Survey of India.

EXTRACTS

FROM

NARRATIVE REPORTS

FOR THE SEASON

1902-1903.

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FROM

NARRATIVE REPORTS

OF THE

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FOR THE SEASON

1902-03.

PREPARED UNDER THE DIRECTION OF

LIEUT.-COLONEL F. B. LONGE, R.E.,
SURVEYOR GENERAL OF INDIA.

CONTENTS.

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CONTENTS.

I

TRIANGULATION IN UPPER BURMA.

Extracted from the Narrative Report of Captain H. Wood, R.E., in charge of No. 24 Survey Party (Triangulation) for Season 1902-1903.

The programme was to continue eastwards the Great Salween Series which had been started 2 years previously by Captain Turner, R.E.

On the 7th November the party at full strength embarked at Calcutta for Rangoon, from whence it proceeded by train to Sagaing. Here the advance parties were despatched *viâ* Bhamo to begin building stations for the principal series, while Captain Wood and Lieutenant Tillard were employed in observing simultaneous vertical angles from 2 stations, one on either bank of the Irrawaddy river, for the purpose of obtaining the difference in height between them for the use of the Levelling Detachment of No. 25 Party.

Vertical angles were measured with the 12-inch theodolites on 4 consecutive days (12 sets being taken daily) at the time of minimum refraction. A base was measured on the river bank and the distance between the 2 selected stations obtained by triangulation.

Bhamo was reached on November 29th and observations were commenced at the first station on December 6th. The weather caused some slight delay at the commencement of the work, but was afterwards favourable and the haze did not stop the work till 12th March; by that time 2 figures had been completed and a large proportion of the angles of the next figure, a compound one, measured.

The party reassembled at Lashio on March 23rd and travelling *viâ* Rangoon and Calcutta, reached Mussooree, the recess quarters, on April 16th.

Observations were taken with Troughton and Simms No. II Theodolite on the usual 12 zeros with 4 to 8 observations per zero.

The new repeating zero circle was employed for the first time with this instrument and the results, if the very favourable triangular error can be considered due to this cause, were most satisfactory.

At the beginning of the season 4 consecutive measures (two on each face) were made on each zero. If these 4 did not agree within 1·5 seconds more measures were made. Later, when the weather got finer and larger proportions of helio measures were feasible, the following order of measurements was made. First, 2 consecutive measures were taken (one on each face) on each zero. After completing the zeros 2 more measures were made per zero in the reverse order [*i.e.*, if the first set were (I) swing right on Face Right, (II) swing left Face Left, the second set would be taken swing right Face Left, swing left Face Right], and if the first set on any zero were taken to lamps, the second set on that zero would be taken to helios and *vice versâ*. If the 4 measures obtained in this way per zero did not agree within 1·5 seconds, extra measures were made but never more than two (one on each face) at the same time. Endeavours were always made to make these repeat observations under different conditions, *i.e.*, if the first set were lamp measures and made before midnight one of the repeat sets would be, if possible, taken after that hour, while if the first set were helios and made in the morning, the next would be taken in the afternoon. By these means every set was taken under as different conditions as possible. The triangular error of the 3 triangles completely measured under this system was only 0″·16; the error of 4 triangles completely measured under the old system being 0″·25; while the error of 5 triangles measured partly under one and partly under the other was 0″·69. The weather during the first and second groups mentioned above was good, that during the last not so favourable and the error is probably principally due to that generated at the centre station (which affects all 5 triangles) as the weather was very bad while working there, and two out of the five rays passed only about 80 feet clear of intervening hills. In the only 2 triangles which were not affected by these bad rays the error was in both cases only 0·38, while in the 3 triangles affected they were ·86, ·85, ·95.

It is hardly fair to judge the value of this method of observing by such a small trial, but no other reason can be assigned to the more favourable results unless it be due to this cause.

An astronomical azimuth was observed at one station. The method recommended in the new edition of the Hand-book, of employing 4 circumpolar stars in lieu of two, was employed and the results computed on the new azimuth forms. This form simplifies the computations a great deal and the time required is only about ⅓ of that taken under the old methods.

The results of the computations were as below :—

Eastern Elongation.		Western Elongation.	
Star.	Azimuth.	Star.	Azimuth.
B. A. C. 4165 . .	188°—35′—41″·77	B. A. C. 8213 . .	188°—35′—42″·65
B. A. C. 5140 . .	41″·74	Polaris . . .	42″·37
Mean . . .	188°—35′—41″·76	Mean . . .	188°—35′—42″·51
Correction for Diurnal Aberration.	+ ·32	Correction for Diurnal Aberration.	+ ·32
Corrected Mean .	188°—35′—42″·08	Corrected Mean .	188°—35′—42″·83

The difference between observed and computed results is—7″·29.

In addition to the principal work 19 hill peaks were fixed by means of intersections, many of these being stations of the Topographical parties that have been surveying this part of the country.

During the recess the computations were all completed and the observations made during the field season discussed to discover whether the graduation error of theodolite No. II has been improved by its numerous journeys to Messrs. Troughton and Simms for redivision.

Judging from the vastly improved triangular error given by this season's work to those obtained previously and to inspection of the accordance of the zero means, it would appear that the recent regraduation is an improvement on the old one, but the use of the zero circle this year introduces a doubt as to whether the improvement may not be more due to it than to the regraduation. It was intended to discuss the results of last season's work by the method of minimum squares, but the early date on which the recess office was closed prevented this; it is hoped, however, that there will be sufficient time during next recess to do this, and also to compare the present errors with those obtained from work done by the Theodolite before its regraduation, and those from the secondary triangulation executed in the season 1900-1901 after its regraduation but when it was used without the zero circle.

The season's outturn of work was as follows:—

Principal Triangulation (Captain Wood).

Number of stations newly fixed	10
Number of figures completed	2
Length of series completed, in miles	80
Area of triangulation, in square miles	3,310
Number of stations at which astronomical azimuths were observed	1
Mean triangular error (12 triangles)	0·408

Secondary Triangulation for fixing Eagles Nest point at Mussooree (Captain Wood and Lieutenant Tillard).

Number of stations newly fixed	3
Number of figures completed	1
Length of series completed, in miles	10
Area of triangulation, in square miles	120
Number of stations at which astronomical azimuths were observed	1
Mean triangular error (7 triangles)	1·444

II

TOPOGRAPHICAL SURVEYS IN UPPER BURMA.

Extracted from the Narrative Report of Captain F. W. Pirrie, I.A., in charge of No. 10 Party, Survey of India, Season 1902-03.

Introduction.

The work of the party was of a similar nature to that of the previous four seasons and consisted of Topographical survey on the scale of one inch to a mile, and supplementary Topographical survey on the same scale on the ground previously cadastrally surveyed on the scale of 16 inches to a mile.

The work fell in parts of the districts of Meiktila, Myingyan, Kyauksè, Sagaing, Pakôkku, Magwe and Minbu.

Towards the close of the field season additions to the map of Maymyo on the scale of 16 inches to a mile were carried out and the map generally brought up to date for a second edition.

Triangulation for future Topographical and Forest Surveys was carried out in the districts of Sagaing, Myingyan, Shwebo and Lower and Upper Chindwin.

Owing to the country in the Shwebo and Lower Chindwin districts being unsuitable for triangulation in many places and being flatter than hitherto met with by the party in Burma, still greater care will be necessary in testing the clinometers and insisting on accurate heights.

This can best be done by theodolite height traverses between well fixed triangulation stations and points and the Great Trigonometrical bench-marks on the Mandalay-Katha railway which will be carried out by Assistants, and by sub-traverses run with plane table and clinometer by sub-surveyors connecting points already fixed by theodolite.

Data for calculating strength of Detachments on new detail and supplementary Topographical Survey on 1-inch scale.

It is found that where 1-inch reductions of the Cadastral Survey are available fewer triangulation points are required and the reductions add very much to the accuracy of the final maps when published but owing to the amount of detail to be examined in the field the reductions do not shorten the time required for the Topographical survey.

During a field season of six months from leaving recess quarters to returning there, one month approximately being taken up in the journey to and from the field—

An average surveyor can do $\frac{1}{3}$ of a sheet.

A Provincial officer can supervise, if he is not required to do plane-tabling himself, 3 standard sheets.

A Provincial officer, if required to do plane-tabling himself as well as supervision, can supervise 2 standard sheets.

The actual amount given to each sub-surveyor will vary according to the ground and his capabilities between $\frac{1}{6}$ to $\frac{1}{2}$ a standard sheet.

The instruments used were 6-inch transit theodolites by Troughton and Simms with two verniers reading to 10 seconds on both the horizontal and vertical circles.

Mr. P. J. Barrington part of sheets 192, 193, 194, 146, 147, 148.

Mr. P. J. Barrington extended the triangulation westward from the bases Malè-Lethataung Lethataung-Sheinmaga of the Mandalay Meridional principal series, but the country being nearly flat and covered with trees it was impossible to extend the triangulation beyond the eastern halves of 1-inch sheets 192, 193, 194, so Mr. Barrington extended the triangulation in a northerly direction from the base Twin-Thazi of the Mandalay Minor Longitudinal series which provided sufficient points in the western halves of 1-inch sheets 146 and 147.

Theodolite height traverses in western halves of 192, 193, 194, and eastern halves of 146 and 147.

This left a gap in the western halves of sheets 192, 193, 194 and the eastern halves of sheets 146 and 147 without points to assist the Topographical survey. After trying the bar subtense and other methods of fixing points it was found by Mr. Barrington that the only practicable method was to connect the triangulation stations already fixed by careful theodolite height traverses.

This method took a great deal of time and although a great many useful points were fixed by Mr. Barrington before he left the field they will have to be supplemented by the officers in charge of the detail survey.

Remarks regarding the country under survey.

The country topographically surveyed during the field season varied greatly in character.

Detail Survey Sheets 198, 199 and 151.

The ground was open and easy from a topographical point of view in the Myingyan, Meiktila, Sagaing, Kyauksè and Pakôkku districts.

Detail Survey Sheets 110, 111 and 112.

The ground was difficult in the Magwe district on account of the intricate and broken ground along the eastern bank of the Irrawaddy River, and in the Minbu district the view was much obstructed by large trees along the western bank of the Irrawaddy in the nearly flat ground and in the more hilly ground further west the ground was much broken and covered with forest.

Duration and close of the field season.

The Party left recess quarters for the field in two detachments on 29th October and 5th November, respectively, and rejoined there in various detachments between 30th April and 25th June.

Height Traverses in Sheets.

The height traverses carried out by Mr. P. J. Barrington were carefully done and by means of observation from Traverse stations many pagodas and other useful points were fixed by intersection which will be of immense assistance to the detail survey.

III

TOPOGRAPHICAL SURVEYS IN THE SHAN STATES.

Extracted from the Narrative Report of Mr. W. M. Kelly, in charge of Nos. 11 and 21 Parties, Season 1902-03.

The ground over which the triangulation was carried is for the most part covered with jungle, mountainous and very thinly populated. The heavy mist in the winter months and the haze in the spring hampered progress considerably.

The detail survey on the 1-inch scale was carried on in the Southern Shan States. It embraced portions of the states of Kēng Tung, Mōng Nawng, Kēng Hkam, Mōng Nai, Mōng Pan and Mawkmai.

The ground in sheet 510 with the exception of the cultivated plain of Mōng Pu, 5 to 6 square miles in area in the centre of the sheet, is one mass of jungle-clad, high hills.

The ground in sheet 511 is similar to that in 510 but contains more jungle and fewer villages. A quarter of the sheet was surveyed with assistance from the one village in it. The average is one village to 30 square miles.

Eastward from the Salween there is a very high wooded range which rises 5,000 feet from the valley of the river, it is difficult of ascent even along the main route between the towns of Mōng Pan and Mōng Tung; eastward of this high range is the Mōng Tung plateau (1,300 feet above the Salween). The only plain ground in the sheet is on this plateau and is cultivated. The country is thinly populated, the villages being on the average 11 miles apart.

The paucity of roads, the mists of winter and the haze of summer hindered the progress of the survey.

Sheet 444 contains a mass of hills covered with jungle. Beyond the Salween which enters the sheet at the south-east corner, rises a steep mountainous block of hills covered with jungle which were difficult to survey owing to lack of water and roads.

The narrow Nā-wan Valley is populous and cultivated, and is separated on the north-east from the Nampan Valley by a marsh a mile wide.

The remainder of the sheet, though very jungly, has its few hill-villages well scattered.

Sheet 389. Parallel ranges occupy the eastern half of the sheet. The hills in the western half are a series of ridges going every way and in many cases connected as they enclose drainage and valleys, they are jungle-clad, of about the same height and difficult of access and taxed the energies of the skilled surveyor employed on them.

With the exception of some well scattered villages over the hills the population is centred in the two valleys of Mawkmai and Wanhat which equally share the only plain ground in the sheet amounting to 30 or 40 square miles which is well cultivated. The survey of this sheet was much helped by the numerous roads that connected the well-scattered hill-villages. In this sheet there is on the average a village to every 4 square miles.

In sheet 513 which is a continuation of the ground described in sheet 512 above, an area of 70 square miles was completed. This was not in the season's programme, but was taken up as surveyors became available and were not required to assist the others in the completion of the allotted work.

IV

SURVEY OF THE SÁMBHAR LAKE.

Extracted from the Narrative Report of Lieutenant E. T. Rich, R. E., in charge No. 12 Party (Sind).

This survey was executed during the months of November and December 1902, and January, February and part of March 1903, for the Northern India Salt Revenue Authorities, in connection with the research by the Geological Survey into the sources of supply of water in the Sámbhar Salt Lake which lies in Rajputana in Latitude 27° N. and Longitude 75° E.

The survey consisted of a preliminary triangulation of the area to be surveyed followed by a detail survey on a scale of two inches to a mile, combined with a series of spirit levelled lines run along the edge of the lake, and across it in lines about two miles apart, and also a line as nearly as possible longitudinally along the centre of the lake.

In addition a short tertiary series of triangulation was afterwards run connecting up eight of the bench-marks on the edge of the lake with the stations in the preliminary triangulation.

The triangulation was extended east and west in a network across the lake from an old secondary base Mároth-Koharsina.

The instrument used was a Cooke's 6" Transit Theodolite with 3 verniers reading to 10 seconds. The angles to stations were observed on two zeros, with a change of face on each zero, *viz.* :—

F. L. 0°, F. R. 180°, F. L. 30°, F. R. 210°, and the angles to intersected points on one zero only with a change of face. The vertical angles were always observed about the time of minimum refraction, *viz.*, between 1-30 and 3-30 P.M., and always with both verniers, and one change of face to both stations and intersected points. All the observations to stations were taken to heliotropes except on two or three occasions when flags were used.

All the intersected points observed to were well defined objects such as trees, rocky spurs, roofs of huts, etc.

The sides of the triangles are mostly about 7 miles long with the exception of six, which have an average of 13 miles, the two longest sides being 16 miles each.

All the stations are marked by ⊙ either cut in the rock *in situ* or on big stones embedded at the station with the exception of the station on the roof of the Inspection Bungalow at Sámbhar where ⊙ is cut in the stone on the roof.

No platforms were built and no clearing was necessary except at the station sites, as the country round the lake is chiefly sand hills covered in places with low scrub.

The area of the triangulation is about 228 square miles ; 8 secondary stations and 1 tertiary station were observed at and 57 points were intersected.

The average difference per mile in common sides of triangles fixing stations was ·053 feet, and of those fixing intersected points, ·20 feet, and average differences in heights were for stations ·31 feet and intersected points, 2·47 feet. The data for the triangulation, *viz.*, for the stations Mároth and Koharsina were obtained from an old secondary series run when the 1-inch survey was done in 1865-1866.

Astronomical Observations.—Astronomical observations were taken at Sámbhar Station, and the latitude of Sámbhar and the azimuth Sámbhar-Koharsina were checked.

The results obtained were as follows :—

Latitude of Sámbhar.

By triangulation.	By Astronomical observation.
° ′ ″	° ′ ″
26-54-26·44	26-54-11·5

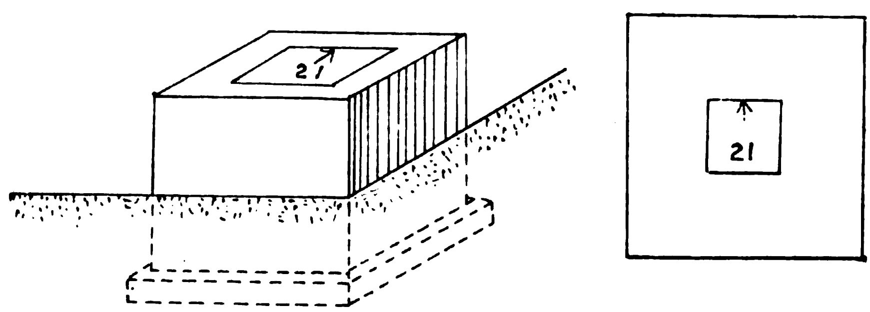
Difference 15 seconds.

Azimuth Sámbhar-Koharsina.

By triangulation.	By Astronomical observation.
° ′ ″	° ′ ″
84-20-19·56	84-19-57

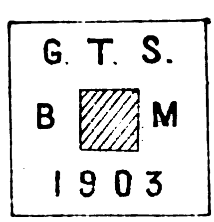
Difference 22 seconds.

Spirit Levelling.—Before the spirit levelling was commenced 21 bench-marks were built right round the lake about two miles apart, and two bench-marks were also built near the Julga lake which were connected with the lake levels. These bench-marks were all paka, built of rough stone and cement on a foundation of 3 inches of concrete. They were 18 inches square and 18 inches high with a dressed stone 6 inches square let into the top surface. This stone was marked with a broad arrow and the number of the bench-mark.



The starting bench-mark was built inside the rain gauge enclosure close to the salt offices at Sámbhar and was much larger, and better built than the bench-marks round the lake being about 2 feet 6 inches square, and the top of the bench-mark standing 2 feet 6 inches above the level of the ground. The whole top of the bench-mark was covered with a single slab of dressed stone with a small hollow square cut in the centre of it just large enough to hold a levelling staff on.

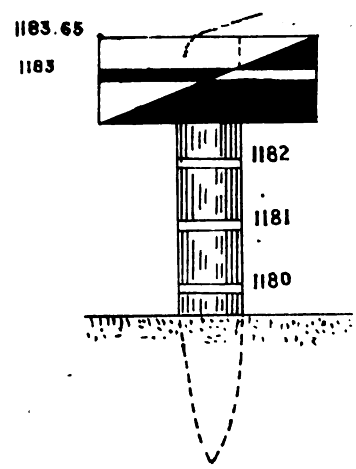
The top of the bench-mark was inscribed according to paragraph 42, Chapter III, Part VI, Trigonometrical Hand Book, 1902, as shown in the figure.



The value of this bench-mark was obtained by spirit levelling from the adjacent Sámbhar secondary station which was only about 100 yards away.

In addition to these principal 24 paka bench-marks, numerous bench-marks were made on the corners of pump houses, bridges, etc., and shewn by ⊙

cut in the stone, and 9 katcha bench-marks were driven all along the centre of the lake on the cross lines connecting bench-mark to bench-mark, consisting of seasoned wood pegs about 6 feet long and 6 inches diameter with wooden planks 2 feet × 1 foot × 1 inch screwed on to them and painted black and white. These bench-marks will also serve as water gauges, as when their levels were fixed bands of paint were painted round them at complete foot intervals, *viz.*, if the level value of the top was found to be 1,183·65 then bands were painted at 1,183, 1,182, 1,181, 1,180, etc.



To commence with, the values of the bench-marks round the lake were found by levelling right round the lake.

Two lines of check levels were also run across it. The total difference at the junction point was only 0·059 feet for a line of about 53 miles.

This primary line being the line on which the levels of all the bench-marks depended was done by two levellers one working behind the other. After this, lines were run across the lake from B. M. to B. M., and longitudinally along the centre of the lake connecting the katcha bench-marks in the centre of the lake; the total length of these lines in the lake bed was 83 miles.

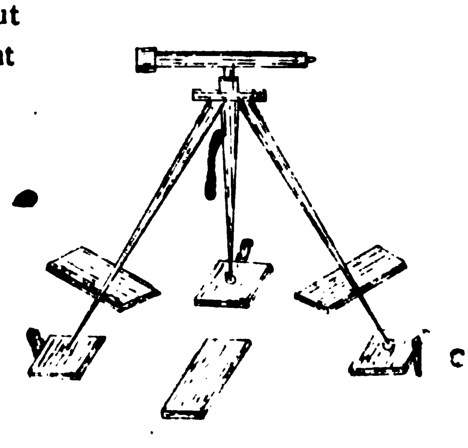
In addition a line was run connecting the Sámbhar Lake bench-marks with the Julga Lake bench-marks, and in a few cases new lines were run along the edge of the lake nearer the centre of the lake than the old lines. The length of these extra lines was about 34 miles.

The total length levelled was thus:—

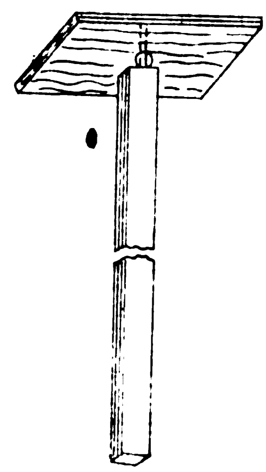
Miles.	
53	in preliminary circuits.
83	of cross lines in Lake bed.
34	of extra lines.
170	

The instruments used were one 14″ and one 12″ level.

The levelling in the bed of the lake was very difficult work as it consisted for the most part of soft sticky mud in which one sunk from 6 inches in some parts to over one's knees in others. In order to keep the level steady, a block of wood 12 inches square by 1 inch deep with a small hole in the centre was put under each leg, and these blocks were kept from slipping outwards on the mud by long wooden stakes driven in the mud. The observer had 3 loose wooden planks to stand on, radiating out from a centre under the instrument through the spaces between the legs.



The levelling staves were held on a big tent-nail driven in the centre of a plank and the plank was pressed in the mud till the top of the nail was on a level with the top of the mud.



These preparations had to be gone through every time the level was set up and made the work very slow at first, but when the khalassies got accustomed to it, they were able to get it all set out very quickly. A rope 100 feet long had to be used for chaining, as a chain could not be dragged over the mud.

Triangulation of bench-marks.—In order to fix accurately the position of some of the bench-marks in case they might at any time get destroyed, eight of them were afterwards connected by a small triangulation series with the stations of the first triangulation, all 3 angles being observed in each case.

Topography.—The topography of the lake was done on a scale of 2 inches to a mile, and extended to a distance of a mile inland from the edge of the lake all round except to the south-east where a large extra portion was surveyed so as to include the Koharsina range of hills and the Julga Lake.

Clinometric heights were taken at nearly every fixing, and the depth of water in all the wells was ascertained.

All the big hills were shown with 100 feet contours, but the low ground was not contoured, only heights being shown.

The area topographically surveyed was 177·84 square miles.

V

LATITUDE OPERATIONS.

Extracted from the Narrative Report of Lieutenant H. McC. Cowie, R.E., in charge Nos. 22 and 23 Parties (Astronomical).

This party was employed during the season 1902-03 on Latitude operations on the Budhon Meridional Series between Latitudes 24° and 27°, on the Calcutta Longitudinal Series at its junction with the Budhon Meridional and at one station, Birond of the North-East Longitudinal Series.

The final results of the season's work are given in Table I:—

TABLE I.

Station.	Height above M. S. L.	Longitude.	Geodetic Latitude. =C.	Astronomical Latitude. =O.	Probable error of Astronomical Latitude.	O—C.
		Budhon Meridional Series.				
	Feet.	° ′	° ′ ″	° ′ ″	″	″
Gúrmi	575	78 33	26 36 3·63	26 36 5·97	±0·049	+2·34
Majhár	1,028	78 31	26 6 17·00	26 6 20·30	±0·039	+3·30
Algi	1,154	78 24	25 29 46·20	25 29 48·15	±0·038	+1·95
Andhiári	1,630	78 16	24 41 6·77	24 41 11·29	±0·026	+4·52
Dargawa	1,452	79 4	24 37 13·21	24 37 17·31	±0·040	+4·10
		Calcutta Longitudinal Series.				
		° ′	° ′ ″	° ′ ″		
Budhon	1,867	78 34	24 5 8·41	24 5 8·99	±0·034	+0·58
Saugor	2,033	78 49	23 49 48·07	23 49 48·71	±0·043	+0·64
Náharmau	2,240	78 52	23 30 18·14	23 30 13·11	±0·049	−5·03
		North-East Longitudinal Series.				
		° ′	° ′ ″	° ′ ″		
Birond	6,967	79 45	29 15 14·15	29 14 29·71	±0·053	−44·44

Table II shows the probable error of observation, the number of pairs of stars observed and the total number of observations made at each station. The probable error of observation is that of the quantity $\frac{Z_n - Z_s}{2}$, the half observed difference of zenith distances:—

TABLE II.

Station.	Total number of observations.	Number of pairs observed.	Probable error of observation.
			″
Gúrmi	107	29	±0·262
Majhár	110	38	·284
Algi	115	35	·280
Andhiári	104	36	·282
Budhon	133	36	·263
Dargawa	218	31	·312
Saugor	146	26	·245
Náharmau	132	24	·260
Mean probable error of observation			±0·274
Same quantity for 1901-02			±0·288
„ „ „ 1900-01			±0·28

The system of combination weights used in deducing the final values for the latitude has been calculated from the formula

$$p = \left\{ e^2_{\frac{xx}{s}} + \frac{e^2}{n} \right\}^{-2}$$

where

p		represents the weight.
$\frac{e_{xx}}{s}$	„	the p. e. of the quantity $\frac{\Delta_n + \Delta_s}{2}$
e	„	the p. e. of observation of $\frac{Z_n - Z_s}{2}$
n	„	the number of observations on the pair.

In the case of compound pairs formed from three stars, the weight allotted to the mean result from each component was taken as ⅔ of the weight a single pair would receive under the same circumstances, as regards the number of observations.

Instrumental Constants.

The micrometer value was determined by the method which has been used for the last several seasons, consisting in the measurement in terms of the micrometer, of a known difference of declination and the deduction from this of the value in seconds of arc of a revolution of the screw. Observations were made at five stations and in the season's computations the value, 69″·220, was adopted for one revolution.

A discussion of the latitude values obtained for each station gave the results shown in Table III :—

TABLE III.

Station.	Value for one Revolution.		Difference.
	Which best suits the observations.	Determined from independent observations.	
	″	″	″
Gúrmi	69·2327	69·2087	+ 0·0240
Majhár	·2115	...	...
Algi	·2116	·2116	0·0000
Andhiári	·2258	·2270	− 0·0012
Budhon	·2191	·2294	− 0·0103
Dargawa	·2387	·2305	+ 0·0082
Saugor	·2185	...	...
Náharmau	·2155	...	...
Mean	69·2217	69·2214	+ 0·0003

To eliminate from the final latitudes, errors due to the use of an incorrect value, the residual correction entering into the final result of the observations has been, by balancing positive and negative micrometer quantities reduced to a minimum.

The differences shown in the above Table between the values deduced from the latitude results and those determined by independent observations may be due to a combination of the following sources of error:—

1. In the independent observations only micrometer wire B is used and in consequence the length of screw involved is from 20 to 40 revolutions.

In the latitude observations when the auxiliary wires A and C are utilized, the intervals A B and B C being approximately each 10 revolutions, a length of screw greater than 15 or 16 revolutions is rarely necessary. It is not difficult to suppose that the accumulated systematic errors of the 40 revolutions used in the first case, differ from those of the central 16 revolutions employed in the latitude observations, and consequently it is to be expected that the respective values for the micrometer given by the two methods should differ slightly.

2. When the auxiliary wires A and C are made use of in the latitude observations, the value of the interval (A—C) will enter as a correction always of one sign when the micrometer correction is positive and always of the other sign when the correction is negative. Consequently the result of a discussion of the respective latitude values given by positive and negative micrometer corrections will be in error unless the interval (A—C) is known absolutely exactly.

