RECORDS

OF THE

SURVEY OF INDIA

Volume XI

(Supplementary to General Report 1916-17).

ANNUAL REPORTS OF

PARTIES AND OFFICES

1916-17.

PREPARED UNDER THE DIRECTION OF

Colonel Sir S. G. BURRARD, K.C.S.I., R.E., F.R.S.

Surveyor General of India.

DEHRA DUN

PRINTED AT THE OFFICE OF THE TRIGONOMETRICAL SURVEY

1918

Price Four Rupees or Five Shillings and Four Pence.

Roll of Honour.

Survey of India.

CAPTAIN E. B. CARDEW, R. E.

BT.-MAJOR (TEMPY. LIEUT.-COLONEL)

A. A. CHASE, D. S. O., R. E.

Roll of Honour.

SURVEY OF INDIA.

CAPTAIN E. B. CARDEW, R.E.

Born 4th April 1883.

Entered the Army, 21st December 1901.

Appointed to the Survey of India, 3rd December 1906.

KILLED IN ACTION, IN FRANCE, PRESUMABLY ON OR AFTER 25TH SEPTEMBER 1915.

Roll of Honour.

SURVEY OF INDIA.

From a photograph by Messrs. Elliot & Fry, Ltd., London.

BREVET-MAJOR (TEMPORARY LIEUTENANT-COLONEL)
A. A. CHASE, D.S.O., R.E.

Born 16th September 1884.
Entered the Army, 29th July 1904.
Appointed to the Survey of India, 22nd June 1908.
DIED OF WOUNDS IN FRANCE ON 11TH MARCH 1917.

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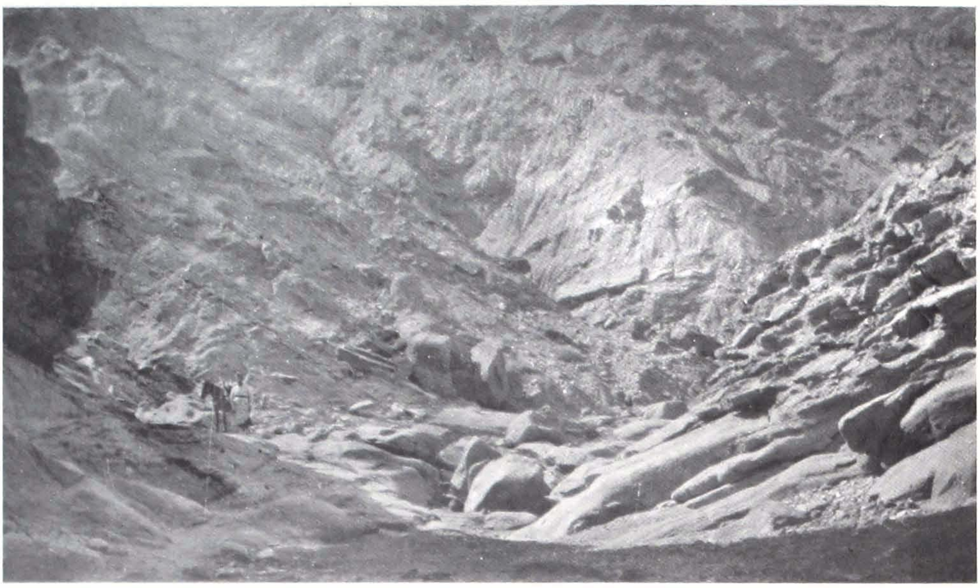


The Tang-i-Zindān defile on the central caravan route between Bandar 'Abbās and Kirmān.

View from the summit of the Sar-i-Sīkh pass looking south over the Tang-i-Zindān defile.

From Photographs by Major E. T. Rich, R.E.

Photo.-engraved & printed at the Offices of the Survey of India, Calcutta, 1918

PART I.—TOPOGRAPHICAL SURVEY.

NORTHERN CIRCLE.

(*Vide* Index Maps 1 and 4.)

Summary.—The Circle comprised four parties and one detachment for topographical work, apart from the special parties and detachment mentioned below. During the year a total area of 14,289 square miles was topographically surveyed. This includes an area of 2,600 square miles beyond the frontier elsewhere.

