10^{-5}		
26th January 1901 .	0·37439	0·37365	+ 74	1001·96	The figures given in column 2 are as supplied by the Director of the Colába Observatory. They are taken from the magnetograph curves standardized by the standard magnetometer and are corrected for temperature.
26th ditto .	33	57	76	·73	
26th ditto .	32	71	61	·84	
26th ditto .	32	65	67	·68	
27th ditto .	37	64	73	·66	
27th ditto .	38	67	71	·75	
27th ditto .	48	79	69	·77	
27th ditto .	45	71	74	·57	
28th ditto .	47	77	70	·59	
28th ditto .	49	85	64	·82	
28th ditto .	40	70	70	·77	
28th ditto .	37	71	66	·80	
29th ditto .	54	84	70	·77	
29th ditto .	56	85	71	·80	
29th ditto .	49	76	73	·64	
29th ditto .	48	83	65	·82	
31st ditto .	49	83	66	·73	
31st ditto .	47	80	67	·64	
31st ditto .	45	80	65	·73	
31st ditto .	45	77	68	·66	
31st ditto .	47	77	70	·71	
31st ditto .	43	79	64	·77	
1st February 1901	49	74	75	·87	
1st ditto .	51	78	73	·98	
1st ditto .	54	88	66	·71	
1st ditto .	57	92	65	·82	
2nd ditto .	53	87	66	·68	
2nd ditto .	59	91	68	·80	
2nd ditto .	32	57	75	·87	
2nd ditto .	26	54	72	·80	
MEANS		0·37376	+69·1	1001·76	

* Corrected for temperature.

Thus Kew-Cooke No. 1 $= + 35{\cdot}9 \times 10^{-5}$ where H $= 0{\cdot}18395$ and
Colába-Cooke No. 1 $= + 69{\cdot}1 \times 10^{-5}$ " " $= 0{\cdot}37376$.

Whence assuming that the Kew instrument would give results at Colába greater than those it gives at Kew in proportion to the change in H at the two places, we should get *at Colába*

$$\text{Kew-Colába} = (72{\cdot}9 - 69{\cdot}1)\ 10^{-5}$$
$$= +3{\cdot}8 \times 10^{-5} \text{ C. G. S. units.}$$

or similarly *at Kew*

$$\text{Kew-Colába} = (35{\cdot}9 - 34{\cdot}0)\ 10^{-5}$$
$$= + 1{\cdot}9 \times 10^{-5} \text{ C. G. S. units.}$$

TABLE 3.

Comparison of Cooke No. 1 Magnetometer with the Kew Standard Magnetometer.

Abstract of Declinations.

DATE.	Time.	Absolute Declination measured from the Kew curves.	Absolute Declination observed with Cooke No. 1.	Kew-Cooke No. 1.	REMARKS.
		West.	*West.*		
	h. m.	° ′	° ′	′	
2nd October 1900 .	3·58	16 52·9	16 52·7	+0·2	The figures given in column 2 are as supplied by the Kew authorities. They are taken from the magnetograph curve standardised by the standard magnetometer.
3rd ditto .	10·51	52·7	53·1	—0·4	
4th ditto .	10·30	51·0	50·8	+0·2	
4th ditto .	3·43	53·9	54·3	—0·4	
5th ditto .	12·22	54·9	55·0	—0·1	
6th ditto .	10·46	51·7	51·9	—0·2	
8th ditto .	3·36	53·2	53·8	—0 6	
MEAN				—0·19	

TABLE 4.

Comparison of Cooke No. 1 Magnetometer with the Colaba Standard Magnetometer.

Abstract of Declinations.

DATE.	Time.	ABSOLUTE DECLINATION FROM Magnetograph curves.	ABSOLUTE DECLINATION FROM Magnetograph eye reading.	ABSOLUTE DECLINATION FROM Grubb eye reading.	Mean of last 3 columns.	Observed value on Cooke No. 1.	Colába-Cooke.
	h. m.	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	′ ″
26th January 1901 .	11 47	0 21 55	0 21 49	0 21 45	0 21 50	0 21 22	+ 0 28
25th ditto	21 12	0 22 56	0 22 52	0 22 55	0 22 54	0 22 48	+ 0 6
27th ditto .	8 35	0 22 48	0 22 35	0 22 34	0 22 39	0 22 38	+ 0 1
27th ditto .	15 16	0 23 0	0 22 43	0 22 47	0 22 50	0 22 47	+ 0 3
28th ditto .	7 15	0 22 15	0 22 21	0 22 32	0 22 23	0 22 0	+ 0 23
28th ditto .	15 32	0 23 0	0 23 9	0 22 53	0 23 1	0 23 0	+ 0 1
29th ditto .	7 17	0 21 28	0 21 32	0 21 29	0 21 30	0 20 41	+ 0 49
29th ditto .	16 16	0 22 39	0 22 28	0 22 34	0 22 34	0 22 3	+ 0 31
31st ditto .	14 28	0 24 1	0 23 58	0 23 50	0 23 55	0 23 45	+ 0 10
31st dtto .	14 53	0 23 9	0 23 17	0 23 3	0 23 16	0 23 12	+ 0 4
1st February 1901 .	9 53	0 24 41	0 24 35	0 24 25	0 24 34	0 24 6	+ 0 28
1st ditto .	10 12	0 24 41	0 24 35	0 24 23	0 24 33	0 23 52	+ 0 41
2nd ditto .	7 18	0 21 45	0 21 44	0 21 29	0 21 39	0 21 11	+ 0 28
2nd ditto .	15 46	0 23 0	0 22 45	0 22 44	0 22 50	0 22 29	+ 0 21
						Mean .	+0′20″ = +0′·33

Colába-Cooke . . . . = +0′·33

From Kew observations (mean of 7) Kew-Cooke = −0′·19

Whence Kew-Colába . . = −0′·19 − 0′·33 = −0′·52

TABLE 5.

Showing the computed value of log $\frac{M}{H}$ (corrected for mean "P") at different distances (with Cooke No. 1).

Kew Observations.

DATE.	Log $\frac{M}{H}$.				REMARKS.
	r=30 c. m.	r=35 c. m.	r=40 c. m.	Mean.	
1st October 1900	3·73584	...	3·73588	3·73586	No deflections taken at 35 cm.
2nd ditto	3·73644	3·73645	3·73645	3·73645	
2nd ditto	3·73604	3·73604	3·73606	3·73605	
3rd ditto	3·73635	3·73620	3·73638	3·73631	
4th ditto	3·73607	3·73613	3·73606	3·73609	
4th ditto	3·73572	3·73580	3·73564	3·73572	
5th ditto	3·73650	3·73644	3·73650	3·73648	
5th ditto	3·73605	3·73605	3·73612	3·73607	
6th ditto	3·73622	3·73618	3·73602	3·73614	
8th ditto	3·73617	3·73622	3·73612	3·73617	
8th ditto	3·73590	3·73591	3·73600	3·73594	
MEANS	3·73612	3·73614	3·73611	3·73612	

Colába Observations.

DATE.	Log $\frac{M}{H}$.				REMARKS.
	r=30 cm.	r=35 cm.	r=40 cm.	Mean.	
26th January 1901	3·42839	3·42845	3·42829	3·42838	
26th ditto	3·42826	3·42822	3·42829	3·42826	
27th ditto	3·42823	3·42833	3·42825	3·42827	
27th ditto	3·42810	3·42819	3·42814	3·42814	
28th ditto	3·42812	3·42814	3·42802	3·42809	
28th ditto	3·42821	3·42842	3·42812	3·42825	
29th ditto	3·42804	3·42811	3·42808	3·42808	
29th ditto	3·42803	3·42814	3·42819	3·42812	
31st ditto	3·42810	3·42802	3·42810	3·42807	
31st ditto	3·42813	3·42803	3·42826	3·42814	
1st February 1901	3·42815	3·42832	3·42824	3·42824	
1st ditto	3·42803	3·42805	3·42794	3·42801	
2nd ditto	3·42805	3·42802	3·42797	3·42801	
2nd ditto	3·42841	3·42846	3·42846	3·42844	
MEANS	3·42816	3·42821	3·42817	3·42818	

TABLE 6.

Showing the values of "P" derived from the observations.

Cooke No. 1.

Kew Observations.

DATE.	P.				REMARKS.
	30 and 35 cm.	35 and 40 cm.	30 and 40 cm.	Mean.	
1st October 1900 .	...	...	8·22	8·22	Observations taken only at 35 and 40 cm.
2nd ditto .	8·34	8·40	8·36	8·37	
2nd ditto .	8·47	8·11	8·33	8·30	
3rd ditto .	9·63	6·23	8·29	8·05	
4th ditto .	7·98	9·15	8·44	8·52	Value adopted in computations of Kew results is P = 8·44.
4th ditto .	7·85	10·29	8·81	8·98	
5th ditto .	9·02	7·71	8·51	8·41	
5th ditto .	8·47	7·45	8·07	8·00	
6th ditto .	8·77	10·19	9·33	9·43	
8th ditto .	8·10	9·43	8·62	8·72	
8th ditto .	8·35	7·33	7·96	7·88	
MEANS .	8·50	8·43	8·45	8·44	

Colába Observations.

DATE.	P.				REMARKS.
	30 and 35 cm.	35 and 40 cm.	30 and 40 cm.	Mean.	
26th January 1901 .	8·02	10·38	8·95	9·12	
26th ditto .	8·77	7·69	8·35	8·27	
27th ditto .	7·65	9·42	8·35	8·47	
27th ditto .	7·78	9·04	8·27	8·36	
28th ditto .	8·27	10·00	8·95	9·07	
28th ditto .	6·91	11·92	8·87	9·23	Value adopted in computation of Colába results is P = 8·51.
29th ditto .	7·90	8·85	8·27	8·34	
29th ditto .	7·65	7·88	7·74	7·76	It would probably have been better to adopt the value derived from 30 and 40 cms. only in each case, *i.e.*, 8·45, but the effect of this change on the results would be very small, *viz.*, about ·00001 C. G. S. units.
31st ditto .	9·01	7·69	8·50	8·40	
31st ditto .	9·26	5·77	7·89	7·64	
1st February 1901 .	7·16	9·42	8·05	8·21	
1st ditto .	8·40	9·81	8·95	9·05	
2nd ditto .	8·64	9·23	8·87	8·91	
2nd ditto .	8·02	8·63	8·26	8·30	
MEANS .	8·10	8·98	8·45	8·51	

H. A. D. FRASER, CAPTAIN, *R.E.*

VI

Survey of India.

TIDAL AND LEVELLING OPERATIONS FOR THE YEAR 1900-1901.

Extracted from the Narrative Report of Captain H. L. Crosthwait, R.E., in charge of No. 25 Party, Survey of India.

TIDAL OPERATIONS.

1. Tidal operations, including the registration of tidal curves by means of self-registering gauges, their reduction, and the publication of tables of predicted times and heights of high and low-water, have been carried on, as usual, during the past survey year.

2. In the following table is given a complete list of the 41 ports at which observations have been, and are still being taken; 12 are now working, 29 have been closed on completion of their registrations, of which one was closed during the current year. The permanent stations are shown in italics; the others are minor stations at which only five years' registrations are required :—

LIST.