3. In consequence of the changes in the objective, in the Telescope tube, and in the micrometer screw owing to variations of temperature, unless the mean temperature during the latitude operations is the same as that for the independent micrometer observations, the values for a revolution of the screw deduced by the different methods will not agree.

There is still another complication introduced in consequence of the effect of changes of temperature. The auxiliary wires A and C are carried by the brass sliding plate of the micrometer, actuated by the steel screw. The determination of the value A C in terms of the screw is made at a certain temperature. The value so determined is correct for that temperature only and by using it for observations taken at any other temperature, errors are introduced. The method of determining this interval is such that it is difficult to get satisfactory results when the field is lighted only faintly by the axis lamp. It has therefore been usual to measure the interval during the day. If we suppose the temperature during the day observation to differ from the night temperature during the latitude operations by 5°C., the error introduced into every result obtained from observations into which the (A—C) interval enters, can be calculated to be about $\frac{1}{8}$ (0″·055). The sign of this error will be according as the sign of the (A—C) reduction is positive or negative and as the change of temperature is a fall or a rise.

From this it is apparent that it is not sufficient to balance positive and negative micrometer quantities without having regard at the same time to the number of times that A C enters as a positive and as a negative quantity. As well as balancing positive and negative corrections, we should effect cancelment of positive and negative (A—C) intervals.

I am of opinion, in view of the complications they introduce, that the advantages, which these auxiliary micrometer wires exhibit in respect to convenience in observing and reduction of the wear of the screw, do not quite justify their employment.

An investigation was made of the effect of changes of temperature on the micrometer value and a temperature co-efficient deduced from the season's observations. This gave as the value of one revolution of the screw at T° centigrade

$$69''\cdot2559 - 0''\cdot0020T.$$

Taking into consideration the focal length of the objective, and the relative co-efficients of expansion of brass and steel, the theoretical effect of a variation of temperature is for this instrument

$$-0''\cdot0005\ T.$$

If it be remembered that as yet the effect of temperature variations on the object glass of the instrument is an unknown quantity, and in consequence, no allowance can be made for such effects, the disagreement between the theoretical and the deduced values for the temperature co-efficient will not be considered surprising.

The values for the scales of the two levels Nos. 6 and 9 by Holmes, were determined in October 1902 and again in March 1903, by means of Cooke & Son's Bubble Tester No. 1.

The values found were:—

	No. 6.	No. 9.
October 1902	0·91798	0·87203
March 1903	0·88970	0·83110
Mean used in the computation	0·90384	0·85157

For six stations, values for the latitude have been computed from the observations, treating the two levels separately.

The differences in Latitude

$$\left(\begin{matrix}\text{Value by}\\ \text{No. 6 level.}\end{matrix}\right) - \left(\begin{matrix}\text{Value by}\\ \text{No. 9 level.}\end{matrix}\right)$$

and the probable errors of the respective values are shown in the following Table:—

TABLE IV.

STATION.	Difference in resulting Latitude No. 6 value — No. 9 value.	Probable error of result by No. 6.	Probable error of result by No. 9.
	"	"	"
Gúrmi	+0·03	±0·050	±0·050
Algi	+0·05	±0·037	±0·040
Andhiári	+0·06	±0·028	±0·026
Budhon	0·00	±0·036	±0·034
Dargawa	−0·01	±0·039	±0·042
Náharmau	−0·03	±0·050	±0·052

There is no conclusive evidence here of a constant difference between the two levels. It is noticeable, however, and not in these seasons' results only, that the addition of the second level has not had as much effect as might have been looked for, in reducing the probable error of the final result.

VI

TIDAL AND LEVELLING OPERATIONS.

Extracted from the Narrative Report of Captain H. H. Turner, R.E., in charge No. 25 Party (Tidal and Levelling) for season 1902-03.

Work of the year.

During the year ending 30th Septembor 1903 the work of recording of the tidal curves by the self-registering tide-gauges and their reduction by harmonic analysis has continued as usual for 12 ports at which observations have been taken.

The publication of Tide-tables giving the predicted times and heights of every high and low-water for the year 1904 has been carried on, and in addition the same work for the Tide-tables for 1905 has been put in hand. In both cases the number of ports for which the predictions are made is 42.

List of Tidal Stations.

The following table gives a complete list of the 42 ports at which observations have been and still are being taken; 11 are now working, 31 have been closed on completion of their registrations. The permanent stations are shown in italics, the others are minor stations at which only five years' registrations are required.

Stations.	Automatic or personal observations.	Date of commencement of observations.	Date of closing of observations.	Number of years of observations.	Remarks.
1. Suez	Automatic	1897	Still working	6	To be closed.
2. Perim	"	1898	1902	5	Closed on 25th February 1903.
3. *Aden*	"	1879	Still working	23	
4. Muscat	"	1893	1898	5	
5. Bushire	"	1892	1901	8	
6. *Kurrachee*	"	1881	Still working	22	
7. Hanstal	"	1874	1875	1	Tide-tables not published.
8. Navánár	"	1874	1875	1	
9. Okha Point	"	1874	1875	1	
10. Porbandar	Personal	1893	1894	2	
10A. Porbandar	Automatic	1898	1902	5	With certain interruptions. Closed.
11. Port Albert Victor (Káthiáwár).	Personal	1881	1882	1	
11A. Port Albert Victor (Káthiáwár).	Automatic	1900	Still working	3	To be closed.
12. Bhávnagar	"	1889	1894	5	
13. *Bombay* (Apollo Bandar)	"	1878	Still working	25	
14. Bombay (Prince's Dock)	"	1888	"	15	Property of Port Trust.
15. Mormugáo (Goa)	"	1884	1889	5	
16. Kárwár	"	1878	1883	5	

Stations.	Automatic or personal observations.	Date of commencement of observations.	Date of closing of observations.	Number of years of observations.	Remarks.
17. Beypore	Automatic.	1878	1884	6	
18. Cochin	"	1886	1892	6	
19. Tuticorin . . .	"	1888	1893	5	
20. Minicoy . . .	"	1891	1896	5	
21. Galle	"	1884	1890	6	
22. Colombo . . .	"	1884	1890	6	
23. Trincomalee . . .	"	1890	1896	6	
24. Pámban Pass . . .	"	1878	1882	4	
25. Negapatam . . .	"	1881	1888	6	Year 1884-85 is excluded.
26. *Madras*	"	1880 re-started 1895	1890 Still working	10 } 8 } 18	
27. Cocanada . . .	"	1886	1891	5	
28. Vizagapatam . . .	"	1879	1885	6	
29. False Point . . .	"	1881	1885	4	
30. Dublat (Saugor Island) .	"	1881	1886	5	
31. Diamond Harbour . .	"	1881	1886	5	
32. *Kidderpore* . . .	"	1881	Still working	22	
33. Chittagong . . .	"	1886	1891	5	
34. Akyab	"	1887	1892	5	
35. Diamond Island . .	"	1895	1899	5	
36. Bassein (Burma) . .	"	1902	Still working	1	
37. Elephant Point . .	"	1880 re-started 1884	1881 1888	1 } 5 } 6	
38. *Rangoon* . . .	"	1880	Still working	23	
39. Amherst . . .	"	1880	1886	6	
40. Moulmein . . .	"	1880	1886	6	
41. Mergui	"	1889	1894	5	
42. *Port Blair* . . .	"	1880	Still working	23	

Observatories closed during the year.

The observatory at Porbandar was closed in December 1902 and that at Perim in February 1903. It is intended to close the observatory at Suez at the end of 1903, and possibly that at Port Albert Victor early in 1904. If arrangements can be completed, it is proposed to open a new observatory at Okha, to renew the observations taken there in 1874 and 1875.

Personal Tidal observations.

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

Inspection of observatories.

All the tidal observatories were inspected during the past year. Portable meteorological instruments were taken on the tours of inspection and compared with those working locally.

Working of Tidal observatories.

The following is a description of the working of the several tidal observatories during the year, commencing with Suez and following the order of the stations round the coast to Burma.

Suez.

There have been four short interruptions of a few hours only in the tidal records during the year due in all instances to the stopping of the tide-gauge clock. The chronometer unfortunately was not compared between October 1902 and June 1903, and was then found to be 14 minutes too slow and corrections to diagrams already read had consequently to be made. Of the auxiliary instruments the S. R. anemometer has been out of order the whole year. The S. R. Aneroid with the exception of a break of 8 days has worked satisfactorily. The annual inspection was conducted by Mr. Shaw in February 1903.

Perim.

This observatory was visited by Mr. Shaw in February 1903 and was closed by him on 25th of that month, five years' observations having been recorded.

During the year there has been no break in the records of any of the instruments.

Aden.

There have been several short breaks in the tidal records at this observatory during the year, in addition to a break of 11 days in February 1903 due to the stoppage of the driving clock. Mr. Shaw inspected the observatory on the 16th February, and after thoroughly cleaning the clock and instruments, re-started the tide-gauge, which has since worked satisfactorily. A new masonry pier is to be built in place of the old one on iron piles, and the observatory will be removed from its present position on the east side to the west side of the new pier. The anemometer has worked without interruption, but the S. R. Aneroid which had been out of order since November 1902, was replaced in March 1903 since which time the records have been satisfactory.

Kurrachee.

There have been no interruptions in the records of the tide-gauge; and self-registering Aneroid during the year. The anemometer was out of order for 4 days in August.

Owing to very high tides having occurred during June of 1902 and 1903, the question of raising the floor of the observatory has arisen. On one occasion the tide-gauge was unable to register the height of the tide owing to the water having risen above the top of the tide-gauge cylinder. The observatory was inspected by Mr. Shaw in January 1903.

Porbandar.

This observatory, which was started in March 1898, was finally closed by Mr. Shaw on the 28th December 1902.

This year there was again considerable interruption in the records owing to the communication pipe becoming choked. During the time that the observatory has been open, annual interruptions have occurred in the monsoon, with the exception of the year 1900; from January 1900 to June 1901, the observations continued without interruption, we have therefore one year's complete record.

The auxiliary instruments were all found to be out of order.

D

Port Albert Victor (Káthiáwár).

No interruptions have occurred in the tidal observations at this observatory during the current year, except for four days when the well was being cement-plastered. The auxiliary instruments have also worked satisfactorily. The observatory was inspected by Mr. Shaw in December 1902. It was thought that the percolation of water through the porous rock affected the registration of the tides, and an attempt was made to plaster the well with cement but without success. The somewhat peculiar tide curves recorded are more probably due to the position in which the observatory is placed. It is built in the base of the light-house and connected by pipe to a creek at the mouth of which shoals are continually forming, and it has not therefore free access to the open sea.

It is probable that this observatory will be closed early in 1904.

Bombay (Apollo Bandar).

During the year interruptions of a few hours in recording the tidal curve occurred on four occasions from the stoppage of the driving clock and several minor interruptions due to the pencil not marking the paper.

The observatory was inspected in February by Lieutenant Tillard, R.E.

Bombay (Prince's Dock).

During the year interruptions of a few hours have occurred occasionally due to causes easily put right by the observatory clerk.

The observatory was inspected in February by Lieutenant Tillard, R.E.

Madras.

The working of the tide-gauge of this observatory was stopped from 4th February to 17th February 1903 to enable the sluice valve to be taken out of the well and cleaned. No other interruption in the observations has occurred during the year. The auxiliary instruments have worked satisfactorily.

The observatory was inspected in January and February 1903 by Lieutenant Tillard, R.E.

Kidderpore.

During the year no interruptions have occurred in recording the tidal curve.

The auxiliary instruments have also worked satisfactorily.

The observatory was inspected in January 1903 by Lieutenant Tillard, R.E.

Bassein (Burma).

During the year there were four interruptions of a few hours of the tidal record owing to the stoppage of the driving clock.

The anemometer has not worked very satisfactorily; the other auxiliary instruments have all worked well.

The observatory is built on wooden piles, and the outer row was found to be much eaten rendering the safety of the observatory precarious.

The Port Officer has undertaken to drive in fresh piles for the support of the cabin.

The observatory was inspected in January by Lieutenant Tillard, R.E.

Rangoon.

During the year there has been no interruption of the tidal record. The auxiliary instruments have all worked satisfactorily.

The observatory was inspected in December 1902 by Lieutenant Tillard, R.E.

Port Blair.

There has been no interruption in the records of the tide-gauge and auxiliary instruments during the year.

Bench-mark A, the bench-mark of reference, has been abandoned owing to its inconvenient position, and a new bench-mark D has been built on a suitable site. Bench-mark C is now the bench-mark of reference.

Supervision of observatories.

As in former years each tidal observatory has been under the direct supervision of a responsible authority, the Port Officer or Engineer where possible.

Thanks are due to these officers for the careful way in which their supervision has been exercised and for the interest taken by them in the operations.

Tidal diagrams and daily reports.

The tidal diagrams together with the diagrams of the auxiliary instruments have been regularly forwarded from each observatory to the Tidal and Levelling Office at Dehra Dún. The clerks in charge of the several observatories have also sent daily reports of the working of the tide-gauges in their charge.

Tidal constants.

The tidal observations for a year at 12 stations have been reduced, and the tabulated values of the tidal constants thus derived are appended. There are no arrears.

VALUES OF THE TIDAL CONSTANTS, SUEZ, 1902.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1902 Observations at Suez; and also the values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1902 Observations.

Short Period Tides.

A_0 = 4·361 feet.

S_1	H = R =	·095	M_6	R =	·015	Q_1	R =	·007	T_2	R =	·025
	κ = ζ =	64°·28		ζ =	182°·58		ζ =	333°·79		ζ =	87°·79
S_2	H = R =	·475		H =	·013		H =	·009		H =	·026
	κ = ζ =	8°·89		κ =	59°·36		κ =	209°·13		κ =	88°·94
S_4	H = R =	·003	M_8	R =	·002	L_2	R =	·074	$(MS)_4$	R =	·021
	κ = ζ =	95°·71		ζ =	187°·60		ζ =	257°·84		ζ =	331°·60
S_6	H = R =	·001		H =	·002		H =	·062		H =	·020
	κ = ζ =	303°·69		κ =	263°·30		κ =	40°·39		κ =	170°·53
S_8	H = R =	·001	O_1	R =	·035	N_2	R =	·606	$(2SM)_2$	R =	·015
	κ = ζ =	9°·46		ζ =	210°·68		ζ =	238°·18		ζ =	67°·62
				H =	·042		H =	·587		H =	·014
				κ =	211°·47		κ =	311°·66		κ =	228°·69
M_1	R =	·003	K_1	R =	·132	λ_2	R =	...	$2N_2$	R =	·132
	ζ =	200°·56		ζ =	349°·94		ζ =	...		ζ =	297°·51
	H =	·003		H =	·146		H =	...		H =	·128
	κ =	287°·76		κ =	185°·27		κ =	...		κ =	245°·56
M_2	R =	1·887	K_2	R =	·093	ν_2	R =	·042	$(M_2N)_4$	R =	·014
	ζ =	144°·14		ζ =	158°·12		ζ =	122°·57		ζ =	219°·75
	H =	1·828		H =	·119		H =	·040		H =	·013
	κ =	343°·06		κ =	7°·95		κ =	284°·77		κ =	132°·16
M_3	R =	·019	P_1	R =	·036	μ_2	R =	·098	$(M_2K_3)_2$	R =	·025
	ζ =	98°·70		ζ =	316°·48		ζ =	168°·78		ζ =	156°·52
	H =	·018		H =	·036		H =	·092		H =	·027
	κ =	37°·09		κ =	126°·37		κ =	206°·64		κ =	190°·77
M_4	R =	·028	J_1	R =	·008	R_2	R =	...	$(2M_2K_1)_2$	R =	·010
	ζ =	112°·57		ζ =	250°·91		ζ =	...		ζ =	216°·53
	H =	·026		H =	·010		H =	...		H =	·011
	κ =	150°·42		κ =	214°·49		κ =	...		κ =	59°·05

Long Period Tides.

	R	ζ	H	κ
		°		°
Lunar Monthly Tide	·066	357·51	.059	122·95
„ Fortnightly „	[illegible]	19·85	·105	37·21
Luni-Solar „ „	·027	305·43	·026	106 51
Solar-Annual „	·518	28·08	·318	308·19
„ Semi-Annual „	·153	222·24	·153	62·46

VALUES OF THE TIDAL CONSTANTS, PERIM, 1902.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1902 Observations at Perim; and also the values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1902 Observations:—

Short Period Tides.

A_0 = 5·443 feet.

S_1	H=R=	·076	M_6	R=	·006	Q_1	R=	·097	T_2	R=	·021
	$\kappa=\zeta=$	156°·40		$\zeta=$	137°·94		$\zeta=$	155°·02		$\zeta=$	290°·49
S_2	H=R=	·562		H=	·006		H=	·116		H=	·021
	$\kappa=\zeta=$	241°·42		$\kappa=$	16°·92		$\kappa=$	31°·53		$\kappa=$	291°·67
S_4	H=R=	·005	M_8	R=	·001	L_2	R=	·031	$(MS)_4$	R=	·012
	$\kappa=\zeta=$	319°·27		$\zeta=$	353°·66		$\zeta=$	90°·19		$\zeta=$	267°·47
S_6	H=R=	·008		H=	·001		H=	·026		H=	·011
	$\kappa=\zeta=$	203°·50		$\kappa=$	72°·31		$\kappa=$	233°·08		$\kappa=$	107°·13
S_8	H=R=	·002	O_1	R=	·500	N_2	R=	·350	$(2SM)_2$	R=	·022
	$\kappa=\zeta=$	19°·44		$\zeta=$	33°·83		$\zeta=$	148°·90		$\zeta=$	281°·05
				H=	·594		H=	·339		H=	·021
				$\kappa=$	35°·38		$\kappa=$	223°·52		$\kappa=$	81°·39
M_1	R=	·026	K_1	R=	1·038	λ_2	R=	...	$2N_2$	R=	·069
	$\zeta=$	13°·77		$\zeta=$	197°·04		$\zeta=$	...		$\zeta=$	243°·89
	H=	·030		H=	1·149		H=	...		H=	·067
	$\kappa=$	101°·33		$\kappa=$	32°·34		$\kappa=$	...		$\kappa=$	193°·46
M_2	R=	1·231	K_2	R=	·121	ν_2	R=	·024	$(M_2N)_4$	R=	·007
	$\zeta=$	25°·24		$\zeta=$	23°·28		$\zeta=$	8°·95		$\zeta=$	53°·31
	H=	1·192		H=	·155		H=	·023		H=	·006
	$\kappa=$	224°·91		$\kappa=$	233°·06		$\kappa=$	172°·23		$\kappa=$	327°·59
M_3	R=	·035	P_1	R=	·355	μ_2	R=	·051	$(M_2K_1)_3$	R=	·018
	$\zeta=$	289°·14		$\zeta=$	221°·60		$\zeta=$	144°·62		$\zeta=$	180°·33
	H=	·033		H=	·355		H=	·047		H=	·019
	$\kappa=$	228°·63		$\kappa=$	31°·51		$\kappa=$	183°·95		$\kappa=$	215°·29
M_4	R=	·016	J_1	R=	·045	R_2	R=	...	$(2M_2K_1)_3$	R=	·017
	$\zeta=$	346°·14		$\zeta=$	57°·13		$\zeta=$	...		$\zeta=$	41°·06
	H=	·015		H=	·052		H=	...		H=	·017
	$\kappa=$	25°·47		$\kappa=$	20°·29		$\kappa=$	...		$\kappa=$	245°·08

Long Period Tides.

	R	ζ	H	κ
		°		°
Lunar Monthly Tide	·005	239·39	·004	4·43
„ Fortnightly „	·057	12·53	·083	29·09
Luni-Solar „ „	·041	83·25	·040	243·59
Solar-Annual „	·291	68·93	·291	349·01
„ Semi-Annual „	·176	260·79	·176	100·95

VALUES OF THE TIDAL CONSTANTS, ADEN, 1902.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1902 Observations at Aden; and also the values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1902 Observations:—

Short Period Tides.

A_0 = 5·990 feet.

S_1	H= R=	·084	M_6	R =	·004	Q_1	R =	·102	T_2	R =	·037
	$\kappa=$ $\zeta=$	170°·73		ζ =	93°·01		ζ =	157°·88		ζ =	291°·31
S_2	H= R=	·674		H =	·004		H =	·121		H =	·037
	$\kappa=$ $\zeta=$	244°·15		κ =	332°·32		κ =	34°·56		κ =	292°·49
S_4	H= R=	·008	M_8	R =	·001	L_2	R =	·038	$(MS)_4$	R =	·012
	$\kappa=$ $\zeta=$	294°·26		ζ =	3[illegible]°·88		ζ =	93°·04		ζ =	1°·06
S_6	H= R=	·006		H =	·001		H =	·032		H =	·012
	$\kappa=$ $\zeta=$	207°·00		κ =	26°·96		κ =	235°·98		κ =	201°·73

Short Period Tides—contd.

S_8	H= R=	·001	O_1	R =	·557	N_2	R =	·442	$(2SM)_2$	R =	·022
	κ= ζ=	290°·56		ζ =	36°·08		ζ =	146°·03		ζ =	284°·93
				H =	·662		H =	·428		H =	·021
				κ =	37°·74		κ =	220°·81		κ =	85°·16
M_1	R =	·035	K_1	R =	1·176	λ_2	R =	...	$2N_2$	R =	·084
	ζ =	30°·82		ζ =	199°·40		ζ =	...		ζ =	238°·74
	H =	·041		H =	1·302		H =	...		H =	·082
	κ =	118°·44		κ =	34°·70		κ =	...		κ =	188°·54
M_2	R =	1·600	K_2	R =	1·35	ν_2	R =	·031	$(M_2N)_4$	R =	·008
	ζ =	26°·92		ζ =	32°·46		ζ =	6°·99		ζ =	317°·58
	H =	1·549		H =	·173		H =	·030		H =	·008
	κ =	226°·69		κ =	242°·23		κ =	170°·43		κ =	232°·13
M_3	R =	·016	P_1	R =	·401	μ_2	R =	·060	$(M_2K_1)_3$	R =	·015
	ζ =	277°·22		ζ =	222°·85		ζ =	132°·82		ζ =	52°·97
	H =	·015		H =	·401		H =	·057		H =	·016
	κ =	216°·87		κ =	32°·77		κ =	172°·36		κ =	88°·03
M_4	R =	·003	J_1	R =	·045	R_2	R =	...	$(2M_2K_1)_3$	R =	·005
	ζ =	207°·65		ζ =	62°·22		ζ =	...		ζ =	148°·39
	H =	·002		H =	·052		H =	...		H =	·005
	κ =	247°·19		κ =	25°·32		κ =	...		κ =	352°·64

Long Period Tides.

	R	ζ	H	κ
		°		°
Lunar Monthly Tide	·024	254·01	·022	19·00
„ Fortnightly „	·043	16·62	·063	33·06
Luni-Solar „ „	·024	94·56	·023	254·79
Solar-Annual „	·263	79·08	·263	359·16
„ Semi-Annual „	·143	277·37	·143	117·53

Values of the Tidal Constants, Kurrachee, 1902.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1902 Observations at Kurrachee ; and also the values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1902 Observations :—

Short Period Tides.

A_0 = 7·306 feet.

S_1	H=R=	·084	M_6	R=	·049	Q_1	R=	·107	T_2	R=	·071
	κ= ζ=	180°·21		ζ=	322°·15		ζ=	167°·09		ζ=	13°·08
S_2	H=R=	·969		H=	·045		H=	·128		H=	·071
	κ= ζ=	322°·99		κ=	205°·92		κ=	46°·11		κ=	14°·32
S_4	H=R=	·011	M_8	R=	·002	L_2	R=	·053	$(MS)_4$	R=	·031
	κ= ζ=	18°·60		ζ=	258°·11		ζ=	165°·75		ζ=	128°·01
S_6	H=R=	·008		H=	·002		H=	·045		H=	·030
	κ= ζ=	286°·04		κ=	343°·14		κ=	309°·39		κ=	329°·27
S_8	H=R=	·002	O_1	R=	·567	N_2	R=	·628	$(2SM)_2$	R=	·013
	κ= ζ=	66°·80		ζ=	43°·94		ζ=	201°·22		ζ=	297°·18
				H=	·674		H=	·608		H=	·012
				κ=	47°·15		κ=	278°·29		κ=	95°·92
M_1	R=	·044	K_1	R=	1·193	λ_2	R=	...	$2N_2$	R=	·100
	ζ=	43°·44		ζ=	210°·53		ζ=	...		ζ=	283° 59
	H=	·052		H=	1·321		H=	...		H=	·097
	κ=	131°·79		κ=	45°·77		κ=	...		κ=	236°·46
M_2	R=	2·669	K_2	R=	·191	ν_2	R=	·058	$(M_2N)_4$	R=	·027
	ζ=	92°·33		ζ=	112°·13		ζ=	70°·45		ζ=	69°·44
	H=	2·585		H=	·245		H=	·056		H=	·025
	κ=	293°·59		κ=	321°·78		κ=	236°·07		κ=	347°·77
M_3	R=	·039	P_1	R=	·396	μ_2	R=	·043	$(M_2K_1)_3$	R=	·023
	ζ=	36°·27		ζ=	232°·98		ζ=	210°·36		ζ=	91°·02
	H=	·037		H=	·396		H=	·040		H=	·025
	κ=	338°·16		κ=	42°·96		κ=	252°·88		κ=	127°·51

Short Period Tides—contd.

Tide			Tide			Tide			Tide		
M_4	R =	·020	J_1	R =	·043	R_2	R =	...	$(2M_2K_1)_3$	R =	·020
	ζ =	305°·57		ζ =	75°·29		ζ =	...		ζ =	141°·79
	H =	·019		H =	·050		H =	...		H =	·021
	κ =	348°·09		κ =	38°·53		κ =	...		κ =	349°·08

Long Period Tides.

	R	ζ	H	κ
		°		°
Lunar Monthly Tide	·041	341·58	·037	105·77
„ Fortnightly „	·108	33·74	·157	48·58
Luni-Solar „ „	·091	85·04	·088	243·79
Solar-Annual „	·175	163·49	·175	83·51
„ Semi-Annual „	·193	287·22	·193	127·26

VALUES OF THE TIDAL CONSTANTS, PORT ALBERT VICTOR, 1902.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1902 Observations at Port Albert Victor; and also the values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1902 Observations:—

Short Period Tides.

A_0 = 9·858 feet

Tide			Tide			Tide			Tide		
S_1	H = R =	·096	M_6	R =	·112	Q_1	R =	·112	T_2	R =	·073
	κ = ζ =	189°·03		ζ =	244°·98		ζ =	191°·70		ζ =	117°·42
S_2	H = R =	1·126		H =	·102		H =	·133		H =	·073
	κ = ζ =	82°·64		κ =	129°·68		κ =	71°·21		κ =	118°·68
S_4	H = R =	·029	M_8	R =	·005	L_2	R =	·117	$(MS)_4$	R =	·172
	κ = ζ =	261°·79		ζ =	80°·54		ζ =	19°·36		ζ =	11°·19
S_6	H = R =	·010		H =	·005		H =	·098		H =	·166
	κ = ζ =	22°·44		κ =	166°·80		κ =	163°·14		κ =	212°·75
S_8	H = R =	·006	O_1	R =	·610	N_2	R =	·826	$(2SM)_2$	R =	·030
	κ = ζ =	310°·18		ζ =	64°·99		ζ =	316°·11		ζ =	295°·63
				H =	·725		H =	·800		H =	·029
				κ =	68°·52		κ =	33°·65		κ =	94°·06
M_1	R =	·097	K_1	R =	1·461	λ_2	R =	...	$2N_2$	R =	·079
	ζ =	66°·15		ζ =	230°·79		ζ =	...		ζ =	69°·44
	H =	·113		H =	1·618		H =	...		H =	·077
	κ =	154°·65		κ =	66°·01		κ =	...		κ =	22°·95
M_2	R =	2·950	K_2	R =	·217	ν_2	R =	·034	$(M_2N)_4$	R =	·100
	ζ =	217°·66		ζ =	229°·95		ζ =	67°·95		ζ =	233°·69
	H =	2·857		H =	·278		H =	·033		H =	·094
	κ =	59°·23		κ =	79°·57		κ =	234°·02		κ =	152°·80
M_3	R =	·034	P_1	R =	·459	μ_2	R =	·327	$(M_2K_1)_3$	R =	·032
	ζ =	199°·54		ζ =	254°·13		ζ =	286°·24		ζ =	199°·72
	H =	·032		H =	·450		H =	·307		H =	·034
	κ =	141°·89		κ =	64°·12		κ =	329°·37		κ =	236°·50
M_4	R =	·225	J_1	R =	·045	R_2	R =	...	$(2M_2K_1)_3$	R =	·040
	ζ =	133°·51		ζ =	116°·79		ζ =	...		ζ =	309°·96
	H =	·211		H =	·052		H =	...		H =	·041
	κ =	176°·64		κ =	78°·85		κ =	...		κ =	157°·87

Long Period Tides.