The work of the Sind-Sāgar Party and of the Punjab Riverain Detachment is, strictly speaking, not topographical survey.

No. 20 Party (Cantonment) was transferred from the administrative control of the Superintendent, Northern Circle to that of the Superintendent, Southern Circle with effect from 1st April 1917. Its operations are dealt with in detail with those of the parties of the Southern Circle on page 21.

The Sind-Sāgar Party was formed from 15th June 1917 for the purpose of undertaking rectangulation in the Sind-Sāgar Doāb and *Thal* as a basis for the Punjab Government's Sind-Sāgar Canal and Colonization Project.

From the same date No. 4 Party was amalgamated with it, and, from the end of the recess season of 1917, this party (No. 4) will be in abeyance as a topographical unit.

A detachment, called the Tānk Survey Detachment, was formed in June to accompany the Wazīristān Field Force.

It remained in existence from 1st June 1917 to 11th August 1917.

The Circle was under the administrative control of Lieut.-Colonel C. L. Robertson, C.M.G., R.E., throughout the survey year.

No. 1 PARTY (KASHMIR AND PUNJAB).

By B. R. Hughes.

PERSONNEL.

Provincial Officers.

Mr. B.R. Hughes in charge.
" G.J.S. Rae.
" H.P.D. Morton.
" P.A.T. Kenny.
" R.C. Hanson.

Upper Subordinate Service.

Mr. Sher Jang, K. B. to 9th November 1916.
" Natha Singh, R. S. to 20th March 1917.
" Hamid Gul, to 15th February 1917.
" Jagdeesh Prasad Vastav.

Lower Subordinate Service.

36 Surveyors, etc.

The head-quarters of the party opened in the field at Gurdāspur on the 10th November 1916, and closed early in May 1917. The office reopened on 14th May at its recess quarters in Mussoorie.

The country surveyed during the winter consisted of well cultivated and partly canal-irrigated plains, and intricate foot hills; that surveyed during the summer being mountainous with well-wooded valleys.

The health of the party was good.

Plane-tabling.—The 4,011 square miles of country surveyed on the scale of 1 inch = 1 mile comprised 2,677 square miles of new survey, 1,056 of resurvey and 278 square miles of supplementary survey, in parts of the Jammu and Chamba States, and the districts of Gurdāspur, Hoshiārpur and Kāngra of the Punjab. Its survey occupied the party from November to August, and the area lay in the following sheets :—

$$43\,\frac{\text{O}}{8,\ 12,\ 16},\ 43\,\frac{\text{P}}{3,\ 4,\ 5,\ 6,\ 7,\ 8,\ 9,\ 10,\ 11,\ 12,\ 13,\ 14,\ 16\ \text{(part)}}\ \text{and}\ 52\,\frac{\text{D}}{1\ \text{(part)};\ 2\ \text{(part)}}.$$

In the earlier part of the field season 22 surveyors were divided up into 3 camps under Messrs. Rae, Morton and Hanson, and the following allotment of work was made :—

No. 1 Camp, under Mr. G. J. S. Rae, comprised 9 surveyors and dealt with sheets $43\,\frac{\text{P}}{4,\ 8,\ 12,\ 15\ \text{(part)}}$ and $43\,\frac{\text{P}}{7,\ 11\ \text{(southern halves)}}$.

No. 2 Camp, under Mr. H. P. D. Morton, comprised 6 surveyors and worked in sheets $43 \frac{P}{3, 6, 7 \text{ (northern half)}}$.

No. 3 Camp, under Mr. R. C. Hanson, comprised 7 surveyors and surveyed sheets $43 \frac{P}{10, 11 \text{ (northern half)}, 14 \text{ (southern half)}, 15 \text{ (northern half)}}$.

In the latter part of the season 15 surveyors were divided into 2 camps under Messrs. Morton and Hanson :—

No. 2 Camp, under the former officer, had 9 surveyors and worked in sheets $43 \frac{O}{8, 12}$, $43 \frac{P}{5, 9 \text{ (part)}}$ and No. 3 Camp, under Mr. R. C. Hanson, with 6 surveyors surveyed sheets $43 \frac{O}{16}$, $43 \frac{P}{9 \text{ (part)}, 13, 14 \text{ (northern half)}}$ and $52 \frac{D}{1, 2 \text{ (parts)}}$.