	Stations.	Automatic or personal observations.	Date of commencement of observations.	Date of closing of observations.	No. of years of observations.	Remarks.
1	Suez	Automatic	1897	Still working.	4	
2	Perim	Ditto .	1898	Ditto	3	
3	*Aden*	Ditto .	1879	Ditto	21	
4	Muscat	Ditto .	1893	1898	5	
5	Bushire	Ditto .	1892	1901	8	Closed during the year.
6	*Karáchi* . . .	Ditto .	1881	Still working.	20	
7	Hanstal	Ditto .	1874	1875	1	Tide-tables not published.
8	Navánár	Ditto .	1874	1875	1	Tide-tables not published.
9	Okha Point . .	Ditto .	1874	1875	1	
10	Porbandar	Personal.	1893	1894	2	
10A	Porbandar . . .	Automatic	1898	Still working.	3	With certain interruptions.
11	Port Albert Victor (Káthiáwádar).	Personal.	1881	1882	1	
11A	Ditto ditto.	Automatic	1900	Still working.	1	
12	Bhávnagar . .	Ditto .	1889	1894	5	
13	*Bombay* (Apollo Bandar)	Ditto .	1878	Still working.	23	

LIST—*contd.*

	STATIONS.	Automatic or personal observations.	Date of commencement of observations.	Date of closing of observations.	No. of years of observations.	REMARKS.
14	Bombay (Prince's Dock)	Automatic	1888	Still working.	13	Property of Port Trust.
15	Mormugão (Goa)	Ditto	1884	1889	5	
16	Kárwár	Ditto	1878	1883	5	
17	Beypore	Ditto	1878	1884	6	
18	Cochin	Ditto	1886	1892	6	
19	Tuticorin	Ditto	1888	1893	5	
20	Minicoy	Ditto	1891	1896	5	
21	Galle	Ditto	1884	1890	6	
22	Colombo	Ditto	1884	1890	6	
23	Trincomalee	Ditto	1890	1896	6	
24	Pámban Pass	Ditto	1878	1882	4	
25	Negapatam	Ditto	1881	1888	6	Year 1884-85 excluded.
26	*Madras*	Ditto	1880 restarted 1895	1890 Still working.	10 } 6 } 16	
27	Cocanada	Ditto	1886	1891	5	
28	Vizagapatam	Ditto	1879	1885	6	
29	False Point	Ditto	1881	1885	4	
30	Dublat (Saugor Island)	Ditto	1881	1886	5	
31	Diamond Harbour	Ditto	1881	1886	5	
32	*Kidderpore*	Ditto	1881	Still working.	20	
33	Chittagong	Ditto	1886	1891	5	
34	Akyab	Ditto	1887	1892	5	
35	Diamond Island	Ditto	1895	1899	5	
36	Elephant Point	Ditto	1880 restarted 1884	1881 1888	1 } 5 } 6	
37	*Rangoon*	Ditto	1880	Still working.	21	
38	Amherst	Ditto	1880	1886	6	
39	Moulmein	Ditto	1880	1886	6	
40	Mergui	Ditto	1889	1894	5	
41	*Port Blair*	Ditto	1880	Still working.	21	

3. In addition to the automatic registrations made at the stations enumerated in the foregoing list, personal tidal observations to graduated staves were taken at Bhávnagar, Tuticorin, Chittagong, Akyab and Moulmein with the object of comparing actual times and heights of high and low-water with predicted times and heights.

4. The observatory at Bushire was closed during the year, 8 years' observations having been recorded. An observatory will be opened at Bassein in Burma next field season.

5. The following are the points of principal interest connected with the working of the various observatories, commencing with Suez and following the order of the stations round the coast, to Burma.

Suez.—There were a few minor interruptions in the tidal records during the year, due to the pencil failing to mark for a few hours. The difficulty of obtaining accurate time at Suez has now been overcome: a chronometer corrected by comparison with His Majesty's ship stationed at Suez, is now being used instead of telegraph time, with excellent results.

The observatory was visited by Mr. H. G. Shaw, in December 1900; the tide-gauge and meteorological instruments were cleaned and repaired where necessary and left in good working order.

On the whole tidal registrations have been most satisfactory during the year.

The self-registering aneroid worked unsatisfactorily from 11th February 1900, and on the 8th March it broke down completely.

The self-registering anemometer, which had been packed away, being out of order since 24th August 1899, was repaired and started on the 26th December 1900. It again broke down in July and will be repaired during next inspection.

The bench-mark G.T.S. □ B M A, embedded in the masonry floor in the verandah of the dwelling house of the Director of the Port, was reported on 9th May 1901 to have been removed owing to alterations and additions to this building. The department is much indebted to Captain N. Fleri, who, under the direction of J. J. Falconer, Esq., Director of the Port, has devoted much time and trouble to the observatory and carried out the duties connected therewith, in a very efficient manner, and to him is due the continued success of observations at Suez.

6. *Perim.*—This observatory was visited by Mr. Shaw in December 1900; he found the tide-gauge and the auxiliary instruments with the exception of the self-registering aneroid, in good working order. Since the last inspection in January 1900, there has been no interruption in the tidal records. The self-registering aneroid, which had been out of order since 5th November last, and which the mechanic was unable to repair, was packed up and despatched to Dehra Dún. Mr. J. G. Meyers, the clerk in charge, takes the greatest interest in the work and has carried out his duties in the most satisfactory manner. My thanks are due to Captain H. Harrison, Political Officer at Perim, for his supervision and the interest he takes in the observatory.

7. *Aden.*—There were only a few trivial interruptions of the gauge, due either to the pencil failing to mark on the diagram or to the driving clock stopping.

Mr. Shaw inspected the observatory in November and December last. The observatory is under the supervision of the Port Officer.

8. *Bushire.*—I inspected this observatory and finally closed it on the 5th March 1901, after eight years' observations had been recorded, which includes a break of four months, caused by the observatory being wrecked on the 19th December 1893 by a very heavy storm. There has been no break in the tidal records during the year. The meteorological instruments, with the exception of the mercurial barometer, were all out of order. The continuous record of the tidal registrations is evidence of the care and interest shown by Mr. F. G. Evans, who was in charge of the observatory during the year.

9. *Karáchi.*—There have been several interruptions in the tidal records during the past year, due to imperfect communication between the sea and the cylinder, caused by the silting up of the mud inside and outside the cylinder. Steps have been taken to guard against such interruptions in future. The anemometer did not work satisfactorily, there being several stoppages due to the clock getting out of order. The clock has been changed. I inspected the observatory in February and March. All the instruments have been cleaned and left in good working order. The tidal observatory clerk, Jhamat Mal, continues to perform his duties satisfactorily.

My best thanks are due to Mr. E. Jackson, M.I C.E., Port Engineer, for his cordial help and careful supervision of the observatory instruments and records.

10. *Porbandar.*—Up to the middle of June 1901 the tide-gauge worked satisfactorily, there being only a few minor interruptions due to the pencil failing to mark on the diagram. On the 14th June the tidal observations were interrupted

again for the second time, due to the communication pipe being choked with sand driven in by the monsoon. As nothing can be done at present owing to the sea being too rough, I intend visiting the observatory in the winter, when, if practicable, without fear of the pipe getting blocked again, work will be re-started.

I am greatly indebted to Mr. J. J. Benson, State Engineer, for his supervision of the observatory.

11. *Port Albert Victor.*—There has been no interruption in the tidal records during the year. The auxiliary instruments worked well, there being a few minor interruptions in the records of the self-registering aneroid and self-registering anemometer. Mr. Shaw inspected the observatory in January last, thoroughly cleaned the instruments and left them in good working order. The clerk in charge and the assistant clerk have worked satisfactorily during the year.

Mr. E. Proctor-Sims, State Engineer, Bhávnagar, kindly continues to supervise the observatory.

12. *Bombay* (*Apollo Bandar*).—This observatory was inspected by me and Mr. Shaw in November last. With the exception of a break of eight days in July, during which time the driving clock was being repaired, the tidal records have been continuous. The clerk in charge, J. Fernandez, has performed his duties most satisfactorily.

Bombay (*Prince's Dock*).—There were only two interruptions, of a few hours each, in the tidal records, due, on the first occasion to the twisting of the diagram paper, and on the second, to the driving clock having stopped. I inspected the observatory in company with Mr. Shaw last November, and found the instrument in good working order. The instrument was cleaned and left in perfect order. This observatory is under the supervision of the Engineer to the Port Trust.

Madras.—The registrations by the tide-gauge for the past year are again highly satisfactory; and are quite complete. A self-registering aneroid was put up, adjusted and started on the 21st February, and up to the present has worked well. Mr. Shaw inspected the observatory in February 1901; he found the gauge clean and in good order. The sluice and well were as usual cleaned. The results of the spirit-levelling showed that since the inspection in 1899 a settlement of 0·019 foot had taken place in the bed-plate of the tide-gauge.

I am very grateful to Mr. F. H. Longhurst, Harbour Engineer, for kindly continuing to supervise the work carried on in the observatory.

13. *Kidderpore.*—There were a few breaks in the tidal records during the past year, caused as usual by the driving clock stopping. A new spring clock was substituted in January last for the old one, the parts of which had become very much worn. The self-registering anemometer has not worked satisfactorily. I inspected this observatory in January. All the instruments were cleaned and left in good working order. This Observatory is under the supervision of the Deputy Conservator of the Port, Calcutta.

14. *Rangoon.*—I inspected this observatory in December and January last; the instruments were cleaned and left in perfect working order. The tidal records, with the exception of a few minor breaks, have been continuous during the year. A new self-registering aneroid by Richard Freres, Paris, was set up and started during this inspection.

15. *Port Blair.*—Tidal records have been most satisfactory during the year, there being only one break of a few hours caused by the clock stopping. An earthquake was registered on the tidal diagram at 10-32 A.M. on the 10th

September 1901. The shock was slight but sufficient to cause the driving clock to stop. The self-registering aneroid has been out of order since May. Mr. Shaw inspected the observatory in February. I am much obliged to Mr. P. Vaux, of the Andaman Commission, for the interest he takes in the observatory.

Reduction of the Tidal Observations and Extra Tidal Work.

16. The observations for one year at thirteen tidal stations have been reduced, and the tabulated values of the tidal constants so derived are appended: there are no arrears.

Values of the Tidal Constants, Suez, 1900.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1900 observations at Suez; and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1900 observations:—

Short Period Tides.

A_0=4·402 feet.