	R	ζ	H	κ
		°		°
Lunar Monthly Tide	·012	176·80	·011	300·82
„ Fortnightly „	·096	323·81	·140	338·32
Luni-Solar „ „	·086	41·84	·083	200·28
Solar-Annual „	·088	58·05	·088	338·06
„ Semi-Annual „	·132	269·64	·132	109·66

VALUES OF THE TIDAL CONSTANTS, BOMBAY (APOLLO BANDAR), 1902.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1902 Observations at Bombay (Apollo Bandar); and also the values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1902 Observations:—

Short Period Tides.

A_0 = 10·310 feet.

S_1	H = R =	·069	M_6	R =	·014	Q_1	R =	·104	T_2	R =	·126
	κ = ζ =	181°·83		ζ =	144°·35		ζ =	170°·86		ζ =	55°·94
S_2	H = R =	1·589		H =	·012		H =	·124		H =	·126
	κ = ζ =	4°·22		κ =	29·32		κ =	50°·51		κ =	57°·20
S_4	H = R =	·010	M_8	R =	·002	L_2	R =	·026	$(MS)_4$	R =	·127
	κ = ζ =	198°·25		ζ =	227°·73		ζ =	189°·72		ζ =	196°·20
S_6	H = R =	·006		H =	·002		H =	·022		H =	·123
	κ = ζ =	187°·25		κ =	314°·35		κ =	333°·54		κ =	37°·85
S_8	H = R =	·001	O_1	R =	·567	N_2	R =	·998	$(2SM)_2$	R =	·039
	κ = ζ =	74°·06		ζ =	46°·88		ζ =	238°·73		ζ =	311°·03
				H =	·673		H =	·966		H =	·038
				κ =	50°·50		κ =	316°·41		κ =	109°·38
M_1	R =	·061	K_1	R =	1·263	$λ_2$	R =	...	$2N_2$	R =	·126
	ζ =	37°·83		ζ =	210°·36		ζ =	...		ζ =	313°·80
	H =	·072		H =	1·399		H =	...		H =	·122
	κ =	126°·37		κ =	45°·58		κ =	...		κ =	267°·50
M_2	R =	4·120	K_2	R =	·301	$ν_2$	R =	·083	$(M_2N)_4$	R =	·014
	ζ =	130°·16		ζ =	154°·32		ζ =	86°·70		ζ =	42°·05
	H =	3·990		H =	·385		H =	·080		H =	·013
	κ =	331°·82		κ =	3°·94		κ =	252°·91		κ =	321°·38
M_3	R =	·087	P_1	R =	·397	$μ_2$	R =	·168	$(M_2K_1)_3$	R =	·081
	ζ =	80°·72		ζ =	235°·08		ζ =	253°·79		ζ =	162°·91
	H =	·083		H =	·397		H =	·158		H =	·087
	κ =	23°·20		κ =	45°·07		κ =	297°·10		κ =	199°·79
M_4	R =	·109	J_1	R =	·049	R_2	R =	...	$(2M_2K_1)_3$	R =	·066
	ζ =	293°·60		ζ =	82°·58		ζ =	...		ζ =	222°·74
	H =	·102		H =	·057		H =	...		H =	·069
	κ =	336°·91		κ =	44°·59		κ =	...		κ =	70°·83

Long Period Tides.

	R	ζ	H	κ
		°		°
Lunar Monthly Tide	·031	226·07	·028	350·04
,, Fortnightly ,, ...	·066	331·93	·096	346·34
Luni-Solar ,, ,, ...	·035	14·95	·034	173·30
Solar-Annual ,, ...	·111	31·44	·111	311·44
,, Semi-Annual ,, ...	·052	265·45	·052	105·46

VALUES OF THE TIDAL CONSTANTS, BOMBAY (PRINCE'S DOCK), 1902.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1902 Observations at Bombay (Prince's Dock); and also the values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1902 Observations:—

Short Period Tides.

A_0 = 8·382 feet.

S_1	H = R =	·069	M_6	R =	·008	Q_1	R =	·104	T_2	R =	·129
	κ = ζ =	179°·67		ζ =	291°·52		ζ =	170°·00		ζ =	58°·45
S_2	H = R =	1·614		H =	·008		H =	·124		H =	·129
	κ = ζ =	4°·41		κ =	176°·49		κ =	49°·65		κ =	59°·71
S_4	H = R =	·018	M_8	R =	·004	L_2	R =	·037	$(MS)_4$	R =	·113
	κ = ζ =	204°·39		ζ =	341°·03		ζ =	181°·26		ζ =	198°·35
S_6	H = R =	·004		H =	·004		H =	·031		H =	·109
	κ = ζ =	220°·60		κ =	67°·65		κ =	325°·08		κ =	40°·01

Short Period Tides—contd.

S_8	H = R =	·002	O_1	R =	·556	N_2	R =	1·022	$(2SM)_2$	R =	·040
	κ = ζ =	213°·02		ζ =	45°·01		ζ =	238°·29		ζ =	316°·83
				H =	·661		H =	·990		H =	·039
				κ =	48°·63		κ =	315°·97		κ =	115°·17
M_1	R =	·057	K_1	R =	1·258	λ_2	R =	...	$2N_2$	R =	·123
	ζ =	37°·15		ζ =	209°·92		ζ =	...		ζ =	319°·16
	H =	·067		H =	1·393		H =	...		H =	·119
	κ =	125°·70		κ =	45°·14		κ =	...		κ =	272°·86
M_2	R =	4·179	K_2	R =	·304	ν_2	R =	·091	$(M_2N)_4$	R =	·006
	ζ =	129°·58		ζ =	151°·06		ζ =	80°·52		ζ =	330°·75
	H =	4·047		H =	·389		H =	·088		H =	·006
	κ =	331°·24		κ =	0°·67		κ =	246°·72		κ =	250°·09
M_3	R =	·084	P_1	R =	·396	μ_2	R =	·177	$(M_2K_1)_3$	R =	·097
	ζ =	79°·83		ζ =	233°·30		ζ =	260°·02		ζ =	163°·38
	H =	·080		H =	·396		H =	·166		H =	·104
	κ =	22°·32		κ =	43°·29		κ =	303°·33		κ =	200°·26
M_4	R =	·089	J_1	R =	·050	R_2	R =	...	$(2M_2K_1)_3$	R =	·064
	ζ =	285°·57		ζ =	84°·29		ζ =	...		ζ =	217°·09
	H =	·084		H =	·058		H =	...		H =	·067
	κ =	328°·88		κ =	46°·30		κ =	...		κ =	65°·18

Long Period Tides.

	R	ζ	H	κ
		°		°
Lunar Monthly Tide	·048	237·97	·043	1·95
„ Fortnightly „	·066	337·49	·096	351·90
Luni-Solar „ „	·023	348·49	·022	146·83
Solar-Annual „	·103	351·01	·103	271·01
„ Semi-Annual „	·038	258·74	·038	98·75

VALUES OF THE TIDAL CONSTANTS, MADRAS, 1902.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1902 Observations at Madras; and also the values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1902 Observations:—

Short Period Tides.

A_0 = 2·094 feet.

S_1	H = R =	·023	M_6	R =	·006	Q_1	R =	·004	T_2	R =	·016
	κ = ζ =	66°·31		ζ =	225°·00		ζ =	168°·18		ζ =	317°·38
S_2	H = R =	·461		H =	·006		H =	·005		H =	·016
	κ = ζ =	269°·33		κ =	111°·48		κ =	48°·62		κ =	318°·65
S_4	H = R =	·002	M_8	R =	·001	L_2	R =	·054	$(MS)_4$	R =	·004
	κ = ζ =	42°·27		ζ =	328°·00		ζ =	125°·85		ζ =	64°·80
S_6	H = R =	·001		H =	·001		H =	·046		H =	·004
	κ = ζ =	82°·88		κ =	56°·64		κ =	269°·90		κ =	266°·96
S_8	H = R =	·001	O_1	R =	·081	N_2	R =	·240	$(2SM)_2$	R =	·016
	κ = ζ =	45°·00		ζ =	319°·57		ζ =	156°·00		ζ =	65°·20
				H =	·096		H =	·233		H =	·016
				κ =	323°·72		κ =	234°·46		κ =	223°·04
M_1	R =	·010	K_1	R =	·272	λ_2	R =	...	$2N_2$	R =	·050
	ζ =	105°·87		ζ =	141°·45		ζ =	...		ζ =	266°·75
	H =	·012		H =	·301		H =	...		H =	·048
	κ =	194°·66		κ =	336°·65		κ =	...		κ =	221°·50
M_2	R =	1·132	K_2	R =	·092	ν_2	R =	·027	$(M_2N)_4$	R =	·002
	ζ =	37°·89		ζ =	59°·20		ζ =	35°·44		ζ =	225°·00
	H =	1·096		H =	·117		H =	·026		H =	·002
	κ =	240°·05		κ =	268°·78		κ =	202°·38		κ =	145°·61
M_3	R =	·004	P_1	R =	·090	μ_2	R =	·034	$(M_2K_1)_3$	R =	·009
	ζ =	58°·78		ζ =	167°·36		ζ =	119°·87		ζ =	90°·66
	H =	·004		H =	·090		H =	·032		H =	·010
	κ =	2°·02		κ =	337°·38		κ =	164°·19		κ =	128°·02

Short Period Tides—contd.

M_4	R =	·007	J_1	R =	·009	R_2	R =	...	$(2M_2K_1)_3$	R =	·002
	ζ =	150°·14		ζ =	322°·47		ζ =	...		ζ =	152°·24
	H =	·006		H =	·010		H =	...		H =	·002
	κ =	194°·46		κ =	284°·19		κ =	...		κ =	1°·36

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·026	289°·76	·023	53°·46
„ Fortnightly „	·052	350·01	·076	3·87
Luni-Solar „ „	·023	214·88	·022	12·72
Solar-Annual „	·283	310·17	·283	230·16
„ Semi-Annual „	·190	257·86	·190	97·82

VALUES OF THE TIDAL CONSTANTS, KIDDERPORE, 1902.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1902 Observations at Kidderpore; and also the values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1902 Observations:—

Short Period Tides.

A_0 = 10·398 feet.

S_1	H = R =	·070
	κ = ζ =	194°·20
S_2	H = R =	1·552
	κ = ζ =	99°·98
S_4	H = R =	·096
	κ = ζ =	109°·63
S_6	H = R =	·002
	κ = ζ =	325°·62
S_8	H = R =	·004
	κ = ζ =	303°·28
M_1	R =	·046
	ζ =	160°·89
	H =	·054
	κ =	249°·96
M_2	R =	3·875
	ζ =	215°·64
	H =	3·753
	κ =	58°·34
M_3	R =	·038
	ζ =	35°·20
	H =	·036
	κ =	339°·25
M_4	R =	·822
	ζ =	353°·19
	H =	·771
	κ =	38°·60

M_6	R =	·183
	ζ =	77°·18
	H =	·166
	κ =	325°·29
M_8	R =	·078
	ζ =	187°·58
	H =	·069
	κ =	278°·39
O_1	R =	·186
	ζ =	15°·34
	H =	·221
	κ =	20°·05
K_1	R =	·388
	ζ =	217°·58
	H =	·429
	κ =	52°·75
K_2	R =	·349
	ζ =	244°·38
	H =	·446
	κ =	93°·91
P_1	R =	·152
	ζ =	236°·27
	H =	·152
	κ =	46°·31
J_1	R =	·020
	ζ =	30°·11
	H =	·023
	κ =	351°·51

Q_1	R =	·021
	ζ =	139°·31
	H =	·025
	κ =	20°·61
L_2	R =	·183
	ζ =	274°·93
	H =	·153
	κ =	59°·23
N_2	R =	·625
	ζ =	328°·92
	H =	·606
	κ =	48°·21
λ_2	R =	...
	ζ =	...
	H =	...
	κ =	...
ν_2	R =	·178
	ζ =	193°·82
	H =	·172
	κ =	1°·56
μ_2	R =	·268
	ζ =	143°·85
	H =	·251
	κ =	189°·26
R_2	R =	...
	ζ =	...
	H =	...
	κ =	...

T_2	R =	·191
	ζ =	172°·37
	H =	·191
	κ =	173°·67
$(MS)_4$	R =	·726
	ζ =	237°·56
	H =	·703
	κ =	80°·27
$(2SM)_2$	R =	·077
	ζ =	221°·06
	H =	·075
	κ =	18°·36
$2N_2$	R =	·179
	ζ =	54°·08
	H =	·173
	κ =	9°·96
$(M_2N)_4$	R =	·247
	ζ =	106°·16
	H =	·232
	κ =	28°·15
$(M_2K_1)_3$	R =	·127
	ζ	341°·11
	H =	·136
	κ =	18°·99
$(2M_2K_1)_3$	R =	·033
	ζ =	111°·64
	H =	·034
	κ =	321°·87

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·263	267°·08	·236	30°·50
„ Fortnightly „	·193	37·47	·281	50·74
Luni-Solar „ „	·874	244·87	·847	42·16
Solar-Annual „	2·314	229·98	2·314	149·94
„ Semi-Annual „	1·004	138·61	1·004	338·53

VALUES OF THE TIDAL CONSTANTS, BASSEIN (BURMA), 1902.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1902 Observations at Bassein (Burma); and also the values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1902 Observations:—

Short Period Tides.

A_0 = 8·806 feet.

S_1	H = R =	·071	M_6	R =	·107	Q_1	R =	·009	T_2	R =	...
	κ = ζ =	137°·85		ζ =	347°·61		ζ =	185°·53		ζ =	...
S_2	H = R =	·754		H =	·097		H =	·011		H =	...
	κ = ζ =	90°·92		κ =	237°·03		κ =	67°·52		κ =	...
S_4	H = R =	·012	M_8	R =	·023	L_2	R =	·195	$(MS)_4$	R =	·184
	κ = ζ =	77°·74		ζ =	72°·63		ζ =	268°·07		ζ =	167°·40
S_6	H = R =	·003		H =	·020		H =	·163		H =	·178
	κ = ζ =	201°·04		κ =	165°·19		κ =	52°·57		κ =	10°·54
S_8	H = R =	·001	O_1	R =	·149	N_2	R =	·371	$(2SM)_2$	R =	·080
	κ = ζ =	233°·13		ζ =	34°·96		ζ =	324°·93		ζ =	143°·58
				H =	·177		H =	·359		H =	·077
				κ =	40°·13		κ =	44°·89		κ =	300°·44
M_1	R =	·025	K_1	R =	·350	λ_2	R =	...	$2N_2$	R =	·120
	ζ =	106°·23		ζ =	211°·00		ζ =	...		ζ =	20°·32
	H =	·029		H =	·388		H =	...		H =	·116
	κ =	195°·51		κ =	46°·15		κ =	...		κ =	337°·10
M_2	R =	2·368	K_2	R =	·131	ν_2	R =	·142	$(M_2N)_4$	R =	·084
	ζ =	205°·14		ζ =	258°·08		ζ =	193°·10		ζ =	32°·66
	H =	2·294		H =	·168		H =	·138		H =	·079
	κ =	48°·28		κ =	107°·57		κ =	1°·47		κ =	315°·76
M_3	R =	·002	P_1	R =	·130	μ_2	R =	·284	$(M_2K_1)_3$	R =	·088
	ζ =	209°·75		ζ =	241°·16		ζ =	131°·78		ζ =	265°·80
	H =	·002		H =	·130		H =	·266		H =	·095
	κ =	154°·46		κ =	51°·22		κ =	178°·06		κ =	304°·09
M_4	R =	·257	J_1	R =	·013	R_2	R =	...	$(2M_2K_1)_3$	R =	·066
	ζ =	279°·46		ζ =	274°·73		ζ =	...		ζ =	49°·90
	H =	·241		H =	·015		H =	...		H =	·069
	κ =	325°·74		κ =	235°·88		κ =	...		κ =	261°·02

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·169	279°·31	·152	42°·49
„ Fortnightly „	·079	3·17	·115	15·97
Luni-Solar „ „	·249	252·65	·241	49·51
Solar-Annual	1·864	232·31	1·864	152·25
„ Semi-Annual „	·570	122·38	·570	322·26

VALUES OF THE TIDAL CONSTANTS, RANGOON, 1902.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1902 Observations at Rangoon; and also the values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1902 Observations:—

Short Period Tides.

A_0 = 10·031 feet.

S_1	H = R =	·112	M_6	R =	·258	Q_1	R =	·016	T_2	R =	·157
	κ = ζ =	125°·44		ζ =	189°·22		ζ =	155°·07		ζ =	203°·20
S_2	H = R =	2·199		H =	·234		H =	·019		H =	·157
	κ = ζ =	164°·89		κ =	78°·93		κ =	37°·21		κ =	204°·55
S_4	H = R =	·073	M_8	R =	·080	L_2	R =	·417	$(MS)_4$	R =	·391
	κ = ζ =	255°·96		ζ =	353°·54		ζ =	355°·66		ζ =	0°·12
S_6	H = R =	·011		H =	·070		H =	·349		H =	·379
	κ = ζ =	35°·60		κ =	86°·49		κ =	140°·21		κ =	203°·36
S_8	H = R =	·007	O_1	R =	·254	N_2	R =	1·044	$(2SM)_2$	R =	·182
	κ = ζ =	102°·34		ζ =	21°·44		ζ =	35°·60		ζ =	250°·59
				H =	·302		H =	1·012		H =	·177
				κ =	26°·71		κ =	115°·71		κ =	47°·35
M_1	R =	·024	K_1	R =	619	λ_2	R =	...	$2N_2$	R =	·354
	ζ =	94°·76		ζ =	198°·52		ζ =	...		ζ =	130°·12
	H =	·028		H =	·685		H =	...		H =	·343
	κ =	184°·09		κ =	33°·68		κ =	...		κ =	87°·10
M_2	R =	6·167	K_2	R =	·415	ν_2	R =	·283	$(M_2N)_4$	R =	·147
	ζ =	284°·70		ζ =	322°·49		ζ =	279°·76		ζ =	232°·92
	H =	5·973		H =	·530		H =	·275		H =	·138
	κ =	127°·94		κ =	171°·98		κ =	88°·28		κ =	156°·26
M_3	R =	·021	P_1	R =	·173	μ_2	R =	·603	$(M_2K_1)_3$	R =	·152
	ζ =	138°·37		ζ =	239°·59		ζ =	245°·28		ζ =	19°·23
	H =	·020		H =	·173		H =	·566		H =	·163
	κ =	83°·22		κ =	49°·65		κ =	291°·75		κ =	57°·62
M_4	R =	·410	J_1	R =	·021	R_2	R =	...	$(2M_2K_1)_3$	R =	·100
	ζ =	116°·47		ζ =	195°·83		ζ =	...		ζ =	190°·64
	H =	·385		H =	·024		H =	...		H =	·104
	κ =	162°·95		κ =	156°·93		κ =	...		κ =	41°·96

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·194	256°·98	·174	20°·21
„ Fortnightly „	·129	27·42	·188	40·12
Luni-Solar „ „	·457	246·22	·443	42·98
Solar-Annual „	1·177	217 50	1·177	137·44
„ Semi-Annual „	·230	120·63	·230	320·51

VALUES OF THE TIDAL CONSTANTS, PORT BLAIR, 1902.

The following are the amplitudes (R) and epochs (ζ) deduced from the 1902 Observations at Port Blair; and also the values of the amplitudes (H) and of the epochs (κ) for each particular tide evaluated from the 1902 Observations:—

Short Period Tides.

A_0 = 4·717 feet.

S_1	H = R =	·019	M_6	R =	·001	Q_1	R =	·011	T_2	R =	·c61
	κ = ζ =	37°·53		ζ =	116°·57		ζ =	355°·68		ζ =	3°·13
S_2	H = R =	·963		H =	·001		H =	·013		H =	·061
	κ = ζ =	314°·79		κ =	5°·58		κ =	237°·46		κ =	4°·44

Short Period Tides—contd.

S_4	H = R =	·015	M_8	R =	·004	L_2	R =	·080	$(MS)_4$	R =	·029
S_4	κ = ζ =	290°·87	M_8	ζ =	335°·10	L_2	ζ =	141°·65	$(MS)_4$	ζ =	44°·27
S_6	H = R =	·001	M_8	H =	·003	L_2	H =	·067	$(MS)_4$	H =	·028
S_6	κ = ζ =	60°·26	M_8	κ =	67°·11	L_2	κ =	286°·[illegible]9	$(MS)_4$	κ =	247°·28
S_8	H = R =	·001	O_1	R =	·131	N_2	R =	·396	$(2SM)_2$	R =	·024
S_8	κ = ζ =	135°·00	O_1	ζ =	296°·09	N_2	ζ =	195°·18	$(2SM)_2$	ζ =	336°·64
			O_1	H =	·155	N_2	H =	·383	$(2SM)_2$	H =	·023
			O_1	κ =	301°·12	N_2	κ =	274°·93	$(2SM)_2$	κ =	133°·64
M_1	R =	·011	K_1	R =	·359	λ_2	R =	...	$2N_2$	R =	·054
M_1	ζ =	141°·09	K_1	ζ =	132°·88	λ_2	ζ =	...	$2N_2$	ζ =	286°·69
M_1	H =	·013	K_1	H =	·397	λ_2	H =	...	$2N_2$	H =	·052
M_1	κ =	230°·30	K_1	κ =	328°·05	λ_2	κ =	...	$2N_2$	κ =	243°·19
M_2	R =	2·063	K_2	R =	·187	ν_2	R =	·052	$(M_2N)_4$	R =	·002
M_2	ζ =	76°·52	K_2	ζ =	103°·16	ν_2	ζ =	55°·54	$(M_2N)_4$	ζ =	141°·34
M_2	H =	1·998	K_2	H =	·239	ν_2	H =	·050	$(M_2N)_4$	H =	·002
M_2	κ =	279°·52	K_2	κ =	312°·66	ν_2	κ =	223°·71	$(M_2N)_4$	κ =	64°·09
M_3	R =	·007	P_1	R =	·128	μ_2	R =	·064	$(M_2K_1)_3$	R =	·017
M_3	ζ =	51°·98	P_1	ζ =	153°·13	μ_2	ζ =	261°·27	$(M_2K_1)_3$	ζ =	154°·86
M_3	H =	·007	P_1	H =	·128	μ_2	H =	·060	$(M_2K_1)_3$	H =	·018
M_3	κ =	356°·49	P_1	κ =	323°·19	μ_2	κ =	307°·28	$(M_2K_1)_3$	κ =	193°·02
M_4	R =	·011	J_1	R =	·009	R_2	R =	...	$(2M_2K_1)_3$	R =	·006
M_4	ζ =	93°·21	J_1	ζ =	319°·40	R_2	ζ =	...	$(2M_2K_1)_3$	ζ =	352°·01
M_4	H =	·011	J_1	H =	·011	R_2	H =	...	$(2M_2K_1)_3$	H =	·006
M_4	κ =	139°·22	J_1	κ =	280°·63	R_2	κ =	...	$(2M_2K_1)_3$	κ =	202°·86

Long Period Tides.

	R	ζ	H	κ
		°		°
Lunar Monthly Tide	·047	219·95	·042	343·20
„ Fortnightly „	·058	359·78	·085	12·73
Luni-Solar „ „	·016	91·06	·016	248·06
Solar-Annual „	·149	213·95	·149	133·90
„ Semi-Annual „	·036	32·45	·036	232·35

Date of commencement of computations.

The tidal computations for the several stations commenced on the 1st January.

State of Tidal computations.

The present state of the tidal computations is shown in the following table together with their state at the end of September 1902. 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 from graduated staves, and compared with predicted values published in the tide-tables.

State of the ordinary reductions of the yearly Tidal registrations at the beginning and end of the Survey year 1902-1903.

Tidal Observatory.	State at end of September 1902.	State at end of September 1903.
Suez	1901 calculations completed. A. P. 1901.	1902 calculations completed. A. P. 1902.
Perim	1901 calculations completed. A. P. 1901.	1902 calculations completed. A. P. 1902.
Aden	1901 calculations completed. A. P. 1901.	1902 calculations completed. A. P. 1902.
Kurrachee	1901 calculations completed. A. P. 1901.	1902 calculations completed. A. P. 1902.
Port Albert Victor	1901 calculations completed. A. P. 1901.	1902 calculations completed. A. P. 1902.
Bhávnagar	A. P. 1901	A. P. 1902.
Bombay { Apollo Bandar	1901 calculations completed. A. P. 1901.	1902 calculations completed. A. P. 1902.
Bombay { Prince's Dock	1901 calculations completed. A. P. 1901.	1902 calculations completed. A. P. 1902.
Madras	1901 calculations completed. A. P. 1901.	1902 calculations completed. A. P. 1902.
Kidderpore	1901 calculations completed. A. P. 1901.	1902 calculations completed. A. P. 1902.
Chittagong	A. P. 1901	A. P. 1902.
Akyab	A. P. 1901	A. P. 1902.
Bassein (Burma)	Started working 1st January 1902.	1902 calculations completed.
Rangoon	1901 calculations completed. A. P. 1901.	1902 calculations completed. A. P. 1902.
Moulmein	A. P. 1901	A. P. 1902.
Port Blair	1901 calculations completed. A. P. 1901.	1902 calculations completed. A. P. 1902.

Auxiliary reports.

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.

The Tide-Tables.

Data for Tide-Tables.

The usual work in connection with the timely issue of the tide-tables for the year 1904 has been carried out. The tide-tables now contain the predictions of high and low-water for 39 ports.

Receipt and Issue of Tide-Tables.

The tide-tables for 1903 were again received late, and could not therefore be distributed to the recipients till after the commencement of the year. After the year 1904, however, this will no longer be the case, as from the data sent to Mr. Roberts this year, the high and low-waters for the two years 1904 and 1905 are being predicted, and the tide-tables for 1905 should therefore be received a year before they are required, and there will be no further difficulty in issuing them in good time.

Datum for Tide-Tables.

The datum for the tide-tables for 1904 is the datum of soundings of the latest admiralty charts with the exception of Bassein. Tables giving the particulars of the datum at each tidal station will be found in the appendix to the general reports for 1891-92, 1893-94, 1895-96 in paragraph 24 of the annual report for 1898-99, and in paragraph 22 of the narrative report for 1900-01.

The datum for the tide-tables of Bassein is the Indian Spring Low-water mark, which has not yet been connected with the admiralty datum.

Sale of Tide-Tables.

The amount realized by the sale of the tide-tables in the financial year 1902-03 was R62-8-7 in defect of the amount realized in the preceding year.

Data supplied to Mr. Roberts.

Mr. E. Roberts has been furnished with the following :—

(i) Mean values of the tidal constants for the tide-tables for 1904 and 1905 calculated in the usual manner and ready for use in the tide-predictor.

(ii) Actual values during 1902 of every high and low-water measured in duplicate from the tidal diagrams at 11 stations and of tide-pole observations taken during day-light at 4 closed stations.

(iii) Comparisons of the above with predicted values for 1902, the errors being tabulated in a convenient form to assist Mr. Roberts in his predictions.

On the completion of the predictions for the tides of 1904 and 1905 the tide predictor will be moved to the National Physical Laboratory at Teddington.

Errors in predicted Times and Heights of High and Low-water.

The usual tabular statements Nos. 1 to 5 are appended showing the percentage and amount of errors in the predicted times and heights of high and low-water for the year 1902 at 15 stations, as determined by comparison of the predictions given in the tide-tables with actual values measured from the tidal diagrams at 11 stations and from tide-poles at 4 stations; the former being made by assistants in this office, and the latter by Port officials.