The cost-rates of the different classes of survey are given in Table III.

Mr. P. A. T. Kenny in charge of 9 surveyors, undertook the special survey, on a scale of 4 inches to a mile, of the Peshāwar Artillery and Aviation Practice Camp during the winter. Mr. Kenny and the surveyors working under him remained on the strength of this party for purposes of pay, etc., but he received his instructions on all professional points connected with the work direct from the Superintendent of the Circle. The out-turn was 208 square miles.

During the summer Mr. Kenny was called upon to carry out surveys in connection with the operations of the Wazīristān Field Force, and was transferred from the party to the charge of the Tānk Survey Detachment for rather over 2 months.

Triangulation.— No triangulation in advance has been done during the year under report for the ordinary programme of the party, since sufficient data in advance already exist over the whole area which will come under survey by this party during the next two survey years, but 20 square miles was carried out in the area surveyed in Peshāwar for military purposes to supplement points already existing.

Traversing.— No traversing was done in advance during the year under report for the ordinary programme of the party for the same reason as given above in regard to triangulation, but 66 linear miles were run in the area surveyed in Peshāwar. The country covered by triangulation and traversing in the Peshāwar area consisted, for the most part, of a highly irrigated cultivated plain intersected by numerous branches of the Kābul and Bārā rivers, and partly barren stony waste cut up by innumerable ravines.

Recess Duties.— Owing to most of the surveyors being employed on what was practically a summer programme, to transfers of men for work overseas, to the employment of others on the Peshāwar fair-drawing and also to the very early re-commencement of work in the field in connection with the special surveys for the Akora Artillery Practice Camp, the fair-mapping of the sheets of the whole of the survey executed during the year under report remained incomplete at its conclusion.

To deal with these arrears of mapping a strong drawing section will be left in Mussoorie during the coming winter. This section will also have to prepare the maps of the Akora Artillery Practice Camp survey, as the work comes in from the field. The publication of these is being treated as a matter of war urgency.

The following fair sheets, for publication on the 1-inch scale, of areas surveyed during the past field season, have been completed and sent in since the 30th September 1916:— $43 \frac{N}{12}$, $\frac{O}{5, 7, 9, 10, 11, 14, 15}$ and $52 \frac{C}{3, 4, 8}$.

There are no arrears of 1-inch fair sheets drawn from surveys executed during previous field seasons.

The half-inch fair sheets, drawn from previously published one-inch sheets, submitted for publication since 30th September 1916 are :— $38 \frac{O}{S.E., S.W.}$ and $43 \frac{G}{N.W.}$.

The cost-rates of mapping on the different scales work out per square mile as follows :—

4-inch scale	Rs.	23.
1½-inch " for publication on the 1-inch scale	"	4.
¾-inch " " " " " ½-inch "	"	40.

The high rate for ¾-inch mapping is due to an excessive ratio having been assumed for the work done on these sheets during the previous survey year.

NO. 2 PARTY (PUNJAB).

BY T. W. BABONAU.

The head-quarters of the party was located at Serai Rohilla (Delhi) during the winter.

PERSONNEL.

Provincial Officers.

Mr. T.W. Babonau in charge.
,, F.B. Powell, to 31st March 1917.
,, R.E. Saubolle.
,, J.H. Johnson.
,, J.A. Calvert.

Upper Subordinate Service.

Mr. Chuni Lal Kapur.
,, Ghulam Hasan.

Lower Subordinate Service.

26 Surveyors, etc.

The party was employed in triangulating and traversing, and in executing detail surveys on the 1-inch and ½-inch scales, in the Gurgaon district and the Nābha State of the Punjab, and in the Alwar, Bharatpur and Jaipur States of the Central India Agency. A revision survey, on the scale of 4 inches = 1 mile, of Imperial Delhi and the New Cantonment of Delhi was also carried out. The town of Alwar, with an area of about 4 square miles, was surveyed on the 1½-inch scale.

The nature of the country covered by the ½-inch and 1-inch survey was hilly, with sand hills and plains between the hills; that covered by the four-inch survey was undulating ground where five feet contour intervals were shewn; that over which the triangulation extended was hilly, a good portion of it being covered by thick jungle. Some of the traversing was done in flat country where triangulation was impracticable.