S_1	H = R =	·085	M_6	R =	·012	Q_1	R =	·014	T_2	R =	·088
	κ = ζ =	68°·69		ζ =	71°·91		ζ =	0°·80		ζ =	0°·92
S_2	H = R =	·454		H =	·011		H =	·015		H =	·088
	κ = ζ =	7°·39		κ =	66°·91		κ =	207°·68		κ =	1°·56
S_4	H = R =	·005	M_8	R =	·002	L_2	R =	·072	$(MS)_4$	R =	·025
	κ = ζ =	71°·20		ζ =	126°·03		ζ =	266°·45		ζ =	147°·32
S_6	H = R =	·002		H =	·002		H =	·095		H =	·024
	κ = ζ =	333°·44		κ =	119°·36		κ =	28°·76		κ =	145°·66
S_8	H = R =	·000	O_1	R =	·036	N_2	R =	·609	$(2SM)_2$	R =	·010
	κ = ζ =	213°·69		ζ =	61°·36		ζ =	262°·65		ζ =	233°·59
				H =	·038		H =	·601		H =	·010
				κ =	216°·23		κ =	312°·99		κ =	235°·26
M_1	R =	·032	K_1	R =	·152	λ_2	R =	...	$2N_2$	R =	·121
	ζ =	264°·48		ζ =	351°·17		ζ =	...		ζ =	150°·20
	H =	·017		H =	·156		H =	...		H =	·120
	κ =	177°·10		κ =	190°·47		κ =	...		κ =	252°·55
M_2	R =	1·875	K_2	R =	·142	ν_2	R =	·196	$(M_2N)_4$	R =	·011
	ζ =	344°·06		ζ =	139°·22		ζ =	19°·79		ζ =	261°·57
	H =	1·850		H =	·155		H =	·193		H =	·011
	κ =	342°·40		κ =	357°·50		κ =	322°·46		κ =	310°·25
M_3	R =	·015	P_1	R =	·050	μ_2	R =	·102	$(M_2K_1)_3$	R =	·040
	ζ =	34°·47		ζ =	302°·16		ζ =	226°·49		ζ =	230°·88
	H =	·014		H =	·050		H =	·099		H =	·040
	κ =	31°·97		κ =	111°·57		κ =	223°·16		κ =	68°·51
M_4	R =	·031	J_1	R =	·024	R_2	R =	...	$(2M_2K^1)_3$	R =	·012
	ζ =	116°·22		ζ =	91°·92		ζ =	...		ζ =	296°·57
	H =	·031		H =	·025		H =	...		H =	·012
	κ =	112°·89		κ =	243°·38		κ =	...		κ =	93°·93

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·125	170°·00	·120	117°·99
" Fortnightly "	·042	303·67	·047	172·26
Luni-Solar " "	·031	79·20	·031	80·87
Solar Annual "	·553	33·07	·553	313·66
" Semi-Annual "	·192	288·53	·192	129·72

Values of the Tidal Constants, Perim, 1900.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1900 observations at Perim; and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1900 observations:—

Short Period Tides.

A_0=5·324 feet.

S_1	H=R=	·088	M_6	R=	·005	Q_1	R=	·136	T_2	R=	·065
	κ=ζ=	156°·10		ζ=	4°·76		ζ=	183°·04		ζ=	237°·75
S_2	H=R=	·557		H=	·005		H=	·143		H=	·065
	κ=ζ=	243°·00		κ=	1°·97		κ=	31°·07		κ=	238°·41
S_4	H=R=	·006	M_8	R=	·001	L_2	R=	·019	$(MS)_4$	R=	·019
	κ=ζ=	314°·27		ζ=	36°·87		ζ=	91°·52		ζ=	91°·55
S_6	H=R=	·007		H=	·001		H=	·025		H=	·019
	κ=ζ=	208°·89		κ=	33°·15		κ=	214°·18		κ=	90°·62
S_8	H=R=	·003	O_1	R=	·558	N_2	R=	·354	$(2SM)_2$	R=	·017
	κ=ζ=	6°·58		ζ=	239°·34		ζ=	175°·01		ζ=	111°·41
				H=	·584		H=	·349		H=	·016
				κ=	34°·97		κ=	226°·48		κ=	112°·34
M_1	R=	·115	K_1	R=	1·116	λ_2	R=	...	$2N_2$	R=	·087
	ζ=	104°·99		ζ=	193°·60		ζ=	...		ζ=	90°·67
	H=	·061		H=	1·148		H=	...		H=	·086
	κ=	17°·97		κ=	32°·87		κ=	...		κ=	194°·54
M_2	R=	1·222	K_2	R=	·158	ν_2	R=	·123	$(M_2N)_4$	R=	·021
	ζ=	227°·03		ζ=	11°·22		ζ=	289°·78		ζ=	198°·80
	H=	1·206		H=	·172		H=	·121		H=	·020
	κ=	226°·10		κ=	229°·45		κ=	233°·52		κ=	249°·34
M_3	R=	·033	P_1	R=	·373	μ_2	R=	·076	$(M_2K_1)_3$	R=	·035
	ζ=	245°·75		ζ=	219°·59		ζ=	197°·83		ζ=	75°·51
	H=	·032		H=	·373		H=	·074		H=	·035
	κ=	244°·35		κ=	29°·03		κ=	195°·97		κ=	273°·85
M_4	R=	·027	J_1	R=	·120	R_2	R=	...	$(2M_2K_1)_3$	R=	·019
	ζ=	17°·30		ζ=	260°·22		ζ=	...		ζ=	112°·76
	H=	·026		H=	·124		H=	...		H=	·019
	κ=	15°·44		κ=	51°·26		κ=	...		κ=	271°·63

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·019	195°·23	·018	142°·83
„ Fortnightly „	·042	137·84	·047	5·65
Luni-Solar „ „	·009	156·15	·009	157·08
Solar-Annual „	·380	55·11	·380	335·67
„ Semi-Annual „	·180	263·94	·180	105·06

Values of the Tidal Constants, Aden, 1900-1901.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1900-1901 observations at Aden; and also the ***mean*** values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1900-1901 observations :—

Short Period Tides.

A_0=5·785 feet.

Tide	H = R =	κ = ζ =
S_1	·086	165°·51
S_2	·668	244°·50
S_4	·005	263°·66
S_6	·006	219°·94
S_8	·001	53°·97

Tide	R =	ζ =	H =	κ =
M_1	·079	323°·94	·043	50°·89
M_2	1·581	244°·28	1·558	226°·26
M_3	·018	53°·00	·018	205°·97
M_4	·004	24°·10	·004	348°·05
M_6	·006	340°·56	·006	286°·49
M_8	·001	233°·13	·001	161°·03
O_1	·618	302°·36	·652	36°·64
K_1	1·258	151°·11	1·300	34°·64
K_2	·171	291°·91	·189	238°·61
P_1	·402	266°·09	·402	31°·18
J_1	·092	329°·46	·096	32°·61
Q_1	·132	124°·41	·140	43°·23
L_2	·057	227°·88	·073	198°·84
N_2	·428	53°·40	·422	219°·91
λ_2	...	...	...	...
ν_2	·113	129°·50	·111	266°·96
μ_2	·069	240°·97	·067	204°·92
R_2	...	...	...	...
T_2	·083	253°·06	·083	209°·38
$(MS)_4$	·015	182°·34	·015	164°·31
$(2SM)_2$	·020	93°·26	·019	111°·29
$2N_2$	·065	174°·51	·064	165°·55
$(M_2N)_4$	·068	225°·69	·066	14°·17
$(M_2K_1)_3$	·019	47°·90	·019	273°·41
$(2M_2K_1)_3$	·009	241°·97	·009	322°·38

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·014	280°·35	·013	95°·81
,, Fortnightly ,, ...	·033	39·98	·037	13·38
Luni-Solar ,, ,, ...	·006	291·15	·006	309·17
Solar-Annual ,, ...	·353	17·42	·353	342·33
,, Semi-Annual ,, ...	·148	193·85	·148	123·68

Values of the Tidal Constants, Bushire 1900.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1900 observations at Bushire; and also the mean values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1900 Observations :—

Short Period Tides.

A_0=4·620 feet.

Tide	H = R =	κ = ζ =
S_1	·065	41°·31
S_2	·406	263°·99
S_4	·008	136°·44
S_6	·001	300°·96

Tide	R =	ζ =	H =	κ =
M_6	·008	34°·80	·008	33°·50
M_8	·002	138°·01	002	136°·29
Q_1	·132	17°·07	·138	225°·89
L_2	·027	101°·18	·035	224°·07
T_2	·053	233°·22	·053	233°·90
$(MS)_4$	·025	44°·83	·025	44°·40

Short Period Tides—contd.

S_8	H = R =	·001	O_1	R =	·653	N_2	R =	·245	$(2SM)_2$	R =	·017
	κ = ζ =	212°·01		ζ =	84°·72		ζ =	133°·29		ζ =	135°·00
				H =	684		H =	·241		H =	·017
				κ =	240° 87		κ =	185°·53		κ =	135°·43
M_1	R =	·118	K_1	R =	·987	λ_2	R =	...	$2N_2$	R =	·051
	ζ =	336°·05		ζ =	79°·83		ζ =	...		ζ =	62°·82
	H =	·062		H =	1·014		H =	...		H =	·050
	κ =	249°·28		κ =	279°·08		κ =	...		κ =	167°·72
M_2	R =	1·125	K_2	R =	·117	ν_2	R =	·084	$(M_2N)_4$	R =	·021
	ζ =	213°·18		ζ =	36°·90		ζ =	255°·33		ζ =	191°·64
	H =	1·110		H =	·128		H =	·083		H =	·021
	κ =	212°·75		κ =	255°·09		κ =	199°·80		κ =	243°·45
M_3	R =	·036	P_1	R =	·320	μ_2	R =	009	$(M_2K_1)_3$	R =	·065
	ζ =	116°·42		ζ =	100°·58		ζ =	284°·34		ζ =	216°·43
	H =	·036		H =	·320		H =	·009		H =	·066
	κ =	115°·77		κ =	270°·04		κ =	283°·47		κ =	55°·25
M_4	R =	·022	J_1	R =	·082	R_2	R =	...	$(2M_2K_1)_3$	R =	·056
	ζ =	326°·85		ζ =	146°·17		ζ =	...		ζ =	241°·02
	H =	·021		H =	·085		H =	...		H =	·056
	κ =	325°·98		κ =	296°·92		κ =	...		κ =	40°·90

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·061	160°·11	·058	107°·45
„ Fortnightly „	·013	291·37	·014	158·64
Luni-Solar „ „	·068	24·49	·067	24·92
Solar-Annual „	·226	230·31	·226	150·85
„ Semi-Annual „	·096	78·35	·096	279·44

Values of the Tidal Constants, Karáchi, 1900.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1900 observations at Karáchi; and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1900 observations:—

Short Period Tides.

A_0=7·065 feet.