No. 1.

Statement showing the percentage and the amount of the errors in the predicted times of high water at the various Tidal stations for the year 1902.

Stations.	Automatic or Tide-pole observation.	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	22	33	15	20	10
Perim	Au.	688	30	39	13	10	8
Aden	Au.	692	44	40	9	5	2
Kurrachee	Au.	703	23	41	18	15	3
Port Albert Victor	Au.	691	29	39	13	11	8
Bhávnagar	T.P.	276	22	69	4	4	1
Bombay { Apollo Bandar	Au.	699	35	45	9	8	3
Bombay { Prince's Dock	Au.	689	36	46	7	6	5
Madras	Au.	706	42	47	6	4	1
Kidderpore	Au.	705	26	33	14	17	10
Chittagong	T.P.	365	20	41	11	8	20
Akyab	T.P.	346	98	2	...	...	...
Rangoon	Au.	695	27	40	15	14	4
Moulmein	T.P.	361	38	49	7	5	1
Port Blair	Au.	706	49	42	4	4	1

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 1902.

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.	705	11	26	17	29	17
Perim	Au.	685	32	44	9	9	6
Aden	Au.	692	36	47	8	5	4
Kurrachee	Au.	703	25	39	15	15	6
Port Albert Victor	Au.	694	23	35	11	15	16
Bhávnagar	T.P.	276	21	68	5	4	2
Bombay { Apollo Bandar	Au.	696	24	42	13	15	6
Bombay { Prince's Dock	Au.	690	22	39	17	15	7
Madras	Au	705	27	48	14	10	1
Kidderpore	Au.	703	20	36	17	19	8
Chittagong	T.P.	365	13	36	11	22	18
Akyab	T.P.	346	39	61	...	...	...
Rangoon	Au.	695	18	33	15	19	15
Moulmein	T.P.	361	33	45	12	8	2
Port Blair	Au.	705	39	46	9	5	1

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 1902.

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	60	28	10	2
Perim	Au.	688	5·6	85	14	1	...
Aden	Au.	692	6·7	90	10	...	...
Kurrachee	Au.	703	9·3	66	30	3	1
Port Albert Victor	Au.	691	11·7	42	29	20	9
Bhávnagar	T.P.	276	31·4	43	36	13	8
Bombay { Apollo Bandar	Au.	699	13·9	72	25	2	1
Bombay { Prince's Dock	Au.	689	13·9	68	27	3	2
Madras	Au.	706	3·5	88	12	...	...
Kidderpore	Au.	705	11·7	46	28	14	12
Chittagong	T.P.	365	13·3	38	22	17	23
Akyab	T.P.	346	8·3	73	21	6	...
Rangoon	Au.	695	16·4	46	31	17	6
Moulmein	T.P.	361	12·7	42	26	15	17
Port Blair	Au.	706	6·6	96	4	...	...

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 1902.

Stations.	Automatic or Tide-pole observations.	Number of comparisons between actual and predicted value.	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.	705	5·5	59	30	8	3
Perim	Au.	685	5·6	90	9	1	...
Aden	Au.	692	6·7	87	13	...	...
Kurrachee	Au.	703	9·3	83	14	2	1
Port Albert Victor	Au.	694	11·7	52	31	12	5
Bhávnagar	T. P.	276	31·4	28	44	17	11
Bombay { Apollo Bandar	Au.	696	13·9	72	23	4	1
Bombay { Prince's Dock	Au.	690	13·9	68	26	4	2
Madras	Au.	705	3·5	84	15	1	...
Kidderpore	Au.	703	11·7	44	23	17	16
Chittagong	T. P.	365	13·3	41	28	18	13
Akyab	T. P.	346	8·3	66	22	12	...
Rangoon	Au.	695	16·4	18	20	24	38
Moulmein	T. P.	361	12·7	18	28	24	30
Port Blair	Au.	705	6·6	96	4	...	...

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 1902.

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	15	20	·061	·061	4	4
Perim	Au.	5·6	13	12	·045	·030	3	2
Aden	Au.	6·7	9	10	·025	·025	2	2
Kurrachee	Au.	9·3	13	13	·036	·027	4	3
Port Albert Victor	Au.	11·7	13	18	·043	·036	6	5
Bhávnagar	T. P.	31·4	9	10	·016	·021	6	8
Bombay { Apollo Bandar	Au.	13·9	10	13	·018	·024	3	4
Bombay { Prince's Dock	Au.	13·9	10	14	·024	·024	4	4
Madras	Au.	3·5	8	11	·048	·071	2	3
Akyab	T. P.	8·3	1	5	·030	·040	3	4
Port Blair	Au.	6·6	7	9	·025	·025	2	2
General mean			10	12	·034	·035	...	...
Riverain.								
Kidderpore	Au.	11·7	15	15	·043	·050	6	7
Chittagong	T. P.	13·3	17	21	·050	·044	8	7
Rangoon	Au.	16·4	12	17	·030	·056	6	11
Moulmein	T. P.	12·7	8	10	·046	·066	7	10
General mean			13	16	·042	·054	...	...

The foregoing statement for the year 1902 may be thus summarised :—

Percentage of time predictions within 15 minutes of actuals.

		High-water. Per cent.	Low-water. Per cent.
Open Coast stations.	9 at which predictions were tested by S. R. T. gauge	76	67
	2 " " " " Tide-pole	96	95
Riverain stations.	2 " " " by S. R. T. gauge	63	54
	2 " " " " Tide-pole	74	64

Percentage of height predictions within 8 inches of actuals.

		High-water. Per cent.	Low-water. Per cent.
Open Coast stations.	9 at which predictions were tested by S. R. T. gauge	94	95
	2 " " " " Tide-pole	87	80
Riverain stations.	2 " " " by S. R. T. gauge	76	53
	2 " " " " Tide-pole	64	58

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

		High-water. Per cent.	Low-water. Per cent.
Open Coast stations.	9 at which predictions were tested by S. R. T. gauge	96	96
	2 " " " " Tide-pole	100	97
Riverain stations.	2 " " " by S. R. T. gauge	96	90
	2 " " " " Tide-pole	90	88

Accuracy of Summary.

In the above summary the readings taken from the diagrams are accurate both as to time and height, but those from tide-poles are occasionally subject to considerable errors as regards time, owing to the inaccuracy of the time locally kept.

Comparison of predictions at Riverain Stations for years 1901 and 1902.

The predictions at the riverain stations for the year 1902 as compared with those of last year, were better in times and heights at Kidderpore and about the same in times and slightly inferior in heights at Rangoon ; worse in times and heights at Chittagong and about the same in times and heights at Moulmein, these two latter being tide-pole stations.

At Kidderpore the greatest difference between the actual and predicted heights of low water was 2 ft. on the 6th July and 31st August 1902 ; in both these instances the predictions were in excess.

At Chittagong the greatest difference between the actual and predicted heights of low water was 1 ft. 11 inches on the 17th February 1902, the prediction being in excess.

At Rangoon the greatest difference in heights of low water was 3 ft. 7 inches on the 6th May 1902, the actual being in defect of the predicted height.

At Moulmein the greatest error in low water heights was 3 ft. 2 inches on the 18th and 19th August 1902, in both instances the predicted heights were in defect.

Levelling Operations.

Work in which Levelling Detachment was employed.

The levelling detachment was employed in Burma on two separate lines, required by the Irrigation Branch, Public Works Department, Burma—

i. Thazi to Minbu.
ii. Sagaing to Tantabin.

The *personnel* of the detachment is shown in the margin. Mr. Corridon held charge of the detachment throughout the year.

Personnel.

Levellers.

Mr. E. H. Corridon . . 1st Leveller.
Munshi Syed Zille Hasnain 2nd „

Recorders.

Rikhi Ram.
Lachman Singh.
Gopal Singh.

Orders of Detachment.

Mr. Corridon had received orders to first level along the line Thazi to Minbu, crossing the Irrawaddy from Magwe to Minbu and on completion of this line to proceed to Amarapura and connect the pillar erected by No. 24 (Triangulation) Party on the east bank of the Irrawaddy with the old line of levels of 1892-93 which terminated at Mandalay. The heights of the two banks of the Irrawaddy were connected by No. 24 (Triangulation) Party by means of reciprocal vertical angles taken simultaneously by two observers with 12-inch theodolites. On the bench-mark on the east bank of the Irrawaddy being connected with the old line of levels, Mr. Corridon's orders were to continue the line of levels on the west bank along the Burma Railway.

Departure for and arrival in the Field.

The detachment left Dehra for Burma on the 14th October 1902, and arrived at Thazi on the 24th October.

Description of Operations.

After all preliminary arrangements were completed levelling operations were commenced from the embedded bench-mark at Thazi Railway station, and were carried along the Myingyan branch of the Burma Railway as far as Meiktila. Here the line of levels left the railway and proceeded along a cart track running due west to Kyaukpadaung, from which place it ran south as far as the Pin river and then westwards to Yenangyaung, and thence along the east bank of the Irrawaddy to Magwe. At Magwe the Irrawaddy river was crossed to Minbu. The crossing was effected in the following manner. After reconnoitring the river for several miles a suitable crossing was selected. The two levellers then set up their instruments on an island in the centre of the river, and the staves were placed on stout piles driven into the two opposite banks of the river 52 chains apart. Sixty-four sets of observations in all were taken, 30 sets by 1st leveller and 34 by the second; the general means of the results obtained by both levellers differed only by 0·004 of a foot.

The line from Thazi to Minbu was 136 miles and was carried over very undulating and in some places hilly country, making the work difficult and progress slow. The line was completed on the 11th March 1903, and the detachment left immediately for Mandalay.

From here operations were resumed along the Burma Railway and carried *viâ* Sagaing to Shwebo, the crossing of the river having already been effected by No. 24 (Triangulation) Party. Work was closed for the season at Shwebo on the 2nd May 1903.

Summary of work done.

The total outturn of work for the season was 215 miles, in the course of which the instrument was set up at 3,866 stations, and the total rises and falls amounted to 11,314 feet. The heights of 31 embedded and 79 inscribed bench-marks were determined; 2 old embedded and 9 old inscribed bench-marks were connected; 1 Great Trigonometrical Survey Station and 2 railway bench-marks were also determined.

Tables.

The usual tabular statements are appended.

TABLE A.

List of Great Trigonometrical Survey Stations connected by spirit-levelling—season 1902-03.

NAME OF STATION.	HEIGHT IN FEET ABOVE MEAN SEA-LEVEL.		Error of height by triangulation in feet.	REMARKS.
	By spirit-levelling.	By triangulation.		
Sheinmaga, H.S., of the Mandalay Meridional Series . . .	446·2	455·5	—9·3	The height refers to upper mark.

TABLE B.

Results of comparison of staves—season 1902-03.

PLACE AND DATE OF COMPARISON.	Staff No. B 1.	Staff No. B 2.	Staff No. 13.	Staff No. 4.
Thazi, 30th October 1902 . .	+0·0018802	+0·0001711	+0·0007822	+0·0003266
Shanma-nge, 30th November 1902	+0·0026450	+0·0001595	+0·0013313	+0·0011971
Taukshabin, 12th March 1903 .	+0·0012387	—0·0017654	—0·0023225	—0·0016887
Shwebo, 2nd May 1903 . .	+0·0002069	—0·0025858	—0·0035660	—0·0017790

Tabular statement of outturn of work for the field season 1902-03.

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.	Other points.	Remarks.
Thazi *viâ* Meiktila and Magwe to Minbu.	November 1902	34	10	62	0	29	56	1161·765	642·583	698	...	6*	5	12	...	...	...	...	Ms. Chs. Lks. Exclusive of 5 74 94 check levelling. * Include 5 old inscribed B. Ms.
	December "	30	7	10	0	7	78	1867·468	2029·815	799	...	...	3	12	...	...	...	...	
	January 1903	38	19	46	1	75	42	773·329	1346·750	660	...	...	5	10	...	...	...	...	
	February "	27	57	2	0	68	80	1091·510	1257·215	661	...	...	4	10	...	...	...	...	
	March "	5	46	44	4	54	54	138·436	113·580	199	...	...	3	5	...	...	...	...	
	TOTALS	135	60	64	7	76	10	5032·508	5389·943	3,017	...	6	20	49	...	...	...	...	
Mandalay to Shwebo	March 1903	21	10	10	0	17	46	192·517	150·627	293	...	5†	5	9	...	...	...	...	† Include 4 old Inscribed B. Ms.
	April "	39	38	66	8	45	54	269·051	218·314	529	...	...	4	20	1	2	...	...	
	May "	2	26	50	0	3	66	20·545	4·589	27	...	...	2	1	...	...	...	...	
	TOTALS	62	75	26	8	66	66	482·113	373·530	849	...	5	11	30	1	2	...	...	
	GRAND TOTALS	198	55	90	16	62	76	5514·621	5763·473	3,866	...	11	31	79	1	2	...	...	

Season's outturn . . Ms. 215 Chs. 38 Lks. 66; Rises and Falls 11278·094 feet.

VII

THE MAGNETIC SURVEY OF INDIA.

Extracted from the Narrative Report of Captain H. A. D. Fraser, R.E., in charge No. 26 Party (Magnetic) for season 1902-03.

General accuracy of the field work.

The routine adopted for all field observations was fully detailed in the Annual Report for season 1901-1902, and remained practically unchanged during the past season. There were comparatively very few cases in which observations had to be repeated, because those first taken fell outside the limits laid down and the standard of accuracy attained was much higher than that reached during the first season, and leaves little room for improvement in future. These results were due chiefly to the fact that the peculiarities of the instruments were known and the rules for observing framed to meet them, but partly also to the previous experience of some observers and the more complete training of those who were new. In some cases a considerable portion of the working season was occupied in completing the training of the new observers and though their outturn of work was on this account unavoidably small, it may be noted that in no single instance has the work done at a station had to be rejected as lacking in accuracy.

Number of field detachments.

In addition to the officer in charge five detachments worked for various periods in the field as shown below:—

	1	2	3	4	5	6	7	8	
Name of observer.	Commenced field work.	Finished field work.	Total days of field work.	New stations visited.	Old work revised.	Duplicate stations.	Total stations occupied.	Average outturn per week.	REMARKS.
Mr. Morton	18th November 1902.	27th April 1903	161	64	...	...	64	2·78	Chiefly along railways.
R. P. Ray	5th November 1902.	25th May 1903	202	37	32	...	69	2·39	Railways and desert.
Mr. Talati	31st March 1903	29th April 1903	30	14	...	...	14	3·27	Railways.
„ Meyer	8th January 1903.	23rd March 1903	75	29	...	3	32	2·99	Railways.
K. K. Dutta	2nd November 1902.	22nd April 1903	172	60	5	...	65	2·65	Some railways chiefly desert.
TOTALS	. . . .	. . . .	640	204	37	3	244	2·67	

NOTES.—In the above table columns 1 and 2 do not include the time spent in journeys before commencing and after finishing field work.

At all stations entered in columns 4 and 6 observations for Dip, Declination and Force were completed, but at most of those visited by R. P. Ray and entered in column 5 Force observations only were taken.

The duplicate stations entered in column 6 are railway junctions visited by two observers during the same season.

During the previous season 163 stations were visited, so that the total number at the end of the second season amounts to 367.

As the total stations to be included in the fundamental survey amount to about 1,100, there remain some 733 stations to complete the initial programme which contemplates a distribution interval between stations of from 35 to 40 miles throughout India and the most accessible parts of Burma.

Mr. Morton's detachment.

The detachment under Mr. Morton made a preliminary tour to 5 stations in the vicinity of Dehra Dún, before commencing their prescribed programme of work along the system of railways in the Bombay and Madras Presidencies.

Mr. Morton used magnetometer No. 6 by Cooke and Dip Circle No. 138 by Dover and both instruments behaved well throughout the season. It was found, however, that the "magnetic collimation" of magnet No. 6 A., was by no means constant owing to the defective turnover of the aluminium cell holding the collimator lens. As a satisfactory mean value of the "magnetic collimation" could not be obtained, the ordinary criterion for declination observations could not be applied and to prevent gross errors Mr. Morton was ordered to take duplicate sets of declination observations at each station. The results indicate that the "magnetic collimation" was generally a constant at each place, but changed considerably under the jarring to which the instrument was subjected when moving camp. Hence the declination observations may be accepted with confidence.

Any longitudinal displacement of the lens in its cell would have altered the moment of inertia of the magnet and vitiated to some extent the force observations. To guard against this the observer made a practice of pressing the lens well home before commencing a set of vibrations and the computed values of m (the moment of the magnet at 0° C) are so accordant that it is certain that the Force observations did not suffer from this defect in the magnet.

R. P. Ray's detachment.

The detachment under Sub-Assistant Superintendent R. P. Ray was ordered to repeat the Force observations at 32 of the stations they had occupied the previous season and in addition to march along the trans-*Indus* frontier from *Kurrachee* to *Kohát*. To complete this programme the observer had to remain out till nearly the end of May, but though his progress was slower than had been anticipated the work was good.

Ray used magnetometer No. 3 by Cooke and Dip Circle No. 135 by Dover, both of which behaved well throughout the season.

Mr. Talati's detachment.

Mr. Talati joined the party after the field work had begun and accompanied the officer in charge during January and February 1903 in order to gain experience in field work. He worked independently for about one month at the end of the season with satisfactory results.

Mr. Talati used magnetometer No. 1 by Cooke and Dip Circle No. 136 with needles No. $\frac{139}{2}$ and $\frac{139}{3}$. During a sudden and violent dust storm the former together with the tent in which it was standing, was blown down and sustained some slight injuries. At the time of the accident, the magnetometer was being used as the Referring Mark for observing an azimuth and consequently there was only one man near it. To obviate such accidents in future Mr. Talati designed a simple self-centring referring mark which has since been adopted for general use.

Mr. Meyer's detachment.

Mr. Meyer joined in November and by the end of December was thoroughly trained. Early in January 1903 he commenced work at *Tuticorin* whence he worked northwards along the railways till he reached *Bellary* on the 23rd March.

At this place he received orders to relieve the observer at *Kodaikánal* Magnetic Observatory whose health had failed, and consequently had to abandon the rest of his programme. He remained at Kodaikánal till 2nd July 1903 where his work was quite satisfactory. In the field he used magnetometer No. 5 by Cooke and Dip Circle No. 140 by Dover, both of which instruments behaved well and gave no trouble, though latterly the differences in the Dip given by the two needles (Nos. 1 and 2) were at several stations rather abnormally large.

K. K. Dutta's detachment.

Sub-Surveyor K. K. Dutta did a good season's work. For the greater part of the time he was moving through the arid tracts of the Rajputana desert, where water of any kind was scarce and good drinking water very rare. Thanks to his energy and the cordial co-operation given by the Native States traversed, he produced a large outturn of accurate work and revisited three of the desert stations occupied by Mr. Hunter in the previous season. He used magnetometer No. 4 by Cooke and Dip Circle No. 137 by Dover with needle No. 3 and an old needle No. 1 taken from Barrow Circle No. 44.

The accordance of the results given by the two needles was fair, though not quite as close as is desirable.

Captain Fraser's detachment.

The officer in charge took a series of Declination and Force observations with each of the magnetometers used in the field, with the object of supplying observers with reliable preliminary values of the constants of each instrument and for the purposes of comparison with the Survey standard. Subsequently he inspected each detachment in the field (except that under Mr. Talati) and observed at 5 old and 4 new Repeat Stations, besides visiting the base stations at Kodaikánal and Colába.

During the recess season the officer in charge accompanied by Lieutenant R. H. Thomas erected the magnetographs at Barrackpore, *vide* paragraph 40.

Values of P.

The following tables show the values of the distribution Constant P derived from the season's observations.

Number of magnet.	P from 22·5 and 30 cms.					P from 30 and 40 cms.					Remarks.
	Mean from all observations.	Adopted mean value.	Total number of observations.	Number of rejected observations.	Number of observations used in finding mean.	Mean from all observations.	Adopted mean value.	Total number of observations.	Number of rejected observations.	Number of observations used in finding mean.	
1 A	7·47	7·47	115	2	113	7·80	7·78	115	12	103	
3 A	6·70	6·71	90	6	84	7·92	7·74	112	36	76	
4 A	7·54	7·55	98	6	92	8·58	8·60	103	20	83	
5 A	6·99	6·99	44	10	34	7·80	7·85	42	7	35	As used in the field early in 1903.
5 A	7·13	7·12	49	1	48	7·77	7·83	49	7	42	As used at Dehra Dún Observatory for year 1902.
6 A	7·91	7·91	79	1	78	7·98	8·11	81	14	67	

The empirical method adopted for rejecting extreme values is as follows:—

The general mean from all values is first obtained and limiting values are thence derived: in the case of P from $\frac{22 \cdot 5 \text{ and } 30}{30 \text{ and } 40}$ cms. the limits are $\frac{5}{10}$ per cent. from the G. M. All values outside limits are rejected; a fresh mean is then taken with fresh limits and the process repeated till it is found that further operations will not appreciably change the value obtained (*vide* Annual Report, 1901-02, paragraph 12). It will be noticed that the original and adopted mean values for P from 22·5 and 30 cms. are in every case practically identical: in the case of P from 30 and 40 cms. the average difference between these means is less than 0·1.

It is of course open to doubt whether the adopted value is appreciably better than the original one, but it at least serves to exclude values which are largely in error either owing to gross errors in observations or to unfavourable conditions at the time of observation.

Values of P and Q.

The expression for the connection between the magnetic moment m of the deflecting magnet, the horizontal component H, the distance r between the magnet and the needle (*i.e.*, the suspended magnet) and the angle of deflection u in the position employed in the Cooke and Kew pattern magnetometers is—

$$\frac{H}{m} = \frac{2}{r^3 \sin u}\left\{1 + \frac{P}{r^2} + \frac{Q}{r^4} + \text{etc.}\right\}$$

where P, Q, etc., are the "distribution" constants. If we assume $\frac{Q}{r^4}$ and terms involving higher powers of r to be negligible and if we call A_1 and A_2 the values of $\frac{r^3 \sin u}{2}$ at the distances r_1 and r_2 respectively, we have

$$\frac{1}{A_1}\left(1 + \frac{P}{r_1^2}\right) = \frac{1}{A_2}\left(1 + \frac{P}{r_2^2}\right)$$

$$\text{whence } P = \frac{A_1 - A_2}{\frac{A_2}{r_1^2} - \frac{A_1}{r_2^2}} \quad \ldots\ldots\ldots \quad \text{(i)}$$

Now the value of P is calculated from this relation even when $\frac{Q}{r^4}$ is not negligible and consequently the P thus obtained is not the same as the P which forms the numerator of the second term in the distribution term $\left\{1 + \frac{P}{r^2} + \frac{Q}{r^4} + \ldots\ldots\ldots\ldots\right\}$.

To avoid confusion on this score the numerators in the distribution term will be denominated in future by small letters and P will only be used as in relation (i) above.

$$\text{Now } A_1 = \frac{m}{H}\left\{1 + \frac{p}{r_1^2} + \frac{q}{r_1^4} + \ldots\ldots\ldots\ldots\right\}$$

$$A_2 = \frac{m}{H}\left\{1 + \frac{p}{r_2^2} + \frac{q}{r_2^4} + \ldots\ldots\ldots\ldots\right\}$$

$$\text{Hence } \frac{A_1 - A_2}{\frac{A_2}{r_1^2} - \frac{A_1}{r_2^2}} = \frac{\left(\frac{1}{r_1^2} - \frac{1}{r_2^2}\right)\left\{p + q\left(\frac{1}{r_1^2} + \frac{1}{r_2^2}\right)\right\}}{\frac{1}{r_1^2}\left(1 + \frac{p}{r_2^2} + \frac{q}{r_2^4}\right) - \frac{1}{r_2^2}\left(1 + \frac{p}{r_1^2} + \frac{q}{r_1^4}\right)}$$

$$\text{or } P = \frac{p + q\left(\frac{1}{r_1^2} + \frac{1}{r_2^2}\right)}{1 + \frac{q}{r_1^2 r_2^2}}$$

$$= \left\{p + q\left(\frac{1}{r_1^2} + \frac{1}{r_2^2}\right)\right\}\left\{1 + \frac{q}{r_1^2 r_2^2} - \text{etc.}\right\}$$

$$P = p + q\left(\frac{1}{r_1^2} + \frac{1}{r_2^2}\right) + \frac{pq}{r_1^2 r_2^2} + \text{etc.}$$

It would be better to write P when derived from two distances r_1 and r_2 as $P_{1\cdot 2}$, so that we have—

$$P_{1\cdot 2} = p + q\left(\frac{1}{r_1^2} + \frac{1}{r_2^2}\right) + \frac{pq}{r_1^2 r_2^2} + \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(ii)*}$$

Similarly $P_{2\cdot 3} = p + q\left(\frac{1}{r_2^2} + \frac{1}{r_3^2}\right) + \frac{pq}{r_2^2 r_3^2} + \quad . \quad . \quad . \quad . \quad . \quad .$

Now the third term in these two expressions is relatively small and may be neglected in the first instance, so that we get,

$$P_{1\cdot 2} - P_{2\cdot 3} = q\left(\frac{1}{r_1^2} - \frac{1}{r_3^2}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(iii)}$$

Equation (iii) affords an easy method of evaluating q, for $P_{1\cdot 2}$ and $P_{2\cdot 3}$ are the values actually found experimentally by using relation (i) and have been tabulated in the preceding paragraph for various instruments. In solving equations (ii) and (iii) it will suffice to give r_1 r_2 r_3 the values 22·5, 30·0 and 40·0 cms. instead of their actual values as found at Kew, the differences being small in every case.

Hence we get $q = (P_{1\cdot 2} - P_{2\cdot 3})\ 740$ . . . . (iv)

The following table gives the values of $P_{1\cdot 2}$, $P_{2\cdot 3}$ and of p and q, the latter being computed from equations iv and ii.

Magnet.	$P_{1\cdot 2}$	$P_{2\cdot 3}$	p	q	Remarks.
1A . . .	+7·47	+7·78	+8·18	−229	
3A . . .	+6·71	+7·74	+9·08	−762	
4A . . .	+7·55	+8·60	+9·97	−777	
5A . . .	+6·99	+7·85	+8·97	−636	Field values.
5A . . .	+7·12	+7·83	+8·75	−525	Observatory values.
6A . . .	+7·91	+8·11	+8·37	−148	

From these values the following table has been computed.

Instrument.	1	2	3	4	5	6	Remarks.
	$\text{Log.}\left\{1 - \frac{p}{r^2} - \frac{q}{r^4}\right\}$			$\text{Log.}\left\{1 - \frac{P}{r^2}\right\}$		Correction. (1) − (4)	
	r = 22·5	r = 30	r = 40	r = 22·5	r = 30		
1	$\bar{1}$·99332	$\bar{1}$·99616	$\bar{1}$·99781	$\bar{1}$·99354	$\bar{1}$·99638	−22	
3	345	601	766	421	675	−76	
4	270	558	742	348	634	−78	
5	333	599	767	396	661	−63	As used in field.
5	333	604	771	385	655	−52	As used in observatory.
6	301	602	775	316	617	−15	

* I am indebted to Professor W. Watson, F.R.S., for the above demonstration.

The values in columns 4 and 5 are those actually used in deriving log $\frac{m}{H}$ from log. $\frac{m_1}{H_1}$ and in almost every case the value of log. $\frac{m}{H}$ derived from the distance r=22·5 cms. has been used for finding m and H (*vide* paragraph 6 of Annual Report for 1901-1902).

The values in the first 3 columns show the corrections which should have been applied in order to take into account the q term in the distribution constant; hence the sixth column gives the correction which must be added to log. $\frac{m}{H}$ as actually used in the computations if it is desired to correct for the q term.

The changes thus made in the values of H depend on the magnitude of H, but at Dehra Dún where H may be taken equal to 0·335 C. G. S., they are as follows:—

Instrument.	Change in H at Dehra Dun due to taking the q term into account.	REMARKS.
1	+ 9γ	
3	+29	
4	+30	
5	+24	As used in field.
5	+20	" " " observatory.
6	+ 6	

These corrections are in most cases large and show that the q term cannot be neglected with magnets of the ordinary Kew * pattern, where the greatest accuracy in absolute values is desired.