The field season began on the 15th November 1916 and ended on the 30th April 1917.

The health of the establishment was good throughout the season.

Plane-tabling.—The one-inch survey was executed in five sheets:—53 $\frac{D}{16}$ and 54 $\frac{A}{1, 9, 13, 14}$. One camp, consisting of 7 surveyors under Mr. Saubolle, carried out the survey of these sheets.

The half-inch survey lay in sheets 54 $\frac{A}{2, 5, 6, 10, 11, 12, 15, 16}$.

This work was under Mr. Johnson till 15th January, when he fell sick and was succeeded by Mr. Saubolle, who carried it on with 5 surveyors and completed the survey of all but sheets 54 $\frac{A}{2, 5, 6}$.

The survey was based partly on revenue traverse data and partly on triangulation.

The 4-inch revision survey of the Imperial Delhi and Delhi New Cantonment area was carried out on blue prints of the previous survey executed in 1911-12 and 1913-14 respectively.

The height values used for the purpose of running contours at 5 feet vertical intervals were reduced to the terms of the triangulation carried out during the current and previous seasons by No. 19 Party.

The positions of a number of points appearing on the previous maps were fixed in terms of the new triangulation over an area of some 110 square miles (including the 64 square miles of revision survey) for the purpose of determining the direction and degree of error in the geographical position of information given in those maps. The result of the operation disclosed the fact that all detail in the previous map had been placed 4 chains too far to the north and 20 links too far to the east. The error was probably due to the earlier survey having been based on old revenue traverse data which had been insufficiently tied down.

Triangulation.— This was carried out in sheets 54 $\frac{A}{3,4,7}$ and in portions of sheets 54 $\frac{A}{1,8}$ by Messrs. Chuni Lal Kapur and Ghulam Hasan, Sub-Assistant Superintendents. The area executed by these two officers was 800 and 150 square miles respectively.

Traversing.— This was run with theodolite and chain in sheets 54 $\frac{A}{7}$ and 54 $\frac{E}{4,8,12}$ by Mr. Ghulam Hasan and a surveyor. Heights were observed and connections were made with conspicuous objects to which heights were given.

31 linear miles of traversing were executed along the Imperial Delhi boundary on the east bank of the river Jumna, and 28 linear miles for the purpose of connecting the traverse stations, on which the original 4-inch survey of Delhi was based, with the points of the new triangulation by No. 19 Party.

Recess Duties.— (*a*) Mr. F. B. Powell was in charge of the fair-mapping of 6 half-inch frontier sheets drawn from published modern 1-inch sheets and old style ½-inch maps. From the commencement of the field season he also took over from Messrs. Saubolle and Johnson the supervision of the completion of 1-inch sheets 44 $\frac{P}{16}$ and 53 $\frac{D}{3,4,8,12}$.

Mr. Johnson took over the supervision of 4 of the ½-inch frontier sheets, of which Mr. Powell had had charge, on the latter's retirement. He also supervised the fair-mapping of 1-inch sheets 44 $\frac{P}{15}$ and 53 $\frac{D}{3,4,8,12}$ of the previous season's surveys up to his proceeding into the field in 1916.

Of the sheets of current survey Mr. Saubolle supervised the fair-mapping of 1-inch sheets 53 $\frac{D}{16}$ and 54 $\frac{A}{1,9,13,14}$ and that of ½-inch sheets 54 $\frac{A}{N.E., S.E.}$; he also supervised the typing of fair sheets 44 $\frac{P}{15}$ and 53 $\frac{D}{3,4,8,12}$ for a short time in 1916.

Mr. Calvert had charge of the fair-mapping of the four 4-inch sheets of the Imperial Delhi and Delhi New Cantonment revision surveys.

The 1-inch and ½-inch plane-table sections as a rule covered half sheet areas. The fair sheets have therefore been drawn, half by the direct mapping process, and half by tracing and transfer.

The following sheets, drawn from surveys completed prior to the season under report, were submitted for publication during the year:— 44 $\frac{P}{10,14,15}$ and 53 $\frac{D}{3,4,7,8,12}$.

Two half-inch sheets, drawn from published 1-inch sheets, were also submitted for publication but one of these has had to be withheld in the Circle Drawing office for further correction.