S_1	H = R =	·094	M_6	R =	·045	Q_1	R =	·149	T_2	R =	·134
	κ = ζ =	182°·86		ζ =	201°·59		ζ =	194°·67		ζ =	315°·64
S_2	H = R =	·962		H =	·044		H =	·155		H =	·134
	κ = ζ =	333°·68		κ =	203°·59		κ =	45°·21		κ =	316°·37
S_4	H = R =	·013	M_8	R =	·004	L_2	R =	·051	$(MS)_4$	R =	·025
	κ = ζ =	12°·25		ζ =	257°·28		ζ =	166°·35		ζ =	328°·07
S_6	H = R =	·011		H =	·004		H =	·068		H =	·024
	κ = ζ =	289°·39		κ =	259°·94		κ =	289°·75		κ =	328°·74
S_8	H = R =	·002	O_1	R =	·633	N_2	R =	·645	$(2SM)_2$	R =	·014
	κ = ζ =	47°·73		ζ =	249°·11		ζ =	223°·81		ζ =	110°·27
				H =	·662		H =	·637		H =	·014
				κ =	46°·40		κ =	277°·73		κ =	109°·60
M_1	R =	·132	K_1	R =	1·288	λ_2	R =	...	$2N_2$	R =	·113
	ζ =	126°·41		ζ =	206°·73		ζ =	...		ζ =	142°·06
	H =	·069		H =	1·324		H =	...		H =	·111
	κ =	40°·18		κ =	45°·93		κ =	...		κ =	249°·24
M_2	R =	2·638	K_2	R =	·252	ν_2	R =	213	$(M_2N)_4$	R =	·075
	ζ =	292°·73		ζ =	95°·57		ζ =	341°·21		ζ =	246°·89
	H =	2·604		H =	·276		H =	·210		H =	·073
	κ =	293°·39		κ =	313°·67		κ =	287°·29		κ =	301°·47
M_3	R =	·033	P_1	R =	·409	μ_2	R =	·067	$(M_2K_1)_3$	R =	·061
	ζ =	335°·20		ζ =	232°·34		ζ =	262°·80		ζ =	186°·13
	H =	·032		H =	·409		H =	·067		H =	·061
	κ =	336°·20		κ =	41°·85		κ =	264°·13		κ =	26°·00

Short Period Tides—contd.

M_4	R =	·021	J_1	R =	·131	R_2	R =	...	$(2M_2K_1)_3$	R =	·025
	ζ =	1°·73		ζ =	278°·35		ζ =	...		ζ =	227°·46
	H =	·020		H =	·136		H =	...		H =	·025
	κ =	3°·06		κ =	68°·46		κ =	...		κ =	29°·59

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·041	308°·41	·039	255°·16
„ Fortnightly „	·025	21·72	·028	247·80
Luni-Solar „ „	·022	332·21	·022	331·54
Solar-Annual „	·124	159·70	·124	80·20
„ Semi-Annual „	·157	295·06	·157	136·05

Values of the Tidal Constants, Port Albert Victor, 1900.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1900 observations at Port Albert Victor; and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1900 observations:—

Short Period Tides.

A_0=9·660 feet.

S_1	H = R =	·094	M_6	R =	·130	Q_1	R =	·162	T_2	R =	...
	κ = ζ =	186°·66		ζ =	119°·45		ζ =	217°·74		ζ =	...
S_2	H = R =	1·122		H =	·125		H =	·170		H =	...
	κ = ζ =	82°·88		κ =	122°·37		κ =	68°·77		κ =	...
S_4	H = R =	·021	M_8	R =	·011	L_2	R =	·120	$(MS)_4$	R =	·162
	κ = ζ =	265°·66		ζ =	129°·47		ζ =	50°·50		ζ =	211°·99
S_6	H = R =	·010		H =	·010		H =	·159		H =	·160
	κ = ζ =	14°·62		κ =	133°·37		κ =	174°·05		κ =	212°·97
S_8	H = R =	·004	O_1	R =	·698	N_2	R =	·779	$(2SM)_2$	R =	·026
	κ = ζ =	301°·22		ζ =	268°·35		ζ =	341°·20		ζ =	41°·50
				H =	·730		H =	·769		H =	·026
				κ =	65°·97		κ =	35°·59		κ =	40°·53
M_1	R =	·170	K_1	R =	1·584	λ_2	R =	...	$2N_2$	R =	·221
	ζ =	148°·67		ζ =	226°·00		ζ =	...		ζ =	236°·96
	H =	·089		H =	1·628		H =	...		H =	·218
	κ =	62°·59		κ =	65°·19		κ =	...		κ =	344°·78
M_2	R =	2·932	K_2	R =	·247	ν_2	R =	·187	$(M_2N)_4$	R =	·074
	ζ =	57°·29		ζ =	214°·63		ζ =	113°·19		ζ =	39°·95
	H =	2·894		H =	·270		H =	·184		H =	·072
	κ =	58°·27		κ =	72°·70		κ =	59°·72		κ =	95°·32
M_3	R =	·022	P_1	R =	·462	μ_2	R =	·330	$(M_2K_1)_3$	R =	·069
	ζ =	155°·49		ζ =	251°·49		ζ =	334°·39		ζ =	294°·85
	H =	·021		H =	·462		H =	·321		H =	·070
	κ =	156°·95		κ =	61°·01		κ =	336°·33		κ =	135°·02
M_4	R =	·209	J_1	R =	·160	R_2	R =	...	$(2M_2K_1)_3$	R =	·038
	ζ =	170°·09		ζ =	307°·27		ζ =	...		ζ =	358°·59
	H =	·203		H =	·165		H =	...		H =	·038
	κ =	172°·04		κ =	97°·20		κ =	...		κ =	161°·35

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·050	280°·83	·048	227°·41
„ Fortnightly „	·018	99·45	·020	325·19
Luni-Solar „ „	·048	252·98	·047	252·00
Solar-Annual „	·068	325·62	·068	246·10
„ Semi-Annual „	·184	290·66	·184	131·63

VALUES OF THE TIDAL CONSTANTS, PORBANDAR, 1900-1901.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1900-1901 observations at Porbandar; and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1900-1901 observations:—

Short Period Tides.

$A_0 = 7{\cdot}342$ feet.

S_1	H = R =	·091	M_6	R =	·030	Q_1	R =	·103	T_2	R =	...
	κ = ζ =	182°·53		ζ =	248°·75		ζ =	31°·02		ζ =	...
S_2	H = R =	·782		H =	·029		H =	·108		H =	...
	κ = ζ =	323°·69		κ =	307°·23		κ =	63°·82		κ =	...
S_4	H = R =	·005	M_8	R =	·004	L_2	R =	·043	$(MS)_4$	R =	·027
	κ = ζ =	289°·23		ζ =	214°·16		ζ =	319°·82		ζ =	196°·07
S_6	H = R =	·008		H =	·004		H =	·057		H =	·027
	κ = ζ =	163°·65		κ =	292°·13		κ =	284°·05		κ =	215°·56
S_8	H = R =	·001	O_1	R =	·544	N_2	R =	·521	$(2SM)_2$	R =	·011
	κ = ζ =	30°·96		ζ =	243°·10		ζ =	24°·54		ζ =	131°·19
				H =	·571		H =	·514		H =	·011
				κ =	45°·45		κ =	274°·47		κ =	111°·69
M_1	R =	·067	K_1	R =	1·126	λ_2	R =	...	$2N_2$	R =	·080
	ζ =	302°·67		ζ =	190°·81		ζ =	...		ζ =	113°·07
	H =	·036		H =	1·160		H =	...		H =	·079
	κ =	46°·64		κ =	43°·78		κ =	...		κ =	233°·44
M_2	R =	2·160	K_2	R =	·203	ν_2	R =	·183	$(M_2N)_4$	R =	·101
	ζ =	273°·66		ζ =	71°·94		ζ =	132°·13		ζ =	237°·17
	H =	2·130		H =	·223		H =	·180		H =	·098
	κ =	293°·16		κ =	317°·55		κ =	298°·69		κ =	146°·59
M_3	R =	·028	P_1	R =	·342	μ_2	R =	·073	$(M_2K_1)_3$	R =	·025
	ζ =	108°·77		ζ =	246°·90		ζ =	230°·37		ζ =	343°·80
	H =	·027		H =	·342		H =	·071		H =	·025
	κ =	318°·01		κ =	42°·61		κ =	269°·35		κ =	216°·26
M_4	R =	·034	J_1	R =	·057	R_2	R =	...	$(2M_2K_1)_3$	R =	·004
	ζ =	84°·69		ζ =	54°·69		ζ =	...		ζ =	130°·31
	H =	·033		H =	·059		H =	...		H =	·004
	κ =	123°·68		κ =	41°·38		κ =	...		κ =	316°·32

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·009	122°·83	·009	252°·39
" Fortnightly "	·016	260·83	·018	135·61
Luni-Solar " "	·030	298·92	·030	279·43
Solar-Annual "	·060	312·11	·060	246·40
" Semi-Annual "	·170	289·06	·170	157·64

VALUES OF THE TIDAL CONSTANTS, BOMBAY, 1900.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1900 observations at Bombay; and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1900 observations:—

Short Period Tides.

$A_0 = 10{\cdot}176$ feet.

S_1	H = R =	·077	M_6	R =	·007	Q_1	R =	·149	T_2	R =	·223
	κ = ζ =	183°·96		ζ =	36°·53		ζ =	197°·81		ζ =	358°·70
S_2	H = R =	1·580		H =	·007		H =	·155		H =	·223
	κ = ζ =	5°·59		κ =	39°·72		κ =	48°·99		κ =	359°·44
S_4	H = R =	·015	M_8	R =	·007	L_2	R =	·012	$(MS)_4$	R =	·121
	κ = ζ =	219°·71		ζ =	16°·09		ζ =	127°·34		ζ =	37°·48
S_6	H = R =	·002		H =	·006		H =	·016		H =	·119
	κ = ζ =	157°·75		κ =	20°·35		κ =	250°·92		κ =	38°·54

Short Period Tides—contd.

S_8	H = R =	·000	O_1	R =	·622	N_2	R =	·992	$(2SM)_2$	R =	·036
	κ = ζ =	161°·57		ζ =	250°·34		ζ =	260°·31		ζ =	106°·14
				H =	·651		H =	·979		H =	·036
				κ =	48°·04		κ =	314°·84		κ =	105°·08
M_1	R =	·136	K_1	R =	1·365	λ_2	R =	...	$2N_2$	R =	·217
	ζ =	126°·97		ζ =	206°·77		ζ =	...		ζ =	180°·59
	H =	·072		H =	1·403		H =	...		H =	·214
	κ =	40°·94		κ =	45°·96		κ =	...		κ =	288°·59
M_2	R =	4·098	K_2	R =	·387	ν_2	R =	·284	$(M_2N)_4$	R =	·094
	ζ =	330°·60		ζ =	133°·21		ζ =	15°·53		ζ =	267°·00
	H =	4·044		H =	·422		H =	·281		H =	·092
	κ =	331°·67		κ =	351°·28		κ =	322°·19		κ =	324°·60
M_3	R =	·064	P_1	R =	·415	μ_2	R =	·204	$(M_2K_1)_3$	R =	·060
	ζ =	10°·98		ζ =	231°·47		ζ =	300°·15		ζ =	271°·87
	H =	·062		H =	·415		H =	·199		H =	·061
	κ =	12°·58		κ =	40°·99		κ =	302°·28		κ =	112°·13
M_4	R =	·107	J_1	R =	·146	R_2	R =	...	$(2M_2K_1)_3$	R =	·076
	ζ =	334°·49		ζ =	278°·78		ζ =	...		ζ =	280°·44
	H =	·104		H =	·151		H =	...		H =	·076
	κ =	336°·62		κ =	68°·67		κ =	...		κ =	83°·38

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·033	313°·83	·032	260°·36
„ Fortnightly „	·032	189·05	·036	54·70
Luni-Solar „ „	·011	102·73	·011	101·66
Solar-Annual „	·056	342·69	·056	263·17
„ Semi-Annual „	·117	344·06	·117	185·02

Values of the Tidal Constants, Prince's Dock, Bombay, 1900.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1900 observations at Prince's Dock, Bombay; and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1900 observations :—

Short Period Tides.

A_0=8·065 feet.