The following tables exhibit the results of the comparisons (in Declination and Force) of the various instruments with the survey standard magnetometer No. 17 by Elliott.

Comparison of houses and instruments in Declination.

This instrument was not taken into regular use as the standard till 1st January 1903, previous to which date No. 5 by Cooke was used at the Dehra Dún Observatory for the standardization of the magnetograph curves. Consequently all the comparisons made at the beginning of field season 1901-1902 were made against No. 5 instrument in the first instance and the differences from the standard have been deduced.

The comparison in Declination between No. 17 and No. 5 magnetometers was effected by two methods (*a*) simultaneous observations taken in the old and new South houses, the instruments being interchanged after each group of observations and (*b*) a direct comparison through the magnetograph curves.

(*a*) The simultaneous comparison gives the differences between sites as well as the instrumental difference.

Let D be the true value of the declination at the moment of simultaneous observations.

Let I_x be the absolute error of Instrument number x.

I_y " " " " " y.

so that the difference between Instruments or I is represented by $I_x—I_y$.

Let S_o be the absolute error due to the site of the Old South House

S_n " " " " " New " "

so that the difference between sites or S is represented by $S_o — S_n$.

* The ratio $\frac{\text{short}}{\text{long}}$ magnet = $\frac{1}{1·46}$, the dimensions of the long magnet being—length 3·65 inches, external diameter 0·4 inch, and internal diameter 0·3 inch. (v. Terrestrial Magnetism, p. 65, Vol. IV).

If we use the symbol $\frac{O.H}{x}$ to represent the declination value given by Instrument x in the Old South House we have for simultaneous observations the following equations:—

$$\frac{O.H}{x} = D + I_x + S_o$$
$$\frac{O.H}{y} = D + I_y + S_o$$
$$\frac{N.H}{x} = D + I_x + S_n$$
$$\frac{N.H}{y} = D + I_y + S_n$$

Hence $\frac{O.H}{x} - \frac{N.H}{y} = I_x - I_y + S_o - S_n$

$= s + i$

and $\frac{O.H}{y} - \frac{N.H}{x} = I_y - I_x + S_o - S_n$

$= s - i$

Let X be the tabulated quantity represented by $\frac{O.H}{x} - \frac{N.H}{y}$

and X_1 „ „ „ „ by $\frac{O.H}{y} - \frac{N.H}{x}$

Then $X = s + i$

$X_1 = s - i$

or $s = \frac{1}{2} \left\{ X + X_1 \right\}$

$i = \frac{1}{2} \left\{ X - X_1 \right\}$

The following tables give the results obtained at the time of observation, values on the same horizontal line being simultaneous values:—

Date.	No. 5 in O. S. House or $\frac{O.H}{5}$.	No. 17 in N. S. House or $\frac{N.H}{17}$.	X or $\left(\frac{O.H}{5} - \frac{N.H}{17}\right)$	Remarks.
	° ′ ″	° ′ ″	″	
12th December 1902 .	2 43 29	2 42 18	+71	K. N. Mukerji and Captain Fraser were the observers throughout.
	2 43 39	2 42 38	+61	
	2 43 39	2 42 37	+62	
13th „ „ .	2 42 54	2 41 54	+60	
	2 43 7	2 42 21	+46	
	2 43 25	2 42 48	+37	
		Mean X =	+56″	

Date.	No. 17 in O. S. House or $\frac{O.H}{17}$.	No. 5 in N. S. House or $\frac{N.H}{5}$.	X_1 or $\left(\frac{O.H}{17} - \frac{N.H}{5}\right)$	Remarks.
	° ′ ″	° ′ ″	″	
12th December 1902 .	2 44 2	2 43 2	+60	Observers as above.
	2 43 58	2 43 11	+47	
	2 43 49	2 42 59	+50	
13th „ „ .	2 42 20	2 41 30	+50	
	2 42 37	2 41 16	+81	
	2 42 26	2 41 16	+70	
		Mean X_1 =	+60″	

Hence No. 5 — No. 17 = i = — 2″
and O.H — N.H = s = + 58″

(*b*) The following table shows the comparison of Instruments Nos. 5 and 17 made through the magnetograph curves, standardized by observations taken with No. 5 Instrument; all observations were taken in the Old South House.

This and subsequent comparisons of the same nature are exhibited in the form used by Professors Rücker and Thorpe (*vide* Volume 188-A Phil. Trans. for 1896, page 12).

DATE.	S (No. 17 Instrument.)	D.D (Dehra Dún Instrument No. 5.)	D.D—S = β	D. D—β = D_1	S—D_1	OBSERVER.
	° ′	° ′	′	° ′	′	
10th December 1902.	2 43·4	2 43·5	+0·1	2 43·44	−0·04	Captain Fraser.
	43·6	43·7	+0·1	43·64	—0·04	„
19th „ „ .	2 43·2	2 43·3	+0·1	43·24	—0·04	K. N. Mukerji.
	43·6	43·6	0·0	43·54	+0·06	„
	43·7	43·8	+0·1	43·74	—0·04	„
22nd „ „ .	2 43·4	2 43·5	+0·1	43·44	—0·04	„
	43·7	43·6	—0·1	43·54	+0·16	„
			β = +0·06	Mean =	± 0·06	

These two comparisons show that Instruments 5 and 17 were in very close agreement at the time of comparison and the difference between them may be considered negligible.

The results of the remaining comparisons are exhibited below :—

Comparison of Magnetometers with No. 5 Instrument.

DATE.	No. of Instrument.	S (Instrument under comparison.)	D.D (No. 5)	D.D—S = β	D.D—β = D_1	S—D_1	OBSERVER.
		° ′	° ′	′	° ′	′	
27th April 1902 .	1	2 44·37	2 44·69	+0·32	2 44·19	+0·18	Captain Fraser.
10th November 1902		41·73	41·73	+0·36	41·23	+0·14	
		41·69	42·14	+0·45	41·64	+0·05	
		42·70	43·58	+0·88	43·08	—0·38	
				β= +0·50	Mean=	±0·19	
24th October 1902 .	3	2 42·42	2 42·64	+0·22	2 42·55	—0·13	
		42·10	42·12	+0·02	42·03	+0·07	
		41·90	41·92	+0·02	41·83	+0·07	
				β= +0·09	Mean=	±0·09	
„ „ .	4	2 43·47	2 42·95	—0·52	2 43·63	—0·16	
		43·93	43·15	—0·78	43·83	+0·10	
		43·90	43·15	—0·75	43·83	+0·07	
				β= —0·68	Mean=	±0·11	
5th December 1902	6	2 43·43	2 43·49	+0·06	2 43·37	+0·06	
		43·62	43·91	+0·29	43·79	—0·17	
		43·85	43·90	+0·05	43·78	+0·07	
		43·73	43·80	+0·07	43·68	+0·05	
				β= +0·12	Mean=	±0·09	

As the difference between No. 5 and the standard No. 17 is *nil*, the above comparisons refer equally to the latter instrument.

Abstract of Declination Comparisons in 1902.

Standard No. 17— Instrument No.	Minutes of arc.
1	+0.50
3	+0·09
4	—0·68
5	0·00
6	+0·12

Comparisons of Instruments in H. F.

13. Comparison of Magnetometers Nos. 5 and 17:—

Date.	S (No. 17).	D. D (No. 5).	D.D.—S=β.	D. D—β=D₁	S – D₁	Observer.
1st December 1902	·33477	·33480	+ 3γ	·33467	+10γ	Captain Fraser.
	473	476	+ 3	463	+10	K. N. Mukerji.
8th " "	462	479	+17	466	— 4	Captain Fraser.
	467	479	+12	466	+ 1	" "
9th " "	476	489	+13	476	0	" "
	483	496	+13	483	0	" "
	491	505	+14	492	— 1	" "
	494	507	+13	494	0	" "
	493	505	+12	492	+ 1	" "
	488	503	+15	490	— 2	" "
10th " "	486	494	+ 8	481	+ 5	" "
	480	492	+12	479	+ 1	" "
18th " "	470	480	+10	467	+ 3	K. N. Mukerji.
	457	476	+19	463	— 6	" "
20th " "	468	480	+12	467	+ 1	" "
	456	483	+27	470	—14	" "
23rd " "	443	454	+11	441	+ 2	" "
	443	458	+15	445	—2	" "
	442	456	+14	443	— 1	" "
	444	454	+10	441	+ 3	" "
26th " "	459	471	+12	458	+ 1	" "
27th " "	459	466	+ 7	453	+ 6	" "
	451	468	+17	455	— 4	" "
			β=+13γ	Mean=± 3·4γ		

Comparison of Magnetometers with No. 5.

Date.	No. of Inst.	S (Inst. under comparison).	D.D (No. 5).	D.D—S=β.	β= D₁	S—D₁	Observer.
27th April 1902	1	·33493	·33505	+12γ	·33486	+ 7γ	Captain Fraser.
		495	508	+13	489	+ 6	" "
		493	511	+18	492	+ 1	" "
		497	512	+15	493	+ 4	" "
4th May 1902	...	·33492	·33502	+10	483	+ 9	" "
		487	502	+15	483	+ 4	" "
7th November 1902	...	·33463	·33486	+23	467	— 4	" "
		462	487	+25	468	— 6	" "
		463	487	+24	468	— 5	" "
		464	489	+25	470	— 6	" "
		481	494	+13	475	+ 6	" "
		477	492	+15	473	+ 4	" "
		474	488	+14	469	+ 5	" "
		472	486	+14	467	+ 5	" "
8th " "	...	·33471	·33501	+30	482	—11	" "
		479	498	+19	479	0	" "
		463	490	+27	471	— 8	" "
		459	490	+31	471	—12	" "
		468	490	+22	471	— 3	" "
		467	491	+24	472	— 5	" "
		...	...	β=+19γ	Mean=	± 5·6	
22nd October 1902	3	·33451	·33475	+24γ	·33450	+1γ	Captain Fraser.
		444	473	+29	448	—4	" "
		464	490	+26	465	—1	" "
		464	490	+20	465	—1	" "
		464	490	+26	465	—1	" "
		464	491	+27	406	—2	" "

Comparison of Magnetometers with No. 5—contd.

Date.	No. of Inst.	S (Inst. under comparison).	D.D (No. 5).	D.D−S=β.	D.D−β=D₁	S−D₁	Observer.
23rd October 1902	...	458	484	+26	459	−1	Captain Fraser.
		456	484	+28	459	−3	" "
		456	484	+28	459	−3	" "
		455	484	+29	459	−4	" "
		475	496	+21	471	+4	" "
		476	496	+20	471	+5	" "
		478	496	+18	471	+7	" "
		479	496	+17	471	+8	" "
		...	...	β=+25γ	Mean=	±3·2	
25th " "	4	·33440	·33487	+47γ	·33447	−7γ	Captain Fraser.
		439	487	+48	447	−8	" "
		446	485	+39	445	+1	" "
		450	486	+36	446	+4	" "
		448	490	+42	450	−2	" "
		453	493	+40	453	0	" "
		456	493	+37	453	+3	" "
		450	492	+42	452	−2	" "
26th " "	...	·33443	·33486	+43	446	−3	" "
		447	487	+40	447	0	" "
		453	490	+37	450	+3	" "
		456	489	+33	449	+7	" "
		441	482	+41	442	−1	" "
		443	481	+38	441	+2	" "
		440	482	+42	442	−2	" "
		441	481	+40	441	0	" "
		...	...	β=+40γ	Mean=	±2·8γ	
5th December 1902	6	·33488	·33477	−11γ	·33488	0γ	Captain Fraser.
		487	476	−11	487	0	" "
		486	476	−10	487	−1	" "
		487	475	−12	486	+1	" "
6th " "	...	·33502	·33488	−14	499	+3	" "
		499	487	−12	498	+1	" "
		498	487	−11	498	0	" "
		499	486	−13	497	+2	" "
		501	485	−16	496	+5	" "
		498	484	−14	495	+3	" "
		495	482	−13	493	+2	" "
		493	480	−13	491	+2	" "
		476	470	−6	481	−5	" "
		476	470	−6	481	−5	" "
		476	470	−6	481	−5	" "
		479	470	−9	481	−2	" "
		...	...	β=−11γ	Mean=	±2·3γ	

Abstract of H. F. Comparisons in 1902.

Standard No. 17 – Instrument No.	γ
1	+ 6
3	+12
4	+27
5	−13
6	−24

Comparison of Houses in H. F.

During 1902 all observations for standardizing the magnetograms were taken in the Old South House with No. 5 Instrument. This arrangement resulted from the fact that neither the New South House nor No. 17 magnetometer were available when the magnetographs were started. In December 1902 a comparison was made between the Old and New South Houses in Horizontal Force by taking sets of vibrations with the same magnet in the two buildings on the same or following days. The moment of the magnet used was found from observations before and after these vibrations and to obtain a better result a second magnet was then employed in a similar manner.

The values of the Force being computed the curves were measured at the time of each set of vibrations and independent values of the base line (corrected for variations of temperature) were thus found corresponding to the observations taken in each house. The following tables exhibit the results obtained :—

New South House.			Old South House.			New—Old, *i.e.* (3) − (6).	Remarks.
1	2	3	4	5	6		
Date.	H. F. deduced from vibrations.	Corresponding values of Base Line.	Date.	H. F. deduced from vibrations.	Corresponding values of Base Line.		
	C. G. S.	C. G. S.		C. G. S.	C. G. S.	γ	
10th December 1902.	·33446	·33235	11th December 1902.	·33500	·33265		Vibrations taken by chronograph with magnet 1 A in Instrument No. 1. Mean m_0=1004·53.
	49	38		490	55		
	49	38		490	55		
	49	40		485	50		
	48	38		492	57		
11th December 1902.	·33459	·33236		...	...		
	63	38		...	...		
	66	41		...	...		
	Mean	·33238		Mean	·33256	—18	
11th December 1902.	·33473	·33248	10th December 1902.	·33463	·33256		Vibrations taken by chronograph with magnet 5A in Instrument No 5. Mean m_0=928·90.
	78	54		70	63		
	72	50		66	60		
	71	46		69	63		
	70	45		65	58		
	...	...		·33487	·33262		
	...	...		85	60		
	..	...		82	58		
	Mean	·33249		Mean	·33260	—11	
		Mean difference New—Old =				—15	

Corrections applied to tabulated results for Dehra Dún.

To convert the tabulated results derived from observations in the Old South House with No. 5 Instrument to corresponding values for the New South House with No. 17, the Standard Instrument, corrections should therefore be applied as follows :—

(*a*) Horizontal Force—

—13γ (Instrumental difference) — 15γ (difference in site) = —28γ.

(*b*) Declination—

—58″ (difference in site) + o (instrumental difference).

The results hereafter tabulated for the Dehra Dún Observatory have been actually corrected by — 28γ in H. F. and — 1′ in Declination and can therefore be directly compared with those which will be obtained in future years.

Determinations of Moments of Inertia.

During the past year magnetometers Nos. 19 and 20 by Elliott were received back after alterations and additions and a new instrument No. 10 by Cooke also arrived. Observations for finding the moments of inertia were in each case carried out as explained in paragraph 15 of the Annual Report for 1901-02 and the following results obtained :—

Values of Log. $\pi^2 K$ for various magnets.

Inertia Bar No. 17.				Inertia Bar No. 2.
Magnet number.				
10	17	19	20	10
3·401550	3·415517	3·384696	3 399503	3·401575
399	489	666	438	703
4'5	500	735	408	708
372	602	755	341	503
421	752	646	214	447
486	719	652	185	626
522	572	897	374	554
605	379	805	191	804
555	374	783	300	902
603	468		309	882
478	580		241	685
554	389		174	645
583	461		247	706
•	684		324	798
			254	883
3·401503	3·415535	3·384719	3·399300	3·401718

REMARKS.

(*a*) Magnet No. 10 was used with both inertia bars in order to check the value of the constant difference between bars as determined last year.

In the last column the mean was obtained by giving full weight to the last group of 5 determinations and ½ and ⅓ weight to the centre and first groups respectively. The first group was found from a series of observations on one day in which the observer failed to balance the system perfectly, whilst the second was found from observations taken during a continuous though slight disturbance.

The difference between means gives ·000215 for the difference between bars 2-17, which agrees satisfactorily with the previous determination, *viz.*, ·000239. As this latter quantity had been used in finding certain accepted values, it was decided to adhere to it instead of taking a mean from the two results. The final value for magnet 10 is obtained by taking the mean between the direct and deduced values, thus—

$$\text{Log. } \pi^2 K = \tfrac{1}{2}\{3{\cdot}401718 + (3{\cdot}401503 + {\cdot}000239)\} = 3{\cdot}401730.$$

(*b*) No. 17 being the standard survey magnetometer, fresh observations were taken by a different observer to check the result previously obtained. This result (as published in the last Annual Report) was 3·415570 which accords well with the new value 3·415535. The general mean of the whole series gives 3·415553, to which ·000239 is added to reduce it to terms of the standard bar No. 2, giving 3·41579 as the finally accepted value.

(*c*) During the last 3 sets taken with magnet 19 the temperature conditions were unfavourable and these values have been given only ½ weight in obtaining the mean shown.

The following is a list of the accepted values of Log. π^2 K for all magnets so far tested:—

Magnet.	Log. π^2 K.
1A*	3·37046
3A	3·38733
4A	3·37936
5A	3·37894
6A	3·39887
10	3·40173
16	3·38717
17	3·41579
19	3·38496
20	3·39954

General remarks.

During the recess season the whole of the field work was computed and the tabulation of the Dehra Dún records for 1902 completed.

The results of the field work are exhibited in Table X, and the index chart at the end of this report shows the situation of the stations occupied up to date.

Arrangements for the further reduction of the work by sections have been initiated at the suggestion of Sir Arthur Rücker, F.R.S., and the computing strength of the party has been increased to deal with this work and with the tabulation of results from the Kodaikánal and Rangoon Observatories.

In July 1903, a second Imperial officer (Lieutenant R. H. Thomas, R.E.,) was posted to the party for instruction and his training has been completed.

Distribution of Magnetic Instruments.

The following table shows the distribution of the field instruments during the year under report:—

Observatories or Field detachments.	Magnetographs.			Magnetometers.	Dip Circles.	Remarks.
	Horizontal Force.	Declination.	Vertical Force.			
Dehra Dún . .	1	1	...	17	44	Magnetometers Nos. 1 to 6 are by Messrs. Cooke and Sons.
Kodaikánal . .	2	2	...	16	46	
Barrackpore . .	3	3	...	20	45	Magnetometers 16, 17 and 20 are old Elliott instruments, repaired by Messrs. Cooke and Sons.
Captain Fraser . .	...	...	...	1	{ 136 139	
Mr. Morton . .	...	...	...	6	138	
R. P. Ray . .	...	...	...	3	135	Dip Circles 135 to 140 are by Dover.*
Mr. Talati . .	...	...	...	1	136	
„ Meyer . .	...	...	...	5	140	Dip Circles 44 to 46 are by Barrow repaired by Dover.
K. K. Dutta . .	...	...	...	4	137	

Magnetometer No. 2 by Messrs. Cooke and Sons has never given satisfactory force results and has only been used for practice. The cause of the discrepant results given by this instrument has not been discovered and is still under investigation.

Dip circle No. 139 behaved uniformly well till January 1903, when the results given became discordant for some unknown reason, and No. 136 was then used in its place. No. 139 has since been sent to its maker for readjustment and repair.

Magnetometer No. 19 by Elliott Brothers, repaired by Messrs. Cooke and Sons and Dip circle No. 43 by Bar row (altered at the Mathematical Instrument office, Calcutta), are intended for use at the Rangoon Observatory. A number of observations have been made at Dehra Dún with the former instrument for purposes of comparison.

The new set of Watson's Magnetographs for Rangoon and the new Vertical Force Magnetograph for Dehra Dún have not yet been received.

In addition to the above a new Dip circle by Dover has been ordered and sanction has been given for the purchase of 3 more Vertical Force Magnetographs of Professor Watson's pattern.

These will be supplied by the Cambridge Scientific Instrument Company and will be installed at Kodaikánal, Barrackpore and Rangoon.

Dehra Dún Observatory.

Description of the new absolute houses.

On 1st January 1903 the new south absolute house was taken into regular use, and No. 17 magnetometer was employed for the routine work: it has given satisfactory results throughout the year.

The old south house being no longer required was dismantled and re-erected to the north of the new south house, the work being completed in March. A series of comparative observations in Dip, Declination and Horizontal Force have since been made in the two houses, the results of which will be published in the next Annual Report.

The Referring mark consists of a small circular brass disc painted black and white, which is built into the top of a substantial masonry pillar about 200 yards south of the absolute houses. The mark is on the same level as the telescope of a magnetometer mounted on the pillar in the south house, and there is an arrangement for illuminating it at night.

The azimuth of the mark was found by different observers using different instruments, all observations being taken to Polaris, through windows constructed for this purpose in each house. The results showed that the difference in the azimuth from the two houses is a few seconds only and is therefore negligible. The accepted azimuth of the R. M. from south is taken as $1° 25' 23''$ for each house and the error is probably less than $5''$.

As the mark is at a considerable height from the ground it was considered advisable to repeat the azimuth observations after the rainy season, to find whether it had been displaced by unequal settlement of the foundations, but the results proved that no appreciable shift had occurred.

The pillars of the two houses lie very nearly in the magnetic meridian and are separated by an interval of 35 feet, which was found by trial to be sufficient to prevent any visible interference when taking simultaneous observations.

The walls of the houses and the pillars for the instruments are built of limestone masonry of a perfectly non-magnetic nature, but it was found necessary to use a certain number of bricks in the corners and for the various openings in the walls in order to avoid the expense involved in squaring the stones. These bricks were found to be slightly magnetic, but, as relatively few were used and none were placed nearer than 6 feet from the central pillar, it was considered that their effect would be negligible.

Each house is 11½ feet square inside and is protected by a wood and canvas roof.

A telegraph line was made connecting each house with the photo-helio observatory in which one of the chronographs by Warner and Swasey and the standard sidereal clock are erected.

Copper wires were used for a distance of 300 feet from the north house and tests showed that no visible deflection of a suspended magnet was caused when the normal current used for working the chronograph was passing.

The south house is about 65 yards distant in a N. E. direction from the magnetograph room.

The staff.

Observer K. N. Mukerjee was in charge of the routine work up till 5th March 1903 on which date he was relieved by Observer Shri Dhar who carried out the duties during the remainder of the year.

Fixing new mirrors to magnetographs.

The magnetographs continued to work satisfactorily till the month of August, when the faintness of the traces became so marked that it was decided to mount fresh mirrors. It was apparent also that the H. F. magnet was suffering from interference as there was a sudden large drop in the deflection readings on the 10th of that month. On the 9th September therefore the instruments were opened and fresh mirrors inserted and adjusted in place of the old ones, the silvering on two of which had almost entirely disappeared. These original mirrors had been in place since February 1902 and had been exposed to a saturated atmosphere for many months before the underground room could be properly dried ; but, as there has been no visible evidence of damp on the walls during 1903, it is hoped that the new mirrors will have a much longer life. It may be noted as a curious fact that in both instruments the fixed mirrors were in very fair condition and the deterioration was confined to the mirrors attached to the magnets. Before opening the instruments, the H. F. magnet was artificially given a large deflection after which deflection observations were taken, the results of which were again normal. This indicated that there was some slight connection between the fixed and moveable parts of the instrument, though nothing could be found when the instrument was opened next day. There was nothing in the nature of fungus, nor were any insects or spider webs visible, so that it is hard to account definitely for the obstruction which undoubtedly existed from the 9th or 10th August.

It is the practice to take a set of visual deflections for finding the scale value of the H. F. instrument every day or alternate day, and it is unfortunate that the observer did not appreciate what the sudden drop in the deflections indicated and make an immediate report on the subject. To guard against similar failures in future, orders have been issued to give each magnet a large artificial deflection once a week and to report at once any change in the deflections exceeding 2 per cent. from the normal.

The opportunity was taken to fix stops ⅜ inch square over the lenses of both instruments, as this had been found to improve the definition at Kodaikánal and was also successful in this case.

No change was made in the position of the slit in the Declination instrument, so that the scale value formerly found requires no alteration.

Precautions against damp.

No further trouble has arisen through damp, but the various precautions detailed in para. 19 of the last annual report have not been relaxed and will be continued for the present.

Tabulation of results for 1902.

Tables I to III give the actual absolute values obtained throughout the year and in addition the first two tables show, as a test of accuracy, the base line values of the magnetograms deduced from each observation and corrected for temperature in the case of the Horizontal Force values. Tables V to VIII give the results in Declination and Horizontal Force as tabulated from the curves, whilst table IV gives the disturbances for the year and the selected quiet days utilized in the tabulations.

The Declination and Dip results.

The Declination and Dip results are fairly satisfactory in the matter of accuracy. The "magnetic collimation" tabulated in column 3 of table II shows the difference in the circle readings when the magnet is reversed in its stirrup. This quantity should be a constant and the fact that it varied a good deal during the months of March and April showed that there was something wrong with the observations or with the magnet itself. At the beginning of June the turn-over of the aluminium cells on to their contained glasses was well pressed down with a smoothly rounded stylus and this seems to have had the desired effect, for the mean monthly values of the collimation did not vary largely thereafter as the following figures show :—

Month.	Magnetic Collimation.
June . . .	+ 6' 14"
July . . .	6 18
August . . .	6 18
September . .	6 22
October . . .	6 21
November . .	6 18
December . .	6 10

The setting of the Dip circle in the magnetic meridian was effected by means of its sights and the adjustment of the latter was checked at intervals to prevent accumulation of error.

The Horizontal Force results.

Table I gives an abstract of the accepted observations only. In cases where column 3 is left blank the value of H has been derived by applying the mean observed value of m_0 (the moment of the magnet at 0°C) to the values computed for m H or $\frac{m}{H}$.

In addition to the results shown, a large number of observations made by Observer K. N. Mukerji have been rejected as untrustworthy. The causes which led to their rejection may be summarised as follows :—

Deflections.—The observer took no precautions to check the height of the suspended magnet, with the result that the computed values of P differed widely *inter se*, and their mean value differed considerably from that obtained from reliable observations. The figures in column 4 of table I show that the values of the two P's were the same throughout the year within observational limits and this in spite of the large changes which occurred from time to time in m_0. Hence, as the amount of dislevelment of the suspended magnet was an unknown quantity, nothing could be made of Mukerji's deflection observations from 1st July to 21st October and they were therefore rejected.

Vibrations.—It will be seen that the mean value of m_0 found from R. P. Ray's observations on the 18th and 25th June is practically the same as that found by Captain Fraser at the end of October. The value of m_0 is not liable to appreciable fluctuations, though it may and does occasionally become suddenly reduced, so that if R. P. Ray's observations are reliable, it would be fairly safe to assume that m_0 remained practically constant in the interval. The evidence in favour of the reliability of R. P. Ray's work is as follows: —

(*a*) The base line values deduced therefrom are in good accordance.
(*b*) His individual values for P are fairly close to the mean value.
(*c*) His vibration observations were taken by chronograph, a method in which he had much practice.

Assuming therefore $m_0 = 942 \cdot 11$ and applying this value to K. N. Mukerji's vibration observations, we might still expect fair results.

Unfortunately this test showed that the vibration observations had been carelessly taken, and could not be relied on for accuracy. In many cases his observations indicated large apparent variations in H within the hour, though the magnetograph proved that no appreciable change had occurred. Hence it was considered best to reject the whole of his Force observations and to find the mean monthly base line values by interpolation between June and October. It is hardly likely that the change in the base line value really took place uniformly, but the error due to this assumption is probably not great.

After the 22nd October K. N. Mukerji's work improved and can be confidently accepted.

The scale value of the H. F. magnetograph.

The routine work of the observatory and method of taking observations has been described in paragraph 20 of the Annual Report for 1901-02, and the only important change since made concerns the taking of deflections on the H. F. magnetograph for the purpose of finding the scale value. Formerly this was done every day, but the accordance of the monthly mean scale values in 1902, indicated that fewer readings would suffice and they are now therefore taken only on alternate days, and at the nearest of the two distances.