Owing to shortage of establishment none of the sheets drawn from surveys completed during the current season have been finished by the end of September 1917.

Four ½-inch sheets drawn from 1-inch published sheets, the fair-mapping of which has been in hand in the party for well over a year, also remain incomplete.

The areas of mapping, in square miles, completed on the various scales during the survey year, as also the cost-rates per square mile, are as under :—

Scale of mapping.	Area.	Cost-rate.
4-inch ...	84	Rs. 55·1
1½-inch ...	1, 144	,, 4·4
¾-inch ...	3, 498	,, 4·5

(*b*) The computation of the triangulation and traversing was completed in every respect by the end of August. That of the triangulation was executed by Messrs. Calvert and Chuni Lal Kapur and of the traversing by a computer.

Inspections.—The Superintendent, Northern Circle, inspected the party both during the field season and during recess.

The Surveyor General inspected the party during the month of September 1917.

No. 3 PARTY (UNITED PROVINCES AND OUDH).

BY H. H. B. HANBY.

PERSONNEL.

Provincial Officers.

Mr. H. H. B. Hanby in charge.
,, E. J. Biggie.
,, A. M. Talati.
,, H. T. Hughes.
,, G. E. B. Cooper.
,, Moqimuddin.

Upper Subordinate Service.

Mr. Mohammad Husain.
,, A. A. S. Matlub Ahmad.

Lower Subordinate Service.

54 Surveyors, etc.

The party, with the exception of one small section, assembled at Bareilly on the 9th November 1916, and returned to Mussoorie on the 22nd May 1917. Plane-tabling was however carried into June, and the last traverser did not return till nearly the end of August.

The health of the party was on the whole good.

Plane-tabling.—The country surveyed was flat and fairly open in the south. In the centre lay the Tarai and Bhābar tracts of district Nainī Tāl and the well-irrigated and wooded lands of the Rāmpur State, while, to the north, the area consisted of well-wooded hills, the highest point touched being over 8, 000 feet.

The party was divided into four camps.

No. 1 Camp.—Mr. H. T. Hughes in charge, with one Upper Subordinate Service officer and six surveyors, completed the resurvey of sheets 53 $\frac{O}{3,4,7,8}$ on the 1-inch scale, and surveyed 11 square miles on the 2-inch scale in sheet 53 $\frac{K}{14}$.

No. 2 Camp.—Mr. G. E. R. Cooper in charge, with six surveyors executed the survey of 121 square miles lying in sheets $53\frac{O}{7, 10, 11, 12}$ on the scale of 4 inches to a mile. Of this area, 3 square miles were supplementary survey, leaving a balance of 118 square miles of original 4-inch special forest survey. Of the 118 square miles, 72 square miles represent the actual area of reserved forests, and 46 square miles of contiguous non-forest areas.

No. 3 Camp.—Mr. Moqimuddin in charge, with seven surveyors completed the resurvey of sheets $53\frac{P}{1, 2, 5, 6}$ on the scale 1 inch = 1 mile.

No. 4 Camp.—A senior surveyor in charge, with six surveyors completed the resurvey of sheets $53\frac{P}{12, 16}$ on the scale 1 inch = 1 mile.

To meet military requirements, during the middle of August a section was formed consisting of one Upper Subordinate Service officer and twelve surveyors. This section, with Mr. G. E. R. Cooper in charge, was sent to Campbellpore (Punjab) to survey 112 square miles on the scale 3 inches to the mile, the area appertaining to the Hatti Artillery Practice Camp.

Triangulation.—The work of triangulation was done by the following officers :—

Mr. A. M. Talati triangulated 843 square miles in sheets $53\frac{O}{1, 2, 5, 9, 10}$ for 2-inch work, and 95 square miles in sheets $53\frac{O}{10, 11, 15, 16}$ for 4-inch work. One computer and 1 surveyor of the party between them triangulated 650 square miles in sheets $53\frac{O}{9, 10, 13, 14, 15}$ for 2-inch survey.

The cost-rate of triangulation is :—

for 2-inch survey	...	... Rs. 7·4	per square mile.
for 4-inch survey	...	... ,, 21·4	ditto.

Traversing.—The area traversed embraces the following sheets:—$53\frac{O}{11, 12, 15, 16}$.