S_1	H = R =	·091	M_6	R =	·003	Q_1	R =	·149	T_2	R =	·228
	κ = ζ =	186°·96		ζ =	199°·18		ζ =	197°·37		ζ =	358°·50
S_2	H = R =	1·603		H =	·003		H =	·155		H =	·228
	κ = ζ =	4°·73		κ =	202°·37		κ =	48°·55		κ =	359°·24
S_4	H = R =	·021	M_8	R =	·005	L_2	R =	·033	$(MS)_4$	R =	·122
	κ = ζ =	213°·00		ζ =	52°·85		ζ =	127°·95		ζ =	39°·78
S_6	H = R =	·002		H =	·005		H =	·044		H =	·120
	κ = ζ =	173°·29		κ =	57°·11		κ =	251°·54		κ =	40°·84
S_8	H = R =	·002	O_1	R =	·618	N_2	R =	1·006	$(2SM)_2$	R =	·045
	κ = ζ =	68°·75		ζ =	250°·45		ζ =	260°·02		ζ =	106°·71
				H =	·647		H =	·993		H =	·044
				κ =	48°·16		κ =	314°·55		κ =	105°·65
M_1	R =	·138	K_1	R =	1·347	λ_2	R =	...	$2N_2$	R =	·219
	ζ =	125°·70		ζ =	205°·93		ζ =	...		ζ =	181°·59
	H =	·073		H =	1·385		H =	...		H =	·216
	κ =	39°·67		κ =	45°·13		κ =	...		κ =	289°·59
M_2	R =	4·113	K_2	R =	·382	ν_2	R =	·300	$(M_2N)_4$	R =	·091
	ζ =	329°·43		ζ =	131°·54		ζ =	15°·59		ζ =	263°·69
	H =	4·059		H =	·417		H =	·296		H =	·088
	κ =	330°·49		κ =	349°·61		κ =	322°·25		κ =	319°·29
M_3	R =	·071	P_1	R =	·409	μ_2	R =	·201	$(M_2K_1)_3$	R =	·056
	ζ =	13°·38		ζ =	232°·22		ζ =	304°·55		ζ =	257°·01
	H =	·070		H =	·409		H =	·196		H =	·057
	κ =	14°·97		κ =	41°·74		κ =	306°·68		κ =	97°·26

Short Period Tides—contd.

M_4	R =	·096	J_1	R =	·143	R_2	R =	...	$(2M_2K_1)_3$	R =	·079
	ζ =	331°·70		ζ =	279°·18		ζ =	...		ζ =	275°·04
	H =	·094		H =	·148		H =	...		H =	·080
	κ =	333°·83		κ =	69°·07		κ =	...		κ =	77°·98

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide . . .	·025	319°·62	·024	266°·16
„ Fortnightly „ . . .	·038	169·43	·042	35·08
Luni-Solar „ „ . . .	·024	41·43	·024	40·36
Solar-Annual „ . . .	·086	345·63	·086	266·11
„ Semi-Annual „ . . .	·126	341·51	·126	182·47

Values of the Tidal Constants, Madras, 1900.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1900 observations at Madras; and also the *mean* values of the amplitudes (H) and of the epoch (κ) for each particular tide evaluated from the 1900 observations:—

Short Period Tides.

A_0=2·168 feet.

S_1	H = R =	·031	M_6	R =	·003	Q_1	R =	·006	T_2	R =	·050
	κ = ζ =	77°·96		ζ =	112°·48		ζ =	57°·05		ζ =	248°·39
S_2	H = R =	·460		H =	·003		H =	·007		H =	·050
	κ = ζ =	274°·90		κ =	117°·18		κ =	269°·02		κ =	249°·16
S_4	H = R =	·001	M_8	R =	·002	L_2	R =	·040	$(MS)_4$	R =	·004
	κ = ζ =	225°·00		ζ =	247°·38		ζ =	177°·82		ζ =	202°·38
S_6	H = R =	·001		H =	·002		H =	·053		H =	·004
	κ = ζ =	104°·04		κ =	253°·65		κ =	301°·64		κ =	203°·95
S_8	H = R =	·001	O_1	R =	·094	N_2	R =	·245	$(2SM)_2$	R =	·019
	κ = ζ =	126°·87		ζ =	167°·28		ζ =	183°·69		ζ =	221°·10
				H =	·099		H =	·242		H =	·019
				κ =	325°·51		κ =	239°·00		κ =	219°·53
M_1	R =	·009	K_1	R =	·287	λ_2	R =	...	$2N_2$	R =	·055
	ζ =	55°·27		ζ =	140°·87		ζ =	...		ζ =	99°·69
	H =	·005		H =	·295		H =	...		H =	·055
	κ =	329°·49		κ =	340°·04		κ =	...		κ =	208°·73
M_2	R =	1·094	K_2	R =	·114	ν_2	R =	·076	$(M_2N)_4$	R =	·023
	ζ =	242°·72		ζ =	50°·97		ζ =	302°·22		ζ =	211°·01
	H =	1·080		H =	·124		H =	·075		H =	·022
	κ =	244°·29		κ =	268°·99		κ =	249°·62		κ =	267°·88
M_3	R =	·004	P_1	R =	·097	μ_2	R =	·030	$(M_2K_1)_3$	R =	·018
	ζ =	41°·88		ζ =	172°·63		ζ =	190°·46		ζ =	135°·95
	H =	·004		H =	·097		H =	·029		H =	·018
	κ =	44°·23		κ =	342°·16		κ =	193°·60		κ =	336°·69
M_4	R =	·006	J_1	R =	·025	R_2	R =	...	$(2M_2K_1)_3$	R =	·003
	ζ =	183°·88		ζ =	182°·98		ζ =	...		ζ =	213°·69
	H =	·006		H =	·026		H =	...		H =	·003
	κ =	187°·02		κ =	332°·57		κ =	...		κ =	17°·66

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·008	306°·01	·008	252°·27
„ Fortnightly „	·053	176·24	·059	41·34
Luni-Solar „ „	·033	330·34	·033	328·77
Solar-Annual „	·333	294·42	·333	214·88
„ Semi-Annual „	·381	278·18	·381	119·10

VALUES OF THE TIDAL CONSTANTS, KIDDERPORE 1900.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1900 Observations at Kidderpore; and also the mean values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1900 observations :—

Short Period Tides.

A_0 = 10·604 feet.

S_1	H = R =	·076	M_6	R =	·162	Q_1	R =	·023	T_2	R =	·151
	κ = ζ =	188°·75		ζ =	314°·28		ζ =	131°·09		ζ =	106°·91
S_2	H = R =	1·543		H =	·156		H =	·024		H =	·151
	κ = ζ =	99°·17		κ =	320°·61		x =	343°·92		κ =	107°·69
S_4	H = R =	·104	M_8	R =	·072	L_2	R =	·186	$(MS)_4$	R =	·697
	κ = ζ =	110°·00		ζ =	256°·17		ζ =	318°·78		ζ =	76°·90
S_6	H = R =	·006		H =	·068		H =	·246		H =	·687
	κ = ζ =	70°·97		κ =	264°·62		x =	82°·85		κ =	79°·02
S_8	H = R =	·004	O_1	R =	·187	N_2	R =	·758	$(2SM)_2$	R =	·076
	κ = ζ =	336°·19		ζ =	215°·57		ζ =	347°·69		ζ =	20°·27
				H =	·196		H =	·748		H =	·075
				κ =	14°·37		x =	43°·83		κ =	18°·16
M_1	R =	·012	K_1	R =	·400	λ_2	R =	...	$2N_2$	R =	·060
	ζ =	206°·35		ζ =	214°·00		ζ =	...		ζ =	299°·06
	H =	.006		H =	·411		H =	...		H =	·059
	κ =	120°·84		κ =	53°·15		κ =	...		κ =	49°·24
M_2	R =	3·797	K_2	R =	·445	ν_2	R =	·330	$(M_2N)_4$	R =	·103
	ζ =	55°·05		ζ =	231°·50		ζ =	78°·26		ζ =	42°·37
	H =	3·748		H =	·486		H =	·326		H =	·101
	κ =	57°·16		κ =	89°·48		x =	26°·46		κ =	100°·63
M_3	R =	·030	P_1	R =	·166	μ_2	R =	·265	$(M_2K_1)_3$	R =	·123
	ζ =	356°·49		ζ =	237°·28		ζ ×	184°·87		ζ =	210°·50
	H =	·030		H =	·166		H =	·258		H =	·125
	κ =	359°·65		κ =	46°·84		x =	189°·09		κ =	51°·76
M_4	R =	·782	J_1	R =	·032	R_2	R =	...	$(2M_2K_1)_3$	R =	·037
	ζ =	32°·37		ζ =	293°·29		ζ =	...		ζ =	157°·87
	H =	·761		H =	·033		H =	...		H =	·037
	κ =	36°·59		κ =	82°·57		x =	...		κ =	322°·95

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·297	32°·39	·284	338°·26
„ Fortnightly „	·301	179·38	·334	43·89
Luni-Solar „ „	·996	43·84	·983	41·73
Solar-Annual „	2·569	238·09	2·569	158·53
„ Semi-Annual „	1·093	150·30	1·093	351·17

VALUES OF THE TIDAL CONSTANTS, RANGOON 1900.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1900 observations at Rangoon; and also the mean values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1900 Observations:—

Short Period Tides.

A_0=10·155 feet.

S_1	H= R =	·116	M_6	R =	·241	Q_1	R =	·034	T_2	R =	·336
	κ= ζ =	140°·09		ζ =	73°·78		ζ =	154°·42		ζ =	148°·43
S_2	H= R =	2·186		H =	·232		H =	·036		H =	·336
	κ= ζ =	167°·61		κ =	81°·71		κ =	8°·09		κ =	149°·24
S_4	H= R =	·085	M_8	R =	·099	L_2	R =	·449	$(MS)_4$	R =	·467
	κ= ζ =	254°·35		ζ =	84°·74		ζ =	30°·21		ζ =	208°·56
S_6	H= R =	·007		H =	·094		H =	·595		H =	·461
	κ= ζ =	26°·95		κ =	95°·31		κ =	154°·53		κ =	211°·20
S_8	H= R =	·003	O_1	R =	·301	N_2	R =	1·122	$(2SM)_2$	R =	·164
	κ= ζ =	139°·90		ζ =	223°·47		ζ =	57°·29		ζ =	50°·65
				H =	·315		H =	1·108		H =	·162
				κ =	22°·83		κ =	114°·25		κ =	48°·00
M_1	R =	·020	K_1	R =	·661	λ_2	R =	...	$2N_2$	R =	·043
	ζ =	52°·02		ζ =	195°·33		ζ =	...		ζ =	285°·05
	H =	·010		H =	·679		H =	...		H =	·042
	κ =	326°·78		κ =	34°·45		κ =	...		κ =	36°·33
M_2	R =	6·094	K_2	R =	·571	ν_2	R =	·455	$(M_2N)_4$	R =	·214
	ζ =	126°·38		ζ =	300°·98		ζ =	170°·25		ζ =	67°·34
	H =	6·014		H =	·623		H =	·449		H =	·209
	κ=	129°·03		κ =	158°·91		κ =	119°·23		κ =	126°·94
M_3	R =	·035	P_1	R =	·162	μ_2	R =	·551	$(M_2K_1)_3$	R =	·117
	ζ =	132°·72		ζ =	238°·99		ζ =	282°·62		ζ =	256°·71
	H =	·034		H =	·162		H =	·536		H =	·119
	κ =	136°·69		κ =	48°·58		κ =	287°·91		κ =	98°·48
M_4	R =	·538	J_1	R =	·056	R_2	R =	...	$(2M_2K_1)_3$	R =	·116
	ζ =	162°·39		ζ =	286°·70		ζ =	...		ζ =	243°·39
	H =	·524		H =	·057		H =	...		H =	·117
	κ =	167°·68		κ =	75°·68		κ =	...		κ =	49°·55

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·175	56°·12	·167	1°·80
„ Fortnightly „	·165	183·56	·183	47·56
Luni-Solar „ „	·436	51·10	·430	48·48
Solar-Annual „	1·161	220·37	1·161	140·79
„ Semi-Annual „	·062	167·81	·062	8·65

VALUES OF THE TIDAL CONSTANTS, PORT BLAIR, 1900.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1900 observations at Port Blair; and also the *mean* values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1900 observations:—

Short Period Tides.