The following table shows the values calculated for 1902, together with the mean monthly temperature of the underground room.

1	2	3	4	5	6	7
Month. 1902.	Mean scale value from		Mean of columns 2 and 3.	Monthly mean temperature		
	r=96 cms.	r=120 cms.		of observatory.	in shade.	of underground thermometer at 12·8 feet depth.
	γ	γ	γ	Cent.	Cent.	Cent.
March	4·03	4·04	4·03	22°·17	21°·2	21°·7
April	4·01	4·02	4·01	23·14	24·7	21·9
May	4·00	4·01	4·00	25·42	28·2	22·9
June	3·98	3·99	3·98	27·10	28·3	24·1
July	3·98	3·98	3·98	28·05	25·2	25·4
August . . .	3·97	3·98	3·97	28·18	24·9	26·4
September . . .	3·97	3·98	3·97	28·23	24·4	26·6
October . . .	3·99	3·99	3·99	28·18	20·4	26·4
November . . .	4·00	4·00	4·00	27·34	16·7	25·9
December . . .	4·02	4·02	4·02	25·70	12·4	24·9
Means . . .	4·00	4·00	4·00	26·35	22·64	24·62

NOTE.—The figures in column 6 are those supplied by the Trigonometrical Branch office for 1902; those in column 7 are the mean values derived from the period 1887-1901.

KODAIKÁNAL MAGNETIC OBSERVATORY.

Fitting new mirrors to the magnetographs.

Routine work was commenced in September 1902, but practically broke down in the following December owing to causes induced by the excessive dampness of the underground room in which the magnetographs are erected. Early in January 1903, the officer in charge visited Kodaikánal to take comparative observations, etc. As the traces for the previous month were very faint and there was evidence that the magnets were not perfectly free, both the Declination and Horizontal Force magnetographs were opened out. It was found that the moveable and fixed mirrors were in both cases connected by a fungoidal growth resembling spider webs and that the silvering had very largely perished. The lenses were also covered with fungus which, however, had fortunately not penetrated and was easily removed.

Both instruments were fitted with new mirrors and readjusted by the 19th January, the constants previously determined remaining unaltered.

Precautions against damp.

The following alterations of the building were subsequently undertaken and completed by the Public Works Department, to prevent the percolation of water on to the arched concrete roof which seemed to be the main cause of the internal dampness of the room :—

(1) The surface catchment drain on the east side of and above the building was carried down to the solid rock and its bottom rendered waterproof.

(2) A pent roof of wood and canvas was built out from the lower part of the absolute house (which rests on the arch of the underground room) and carried several feet down the earth slopes which protect the magnetograph room from changes of temperature.

(3) The south side of the earth slopes was opened out and a new drain of loose boulders was made close to the building, after which the earth was replaced and fresh grass planted on the slope.

(4) The earth slopes on the north-east and south-east sides were tiled over between the absolute house and the open surface drain.

It is hoped that these measures will prevent the percolation of water on to the underground masonry, but if not entirely successful the pent roof will be still further prolonged down the outer slopes. Meantime active measures were initiated to reduce the amount of damp already present in the magnetograph room :—

(*a*) After the readjustment in January, the glass covering cases were replaced and as far as possible sealed up with wax, whilst the felt on which they rest was saturated with a solution of corrosive sublimate to prevent the access of small insects, of which a large number was found when the covers were removed.

(*b*) Small vessels containing pumice stone saturated with strong sulphuric acid were put inside the cases to dry the air round the instruments.

(*c*) Calcium chloride was obtained and placed about the floor of the room in wooden trays, the material being renewed every day.

(*d*) Dried blankets were suspended all round the walls, some being placed on the dampest parts of the floor.

Thanks to these measures, the instruments remained in good working order throughout 1903, but the walls were by no means dry at the latter end of the year, owing probably to the great delay in completing the external additions above alluded to.

The staff.

Mr. Charles Theodore was in charge of the Observatory up till 2nd April 1903 on which date he proceeded on 3 months' sick leave and was relieved by Mr. Meyer who was withdrawn from field work for this purpose. Mr. Theodore resigned his appointment in November 1903, being relieved by H. N. Gupta, an observer trained originally for the Rangoon base station. Steps are now being taken to entertain and train an observer in Mr. Theodore's place.

New referring mark.

The absolute instruments gave good results throughout the year, but difficulty was not infrequently met with in the declination observations owing to the liability of the referring mark to be obscured by mist. The Director of the Observatory is now taking steps to erect a second mark quite close to the Observatory which will be visible except when the whole hill top is covered with mist.

General remarks.

The tabulation of the records to the end of December 1903 is now in hand and the results will be published in the next Annual Report. Thanks are due to the Director for the general assistance given and in particular for the completion of the additional works and the precautions taken against damp.

RANGOON OBSERVATORY.

General remarks.

Owing to pressure of other work at Kew, the testing of these instruments had to be postponed. They have not yet been received. Steps have been taken to dry the underground vault by means of blankets and the room is now in a fit state to receive the instruments. This work was carried out under the direction of the Sub-Assistant Superintendent of Telegraphs at Rangoon.

BARRACKPORE OBSERVATORY.

Description of the buildings.

After considerable delay the buildings were sufficiently advanced by the middle of July 1903 to permit of the installation of the instruments.

The Observatory consists of the following buildings :—

(1) The magnetograph house.
(2) The absolute house.
(3) The lamp room.
(4) The observer's quarters and dark room.

The first three buildings are grouped together in an enclosure some 80 yards S.-W. from the observer's quarters, and the site chosen lies about one mile to the north of the British Infantry Barracks and some 500 yards to the east of the main road leading to Ishapur.

The magnetograph house.

The magnetograph room is entirely above ground and consists of an inner chamber about 15'×20' the walls of which are made of $\frac{3}{4}$ inch tongued and grooved teak planking.

Above and all round this is an air space of about $2\frac{1}{2}$ feet. Then come the main walls and inner roof of the building consisting of packed sawdust contained between tongued and grooved teak partitions—the thickness of the saw-dust packing being about 2 feet. The whole is covered by a wood and canvas roof (painted white) which projects some 8 feet over the main walls, forming an open verandah all round. The entrance is through a vestibule with double doors into the passage way, and thence by a single door to the inner room. The floor of the whole building is of wood supported on 2 feet of fine sand which is contained in a basin formed of non-magnetic stone slabs resting on the natural surface of the ground.

The passage-way is fitted with 4 six-inch ventilation pipes, one over each corner, and five similar pipes are provided in the inner room, any or all of which can be blocked at will.

It is intended to keep the temperature of the inner room as constant as possible by the use of oil lamps, but the data are at present insufficient to give any idea of what the annual range of temperature is likely to be.

The absolute house.

The absolute room is placed about 40 yards to the east of the magnetograph room. It is constructed entirely of non-magnetic material, the walls and roof being of teak wood, packed with sawdust, and the floor of wood resting on sand.

It contains two marble-topped pillars, built of concrete made of non-magnetic materials, the south of which is reserved for observations of Declination and Force and the north for Dip observations.

The referring mark.

The referring mark is embedded in a masonry pillar about 200 yards south of the building, an arrangement being provided for illumination at night.

Observations for azimuth were taken to Polaris from the north pillar with a ten-inch theodolite No. 102 by Troughton and Simms. The mean of several sets taken by each of two observers gives the azimuth (reckoned westwards from south) = 0° 50′ 50″.

The south pillar is slightly west of the line joining the R. M. to the centre of the north pillar. A perpendicular from the centre of the south pillar to this line was measured and found to be 0·53 inch and the distance of the south pillar from the mark being 595 feet, the angle at the mark between the two pillars becomes 15″.

Hence the azimuth of the R. M. from the south pillar is 0° 50′ 35″.

Time observations.

About 20 yards north of the absolute house stands the pillar for time observations, which are taken with the above-mentioned theodolite to E. and W. stars once or twice a week, in order to correct and rate the chronometers.

The Latitude and Longitude of the observatory as taken from a reliable map are—

Latitude	22°	45′	29″	North.
Longitude	88	21	39	East.

(The longitude is referable to that of Madras taken at its latest value, *viz.*, 80° 14′ 47″ East.)

The erection of the instruments.

The installation of the instruments was effected by the officer in charge assisted by Lieutenant R. H. Thomas, R.E., and by observer K. N. Mukerji.

A commencement was made on 24th July and after the usual trials for focus had been made fair work was begun on 8th August.

The deflection distance for the Horizontal Force instrument, and the measures for finding the scale value of the Declination instrument were made exactly as described in paragraph 17 of the last report, except that a six-foot iron bar was used for reading off the measures made with the beam compasses in place of the ten-foot standard by Troughton and Simms.

The deflection distance proved to be 39″·477 or 100·27 cms.

Using the notation and formula explained in paragraph 17 above alluded to, the following values were obtained :—

Distance from slit to front of lens	. . . .	$= l =$ 59″·94.
" drum " "	. . . . .	$= L =$ 67 ·185.
" back of mirror "	. . . . .	$= d =$ 0 ·68.
Thickness of cylindrical lens	. . . . . .	$= t =$ 0 ·15.

substituting in the formula—

$$a = \frac{\times}{2\,(L - 0{\cdot}33t)} \left\{ 1 + \frac{d}{v + d} \right\} \text{ where } v = \frac{2\,Ll}{L - l}$$

and putting $\times = 1$.

we obtain $a = 61''{\cdot}5$ for a scale division of $\frac{1}{18}$th inch.

The corresponding value for 1 min. of ordinate = 60″·5.

It was again found that the definition was much improved by the use of square stops cut out of thin brass sheeting and placed in front of the lenses—the aperture being $\frac{3}{4}'' \times \frac{3}{4}''$.

The instruments have given very good traces since they were started and the results to end of December 1903 are now being tabulated.

TABLE I.

ABSOLUTE MAGNETIC OBSERVATIONS.

Observations of Horizontal Force at Dehra Dún Observatory.

1	2	3	4	5	6	7	8	9
Date.	Observer.	Values of m_o.	P from 22·5 and 30 cms.	P from 30 and 40 cms.	Observed values of Horizontal Force.	Monthly mean observed value of H. F.	Base Line values corrected for temperature.	Monthly mean Base Line value.
1902.		C. G. S.	C. G. S.	C. G. S.	C. G. S.	C. G. S.	C. G. S.	C. G. S.
March 10	H. F.	958·72	7·11	7·67	·33506		·33320	
10	"	958·54	...	...	·33500		·33317	
11	"	958·78	7·11	7·72	·33520		·33322	
11	"	958·58	...	...	·33513		·33318	
16	K. N. M.	958·58	7·04	7·01	·33493	·33503	·33308	·33315
20	"	...	6·96	...	·33524		·33315	
26	"	...	...	...	·33491		·33309	
26	"	...	...	...	·33480		·33307	
April 6	"	958·69	6·98	7·30	·33504	·33504	·33319	·33312
6	"	...	...	...	·33502		·33323	

TABLE I—*contd.*

ABSOLUTE MAGNETIC OBSERVATIONS.

Observations of Horizontal Force at Dehra Dún Observatory.

1	2	3	4	5	6	7	8	9
Date.	Observer.	Values of m_o.	P from 22·5 and 30 cms.	P from 30 and 40 cms.	Observed values of Horizontal Force.	Monthly mean observed value of H. F.	Base Line values corrected for temperature.	Monthly mean Base Line value.
1902.		C. G. S.	C. G. S.	C. G. S.	C. G. S.	C. G. S.	C. G. S.	C. G. S.
April 26	H. F.	952·62	7·22	7·44	·33511		·33307	
26	"	952·55	...	...	·33509	·33504	·33307	·33312
26	"	952·62	7·27	7·15	·33499		·33306	
26	"	952·69	...	...	·33501		·33310	
May 4	H. F.	952·45	7·01	7·72	·33517		·33323	
4	"	952·36	...	...	·33514		·33316	
4	"	952·36	6·98	7·95	·33514		·33314	
4	"	952·38	...	...	·33515		·33315	
4	"	952·34	6·91	7·86	·33517		·33317	
4	"	952·40	...	...	·33519		·33320	
13	K. N. M.	...	...	...	·33538		·33328	
13	"	...	...	...	·33520	·33513	·33307	·33312
17	"	...	...	...	·33544		·33320	
17	"	...	...	...	·33539		·33325	
22	"	...	...	...	·33487		·33308	
22	"	...	...	...	·33473		·33286	
26	"	...	...	...	·33490		·33292	
29	"	...	...	...	·33501		·33295	
June 8	"	...	...	...	·33499		·33295	
8	"	...	...	...	·33514		·33317	
8	"	...	...	...	·33496		·33305	
11	"	...	...	...	·33525		·33318	
11	"	...	...	...	·33519	·33506	·33306	·33302
11	"	...	...	...	·33527		·33318	
18	R. P. R.	942·17	6·98	...	·33493		·33290	
18	"	942·30	...	...	·33497		·33293	
25	"	942·00	6·80	...	·33511		·33307	
25	"	941·93	...	...	·33509		·33305	

TABLE I—*contd.*

ABSOLUTE MAGNETIC OBSERVATIONS.

Observations of Horizontal Force at Dehra Dún Observatory.

1		2	3	4	5	6	7	8	9
Date.		Observer.	Values of m_o.	P from 22·5 and 30 cms.	P from 30 and 40 cms.	Observed values of Horizontal Force.	Monthly mean observed value of H. F.	Base Line values corrected for temperature.	Monthly mean Base Line value.
1902.			C. G. S.	C. G. S.	C. G. S.	C. G. S.	C. G. S.	C. G. S.	C. G. S.
June	25	R. P. R.	942·17	7·35	...	·33501	·33506	·33297	·33302
	25	„	942·08	...	...	·33498		·33296	
	28	K. N. M.	...	...	...	·33504		·33295	
	28	...	...	...	...	·33489		·33286	
July		...	...	...	...	...		...	·33295
August		...	...	...	...	...		...	·33289
Sept.		...	...	...	...	...		...	·33282
Oct.	22	H. F.	942·13	7·06	7·86	·33481	·33483	·33279	·33275
	22	„	942·13	...	...	·33481		·33279	
	22	„	942·15	7·24	...	·33481		·33279	
	22	„	942·22	...	...	·33483		·33278	
	23	„	942·08	7·11	7·86	·33490		·33275	
	23	„	942·13	...	...	·33491		·33277	
	23	„	942·11	7·04	8·32	·33492		·33278	
	23	„	942·11	...	...	·33492		·33278	
	25	„	942·15	7·09	7·86	·33475		·33272	
	25	„	942·02	...	...	·33470		·33271	
	25	„	942·13	7·06	7·86	·33466		·33270	
	5	„	942·13	...	...	·33466		·33272	
	26	„	942·04	7·11	8·00	·33476		·33269	
	26	„	941·98	...	...	·33473		·33268	
	26	„	942·06	7·14	8·18	·33471		·33267	
	26	„	941·98	...	...	·33468		·33265	
	29	K. N. M.	942·24	7·04	8·18	·33501		·33282	
	29	„	942·13	...	...	·33492		·33278	
	29	„	...	...	...	·33493		·33286	
	30	„	942·26	7·27	7·34	·33504		·33293	
	30	„	941·87	...	...	·33494		·33281	
	30	„	...	...	...	·33477		·33262	

TABLE I—*contd.*

ABSOLUTE MAGNETIC OBSERVATIONS.

Observations of Horizontal Force at Dehra Dún Observatory.

1		2	3	4	5	6	7	8	9
Date.		Observer.	Values of m_o.	P from 22·5 and 30 cms.	P from 30 and 40 cms.	Observed values of Horizontal Force.	Monthly mean observed values of H. F.	Base Line values corrected for temperature.	Monthly mean Base Line value.
1902.			C. G. S.	C. G. S.	C. G. S.	C. G. S.	C. G. S.	C. G. S.	C. G. S.
Nov.	1	K. N. M.	942·11	7·22	7·58	·33458		·33275	
	1	,,	942·06	...	...	·33456		·33273	
	5	,,	942·28	6·88	8·23	·33509		·33291	
	5	,,	942·00	...	...	·33499		·33283	
	6	H. F.	941·95	7·06	7·39	·33485		·33273	
	7	,,	942·02	6·93	...	·33480		·33278	
	7	,,	942·04	...	...	·33480		·33278	
	7	,,	942·08	6·96	8·23	·33479		·33277	
	7	,,	942·13	...	...	·33480		·33278	
	9	K. N. M.	942·00	7·14	...	·33498		·33276	
	9	,,	942·06	...	...	·33500		·33282	
	9	,,	942·19	7·09	8·04	·33492		·33283	
	9	,,	942·08	...	...	·33488	·33488	·33279	·33277
	12	,,	941·95	7·01	8·18	·33486		·33272	
	12	,,	942·08	...	...	·33490		·33276	
	15	,,	942·26	7·14	7·76	·33507		·33279	
	15	,,	942·15	...	...	·33503		·33283	
	19	,,	942·30	7·19	8·18	·33513		·33271	
	19	,,	942·22	...	...	·33510		·33270	
	22	,,	942·06	7·14	7·81	·33487		·33276	
	22	,,	941·93	...	...	·33483		·33275	
	26	,,	942·22	7·27	7·72	·33473		·33276	
	26	,,	942·17	...	...	·33471		·33275	
	29	,,	942·24	7·06	8·32	·33489		·33275	
	29	,,	941·85	...	...	·33475		·33264	
Dec.	3	K. N. M.	941·76	7·06	8·23	·33470		·33248	
	3	,,	941·72	...	...	·33468		·33244	
	5	,,	929·07	7·17	7·72	·33496	·33478	·33272	·33258
	5	,,	928·80	...	...	·33486		·33261	
	6	,,	928·60	7·14	8·00	·33487		·33258	
	6	,,	928·75	...	...	·33492		·33261	

TABLE I—*concld.*

ABSOLUTE MAGNETIC OBSERVATIONS.

Observations of Horizontal Force at Dehra Dún Observatory.

1	2	3	4	5	6	7	8	9
Date.	Observer.	Values of m.	P from 22·5 and 30 cms.	P from 30 and 40 cms.	Observed values of Horizontal Force.	Monthly mean observed values of H. F.	Base Line values corrected for temperature.	Monthly mean Base Line value.
1902.		C. G. S.	C. G. S.	C. G. S.	C. G. S.	C. G. S.	C. G. S.	C. G. S.
Dec. 8	H. F.	928·90	7·37	8·42	·33493		·33258	
8	"	929·01	...	...	·33497		33262	
8	"	929·01	7·14	...	·33497		·33262	
8	"	928·95	...	...	·33495		·33262	
8	"	928·97	6·93	...	·33494		·33262	
8	"	928·86	...	...	·33490		·33261	
9	"	929·05	7·24	7·90	·33493		·33260	
9	"	928·80	...	...	·33483		·33254	
9	"	928·82	7·22	7·62	·33483		·33255	
9	"	928·82	...	...	·33483		·33256	
10	K. N. M.	928·97	7·24	7·95	·33473		·33258	
10	"	928·60	...	...	·33460		·33251	
10	H. F.	...	...	...	·33463		·33256	
10	"	...	...	...	·33470		·33263	
10	"	...	...	...	·33466		·33260	
10	"	...	...	...	·33469	·33478	·33263	·33258
10	"	...	...	...	·33465		·33258	
11	"	...	...	...	·33487		·33262	
11	"	...	...	...	·33485		·33260	
11	"	...	...	...	·33482		·33258	
13	K. N. M.	929·09	7·17	7·48	·33480		·33260	
13	"	929·39	...	...	·33491		·33279	
17	"	928·84	7·19	7·76	·33468		·33254	
17	"	928·97	...	...	·33473		·33260	
20	"	928·62	7·32	7·72	·33460		·33242	
20	"	929·20	...	...	·33480		·33262	
24	"	929·01	7·14	7·58	·33463		·33256	
24	"	928·90	...	...	·33460		·33256	
27	"	928·73	7·01	7·48	·33460		·33248	
27	"	928·65	...	...	·33457		·33248	
31	"	929·01	6·96	7·90	·33483		·33256	
31	"	928·90	...	...	·33479		·33253	

NOTE.—These are the actual results observed with No. 5 magnetometer in the Old South House.

TABLE II.

ABSOLUTE MAGNETIC OBSERVATIONS.

Observations of Declination at Dehra Dún Observatory.

1		2	3	4	5	6	7
Date.		Observer.	Magnetic Collimation.	Observed Declination, East.	Monthly mean observed Declination, East.	Base Line values.	Monthly mean Base Line values.
1902.			′ ″	° ′	° ′	′	′
March	10		+7 49	2 42·3	2 43·2	97·1	97·9
	11		8 0	2 42·1		98·1	
	21		7 54	2 44·8		98·8	
	26		7 36	2 43·7		97·4	
April	5		+7 8	2 42·3	2 43·5	97·5	97·9
	11		8 18	2 45·4		98·6	
	15		8 20	2 43·7		98·2	
	21		7 33	2 42·6		97·7	
	23		7 39	2 42·6		97·7	
	25		7 53	2 43·6		98·0	
	26		7 46	2 44·4		97·7	
	26		7 34	2 43·4		97·5	
May	3		+8 13	2 43·2	2 43·3	98·1	97·6
	4		8 19	2 45·0		96·9	
	11		8 18	2 44·0		98·1	
	15		7 36	2 43·3		97·4	
	19		6 17	2 43·0		97·7	
	20		7 35	2 41·3		97·2	
	20		6 18	2 42·2		97·2	
	25		8 19	2 44·2		98·1	
June	3		+5 55	2 41·7	2 42·3	96·8	96·8
	4		6 18	2 43·1		96·9	
	7		6 15	2 41·1		96·5	
	20		6 25	2 41·7		96·8	
	24		6 15	2 44·1		97·1	
	27		6 15	2 41·8		96·9	
July	1		+6 31	2 43·7	2 41·8	96·6	96·2
	4		6 30	2 40·9		96·5	
	11		6 0	2 42·0		96·4	
	15		6 18	2 42·1		96·2	
	18		6 17	2 42·1		96·2	
	22		6 26	2 41·1		96·3	
	25		6 10	2 40·2		95·8	
	29		6 11	2 42·1		95·9	
August	1		+5 59	2 41·6	2 40·2	96·2	96·3
	5		6 32	2 39·7		96·8	
	8		6 27	2 39·9		96·0	
	12		6 28	2 40·7		96·0	
	15		6 24	2 40·6		96·4	
	19		6 3	2 37·7		96·0	
	22		6 45	2 40·5		96·3	
	26		6 13	2 41·8		96·7	
	29		6 24	2 39·7		96·6	

TABLE II—*concld.*

ABSOLUTE MAGNETIC OBSERVATIONS.

Observations of Declination at Dehra Dún Observatory.

1		2	3		4		5	6	7
Date.		Observer.	Magnetic Collimation.		Observed Declination, East.		Monthly mean observed Declination, East.	Base Line values.	Monthly mean Base Line values.
			′	″	°	′	° ′	′	′
1902.									
September	2		+6	18	2	40·2		97·0	
	5		6	16	2	40·6		96·7	
	9		6	13	2	40·8		96·9	
	12		6	23	2	41·7		97·3	
	16		6	32	2	39·9	2 40·5	97·1	97·1
	19		6	24	2	39·6		96·9	
	23		6	36	2	39·9		97·1	
	26		6	20	2	41·1		97·3	
	30		6	18	2	40·4		97·2	
October	3		+6	22	2	40·8		96·9	
	7		6	4	2	41·9		97·1	
	10		6	22	2	42·3		97·3	
	14		6	23	2	42·6		97·2	
	17		6	18	2	41·1		97·2	
	17		6	13	2	42·8		96·9	
	21		6	45	2	41·6	2 42·5	97·1	97·3
	21		6	22	2	41·5		97·1	
	24		6	26	2	44·8		97·4	
	24		6	30	2	44·1		97·5	
	24		6	16	2	43·5		97·6	
	28		6	12	2	42·7		97·8	
	31		6	16	2	43·2		97·5	
November	4		+6	17	2	41·2		97·3	
	7		6	14	2	43·9		97·8	
	10		6	15	2	44·4		97·8	
	10		6	14	2	44·7		97·5	
	11		6	34	2	43·8		97·5	
	11		6	29	2	43·4		97·3	
	14		6	20	2	43·2	2 43·5	97·4	97·7
	14		6	15	2	43·3		98·0	
	18		6	22	2	43·8		97·9	
	21		6	10	2	43·6		98·0	
	21		6	14	2	43·6		97·6	
	25		6	15	2	43·4		97·9	
	28		6	12	2	43·4		97·5	
December	2		+6	22	2	44·3		97·7	
	5		6	9	2	43·8		97·8	
	5		6	6	2	43·9		97·9	
	9		6	17	2	43·9		98·2	
	9		5	59	2	43·5		97·8	
	9		5	58	2	43·5		97·7	
	9		5	59	2	43·6		97·8	
	12		6	11	2	43·5		97·6	
	12		6	22	2	43·7	2 43·7	97·7	97·7
	12		6	23	2	43·7		97·7	
	13		6	7	2	42·9		97·6	
	13		6	8	2	43·1		97·5	
	13		6	0	2	43·4		97·5	
	16		6	23	2	43·7		97·7	
	19		5	55	2	43·2		97·5	
	23		6	16	2	44·6		97·6	
	26		6	14	2	44·0		97·6	
	30		6	12	2	43·5		97·9	

NOTE.—The above figures refer to No. 5 magnetometer in the Old South House.

Table III.

Absolute Magnetic Observations.

Observations of Dip at Dehra Dún Observatory taken with Barrow's Dip Circle No. 44 and needles Nos. 1 and 2 by Dover.