In addition to the above, the party traversed 183 linear miles in district Gorakhpur, at the expense of the Settlement Officer of this district who was supplied with 16-inch plots of 38 villages.

Recess Duties.—(*a*) The fair-mapping was divided into four sections under Messrs. E. J. Biggie, H. T. Hughes, Moqimuddin and a senior surveyor.

Mr. E. J. Biggie, assisted by Mr. Muhammad Husain supervised the drawing of last year's arrears of mapping, which included four half-inch sheets and the seven 2-inch sheets $53\frac{K}{5(N \& S), 9(N \& S), 13(N \& S), 14N}$ and 1-inch sheets $53\frac{K}{5, 10}$; he also looked after the drawing of 2-inch sheet $53\frac{K}{14(S)}$ of the current season's survey. For over two months in the middle of the recess season however he was removed from these duties to take charge of the fair-mapping of the Peshāwar Artillery and Aviation sheets of No. 1 Party during the absence of Mr. P. A. T. Kenny with the Wazīristān Field Force.

For want of men no further progress could be made on sheets $53\frac{K}{N.W., N.E.}$ which were commenced last season.

Mr. H. T. Hughes supervised the drawing of sheets $53\frac{O}{3, 4, 7, 8}$ on the scale 1½ inches = 1 mile, Mr. Moqimuddin that of sheets $53\frac{P}{1, 2, 5, 6}$. Sheets $53\frac{P}{12, 16}$ were supervised by a senior surveyor.

There are therefore at present in hand, or awaiting completion, 6 sheets for publication on the 2-inch scale, 5 sheets for publication on the 1-inch scale, and 2 sheets for that on the ½-inch scale, all of seasons prior to that under report; while, of the sheets surveyed during the last field season, none have as yet been completed for publication. The following sheets however have been practically completed, and will be submitted for publication during the next two months, viz: $53\frac{P}{1, 2, 5, 6, 12, 16}$.

There are also in hand in the party 4 half-inch frontier sheets drawn from modern published one-inch sheets and old style half-inch published sheets.

The sheets of Mr. Hughes' section are backward as he did not return from the field till nearly the middle of June.

A strong section of 15 men under Messrs. H. T. Hughes and G. E. R. Cooper is being left at Mussoorie during the coming winter to deal with these arrears of mapping and every endeavour will be made to clear them off.

The cost-rate of 1½-inch mapping is Rs. 7·4 per square mile, and that of 2-inch mapping Rs. 26·2 per square mile.

The mapping of the 4-inch forest surveys is being dealt with in the Forest Map Office at Dehra Dūn.

(*b*) The computation of all triangulation and traversing which had been carried out during the field season of the year under report has been completed with the exception of that of the intersected points of 1,043 square miles of the triangulation for 2-inch survey.

No triangulation charts have been drawn.

Miscellaneous.—One pupil draftsman, and two draftsmen received instruction in the field.

Inspections.—The party was inspected during the recess by the Superintendent, Northern Circle, and by the Surveyor General.

No. 4 PARTY (UNITED PROVINCES AND OUDH).

By Major H. L Crosthwait, R. E.

PERSONNEL.

Imperial Officer.

Major H. L. Crosthwait, R.E., in charge from 7th May 1917.

Provincial Officers.

Mr. H. W. Biggie in-charge, to 5th April 1917.
" J. A. Freeman, in charge from 6th April 1917 to 6th May 1917.
" J. C. C. Lears to 14th June 1917.
" E. C. O'Sullivan, from 14th November 1916 to 18th September 1917.
" F. J. Grice, from 21st April 1917 to 14th June 1917.
" Duni Chand Puri, to 31st May 1917 and again from 12th August 1917.

Upper Subordinate Service.

Mr. Mohammad Husain Khan to 14th June 1917.
" Daulat Ram Vohra.

Lower Subordinate Service.

23 Surveyors, etc.

The field programme allotted to the party embraced 5 sheets for resurvey in the United Provinces. The head-quarters of the party remained at Mussoorie throughout the year, but a field camp with its head-quarters at Gorakhpur took the field on the 4th November 1916, and completed the work assigned to it on the 16th April 1917.

The health of the party was good.