A_0=4·752 feet.

S_1	H= R =	·016	M_8	R =	·005	Q_1	R =	·026	T_2	R =	·103
	κ= ζ =	46°·83		ζ =	18°·03		ζ =	39°·95		ζ =	299°·45
S_2	H= R =	·967		H =	·005		H =	·027		H =	·103
	κ= ζ =	314°·54		κ =	25°·27		κ =	253°·25		κ =	300°·25

Short Period Tides—contd.

S_4	H = R =	·010	M_8	R =	·001	L_2	R =	·052	$(MS)_4$	R =	·028
	κ = ζ =	244°·98		ζ =	68°·20		ζ =	161°·53		ζ =	184°·69
S_6	H = R =	·002		H =	·001		H =	·069		H =	·028
	κ = ζ =	254°·06		κ =	77°·85		κ =	285°·74		κ =	187°·11
S_8	H = R =	·002	O_1	R =	·146	N_2	R =	·409	$(2SM)_2$	R =	·022
	κ = ζ =	345°·96		ζ =	143°·87		ζ =	217°·21		ζ =	157°·46
				H =	·153		H =	·404		H =	·022
				κ =	302°·98		κ =	273°·81		κ =	155°·05
M_1	R =	·020	K_1	R =	·393	λ_2	R =	...	$2N_2$	R =	·091
	ζ =	16°·57		ζ =	128°·09		ζ =	...		ζ =	155°·59
	H =	·011		H =	·404		H =	...		H =	·090
	κ =	291°·21		κ =	327°·23		κ =	...		κ =	266°·39
M_2	R =	2·041	K_2	R =	·247	ν_2	R =	·124	$(M_2N)_4$	R =	·060
	ζ =	276°·82		ζ =	85°·77		ζ =	326°·84		ζ =	238°·69
	H =	2·015		H =	·270		H =	·123		H =	·059
	κ =	279°·24		κ =	303°·73		κ =	275°·48		κ =	297°·71
M_3	R =	·006	P_1	R =	·134	μ_2	R =	·078	$(M_2K_1)_3$	R =	·022
	ζ =	2°·77		ζ =	153°·01		ζ =	292°·02		ζ =	151°·13
	H =	·006		H =	·134		H =	·076		H =	·022
	κ =	6°·39		κ =	322°·59		κ =	296°·85		κ =	352°·68
M_4	R =	·025	J_1	R =	·037	R_2	R =	...	$(2M_2K_1)_3$	R =	·007
	ζ =	100°·94		ζ =	181°·24		ζ =	...		ζ =	351°·74
	H =	·025		H =	·038		H =	...		H =	·007
	κ =	105°·76		κ =	330°·35		κ =	...		κ =	157°·43

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·010	0°·55	·010	306°·36
" Fortnightly "	·045	155·76	·050	19·95
Luni-Solar " "	·007	315·37	·007	312·96
Solar-Annual "	·166	241·59	·166	162·01
" Semi-Annual "	·140	322·93	·140	163·78

17. The computations for each tidal station commence on 1st January, except for Aden, where they commence on February 15th, and for Porbandar, where they commence on 15th January.

18. The present state of the tidal computations is shown in the following table, together with their state at the end of September 1900. The letters A. P. in this table indicate that the actual times and heights of high and low-water have been measured either from the tidal diagrams or graduated staves, and compared with their predicted values published in the Tide-Tables.

The actual amount of work done during the year under report can thus be seen at a glance.

State of the ordinary reductions of the yearly Tidal registrations at the beginning and end of the Survey year 1900-1901.

Tidal Observatory.		State at end of September 1900.	State at end of September 1901.
Suez		1899 calculations completed. A. P. 1899.	1900 calculations completed. A. P. 1900.
Perim		1899 calculations completed.	1900 calculations completed. A. P. 1900.
Aden		1899 calculations completed. A. P. 1899.	1900-1901 calculations completed. A. P. 1900.
Bushire		1899 calculations completed. A. P. 1899.	1900 calculations completed. A. P. 1900.
Karáchi		1899 calculations completed. A. P. 1899.	1900 calculations completed. A. P. 1900.
Porbandar		1899 observations rejected. A. P. 1899.	1900-1901 calculations completed. A. P. 1900.
Port Albert Victor (started 31st December 1899).		Newly started observatory. No diagrams read.	1900 calculations completed. A. P. 1900.
Bhávnagar		A. P. 1899.	A. P. 1900.
Bombay	Apollo Bandar	1899 calculations completed. A. P. 1899.	1900 calculations completed. A. P. 1900.
	Prince's-Dock.	1899 calculations completed. A. P. 1899.	1900 calculations completed. A. P. 1900.
Tuticorin		A. P. 1899	A. P. 1900.
Madras		1899 calculations completed. A. P. 1899.	1900 calculations completed. A. P. 1900.
Kidderpore		1899 calculations completed. A. P. 1899.	1900 calculations completed. A. P. 1900.
Chittagong		A. P. 1899	A. P. 1900.
Akyab		A. P. 1899	A. P. 1900.
Diamond Island (closed 4th December 1899).		1898-99 calculations completed. A. P. 1899.	
Rangoon		1899 calculations completed. A. P. 1899.	1900 calculations completed. A. P. 1900.
Moulmein		A. P. 1899.	A. P. 1900.
Port Blair		1899 calculations completed. A P. 1899.	1900 calculations completed. A. P. 1900.

19. In addition to the computations enumerated in the foregoing table, reports on the operations carried on in the Bombay Presidency, at Suez, and in Burma, were prepared and submitted, the first two to the Local Governments and the last to the Port Officer, Rangoon, at the request of the Burma Government.

20. No completed tidal diagrams nor duplicate volumes of the daily reports appertaining to them were sent for safe custody to the Surveyor General's Office, Calcutta, during the year.

The Tide-Tables.

21. The routine in connection with the issue of Tide-Tables for 1901 was gone through; they were received in this office in three instalments from London, on the 5th and 21st December 1900 and on the 5th Jannary 1901, and were at once distributed.

22. The usual work in connection with the preparation of the Tide-Tables for 1902 has been satisfactorily gone through; they will contain predictions of high and low-water times and heights for 39 ports.

The datum for the Tide-Tables for 1902 is the datum of soundings of the latest Admiralty Charts. Tables giving particulars of the datum at each tidal station will be found in the appendix to the General Reports for 1891-92, 1893-1894, 1895-96 and in paragraph 24 of the annual report for 1898-99. For Porbandar this datum is 21·80 feet below the bench-mark of reference, which is a Marine Survey bench-mark 𐊒 cut on the south face of the sea-wall. It is also 2·03 feet below "Indian Spring low-water mark."

23. The amount realised on the sale of Tide-Tables in the financial year 1900-01 is R1,314-4-7 or about R233 in excess of the amount realised in the preceding year. The presentation copies of the Tide-Tables for 1901 were distributed in strict accordance with the lists sanctioned by Government.

24. Mr. Roberts was furnished as usual with the following:—

(i) Values of the constants for the Tide-Tables for 1902 calculated in the usual manner and ready for use in the tide-predictor.

(ii) Actual values during 1900 of every high and low-water measured in duplicate from the tidal diagrams at 13 stations, and of tide-pole observations taken during daylight at five closed stations under the supervision of the Port Officers and supplied to my office.

(iii) Comparisons of the above with predicted values for 1900, the errors being tabulated in a convenient form to help Mr. Roberts in improving the predictions.

25. The usual tabular statements Nos. 1 to 5 are appended, showing the percentage and the amount of errors in the predicted times and heights of high and low-water for the year 1900 at 18 stations, as determined by comparison of the predictions given in the Tide-Tables with actual values measured from the tidal diagrams at 13 stations, and from tide-poles at five stations; the former being made by assistants in this office and the latter by Port Officers' subordinates.

No. 1.

Statement showing the percentage and the amount of the errors in the peredicted times of High Water at the various Tidal Stations for the year 1900.

Stations.	Automatic or tide-pole observations.	Number of comparisons between actual and predicted values.	Errors of 5 minutes and under.	Errors over 5 minutes and under 15 minutes.	Errors over 15 minutes and under 20 minutes.	Errors over 20 minutes and under 30 minutes.	Errors over 30 minutes.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Suez	Au.	702	26	39	13	14	8
Perim	Au.	676	31	40	9	13	7
Aden	Au.	622	40	45	9	4	2
Bushire	Au.	703*	26	39	12	11	9
Karáchi	Au.	701	38	43	8	8	3
Porbandar	Au.	678	10	24	14	24	28
Port Albert Victor	Au.	684	21	40	13	16	10
Bhávnagar	T. P.	273	58	39	2	1	0
Bombay { Apollo Bandar	Au.	704	36	44	10	8	2
Bombay { Prince's Dock	Au.	703	39	42	9	8	2
Tuticorin	T P.	137	99	0	0	0	1
Madras	Au.	704	6	17	12	30	35
Kidderpore	Au.	704	22	35	15	20	8
Chittagong	T. P.	367	7	47	14	14	18
Akyab	T. P.	365	92	8	0	0	0
Rangoon	Au.	703	24	36	14	18	8
Moulmein	T. P.	350	74	22	3	1	0
Port Blair	Au.	701	37	46	11	5	1

* Including 23 comparisons which gave no definite results owing in some cases to the peculiarity of the tide-curve being such as to show no definite high water, and in some cases to the prediction showing there would be no high water, when a high water actually occurred.

No. 2.

Statement showing the percentage and the amount of the errors in the predicted times of low water at the various Tidal Stations for the year 1900.