Date.		Dehra Dún L. M. Time of observation (0 to 24 hours).		Observer.	Needle No.	Observed Dip.		Monthly mean for each needle.	Monthly mean.
		h.	m.			°	′		° ′
1902.									
March	11	11	54·0	H. A. D. F.	1	43	6·9		
					2		6·9	No. 1	
	13	15	3·0	K. N. M.	1		5·3	43° 6′·7	
	17	15	39·0		2		9·4		
	24	14	3·5		1		6·8	No. 2	43 7·3
	27	14	30·5		2		7·5		
	30	14	16·5		1		7·6	43° 8′·0	
					2		8·3		
April	4	12	3·0		1	43	8·0		
	7	15	24·5		1		7·9		
	9	12	15·0		1		8·4	No. 1	
					2		7·4	43° 8′·1	
	17	13	50·5		1		4·1		43 8·5
	25	15	4·0		1		10·0		
					2		10·4	No. 2	
	29	7	29·5		1		10·0	43° 9′·5	
					2		10·7		
May	6	16	23·5		1	43	9·1		
					2		8·4		
	10	8	32·5		1		9·0	No. 1	
					2		8·5	43° 8′·7	
	15	14	4·0		1		8·2		
					2		8·1		43 8·6
	21	11	29·5		1		8·2	No. 2	
					2		8·8	43° 8′·4	
	27	13	44·0		1		8·9		
					2		8·3		
June	5	15	58·5		1	43	10·4		
					2		10·3		
	7	15	30·5		1		11·0		
					2		11·5	No. 1	
	16	16	51·0	R. P. R.	1		9·8	43° 9′·6	
					2		9·9		
	19	14	32·5		1		9·6		
					2		8·7		43 9·7
	23	12	33·0		1		8·2		
					2		8·9	No. 2	
	26	15	18·0		1		8·5	43° 9′·9	
					2		9·8		
	30	13	1·0	K. N. M.	1		9·4		
					2		10·2		
July	3	12	25·5		1	43	10·2		
					2		9·7		
	7	15	20·5		1		10·5	No. 1	
					2		8·6	43° 9′·8	
	10	14	30·5		1		9·6		
					2		10·7		43 9·9
	14	15	42·0		1		9·1	No. 2	
					2		10·4	43° 10′·1	
	17	14	21·5		1		10·7		
					2		11·1		

TABLE III—*contd.*

Date.		Dehra Dún L. M. Time of observation (0 to 24 hours). h.	m.	Observer.	Needle No.	Observed Dip. °	′	Monthly mean for each needle.	Monthly mean. °	′
1902.		h.	m.			°	′		°	′
July	21	15	34·5	K. N. M.	1	43	9·4	No. 1		
					2		10·5	43° 9′·8		
	24	14	47·5		1		10·8			
					2		10·5			
	28	14	51·0		1		9·4		43	9·9
					2		10·1	No. 2		
	31	12	36·5		1		8·7	43° 10′·1		
					2		8·9			
August	4	14	19·5		1	43	9·2			
					2		9·8			
	7	12	44·0		1		10·5			
					2		12·9			
	11	12	6·0		1		12·9	No. 1		
					2		12·4	43° 10′·4		
	14	12	28·5		1		10·1			
					2		11·9			
	18	12	28·0		1		8·5		43	10·9
					2		10·3			
	21	13	2·5		1		9·1			
					2		9·9	No. 2		
	25	12	45·5		1		10·7	43° 11′·4		
					2		12·7			
	28	12	11·0		1		12·1			
					2		10·9			
September	1	12	20·0		1	43	11·7			
					2		11·7			
	4	13	12·0		1		12·9			
					2		12·9			
	8	11	19·0		1		12·5			
					2		12·3	No. 1		
	11	13	6·0		1		11·5	43° 11′·8		
					2		12·7			
	15	12	54·0		1		12·1			
					2		11·3			
	18	13	8·0		1		12·1		43	12·0
					2		10·6			
	22	11	52·5		1		12·3			
					2		11·8	No. 2		
	25	15	1·5		1		12·2	43° 12′·2		
					2		14·6			
	26	13	45·0		2		12·4			
	29	12	26·0		1		9·0			
					2		11·2			
October	2	15	5·5		1	43	12·5			
					2		10·5			
	3	11	44·0		2		11·3			
	6	12	24·0		1		8·3	No. 1		
					2		11·2	43° 11′·7		
		14	35·0		1		10·4			
	9	14	27·5		1		12·7			
					2		12·7		43	11·6
	13	13	5·5		1		11·2			
					2		11·8			
	16	13	2·5		1		12·5	No. 2		
					2		11·2	43° 11′·6		
	20	12	26·0		1		11·3			
					2		12·6			

TABLE III—*contd.*

Date.		Dehra Dún L. M. Time of observation (0 to 24 hours).	Observer.	Needle No.	Observed Dip.	Monthly mean for each needle.	Monthly mean.
		h. m.			° ′		° ′
October	23	16 53·0	K. N. M.	1	43 12·8	No. 1	
				2	10·4	43° 11′·7	
	27	12 51·5		1	12·9		
				2	11·0		
	28	13 2·0		1	10·8		43 11·7
				2	11·6		
	30	14 38·5		1	13·0	No. 2	
				2	13·4	43° 11′·6	
November	3	12 5·0		1	43 9·9		
				2	11·7		
	6	10 59·5		1	11·0		
				2	11·8	No. 1	
	10	16 57·5		1	12·2	43° 12′·1	
				2	13·0		
	13	14 33·5		1	12·0		
				2	12·5		
	17	12 34·5		1	11·4		43 12·3
				2	10·6		
	20	16 8·5		1	12·6		
				2	12·0		
	24	12 56·0		1	14·6	No. 2	
				2	14·7	43° 12′·5	
	27	14 23·5		1	12·7		
				2	13·6		
December	1	14 33·0		1	43 13·6		
				2	12·4		
	4	8 42·5		1	12·2		
				2	14·0		
	8	8 51·5		1	12·8	No. 1	
				2	12·3	43° 12′·2	
	11	8 27·5		1	13·8		
				2	12·1		
	15	11 36·0		1	13·7		43 12·3
				2	14·5		
	18	8 58·5		1	11·1		
		1 33·5		2	11·3		
	22	13 4·5		1	11·4	No. 2	
				2	12·4	43° 12′·4	
	25	15 20·5		1	11·7		
				2	11·5		
	29	14 42·0		1	9·8		
				2	10·7		

TABLE IV.

Dates of Magnetic Disturbances at Dehra Dún in 1902.

Lat. of observatory = 30°.19′.29″.
Long. " = 78°.5′.42″.

1902.	Month.									
Date.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1	C	S	C	S	C	C	C	C	C	C
2	C	(S)	C	C	(C)	C	S	C	C	S
3	(C)	S	C	(C)	C	C	C	C	C	C
4	C	C	C	C	S	C	C	(S)	(C)	(C)
5	C	C	C	S	S	(C)	(C)	C	C	C
6	S	C	(C)	S	(C)	C	C	C	S	C
7	S	(C)	S	C	C	C	C	C	C	C
8	S	S	M	(S)	M	C	(C)	(C)	(C)	(C)
9	(C)	S	M	C	C	S	C	C	C	S
10	C	M	S	S	C	S	C	C	C	C
11	M	M	(C)	S	S	S	C	S	C	S
12	S	C	C	S	S	(C)	S	C	C	S
13	C	S	S	S	C	C	C	C	S	S
14	(C)	(C)	C	C	S	...	(C)	C	S	C
15	S	C	(C)	S	S	(C)	C	C	S	C
16	C	S	C	(C)	C	S	C	C	C	C
17	S	S	C	...	(C)	C	C	(S)	(C)	C
18	C	C	C	C	C	C	S	C	C	(C)
19	C	S	S	C	C	(C)	S	C	C	C
20	C	M	S	(C)	C	S	S	(C)	(C)	(C)
21	S	S	(S)	...	C	M	C	C	S	C
22	(C)	S	C	S	C	S	S	C	S	C
23	S	(S	C	C	S	S	C	S	M	S
24	M	C	C	C	M	C	C)	S	M	S
25	S	C	C	C	S	S	C	C	S	C
26	S	C	C	S	S	C	(C)	C	S	S
27	C	C	C	C	(C)	C	S	S	S	C
28	C	C	(C)	S	C	(C)	C	C	(C)	C
29	(C)	(C)	S	S	C	C	S	(S)	C	C
30	C	S	C	(C)	C	C	S	S	C	(C)
31	S	...	C	...	(C)	S	...	M	...	C
Total C.	18	14	22	15	20	20	21	22	19	23
Total S.	11	13	7	13	9	9	9	8	9	8
Total M.	2	3	2	...	2	1	...	1	2	...
Total G.	...	...	...	...	...	...	...	...	...	...
Total V.G.	...	...	...	...	...	...	...	...	...	...

NOTES.—The magnitudes of the disturbances are determined from Horizontal Force traces.
C = calm. S = slight. M = moderate. G = great. V. G. = very great.
Days are reckoned from 10 A. M. to 10 A. M. on the next day.
The five selected quiet days in each month are distinguished by brackets. The selections are made from the Colába curves by the Director of the Colába Observatory. Unclassified days denote that the record was lost.

TABLE V.

Hourly Means of the Horizontal Force in C. G. S. units (corrected for temperature) at Dehra Dún from the selected quiet days in 1902.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	1	2	3	4	5	6	7	8	9	10	11
0·33000+												Winter.												
1902 Months.	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
March	467	466	464	464	466	465	467	466	466	470	475	481	485	486	481	473	468	465	465	465	464	465	466	466
October	451	450	450	450	452	452	453	451	447	448	455	462	467	468	465	462	457	451	453	453	451	451	452	453
November	454	455	455	455	454	456	455	458	461	466	471	474	477	471	463	458	458	456	456	456	456	455	456	457
December	441	442	442	442	442	442	444	447	452	455	455	454	455	454	449	447	445	444	443	443	443	443	444	445
												Summer.												
April	460	462	461	463	462	461	460	458	456	457	462	468	474	480	481	474	467	464	460	459	460	461	461	463
May	468	470	470	471	470	471	471	470	468	468	475	485	492	494	489	483	476	470	469	469	469	470	470	470
June	470	470	469	469	469	468	469	465	462	459	462	468	472	479	477	471	468	465	463	462	464	462	463	464
July	458	458	456	455	456	456	459	461	461	464	465	475	480	482	482	477	471	466	464	463	464	465	467	467
August	459	458	457	457	457	457	457	452	444	439	443	452	464	473	478	475	469	461	457	458	458	458	458	458
September	452	453	455	456	456	456	457	453	445	442	443	446	457	468	471	467	462	458	458	457	456	455	456	455
Summer Means	461	462	461	462	462	462	462	460	456	455	458	466	473	479	480	475	469	464	462	461	462	462	463	463

NOTE.—These are the actual values corrected by—28 γ and are therefore comparable with observations taken with No. 17 (the standard) magnetometer in the new south house.

TABLE VI.

Diurnal inequality of the Horizontal Force at Dehra Dún as deduced from Table V.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11
Winter.																								
1902 Months.	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
March	−2	−3	−5	−5	−3	−4	−2	−3	−3	+1	+6	+12	+16	+17	+12	+4	−1	−4	−4	−4	−5	−4	−3	−3
October	−3	−4	−4	−4	−2	−2	−1	−3	−7	−6	+1	+8	+13	+14	+11	+8	+3	−3	−1	−1	−3	−3	−2	−1
November	−6	−5	−5	−5	−6	−4	−5	−2	+1	+6	+11	+14	+17	+11	+3	−2	−2	−4	−4	−4	−4	−5	−4	−3
December	−5	−4	−4	−4	−4	−4	−2	+1	+6	+9	+9	+8	+9	+8	+3	+1	−1	−2	−3	−3	−3	−3	−2	−1
Summer.																								
April	−4	−2	−3	−1	−2	−3	−4	−6	−8	−7	−2	+4	+10	+16	+17	+10	+3	0	−4	−5	−4	−3	−3	−1
May	−6	−4	−4	−3	−4	−3	−3	−4	−6	−6	+1	+11	+18	+20	+15	+9	+2	−4	−5	−5	−5	−4	−4	−4
June	+3	+3	+2	+2	+2	+1	+2	−2	−5	−8	−5	+1	+5	+12	+10	+4	+1	−2	−4	−5	−3	−5	−4	−3
July	−8	−8	−10	−11	−10	−10	−7	−5	−5	−2	−1	+9	+14	+16	+16	+11	+5	0	−2	−3	−2	−1	+1	+1
August	+1	0	−1	−1	−1	−1	−1	−6	−14	−19	−15	−6	+6	+15	+20	+17	+11	+3	−1	0	0	0	0	0
September	−4	−3	−1	0	0	0	+1	−3	−11	−14	−13	−10	+1	+12	+15	+11	+6	+2	+2	+1	0	−1	0	−1
Summer Means	−3	−2	−3	−2	−3	−3	−2	−4	−8	−9	−6	+2	+9	+15	+16	+10	+5	0	−2	−3	−2	−2	−2	−1

NOTE.—When the sign is + the reading is above the mean.
In August the trace was lost on the 15th (one of the selected days) and the results have been compiled from the remaining 4 days only.

TABLE VII.

Hourly means of the Declination as determined at Dehra Dún from the selected quiet days in 1902.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11
	East 2°+										Winter													
1902 Months.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
March	44·0	44·1	43·9	43·9	43·7	43·6	43·8	44·8	45·7	46·0	45·3	44·0	42·5	42·1	42·4	43·3	44·0	41·2	43·8	43·7	43·7	43·8	43·8	44·0
October	42·5	42·6	42·6	42·5	42·4	42·4	42·5	43·5	44·2	44·0	43·1	41·6	40·4	40·2	41·0	42·0	42·5	42·5	42·2	42·2	42·3	42·3	42·5	42·7
November	42·8	42·8	42·8	42·8	42·8	42·7	42·7	42·7	43·2	43·4	43·4	42·7	42·2	42·6	42·9	43·0	43·0	43·1	42·9	42·8	42·7	42·7	42·8	42·8
December	42·6	42·5	42·5	42·4	42·3	42·2	42·1	41·9	42·0	42·4	42·6	42·5	42·5	43·1	43·3	43·2	43·0	42·9	42·9	42·8	42·8	42·8	42·6	42·6
										Summer														
April	44·0	43·9	43·9	43·8	43·8	43·8	44·3	45·4	46·4	46·4	45·0	43·3	42·0	41·7	42·1	42·7	43·6	43·7	43·7	43·5	43·6	43·7	43·7	43·9
May	43·7	43·7	43·8	43·7	43·7	43·7	44·4	45·4	45·8	45·4	43·9	42·6	41·4	41·1	41·7	42·4	43·2	43·7	43·7	43·5	43·5	43·5	43·7	43·8
June	43·5	43·6	43·6	43·6	43·5	43·7	45·0	45·8	45·7	44·8	43·6	41·9	40·5	40·4	40·6	41·1	41·7	42·5	43·0	42·8	42·8	42·9	43·0	43·2
July	43·5	43·7	43·8	43·7	43·7	43·9	44·6	45·6	46·4	46·2	44·7	42·6	40·9	40·2	40·0	40·7	41·5	42·3	42·9	42·6	42·5	42·5	42·6	42·7
August	42·4	42·5	42·6	42·8	42·9	43·1	44·4	45·5	45·4	44·0	41·7	39·7	38·8	38·8	39·5	40·7	42·0	42·7	42·9	42·3	42·3	42·3	42·3	42·4
September	42·7	42·7	42·7	42·8	42·8	42·9	43·6	44·8	45·3	44·8	42·8	40·6	39·4	39·3	40·0	41·4	42·4	42·7	42·4	42·3	42·3	42·3	42·3	42·5
Summer Means	43·3	43·4	43·4	43·4	43·4	43·5	44·4	45·4	45·8	45·3	43·6	41·8	40·5	40·3	40·7	41·5	42·4	42·9	43·1	42·8	42·8	42·9	42·9	43·1

NOTE.—These are the actual values corrected by —1′·0 and are therefore comparable with observations taken with No. 17 (the standard) magnetometer in the new south house.

TABLE VIII.

Diurnal Inequality of the Declination at Dehra Dún as deduced from Table VII.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	1	2	3	4	5	6	7	8	9	10	11
Winter.																								
1902 Months.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
March	+0·1	+0·2	0·0	0·0	−0·2	−0·3	−0·1	+0·9	+1·8	+2·1	+1·4	+0·1	−1·4	−1·8	−1·5	−0·6	+0·1	+0·3	−0·1	−0·2	−0·2	−0·1	−0·1	+0·1
October	+0·1	+0·2	+0·2	+0·1	0·0	0·0	+0·1	+1·1	+1·8	+1·6	+0·7	−0·8	−2·[illegible]	−2·2	−1·4	−0·4	+0·1	+0·1	−0·2	−0·2	−0·1	−0·1	+0·1	+0·3
November	0·0	0·0	0·0	0·0	0·0	−0·1	−0·1	−0·1	+0·4	+0·6	+0·6	−0·1	−0·6	−0·2	+0·1	+0·2	+0·2	+0·3	+0·1	0·0	−0·1	−0·1	0·0	0·0
December	0·0	−0·1	−0·1	−0·2	−0·3	−0·4	−0·5	−0·7	−0·6	−0·2	0·0	−0·1	−0·1	+0·5	+0·7	+0·6	+0·4	+0·3	+0·3	+0·2	+0·2	+0·2	0·0	0·0
Summer.																								
April	+0·2	+0·1	+0·1	0·0	0·0	0·0	+0·5	+1·6	+2·6	+2·6	+1·2	−0·5	−1·8	−2·1	−1·7	−1·1	−0·2	−0·1	−0·1	−0·3	−0·2	−0·1	−0·1	+0·1
May	+0·1	+0·1	+0·2	+0·1	+0·1	+0·1	+0·8	+1·8	+2·2	+1·8	+0·3	−1·0	−2·2	−2·5	−1·9	−1·2	−0·4	+0.1	+0·1	−0·1	−0·1	−0·1	+0·1	+0·2
June	+0·5	+0·6	+0·6	+0·6	+0·5	+0·7	+2·0	+2·8	+2·7	+1·8	+0·6	−1·1	−2·5	−2·6	−2·4	−1·9	−1·3	−0·5	0·0	−0·2	−0·2	−0·1	0·0	+0·2
July	+0·4	+0·6	+0·7	+0·6	+0·6	+0·8	+1·5	+2·5	+3·3	+3·1	+1·6	−0·5	−2·2	−2·9	−3·1	−2·4	−1·6	−0·8	−0·2	−0·5	−0·6	−0·6	−0·5	−0·4
August	+0·1	+0·2	+0·3	+0·5	+0·6	+0·8	+2·1	+3·2	+3·1	+1·7	−0·6	−2·6	−3·5	−3·5	−2·8	−1·6	−0·3	+0·4	+0·6	0·0	0·0	0·0	0·0	+0·1
September	+0·3	+0·3	+0·3	+0·4	+0·4	+0·5	+1·2	+2·4	+2·9	+2·4	+0·4	−1·8	−3·0	−3·1	−2·4	−1·0	0·0	+0·3	0·0	−0·1	−0·1	−0·1	−0·1	+0·1
Summer Means	+0·3	+0·3	+0·4	+0·4	+0·4	+0·5	+1·4	+2·4	+2·8	+2·2	+0·6	−1·3	−2·5	−2·8	−2·4	−1·5	−0·6	−0·1	+0·1	−0·2	−0·2	−0·2	−0·1	+0·1

NOTE.—When the sign is +, the magnet points to the east of its mean position.
The traces were lost on 3rd March and 5th August and in these months the results have been compiled from the remaining four selected quiet days only.

TABLE IX.

Statement of loss of Magnetograph Records in 1902.

HORIZONTAL FORCE MAGNETOGRAPH.					DECLINATION MAGNETOGRAPH.					Cause of interruption.
PERIOD OF BREAK				Duration of break.	PERIOD OF BREAK				Duration of break.	
from	on	to	on		from	on	to	on		
h. m.	date	h. m.	date	h. m.	h. m.	date	h. m.	date	h. m.	
	1st January .		28th February	...	...	1st January .	...	28th February	...	Work commenced on 1st March.
					10 3	4th March .	10 20	5th March .	24 17	Reflecting mirror not raised.
					14 0	8th „ .	18 0	8th „ .	4 0	Drum not clamped.
9 50	14th June .	12 0	14th June . .	2 10	...	...	...	...	...	Reflecting mirror not raised.
9 53	16th „ .	11 15	16th „ .	1 22	...	...	...	...	...	„ „ „ „
9 56	17th „ .	10 21	18th „ .	24 25	9 56	17th June .	10 21	18th June .	24 25	Drums not clamped.
9 52	21st „ .	10 20	22nd „ .	24 28	...	...	...	...	...	„ „ „
					10 3	30th July .	11 20	30th July .	1 17	„ „ „
					15 0	„ „ .	17 0	„ „ .	2 0	„ „ „
9 52	14th August .	10 3	15th August .	24 11	9 52	14th August .	10 3	15th August .	24 11	Reflecting mirror not raised.
10 35	12th October	13 10	12th October .	2 35	10 35	12th October .	13 10	12th October .	2 35	Not known.
					19 0	2nd November	10 4	3rd November	15 4	Lamp failed.
23 30	28th November	12 9	29th November	12 39	23 30	28th „	12 9	29th „	12 39	Clock cord broke. New cord fitted.
1 44	30th „	10 14	30th „	8 30	1 44	30th „	10 14	30th „	8 30	Clock weight slipped off cord.
			TOTAL .	100 20				TOTAL .	118 58	

NOTE.—Papers are changed on alternate and lamps shifted on intermediate days commencing at 9·51 L. M. T. in both cases.

APPENDIX.

TABLE X.

Abstract showing the Approximate Magnetic values at stations observed at by No. 26 Party during season 1902-03.

Serial No.	Name of Station.	Survey No.	Latitude. ° ′ ″	Longitude. ° ′ ″	Dip. ° ′	Declination. ° ′	Horizontal Force. C. G. S.	REMARKS.
164	Jhajra . .	$\frac{30}{78}$ 2	30 20 30	77 54 50	43 15	E 2 40	...	
165	Ambári . .	,, 1	30 29 20	77 48 20	43 30	,, 2 45	...	
166	Mirzapur .	,, 3	30 15 30	77 37 40	43 10	,, 2 45	...	
167	Ghuna . .	,, 4	30 3 50	77 34 40	42 50	,, 2 40	...	
168	Fatehpur .	,, 5	30 2 40	77 45 40	42 45	,, 2 45	...	
169	Kalyán . .	$\frac{20}{74}$ 6	19 15 0	73 8 20	23 35	,, 0 25	0·3645	
170	Lonávla . .	$\frac{18}{74}$ 1	18 45 10	73 24 20	22 10	,, 0 15	0·3720	
171	Kirkee . .	,, 2	18 33 30	73 50 0	22 5	,, 0 35	0·3705	
172	Dhond . .	,, 3	18 28 0	74 35 10	21 20	,, 0 25	0·3720	
173	Jeúr . .	$\frac{18}{76}$ 1	18 15 50	75 9 40	21 5	,, 0 15	0·3730	
174	Bársi . .	,, 2	18 14 30	75 42 20	21 0	,, 1 0	0·3745	
175	Hotgi . .	,, 3	17 33 40	76 0 20	19 50	,, 0 30	0·3735	
176	Ghángápur .	,, 4	17 20 20	76 36 0	18 30	,, 0 40	0·3765	
177	Wadi Junction .	$\frac{18}{78}$ 1	17 3 0	77 0 0	18 10	,, 0 25	0·3765	
178	Yádgiri .	$\frac{16}{78}$ 1	16 44 40	77 8 10	17 35	,, 0 20	0·3765	
179	Ráichur .	,, 2	16 12 0	77 20 30	16 30	,, 0 15	0·3790	
180	Ádóni . .	,, 3	15 37 0	77 16 30	15 15	,, 0 5	0·3790	
181	Guntakal .	,, 4	15 10 20	77 22 40	14 40	,, 0 15	0·3805	
182	Kondápuram .	$\frac{14}{78}$ 2	14 46 20	78 11 40	13 20	W 0 10	0·3825	
183	Cuddapah .	,, 4	14 27 10	78 49 20	12 35	E 0 5	0·3815	
184	Reddipalle	$\frac{14}{80}$ 2	14 5 30	79 14 0	11 45	W 0 10	0·3820	
185	Rénigunta .	,, 3	13 38 0	79 30 50	10 40	,, 0 5	0·3810	
186	Arkonam .	,, 5	13 4 30	79 40 20	9 40	,, 0 10	0·3835	
187	Perambúr .	,, 6	13 6 40	80 15 0	9 55	,, 0 10	0·3850	
188	Kátpádi .	$\frac{13}{80}$ 1	12 58 40	79 7 40	9 20	,, 0 15	0·3840	
189	Jalarpet .	$\frac{12}{78}$ 3	12 34 0	78 34 10	8 45	,, 0 35	0·3800	
190	Bowringpet .	,, 1	12 58 50	78 11 0	9 20	,, 0 20	0·3810	
191	Morappúr .	,, 4	12 7 30	78 21 40	7 15	,, 0 30	0·3845	
192	Salem . .	,, 5	11 40 0	78 6 50	5 25	,, 0 30	0·3820	
193	Erode . .	,, 6	11 19 40	77 43 50	5 30	,, 0 30	0·3820	
194	Sómanúr .	,, 7	11 5 10	77 11 0	5 10	,, 0 30	0·3780	
195	Coonoor .	$\frac{12}{76}$ 6	11 20 40	76 47 50	5 40	,, 0 25	0·3795	
196	Olavakkót .	$\frac{10}{76}$ 2	10 48 10	76 38 20	4 30	,, 0 40	0·3775	
197	Pattámbi .	,, 1	10 48 10	76 10 40	5 5	,, 0 25	0·3750	
198	West hills .	$\frac{12}{76}$ 7	11 17 10	75 45 20	7 35	E 0 40	0·3865	
199	Connanore .	$\frac{12}{76}$ 5	11 52 30	75 22 0	7 0	W 0 5	0·3825	
200	Vottekolli .	,, 3	12 7 20	75 50 20	7 35	,, 0 35	0·3785	

TABLE X—*contd.*

Abstract showing the Approximate Magnetic values at stations observed at by No. 26 Party during season 1902-03.

Serial No.	Name of Station.	Survey No.		Latitude. ° ′ ″	Longitude ° ′ ″	Dip. ° ′	Declination. ° ′	Horizontal Force. C. G. S.	REMARKS.
201	Húnsúr	12/76	2	12 18 20	76 16 50	7 40	W 0 40	0·3790	
202	Nanjangúd	„	4	12 7 40	76 40 40	7 30	„ 0 30	0·3820	
203	Seringapatam	„	1	12 25 30	76 40 40	8 5	„ 0 20	0·3800	
204	Channapatna	12/78	2	12 39 40	77 12 0	8 50	„ 0 20	0·3820	
205	Túmkúr	14/78	10	13 20 0	77 6 0	10 5	E 0 15	0·3785	
206	Tiptur	14/76	5	13 15 10	76 28 30	10 5	W 0 15	0·3795	
207	Birur	„	4	13 35 50	75 58 10	10 45	„ 0 10	0·3795	
208	Shimoga	„	3	13 55 30	75 34 0	11 20	„ 0 5	0·3780	
209	Sásalu	„	2	14 12 40	76 6 40	12 10	„ 0 10	0·3790	
210	Ránebennur	„	1	14 37 0	75 38 30	13 0	0 0	0·3785	
211	Yalvigi	16/76	1	15 1 50	75 25 0	14 5	E 0 10	0·3765	
212	Mormugao	16/74	5	15 24 10	73 47 30	15 10	„ 0 25	0·3770	
213	Castle Rock	„	6	15 24 0	74 18 50	13 55	W 0 10	0·3820	
214	Belgaum	„	4	15 50 30	74 31 0	15 50	„ 0 15	0·3735	
215	Gokák Road	„	3	16 14 0	74 44 40	16 25	E 0 15	0·3770	
216	Miraj	„	1	16 49 10	74 38 10	18 30	„ 0 5	0·3795	
217	Kolhápur	„	2	16 41 50	74 14 10	17 25	„ 0 25	0·3755	
218	Kárád	18/74	6	17 18 40	74 13 10	19 5	„ 0 25	0·3730	
219	Wathar	„	5	17 53 20	74 8 10	20 20	„ 0 25	0·3715	
220	Rajewadi	„	4	18 23 0	74 8 30	20 55	„ 0 25	0·3705	
221	Ahmednagar	20/74	7	19 4 20	74 43 10	22 35	„ 0 30	0·3705	
222	Puntámba	„	4	19 45 40	74 37 20	23 55	„ 1 10	0·3690	
223	Manmád	„	2	20 14 40	74 26 20	24 35	„ 0 55	0·3665	
224	Khesav á	„	3	20 2 50	73 58 10	25 10	„ 0 50	0·3670	
225	Igatpuri	„	5	19 41 20	73 34 40	24 0	„ 0 35	0·3650	
226	Dhulia	„	1	20 53 10	74 46 20	26 0	„ 0 50	0·3670	
227	Chálisgaon	20/76	1	20 27 30	75 1 0	25 0	„ 0 55	0·3665	
228	Lhaksar	30/78	7	29 45 20	78 1 20	42 15	„ 2 35	0·3370	
229	Saháranpur	„	6	29 57 50	77 32 40	42 35	„ 2 45	0·3360	
230	Muzaffarnagar	„	8	29 28 30	77 42 0	41 50	„ 2 35	0·3385	
231	Meerut City	28/78	1	28 58 40	77 41 0	40 55	„ 2 30	0·3405	
232	Delhi	„	2	28 40 20	77 14 20	40 30	„ 2 10	0·3415	
233	Samálkha	30/78	9	29 14 40	77 0 10	41 20	E 2 35	0·3385	
234	Taráori	30/78	8	29 48 20	76 56 0	42 15	„ 2 40	0·3365	
235	Sangaria	30/74	6	29 47 50	74 27 40	42 15	„ 2 25	0·3345	
127	Súratgarh	„	5	29 20 0	73 54 30	41 30	„ 2 35	0·3360	
236	Balochia	„	11	29 14 50	73 27 20	41 20	„ 2 30	0·3355	

TABLE X—*contd.*

Abstract showing the Approximate Magnetic values at stations observed at by No. 26 Party during season 1902-03.