Stations.	Automatic or tide-pole observations.	Number of comparisons between actual and predicted values.	Errors of 5 minutes and under.	Errors over 5 minutes and under 15 minutes.	Errors over 15 minutes and under 20 minutes.	Errors over 20 minutes and under 30 minutes.	Errors over 30 minutes.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Suez . . .	Au.	704	27	40	12	12	9
Perim . . .	Au.	672	23	41	12	15	9
Aden . . .	Au.	624	43	38	10	5	4
Bushire . . .	Au.	705*	8	19	10	18	39
Karáchi . . .	Au.	703	32	45	10	9	4
Porbandar . .	Au.	684	23	37	12	17	11
Port Albert Victor .	Au.	681	23	32	13	15	17
Bhávnagar . .	T. P.	273	37	49	5	5	4
Bombay { Apollo Bandar	Au.	705	25	36	17	16	6
Bombay { Prince's Dock	Au.	704	35	41	12	10	2
Tuticorin . .	T. P.	149	98	1	1	0	0
Madras . . .	Au.	705	3	7	7	22	61
Kidderpore . .	Au.	706	25	37	12	15	11
Chittagong . .	T. P.	365	9	42	16	18	15
Akyab . . .	T. P	365	53	47	0	0	0
Rangoon . .	Au.	705	23	38	13	18	8
Moulmein . .	T. P.	343	50	32	8	6	4
Port Blair . .	Au.	696	36	42	11	9	2

* Including 43 comparisons which gave no definite results owing in some cases to the peculiarity of the tide curve being such as to show no definite low water, and in some cases to the prediction showing there would be no low water, when a low water actually occurred.

No. 3.

Statement showing the percentage and the amount of the errors in the predicted heights of High Water at the various Tidal Stations for the year 1900.

Stations.	Automatic or tide-pole observations.	Number of comparisons between actual and predicted values.	Mean range at springs in feet.	Errors of 4 inches and under.	Errors over 4 inches and under 8 inches.	Errors over 8 inches and under 12 inches.	Error over 12 inchs.
			Per cent	Per cent.	Per cent.	Per cent.	Per cent.
Suez . . .	Au.	702	5·5	65	24	10	1
Perim . . .	Au.	676	5·6	94	6	0	0
Aden . . .	Au.	622	6·7	96	4	0	0
Bushire . . .	Au.	703*	4·8	61	22	9	5
Karáchi . . .	Au.	701	9·3	81	17	2	0
Porbandar . .	Au.	678	6·0	47	29	20	4
Port Albert Victor .	Au.	684	11·9	57	28	13	2
Bhávnagar . .	T. P.	273	31·4	58	27	7	8
Bombay { Apollo Bandar	Au.	704	13·9	72	24	4	0
Bombay { Prince's Dock	Au.	703	13·9	67	27	6	0
Tuticorin . .	T. P.	137	3·2	100	0	0	0
Madras . . .	Au.	704	3·5	91	9	0	0
Kidderpore . .	Au.	704	11·7	31	26	16	27
Chittagong . .	T. P.	367	13·3	42	29	17	12
Akyab . .	T. P.	365	8·3	85	14	1	0
Rangoon . .	Au.	703	16·4	53	30	13	4
Moulmein . .	T. P.	350	12·7	43	26	16	15
Port Blair . .	Au.	701	6·6	97	3	0	0

* Including 23 comparisons which gave no definite results owing in some cases to the peculiarity of the tide curve being such as to show no definite high water, and in some cases to the prediction showing there would be no high water, when a high water actually occurred.

No. 4.

Statement showing the percentage and the amount of the errors in the predicted heights of Low Water at the various Tidal Stations for the year 1900.

Stations.	Automatic or tide-pole observations.	Number of comparisons between actual and predicted values.	Mean range at springs in feet.	Errors of 4 inches and under.	Errors over 4 inches and under 8 inches.	Errors over 8 inches and under 12 inches.	Errors over 12 inches.
				Per cent.	Per cent.	Per cent.	Per cent.
Suez	Au.	704	5·5	61	29	8	2
Perim	Au.	672	5·6	93	7	0	0
Aden	Au.	624	6·7	96	4	0	0
Bushire	Au.	705*	4·8	55	28	7	4
Karáchi	Au.	703	9·3	68	29	3	0
Porbandar . . .	Au.	684	6·0	9	22	24	45
Port Albert Victor .	Au.	681	11·9	55	30	12	3
Bhávnagar	T.P.	273	31·4	69	15	6	10
Bombay { Apollo Bandar	Au.	705	13·9	69	25	6	0
Bombay { Prince's Dock	Au.	704	13·9	64	27	8	1
Tuticorin . . .	T.P.	149	3·2	100	0	0	0
Madras . . .	Au.	705	3·5	90	10	0	0
Kidderpore . . .	Au.	705	11·7	40	24	13	23
Chittagong . . .	T.P.	365	13·3	55	25	13	7
Akyab . . .	T.P.	365	8·3	83	16	1	0
Rangoon . . .	Au.	705	16·4	28	22	20	30
Moulmein . . .	T.P.	343	12·7	40	25	13	22
Port Blair . . .	Au.	696	6·6	98	2	0	0

* Including 43 comparisons which gave no definite results owing in some cases to the peculiarity of the tide curve being such as to show no definite low water, and in some cases to the prediction showing there would be no low water, when a low water actually occurred.

No. 5.

Table of average errors in the predicted times and heights of High and Low Water at the several Tidal Stations for the year 1900.

Stations.	Automatic or tide-pole observations.	Mean range at springs in feet.	Average Errors: Of time in minutes.		Of height in terms of the range.		Of height in inches.	
			H. W.	L. W.	H. W.	L. W.	H. W.	L. W.
Open coast.								
Suez	Au.	5·5	14	14	·061	·061	4	4
Perim	Au.	5·6	13	14	·030	·030	2	2
Aden	Au.	6·7	9	9	·025	·025	2	2
Bushire	Au.	4·8	14	29	·087	·069	5	4
Karáchi	Au.	9·3	10	11	·027	·036	3	4
Porbandar . . .	Au.	6·0	23	16	·069	·167	5	12
Port Albert Victor . .	Au.	11·9	16	19	·035	·035	5	5
Bhávnagar . . .	T.P.	31·4	6	9	·013	·013	5	5
Bombay { Apollo Bandar	Au.	13·9	10	14	·018	·024	3	4
Bombay { Prince's Dock	Au.	13·9	9	10	·024	·024	4	4
Tuticorin	T.P.	3·2	2	2	·026	·052	1	2
Madras	Au.	3·5	26	34	·048	·048	2	2
Akyab	T.P.	8·3	2	5	·020	·030	2	3
Port Blair	Au.	6·6	9	10	·025	·025	2	2
General mean		...	12	14	·036	·046	...	...
Riverain.								
Kidderpore	Au.	11·7	15	15	·071	·071	10	10
Chittagong	T.P.	13·3	20	19	·044	·031	7	5
Rangoon	Au.	16·4	14	14	·025	·051	5	10
Moulmein	T.P.	12·7	3	7	·046	·052	8	8
General mean		...	13	14	·047	·051	...	...

The following statements for the year 1900 may be thus summarised :—

Percentage of time predictions within 15 minutes of actuals.

		High water. Per cent.	Low water. Per cent.
Open coast stations.	11 at which predictions were tested by S. R. Tide-gauge	66	60
	3 „ „ „ Tide-pole	99	95
Riverain stations.	2 „ „ „ S. R. Tide-gauge	59	62
	2 „ „ „ Tide-pole	75	67

Percentage of height predictions within 8 inches of actuals.

		High water. Per cent.	Low water. Per cent.
Open coast stations.	11 at which predictions were tested by S. R. Tide-gauge	93	88
	3 „ „ „ Tide-pole	95	94
Riverain stations.	2 „ „ „ S. R. Tide-gauge	70	57
	2 „ „ „ Tide-pole	70	73

Percentage of height predictions within one-tenth of mean range at springs.

		High water. Per cent.	Low water. Per cent.
Open coast stations.	11 at which predictions were tested by S. R. Tide-gauge	93	89
	3 „ „ „ Tide-pole	100	100
Riverain stations.	2 „ „ „ S. R. Tide-gauge	89	87
	2 „ „ „ Tide-pole	95	92

26. In the above summary the tests are of two classes, the first and more accurate class being that made by means of self-registering tide-gauges, and the second by means of tide-poles. Height measurements, except in rough weather, can be accurately taken from a tide-pole, but for the corresponding time readings, owing to the chance of inaccuracy of the time locally kept, a considerable margin for error must be allowed.

27. The predictions at the riverain stations for the year 1900, as compared with those of last year, were about the same at Kidderpore and Rangoon, slightly inferior in times but better in heights at Chittagong, and improved all round at Moulmein.

At Kidderpore the greatest difference between the actual and predicted heights of low-water was 5 feet 6 inches on the 25th and 26th September 1900, the actual being in excess. This tremendous difference is undoubtedly due to the abnormally heavy rainfall at that time of the year, when Calcutta received nearly 40 inches of rain between the 19th and 25th September.

At Chittagong the greatest difference between the actual and predicted heights of low-water was 2 feet 1 inch during the month of September 1900, the actual height being in excess.

At Rangoon the greatest difference between the actual and predicted heights of low-water was 2 feet 7 inches in November 1900, the actual being in defect of the predicted height.

At Moulmein the greatest difference between the actual and predicted heights of low-water was 3 feet in August 1900, the actual height being in defect.

28. In the following tables will be found the average percentage of error for the past 10 years in predicted times and heights of high and low-water at stations where automatic observations have been made.

Percentage of error in predicted times and heights at open Coast Stations from automatic observations.

Year.	Number of stations.	In time.		In height.			
		Within 15 minutes of actuals.		Within 8 inches of actuals.		Within $\frac{1}{10}$th of mean range at springs.	
		H. W.	L. W.	H. W.	L. W.	H. W.	L. W.
1891	10	74	73	94	87	98	97
1892	8	75	74	91	85	98	98
1893	9	73	68	93	98	96	95
1894	10	65	62	95	92	97	95
1895	9	68	65	98	97	94	94
1896	9	71	70	97	97	97	93
1897	8	71	75	96	97	97	97
1898	9	74	70	96	96	95	95
1899	9	74	66	95	95	93	92
1900	11	66	60	93	88	93	89
Average of 10 years	9	71	68	95	93	96	95

Percentage of error in predicted times and heights at riverain stations from automatic observations.

Year.	Number of stations.	In time.		In height.			
		Within 15 minutes. of actuals.		Within 8 inches of actuals.		Within $\frac{1}{10}$ of mean range at springs.	
		H. W.	L. W.	H. W.	L. W.	H. W.	L. W.
1891	3	64	58	66	66	92	92
1892	2	61	60	72	65	94	95
1893	2	57	57	68	50	89	84
1894	2	56	55	66	42	88	80
1895	2	59	55	74	47	94	84
1896	2	56	55	63	42	87	74
1897	2	59	61	75	57	96	91
1898	2	53	59	71	61	90	91
1899	2	55	59	76	65	95	94
1900	2	59	62	70	57	89	87
Average of 10 years.	2	58	58	70	55	91	87

29. With reference to paragraph 49 of last year's annual report, it may be mentioned that none of the closed ports were visited for the purpose of ascertaining whether predictions still held good.

Bench-Marks.

30. The bench-marks of reference at the tidal stations still working were found undisturbed and in good order, except at Suez, where, owing to alterations made to the verandah of the Director of the Port's residence, G.T.S. □ B-M A, one of the bench-marks of reference, was removed.

Levelling Operations.

31. The Levelling Detachment was again employed on the Eastern Bengal State Railway.

32. The *personnel* of the Detachment is shown in the margin. Mr. Barker held charge of the Detachment till 22nd December 1900, when he made over to Mr. Corridon, who has remained in charge since.