Serial No.	Name of Station.	Survey No.	Latitude. ° ′ ″	Longitude. ° ′ ″	Dip. ° ′	Declination. ° ′	Horizontal Force. C. G. S.	REMARKS.
237	Walar or Sardárgarh.	30/74 10	29 15 30	73 1 40	41 25	E 2 25	0·3340	
238	Ranabhana Toba	28/73 6	28 54 30	72 38 10	41 5	" 2 0	0·3350	
239	Maujagarh	30/73 13	29 0 50	72 8 20	40 50	" 2 15	0·3365	
240	Kumhariwala	28/72 8	28 32 0	72 14 10	41 15	" 3 5	0·3365	
24	Khangarh	" 2	28 22 10	71 42 50	40 10	" 2 5	0·3385	
241	Lohita Tibba	" 11	27 55 10	71 32 10	39 50	" 1 50	0·3400	
242	Sarwarka Toba	" 9	28 17 30	71 6 40	39 45	" 2 20	0·3370	
243	Islamgarh	28/70 13	27 51 30	70 48 40	39 15	" 2 10	0·3370	
244	Maruwala Toba	" 11	28 15 30	70 38 50	39 45	" 2 10	0·3355	
245	Bher Tibba	" 12	28 0 25	70 22 10	39 30	" 2 20	0·3375	
57	Sadikabad	" 2	28 18 10	70 7 40	40 0	" 2 35	0·3365	
246	Ganeshgarh	30/74 7	29 45 0	73 54 0	42 10	" 2 50	0·3340	
247	Lálgarh	" 8	29 38 20	73 22 50	42 0	" 2 35	0·3335	
248	Gegra	28/74 7	28 49 10	73 15 0	40 35	" 2 30	0·3365	
249	Kelasar	" 8	28 28 0	73 15 20	40 15	" 2 20	0·3385	
250	Pungal	28/73 7	28 30 50	72 48 40	40 10	" 2 5	0·3385	
251	Angnao	" 10	28 6 0	72 47 0	39 35	" 2 20	0·3400	
252	Hadda	" 12	27 37 50	72 52 30	38 50	" 2 5	0·3415	
253	Ranisar	" 13	27 12 40	72 42 40	37 55	" 2 5	0·3425	
254	Panchora	28/74 13	27 6 40	73 13 30	38 0	" 1 25	0·3445	
255	Khetasar	28/72 3	26 41 0	72 49 20	37 10	" 1 50	0·3465	
256	Jodhpur	26/74 8	26 16 20	73 1 30	36 20	" 1 25	0·3480	
257	Marwar Páli	" 9	25 47 50	73 19 30	35 30	" 1 40	0·3495	
258	Dundára	26/72 4	25 53 40	72 47 50	37 45	" 1 30	0·3475	
259	Bálotra	" 5	25 50 10	72 14 40	36 40	" 1 25	0·3515	
260	Kavas	" 6	25 52 15	71 31 40	35 20	" 2 5	0·3470	
261	Bhachbhar	" 7	25 44 0	70 59 0	36 25	" 2 25	0·3420	
262	Jaisingder	26/70 9	25 45 40	70 24 30	35 35	" 1 50	0·3440	
135(*a*)	Dhoro Naro	" 7	25 29 50	69 33 50	34 55	" 2 0	0·3465	
263	Dugoli	28/74 12	27 22 0	74 10 20	38 15	" 2 10	0·3440	
264	Bana	28/74 10	27 58 40	74 1 50	39 15	" 2 10	0·3415	
265	Sardárshahr	" 9	28 26 10	74 28 50	40 5	" 2 30	0·3395	
266	Saringsar	" 6	28 54 40	74 28 30	40 50	" 2 25	0·3380	
267	Mirjawali	30/74 9	29 20 40	74 30 20	41 30	" 2 35	0·3360	
268	Malsisar	28/76 1	28 58 20	75 1 30	40 55	" 2 30	0·3375	
269	Surpura	" 2	28 40 20	75 37 0	40 30	" 2 25	0·3395	
270	Tamkor	" 4	28 26 20	75 15 10	40 0	" 2 20	0·3415	
271	Fatehpur	" 7	28 0 30	74 57 20	39 35	" 2 0	0·3425	

TABLE X—*contd.*

Abstract showing the Approximate Magnetic values at stations observed at by No. 26 Party during season 1902-03.

Serial No.	Name of Station.	Survey No.		Latitude.	Longitude.	Dip.	Declination.	Horizontal Force.	REMARKS.
				° ′ ″	° ′ ″	° ′	° ′	C. G. S.	
272	Singrawat .	28/74	11	27 26 10	74 52 50	38 25	E 1 55	0·3450	
273	Khátu . .	28/76	12	27 22 10	75 24 10	38 5	„ 2 10	0·3440	
274	Gudha . .	„	9	27 51 40	75 31 40	39 0	„ 2 15	0·3435	
275	Koharwas .	„	5	28 15 40	75 57 30	39 40	„ 2 25	0·3425	
276	Nangal Chaudhri.	„	8	27 53 30	76 6 20	39 10	„ 1 45	0·3440	
277	Shahpura .	„	11	27 23 30	75 58 0	38 15	„ 1 55	0·3440	
162	Jaipur . .	28/76	2	26 55 0	75 47 0	37 45	„ 2 5	0·3465	
278	Alwar . .	28/76	10	27 33 40	76 38 0	38 40	„ 2 15	0·3450	
279	Rewári . .	„	6	28 12 20	76 36 20	39 50	„ 2 15	0·3425	
280	Dádri . .	„	3	28 36 10	76 16 40	40 35	„ 2 15	0·3390	
281	Hánsi . .	30/76	12	29 5 40	75 57 0	41 10	„ 2 30	0·3380	
282	Ádampur .	„	11	29 17 20	75 27 50	41 30	„ 2 20	0·3360	
283	Sirsa . .	„	10	29 32 10	75 2 40	41 50	„ 2 40	0·3355	
284	Budhláda .	„	7	29 55 30	75 33 20	42 25	„ 2 35	0·3335	
285	Kalayat . .	„	9	29 41 10	76 13 40	42 5	„ 2 25	0·3340	
286	Karainthi .	„	13	29 1 10	76 29 0	41 15	„ 2 10	0·3390	
287	Tokara . .	„	14	30 50 50	76 55 20	43 55	„ 2 55	0·3310	
67	Patiála . .	„	4	30 20 40	76 24 0	43 10	„ 2 50	0·3335	
66	Alál . .	„	3	30 21 50	75 43 50	...	...	0·3325	
65	Bhuchhu . .	„	6	30 12 50	75 5 30	...	...	0·3330	
64	Malaut . .	30/74	3	30 11 0	74 29 40	42 50	E 2 45	0·3325	
63(*a*)	Orki . .	„	2	30 8 40	73 54 30	...	...	0·3325	
62	Rojhanwali .	„	4	30 0 50	73 15 40	...	...	0·3320	
61	Bakhshankhan.	30/72	4	29 44 30	72 42 50	...	...	0·3330	
60	Asrani . .	„	6	29 31 30	72 8 10	...	...	0·3335	
37	Samásata. .	„	7	29 21 10	71 32 30	41 30	E 3 0	0·3355	
59	Chanigot .	„	8	29 5 10	71 1 30	...	...	0·3340	
58(*a*)	Khánpur .	28/70	1	28 38 50	70 39 10	...	...	0·3355	
57	Sádikabad .	„	2	28 18 10	70 7 40	...	...	0·3365	
55	Pano Ákil .	„	5	27 50 50	69 6 50	38 55	E 2 15	0·3370	
46	Ruk . .	28/68	3	27 48 20	68 38 20	...	...	0·3370	
52	Jhatpat . .	„	2	28 22 20	68 19 20	...	...	0·3340	
53	Bellpat . .	„	1	28 59 40	68 0 20	...	...	0·3315	
54(*a*)	Sibi . .	30/68	1	29 32 40	67 51 40	41 45	E 2 40	0·3280	
288	Chachar . .	28/68	8	28 12 10	68 9 20	39 45	„ 2 10	0·3345	
289	Shahdádpur .	„	9	27 51 0	67 54 40	39 10	„ 2 20	0·3365	
290	Guibe Dera .	„	10	27 36 0	67 38 50	38 35	„ 2 20	0·3375	
291	Gote Mado .	„	11	27 11 20	67 35 30	37 50	„ 2 20	0·3390	

TABLE X—*contd.*

Abstract showing the approximate values at stations observed at by No. 26 Party during season 1902-03.

Serial No.	Name of Station.	Survey No.	Latitude.	Longitude.	Dip.	Declination.	Horizontal Force.	REMARKS.
			° ′ ″	° ′ ″	° ′	° ′	C.G.S.	
292	Haira Khan .	$\frac{26}{67}$ 12	26 49 20	67 28 10	37 15	E 2 10	0·3400	
293	Tando Rahim Khan.	„ 13	26 30 30	67 25 40	36 45	„ 2 0	0·3415	
294	Narani . .	„ 14	26 7 30	67 32 50	35 55	„ 1 55	0·3440	
295	Pokrun Lundi .	„ 16	25 48 30	67 44 30	35 25	„ 1 50	0·3445	
296	Belo . .	„ 15	25 47 10	67 26 50	35 15	„ 1 50	0·3445	
297	Ḳund . .	„ 17	25 34 50	67 19 0	35 0	„ 1 50	0·3450	
298	Kharr . .	„ 18	25 17 20	67 7 50	34 30	„ 1 40	0·3455	
39	Dabeji . .	$\frac{24}{67}$ 2	24 48 50	67 29 50	...	...	0·3475	
40	Jhimpir . .	$\frac{25}{68}$ 11	25 1 50	68 0 50	...	...	0·3470	
41	Hyderabad .	„ 10	25 22 30	68 22 30	34 35	E 1 45	0·3465	
42	Shahdádpur .	„ 7	25 55 40	68 37 50	...	...	0·3450	
43	Daur . .	„ 4	26 27 40	68 18 30	...	...	0·3425	
44	Kandiáro Road	„ 1	26 59 20	68 20 50	...	...	0·3415	
45	Khairpur . .	$\frac{27}{68}$ 5	27 31 10	68 44 20	38 20	E 2 0	0·3380	
47(*a*)	Lárkhána Nuzzur	„ 4	27 32 30	68 11 50	...	...	0·3375	
48	Sita Road .	„ 6	27 2 30	67 51 10	...	...	0·3400	
49	Bubak Road .	$\frac{26}{67}$ 3	26 29 0	67 46 10	...	...	0·3425	
50	Sann . .	„ 6	26 1 40	68 6 50	35 45	E 1 50	0·3440	
51	Petáro . .	„ 8	25 32 0	68 19 10	...	...	0·3460	
299	Hamid Pawhar	„ 7	28 26 0	68 46 50	39 50	E 2 15	0·3340	
300	Bela (Taz) .	$\frac{28}{69}$ 9	28 23 40	69 14 10	39 50	„ 2 20	0·3350	
301	Bara .	„ 10	28 33 0	69 39 30	40 0	„ 2 40	0·3345	
302	Tuziáni . .	„ 8	28 56 40	69 54 40	40 50	„ 2 45	0·3330	
303	Drigri . .	$\frac{29}{70}$ 7	29 24 30	70 8 30	41 40	„ 2 50	0·3320	
304	Ganehar . .	„ 6	29 44 0	70 20 20	42 15	„ 2 40	0·3290	
305	Vidor . .	„ 4	30 5 10	70 32 20	42 35	„ 2 45	0·3300	
306	Mundrání .	„ 3	30 25 20	70 36 50	43 20	„ 2 50	0·3280	
307	Jhok Bodo .	„ 1	30 55 0	70 32 20	43 55	„ 3 5	0·3250	
308	Gurwáli . .	$\frac{31}{70}$ 5	31 21 50	70 29 0	44 25	„ 3 10	0·3240	
309	Darában .	„ 4	31 44 0	70 19 40	45 0	„ 3 15	0·3235	
310	Tánk . .	„ 3	32 12 30	70 23 20	46 15	„ 3 15	0·3160	
311	Darra Pezu .	„ 2	32 19 20	70 44 20	46 10	„ 3 20	0·3180	
312	Sarai Naurang	„ 1	32 49 40	70 47 0	46 50	„ 3 25	0·3150	
313	Latammar .	$\frac{33}{70}$ 2	33 7 0	70 51 50	47 5	„ 3 35	0·3145	
314	Bánda Dáúd Shah . .	$\frac{33}{71}$ 9	33 16 40	71 11 10	47 25	„ 3 35	0·3130	
315	Kohát . .	„ 8	33 34 40	71 26 30	47 45	„ 3 35	0·3125	
316	Thal . .	$\frac{33}{70}$ 1	33 21 50	70 33 50	47 30	„ 3 30	0·3130	

TABLE X—*contd.*

Abstract showing the approximate values at stations observed at by No. 26 Party during season 1902-03.

Serial No.	Name of Stations.	Survey No.		Latitude.	Longitude.	Dip.	Declination.	Horizontal Force.	REMARKS.
				° ′ ″	° ′ ″	° ′	° ′	C. G. S.	
317	Dhanda . .	$\frac{32}{72}$	6	32 46 30	71 57 40	46 50	E 3 25	0·3160	
318	Talagang .	„	7	32 55 50	72 25 0	47 15	„ 3 25	0·3155	
319	Chakwál . .	„	8	32 56 10	72 51 10	47 5	„ 3 25	0·3160	
320	Khaie Kulan .	„	10	31 46 50	72 11 0	45 35	„ 3 0	0·3215	
321	Atháránhazári .	„	13	31 10 30	72 5 40	44 25	„ 2 40	0·3235	
322	Nawan Kot .	„	14	31 6 30	71 31 0	44 5	„ 3 0	0·3265	
323	Rangpur . .	$\frac{30}{72}$	10	30 31 0	71 34 50	43 10	„ 3 5	0·3285	
324	Muzaffargarh .	„	11	30 4 40	71 10 50	42 25	„ 2 50	0·3305	
70	Kartárpur .	$\frac{31}{75}$	3	31 26 10	75 29 30	...	...	0·3270	
69	Ladhowál .	$\frac{30}{75}$	1	30 59 0	75 47 20	...	...	0·3295	
68	Sirhind . .	„	2	30 37 40	76 22 40	...	...	0·3315	
325									
326									
327	Tuticorin .	$\frac{8}{78}$	1	8 48 10	78 9 0	0 25	W 0 50	0·3810	
328	Palamcottah .	„	2	8 42 50	77 44 30	0 10	„ 0 50	0·3800	
329	Kóvilpatti .	$\frac{10}{78}$	7	9 10 30	77 51 50	0 35	„ 0 55	0·3805	
330	Ammayánáyak-kanúr . .	„	4	10 10 30	77 54 20	2 40	„ 0 35	0·3820	
331	Manappárai .	„	3	10 36 40	78 25 30	3 55	„ 0 40	0·3820	
332	Mandapam .	$\frac{10}{80}$	3	9 16 50	79 8 30	1 0	„ 0 45	0·3815	
333	Sathirakkudi .	$\frac{10}{78}$	6	9 24 0	78 42 10	1 5	„ 0 50	0·3805	
334	Tiruppuvanam .	„	5	9 49 20	78 15 40	2 5	„ 0 50	0·3795	
335	Trichinopoly .	„	2	10 47 30	78 40 40	4 20	„ 0 35	0·3815	
336	Puliyur . .	„	1	10 56 0	78 10 10	4 50	„ 0 50	0·3780	
337	Tanjore . .	$\frac{10}{80}$	1	10 46 40	79 8 20	4 0	„ 0 40	0·3815	
338	Máyavaram .	$\frac{12}{80}$	8	11 5 50	79 38 30	5 0	„ 0 15	0·3835	
339	Tirutturaippúndi	$\frac{10}{80}$	2	10 32 20	79 38 10	3 35	„ 0 30	0·3820	
340	Alappákkam	$\frac{12}{80}$	7	11 37 10	79 43 10	6 15	„ 0 40	0·3845	
341	Villupuram .	„	5	11 56 40	79 29 50	6 25	0 0	0·3775	
342	Pondicherry .	„	6	11 56 0	79 49 50	7 15	„ 0 30	0·3840	
343	Tandarai .	„	4	12 6 40	79 9 0	7 10	„ 0 25	0·3815	
344	Polur . .	„	3	12 30 50	79 7 50	7 25	E 0 5	0·3805	
345	Chingleput .	„	2	12 41 20	79 58 30	8 5	W 0 25	0·3825	
346	Gudur . .	„	1	14 8 40	79 51 10	11 55	0 0	0·3830	
347	Pákala . .	„	4	13 27 0	79 7 20	9 40	„ 0 5	0·3820	
348	Kalikiri . .	$\frac{14}{78}$	8	13 38 40	78 47 40	10 40	„ 0 15	0·3825	
349	Tummanam-gutta.	„	7	13 42 50	78 21 30	11 15	„ 0 10	0·3830	
350	Kadiri . .	$\frac{14}{78}$	5	14 6 50	78 9 0	12 0	„ 0 10	0·3815	
351	Dharmavaram .	„	3	14 25 20	77 42 40	12 55	„ 0 10	0·3800	

TABLE X—*concld.*

Abstract showing the approximate values at stations observed at by No. 26 Party during season 1902-03.

Serial No.	Name of Station.	Survey No.	Latitude.	Longitude.	Dip.	Declination.	Horizontal Force.	REMARKS.
			° ′ ″	° ′ ″	° ′	° ′	C. G. S.	
352	Molugur .	14/78 6	13 54 0	77 32 50	11 45	E 0 10	0·3775	
353	Thondebhavi .	" 9	13 30 10	77 31 0	10 35	W 0 15	0·3825	
354	Gárladinne .	" 1	14 50 0	77 35 20	12 55	E 0 10	0·3815	
355	Bellary . .	16/76 2	15 8 50	76 55 30	14 5	W 0 5	0·3770	
356	......	...	...	...	...	...	...	
357	Mangi . .	30/68 2	30 22 0	67 28 10	42 55	E 2 50	0·3240	
358	Saiyad Hamíd	30/66 2	30 35 20	66 43 20	43 10	" 2 50	0·3230	
359	Chaman . .	" 1	30 56 10	66 25 20	43 50	" 2 40	0·3210	
360	Ab-i-Gum .	30/68 4	29 48 10	67 23 10	42 5	" 2 40	0·3265	
361	Spintangi .	" 3	29 55 50	68 4 50	42 15	" 2 40	0·3270	
362	Ghází Ghat .	30/70 5	30 4 50	70 51 50	42 30	" 2 45	0·3305	
363	Daeradín Panáh	" 2	30 34 10	70 55 30	43 30	" 2 45	0·3270	
364	Dorata . .	32/70 6	31 5 10	70 55 30	44 15	" 3 5	0·3250	
365	Bhakkar .	32/72 11	31 37 10	71 3 0	45 0	" 3 5	0·3225	
366	Shah Alam .	" 9	31 58 40	71 9 0	45 25	" 3 20	0·3205	
367	Kaleke . .	32/74 10	31 58 20	73 36 20	45 40	" 3 10	0·3235	
368	Chiniot Road .	" 11	31 34 20	73 10 40	44 55	" 2 55	0·3255	
369	Gojra . .	32/72 12	31 8 40	72 40 30	44 15	" 3 0	0·3265	
370	Darkhana .	30/72 9	30 30 50	72 11 10	43 35	" 2 45	0·3285	

Repeat Stations.

Serial No.	Name of Station.	Survey No.	Latitude.	Longitude.	Dip.	Declination.	Horizontal Force.	REMARKS.
I	Udaipur . .	...	24 35 33	73 41 57	33 15	E 1 30	·3540	
II	Kurrachee .	...	24 49 50	67 2 2	33 35	" 1 40	·3475	
III	Quetta . .	...	30 11 52	67 0 20	42 35	" 2 50	·3250	
IV	Baháwalpur .	...	29 23 27	71 40 37	41 35	" 2 50	·3335	
V	Ráwalpindi .	...	33 35 16	73 3 6	47 45	" 3 40	·3140	
VI	Bharatpur .	...	27 13 31	77 29 28	38 15	" 2 5	·3470	
VII	Bangalore .	...	12 59 35	77 35 58	9 15	W 0 15	·3815	
VIII	Dhárwár .	...	15 27 26	74 59 35	14 45	0 0	·3765	
IX	Porbandar .	...	21 38 20	69 37 6	28 10	E 1 15	·3610	

NOTES.—The above values of Dip, Declination and Horizontal Force are uncorrected for secular change, diurnal variation, instrumental differences, etc., and are to be considered as preliminary values only.
Where blanks occur, values have been already found during field season 1901-02, or the observations have not been completed.
The survey numbers refer to the published chart :—thus, No. 26/76 3 denotes No. 3 station in the dotted square the spherical co-ordinates of whose centre are 26° North Latitude and 76° East Longitude.
All Longitudes are referable to that of Madras Observatory taken at its latest value, *viz.*, 80° 14′ 47″ east from Greenwich.

VIII

INTRODUCTION OF THE CONTRACT SYSTEM OF PAYMENT IN TRAVERSE SURVEYS.

Extracted from the Narrative Report of Major R. T. Crichton, I.A., Superintendent, Provincial Surveys, Bengal, Season 1902-03.

With a view to the reduction of cost rates, an experiment was carried out by the Traverse Camp (Captain F. C. Hirst in charge) of No. 4 Party to introduce the contract system of work into traverse surveys.

The area selected was a tract of about 165 square miles of uplands (*i.e.*, omitting the Ganges Diára) in the south-west corner of the Purnea District. The following items of field work of a traverse camp were paid for at contract rates, *viz.*, (*a*) line clearing and embedding of station marks, and (*b*) mauzawar traversing with the theodolite and chain. It was decided to pay the line clearers by the number of station marks embedded and the sub-surveyors by the number of stations observed at. The obvious danger of such a system was that both line clearers and sub-surveyors would unnecessarily multiply their stations, *i.e.*, put them unnecessarily close together, and to meet this danger some experienced Cadastral Inspectors were employed on fixed pay to inspect and report especially on this point.

The rates of pay for line clearing tindals varied from R5 a month for men who averaged 8 stations a day, up to R8-8 for men who averaged 18 stations a day (the most that could be expected in this district, where little or no help is afforded by the inhabitants). The sub-surveyors were paid on a sliding scale up to R65 a month for a man who averaged 27 angles a day. All days spent on marching were paid for at lower rates in order to discourage halts and dilatory marching. The squad of a sub-surveyor who gave a large outturn of work also received extra pay and in some cases, there is no doubt, this had an excellent result, as the tindals and khalasies kept their sub-surveyor to his work. Any attempt on the part of the sub-surveyors to send in indifferent work was met by the strict observance of the order that the entire cost of any revision work was to be cut from the original observer, and, as a matter of fact, the work in this tract was found to be better than elsewhere. In office the following items of work were paid for on contract: (*a*) working out traverses by Boileau's and Gurdon's tables, (*b*) entering traverses in the traverse table, (*c*) proving traverses, (*d*) running down plotting columns, (*e*) multiplication and (*f*) plotting on the 4-inch and 16-inch scales. As all the foregoing items of work are always independently examined by men on fixed pay and several of them, such as working traverses and multiplication, are done by different men, by different methods, there is no danger of bad work in introducing the contract system of payment.

In the early stages of the experiment there was some difficulty in overcoming the opposition of the native establishments, who, through ignorance, were averse to any new conditions, but once they understood that by working harder they gained immediate extra remuneration there was little or no more difficulty. As regards men on the fixed pay list any extra remuneration they earned owing to the application of the contract scale was drawn in a contract bill, and when the earnings according to this scale fell short of their fixed pay, they were fined the difference, but as a rule all the men gave considerably increased outturns of work and very few fines were necessary.

The results showed a considerable saving in the cost rates. The normal rate of traverse survey on fixed pay in the Purnea District being about R30 per square mile, the rate for the tract traversed on contract worked out at R25 per square mile. If the scheme were worked in a large area the saving should be still more marked as a considerably smaller establishment than the normal would suffice, and there would be corresponding reductions under the heads of contingencies, office rent, etc.

IX

TRAVERSING WITH THE SUBTENSE BAR.

Extracted from the Narrative Report of Major R. T. Crichton, I.A., Superintendent, Provincial Surveys, Bengal, Season 1902-03.

In Chota Nágpur owing to the hilly nature of the country the subtense bar has to be used very extensively for arriving at the direct distance between traverse stations, and it was found that in previous seasons the sub-surveyors shirked the tedious task of observing the necessary number of repetitions of the subtended angle and merely took two (or perhaps as many as five) repetitions and entered the remaining observations in their field books by simple multiplication, the natural result being indifferent work and consequent heavy revisions. In order to arrive at some simple check on the sub-surveyors it was decided to take observations to an eight-foot bar in addition to the ordinary observations to the ten feet bar, and consequently all the bars of the Chota Nágpur traverse detachment have been fitted, in the Mathematical Instrument Office, with sockets eight feet apart into which the discs are removable as soon as the observation to the ten feet base is completed. The discs are coloured differently on back to front and will only fit into the sockets they are intended for when correctly placed, *i.e.*, the white discs being intended for the ten feet observations will only fit into the sockets which are ten feet apart, and when these discs are reversed and the backs thereof (coloured red) are presented to the observer they will only fit into the sockets which are eight feet apart.

As it had been found that keeping the bar level (or nearly level) helps very much in the rapidity with which the observation can be taken and as levelling a bar mounted on an ordinary plane-table tripod stand by means of shifting the legs about takes up a good deal of time and affects the plumbing, the opportunity was taken to have all the bars and stands fitted with a ball and socket arrangement by which the levelling can easily be effected in whatever position the tripod may happen to be. It having been found from experience that the method advocated and practised by Colonel Tanner of combining the observations for the horizontal angle and the subtended angle in one operation was unsatisfactory, and took a long time owing to the necessity of very carefully plumbing the subtense bar over the station mark, it was decided to make the observation of the horizontal angle a totally separate operation from the observation for the distance. As the horizontal angle is now observed, as usual in all traverse operations, to staves and then the subtense bar is plumbed over the station, very accurate plumbing is not necessary as only the distance is affected, and, therefore, if the bar is not centred accurately by a few inches it does not matter. It is evident that by the procedure now followed a considerable amount of time is saved in plumbing and levelling and the check observation to the ten feet bar has saved a great deal of revision work, and the effect on cost rates has been most satisfactory.

X

COMPILATION AND REPRODUCTION OF THÁNA MAPS.

Extracted from the Narrative Report of Major R. T. Crichton, I.A., Superintendent, Provincial Surveys, Bengal, Season 1902-03.

The old method of preparing Thána maps by compiling them from the proofs of 1-inch standard sheets and then completing them as regards graticule, border, scale, etc., before sending them to the Photo. and Litho. office for reproduction by photography was found to be laborious and expensive. The proofs sent in by the Photo. office had to be examined against the originals, sometimes twice or three times, before final press order was given. This took up a great deal of time and the resulting cost for 100 copies was, on an average, R120. An attempt was therefore made to reproduce Thána maps by the Vandyke process, and an experiment was made on a small Thána in February 1903. As a Thána map is mainly an index to illustrate the Thána list and therefore no very elaborate drawing is necessary, it was evident that all that was required was a "Mujmulli" map prepared from the 1-inch standard sheets, on tracing paper, with the boundaries of villages shown in firm lines, the names and numbers neatly written in round hand, and only principal means of communication for the convenience of District Officers, entered. All other topographical details as well as the border and graticule were considered superfluous and omitted. The trace was then sent through the ordinary Vandyke process. The map prepared on these lines was approved by the Director of Land Records and Agriculture, Bengal, and all subsequent maps have been prepared in a similar manner.

The result has been that the cost of the eight Thána maps prepared during the year averages R29-12 per 100 copies of each map, and there is also a great saving in time.

G. I. C. P. O.—No. 644 S. G.—23-1-05.—350.—J. F.

EXTRACTS

FROM

NARRATIVE REPORTS

OF THE

Survey of India

FOR THE SEASON

1902-1903.

PREPARED UNDER THE DIRECTION OF

LIEUT.-COLONEL F. B. LONGE, R.E.,
SURVEYOR GENERAL OF INDIA.

CONTENTS.

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