Mr. J. P. Barker, Mr. E. H. Corridon, Munshi Syed Zille Hasnain.
Recorders—Sitaram Yeshwant; Balwant Atmaram and Rikhi Ram. Gopal Singh employed during recess.

33. I personally conducted the work of levelling across the Ganges river. This comprised the taking of observations to determine the relative values of bench-marks embedded on opposite banks of the river. The difference in height between these bench-marks was obtained by three different methods giving the following results with their probable errors :—

(i) By vertical angles taken simultaneously by two observers working with 24-inch theodolites on opposite banks	Difference in height = 2·139 feet. Probable error = ±0·005 foot.
(ii) By simultaneous observations to disc signals with standard levels set up on opposite banks	Difference in height = 2·132 feet. Probable error = ±0·016 foot.
(iii) By simultaneous readings of the height of the water on graduated staves attached to piles driven near the edge of the water on opposite banks	Difference in height = 2·211 feet. Probable error = ±0·001 foot.

34. The distance between the bench-marks was 1·28 miles. A detailed account of the river crossing operations will be published in one of the "Professional Papers of the Survey of India." After the operations connected with the crossing of the Ganges river had been completed, regular levelling work was resumed along the line to Siliguri. The total rises and falls amounted to 1,954 feet and the outturn of work to 211 miles, in the course of which the instruments were set up at 2,558 stations. The heights of 26 embedded and 86 inscribed bench-marks were determined. One Great Trigonometrical Survey station and one Railway bench-mark were also connected.

Connection at Parbatipur was made with the single-levelling operations of the previous season.

Owing to the great heat experienced in the latter months of the season and the malarious nature of the Tista valley generally, the health of the Detachment was so seriously affected that the work had to be closed at Siliguri on the 27th April 1901, and connection with the Sonakhoda base-line postponed to nex season.

35. The Detachment left recess quarters, Dehra Dún, for the field on the 26th October 1900. The field season closed on the 27th April 1901. During next field season the Sonakhoda base-line will be connected, and levelling operations will be carried on from Parbatipur up the Brahmaputra river and thence towards Assam.

36. I append the usual tabular statement of the outturn of levelling, also the following tables :—

Table B, giving the Great Trigonometrical Survey station connected, and error in the original height.

Table C, giving the comparisons of the levelling staves with a 10-foot portable standard bar.

H. L. CROSTHWAIT, Captain, *R.E.*

A

Tabular statement of outturn of work for the field season, 1900-1901.

Section.	During the month of	Number of miles, double levelling. Main line. M.	C.	L.	Branch line. M.	C.	L.	Total number of feet. Rise.	Fall.	Number of stations at which instrument was set up.	Number of bench-marks connected. Reference.	Old.	Embedded.	Inscribed.	G. T. Survey.	Railway.	Public Works Department.	Irrigation.
Damukdia to Siliguri.	November 1900	0	28	4	4	46	48	1·985	0·577	98	...	2	...	...	...	1	...	...
	December "	20	8	48	5	15	34	80·717	75·811	286	...	...	9	7	...	...	...	...
	January 1901	41	51	8	0	7	30	241·429	226·798	511	...	...	4	19	...	...	...	...
	February "	44	32	10	0	5	10	138·029	97·872	508	...	...	4	20	...	...	...	...
	March "	52	30	60	0	74	88	358·923	246·855	645	...	1	5	22	...	...	...	...
	April "	39	0	21	2	21	84	328·462	156·456	510	...	...	4	18	1	...	...	...
	TOTAL	197	70	51	13	10	94	1149·545	804·369	2,558	...	3	26	86	1	1	...	...

TABLE B.

List of Great Trigonometrical Survey Principal stations connected by Spirit-levelling.—Season 1900-1901.

NAME OF STATION.	HEIGHT IN FEET ABOVE MEAN SEA-LEVEL.		Error of height by triangulation in feet.	REMARKS.
	By spirit-levelling.	By triangulation.		
Chilaháti T. S. of the Assam Longitudinal Series.	216·7	219·7	+3	The height refers to the lower mark, the tower being entirely destroyed.

TABLE C.

Results of comparison of staves.—Season, 1900-1901.

PLACE AND DATE OF COMPARISON.	DIFFERENCE OF LENGTH OF STAFF FROM 10 FEET.					REMARKS.
	Staff, B 1.	Staff, B 2.	Staff, No. 4.	Staff, No. 13.	Staff, IIII	
Damukdia, 9th November 1900.	+·003984	+·001744	+·001817	+·003225	+·004100	Staff IIII was rejected after the first eight miles.
Jaipur, 10th February 1901.	+·002910	+·000193	+·001264	+·000969	...	
Siliguri, 26th April 1901	+·001525	—·001001	—·000201	—·000254	...	

VII

TOPOGRAPHICAL SURVEYS IN BURMA.

Extracted from the Narrative Report of Captain F. W. Pirrie, I.S.C., in charge of No. 10 Party, Survey of India.

* * * * * *

(WORK BASED ON COMPILATIONS FROM PREVIOUS CADASTRAL SURVEYS.)

5. *Cadastral Survey Details.*—The cadastral surveys of the 3 districts are not consistent as regards the amount and correctness of the topographical detail shewn on the 1-inch reductions. The main streams and roads were always correct, but in hilly ground the small streams were often incorrect. In the Magwe district some attempt had been made to contour the hills, but they were not correctly shewn. In the Meiktila district the broken nature of the country was fairly well shewn, but the hills were not shewn at all. In the Yamethin district neither the hills were shewn nor the broken nature of the country. From this it is evident that, unless a competent topographical staff is attached to a revenue party, they should not attempt to contour the hills, or shew broken ground, other than in a purely conventional manner, or the maps will be misleading to the public. The word "hills," if it were not generally omitted in the cadastral reductions where hills exist, would be a sufficient guide to the topographical party taking up the revision survey.

* * * * *

7. *General procedure.*—The usual methods of survey in use in topographical parties were followed in the hilly open ground, *viz.*, plane-table interpolation and sketching in the minor detail where possible; but where the view was obstructed by jungle, or the course of streams was impossible to make out from a distance, plane-table traverse, and measurements by chain and pace traverse, had to be resorted to.

Time traverse.—Where the ground was free from undergrowth in the forests in the Tagaung sub-division of the Ruby Mines district a good deal of useful work was done by means of time traverses, working on a compass bearing between plane-table fixings.

Shifting of graticules.—Owing to the recent Great Trigonometrical triangulation on which the topographical survey of Upper Burma is based, it is found that, where the revenue maps are based on the Latitude and Longitude of old topographical stations, the whole of the revenue work requires to be shifted in Latitude and Longitude to make it agree with the new positions of these old topographical stations. For instance, the coordinates of Kyaukse h. s., which was the origin of old revenue traverses in that part of Upper Burma, being a station of the old topographical survey executed before the completion of the Great Trigonometrical series, are $\lambda\ 21^\circ-36'-10{\cdot}65''$ L $96^\circ-11'-23{\cdot}51''$, and the new values of the same station deduced from the Great Trigonometrical triangulation are $\lambda\ 21^\circ-36'-5{\cdot}89''$ L $96^\circ-11'-22{\cdot}89''$, which shews a difference of $4{\cdot}76''$ in λ and $0{\cdot}62''$ in L. This necessitates a shift of the entire revenue work based on the old value of Kyaukse h. s. It is found that the general shift is about the same. From this it was decided to check the position of the revenue work on each plane-table as the survey was taken up, and, where found out of position, a new graticule was drawn, and the triangulation stations and points re-plotted. It has been found that the revenue work in Kyaukse and part of Meiktila district required shifting; but in Yamethin, where the revenue traverses were based on Great Trigonometrical triangulation no shifting of the work was required.

Actual method of working.—The actual method of survey is as follows:—

Ferrotype prints of reductions to 1-inch of the revenue maps were obtained and various methods of using them for actual working on in the field were tried but owing to the fact that they were printed on separate pieces of paper and afterwards joined up to form standard sheets, they had some contracted in one way and some in another, so that when the triangulation points were plotted fixings did not come near the proper point on the blue print, and errors innumerable were introduced. Then it was tried to paste down the revenue reductions on a plane-table, and afterwards plot the triangulation points, but this was found unsuitable owing to the fact that the bank post paper expanded on being wetted and refused subsequently to contract, in spite of a hot iron and other methods being used to induce it to do so. Finally it was decided that the only way was to transfer the whole of the work taken from the revenue reduction in blue to the plane-table.

Clinometer.—Owing to the slight difference of the relative heights of the ground the utmost care had to be taken to see that the clinometers in possession of the sub-surveyors were in perfect adjustment, before they left the field base, and they were tested at intervals throughout the field season by the section officers.

Contouring scale.—A contouring scale was issued to each sub-surveyor with a graphic refraction and curvature scale added, calculated for mean refraction; this saved time in consulting tables which are liable to be lost in the field. As an extra precaution this graphic scale was also plotted on the edge of the plane tables.

Height computations.—A new form of height computation was introduced; this avoided to a certain extent algebraical adding and subtracting which have given great difficulty among sub-surveyors hitherto. Great care was taken both by the officer in charge and his assistants to see that the clinometer height computations were thoroughly understood by members of the party.

Sub-surveyors were ordered to take up the revision of each 5 minute section in succession. This was found impossible in a few isolated cases owing to the absence of communications between the various portions of the ground under revision, but as a general rule was found good as it insured the work being thoroughly done.

Sub-surveyors were ordered on arriving on their ground to visit as many revenue traverse stations and village trijunctions shewn both on the ground and on their plane-tables as possible, and to fix their position by plane-table interpolation from at least 3 (if possible) triangulated points.

If the revenue trijunctions and traverse stations were found out of position by plane-tablers they had orders to report the matter at once to their section officer before continuing the revision.

The section officer on finding the revenue work on the surveyors plane-table out of position by investigation on the ground, would ascertain the general shift to be made in Latitude and Longitude and plot a new graticule, and the triangulation stations and points in red, on the plane-table.

When the position of the revenue work was found correct by the plane-tabler he continued his survey.

From the triangulation points plotted on the plane-tables for next season's revision survey it is seen that there is a general slight shift in the Magwe district, as several pagodas have been refixed by the triangulator which are already shewn on the revenue reduction. Pagodas cannot, however, always be depended on, as they are generally built in groups and added to yearly.

Again village trijunctions and revenue traverse stations might be connected with triangulation stations by traverse, which would obtain the shift as far as the individual traverse station was concerned; but even if this were done on level ground, it would not be suitable where the ground was broken or hilly, and would not be so practically useful as the method in use in the party, except in isolated cases where interpolation is impossible and would involve computations in the field.

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F. W. PIRRIE, CAPTAIN, *I.S.C.*

G. I. C. P. O.—No. 205 S. G.—7-8-1903.—250.—C. T.

EXTRACTS

FROM

NARRATIVE REPORTS

OF THE

Survey of India

FOR THE SEASON

1900-1901.

PREPARED UNDER THE DIRECTION OF

COLONEL ST. G. C. GORE, C.S.I., R.E.,
SURVEYOR GENERAL OF INDIA.

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