Plane-tabling.— The country surveyed is a dead level with extensive cultivation interspersed with numerous mango orchards, and village sites. The annual inundation caused by the Rāptī and Amī rivers overflowing their banks maintains a treeless tract of variable width on both sides of these rivers.

There are many small forest reserves in the possession of private owners, and some Government forest reserves. The Government forests are divided into small blocks, the principal one surveyed is known as Rāmgarh Jungle, about 4 miles east of Gorakhpur.

The tree most common is the sal (*Shorea robusta*) which is generally found alternating with munja (*Sachharam munja*).

Mr. Lears, who was in charge of the field camp of surveyors, undertook the resurvey of five 1-inch sheets, viz: sheets 63 $\frac{M}{4}$ and 63 $\frac{N}{1,2,5,6}$. These were completed on the 16th April, when the camp returned to recess quarters.

The area surveyed on the 1-inch scale was 1,329 square miles, and the cost-rate of detail survey worked out to Rs. 11·9 per square mile.

Besides this, 2,600 square miles of survey was executed on the ¼-inch scale beyond the frontier elsewhere at a cost-rate of Rs. 8·6 per square mile.

Triangulation and Traversing.—No triangulation or traversing was done by the party, since the existing traverse data throughout the areas into which its topographical operations were likely to have extended in the course of the next few years are sufficient for the purposes of detail survey on the 1-inch scale.

Recess duties.—These consisted of :—

(*a*) Fair-mapping on 1-inch scale, of current sheets 63 $\frac{M}{4}$, 63 $\frac{N}{1,2,5,6}$.

(*b*) Arrears of fair-mapping on 1-inch scale, of sheets 63 $\frac{E}{13}$, 63 $\frac{J}{12,15}$, 63 $\frac{N}{3,4,7,8}$.

(*c*) Half-inch mapping from 1-inch published maps of 8 frontier sheets.

(*d*) Compilation and preparation of special editions of 1-inch sheets showing village boundaries.

There have been numerous changes of officers in the supervision of recess work. This has been unavoidable owing to the many transfers to and from the party, and to the training of surveyors for the Sind-Sāgar Party; different officers being deputed to supervise the training as changes were made. Messrs. Lears, Grice and Duni Chand Puri were in charge of the current 1-inch fair-mapping. Mr. O'Sullivan supervised the half-inch mapping till he had to be relieved for training of traversers and triangulators for the Sind-Sāgar Party. The half-inch sheets were then taken over by No. 3 Drawing Office.

Messrs. Grice and Duni Chand Puri supervised the arrears of mapping of 1-inch sheets.

The typing of the 1-inch current sheets of the party has again been heavy. This is due to the density of village sites and other detail carrying names, which in this part of the United Provinces is very great.

The mapping of the five 1-inch sheets of current survey remains incomplete at the close of the year under report, and, as the party ceases to exist as a working unit on amalgamation with the Sind-Sāgar Party, these sheets are being made over to No. 2 Party for completion.

The seven following 1-inch sheets left over from 1915-16 with a total area of 1,865 square miles were submitted for publication :—63 $\frac{E}{13}$, 63 $\frac{J}{12, 15}$ and 63 $\frac{N}{3, 4, 7, 8}$.

The fair-mapping of 6 frontier half-inch sheets was carried out during the year; of these four were sent for publication. The remaining two were made over to No. 3 Drawing Office in a practically completed state. Two others were also made over incomplete for completion in that office.

The twenty sheets of the village boundary editions, mentioned below, were also completed and submitted for publication :—62 $\frac{D}{10, 11, 12, 14, 15, 16}$, 62 $\frac{H}{3, 8}$ and 63 $\frac{F}{1, 2, 3, 4, 6, 7, 8, 9, 10, 12, 13, 16}$.

The cost-rates per square mile for the different scales and classes of mapping with which the party has dealt during the year under report are :—

1½-inch scale for publication on that of 1 inch = 1 mile	...	Rs. 9·3
¾-inch ,, ,, ,, ½-inch = 1 mile	...	,, 2·7
1-inch ,, for village boundary editions of 1-inch maps	...	,, 0·3

Miscellaneous.—There are few metalled roads in the country surveyed, and the unmetalled ones are in such a state of disrepair that marching was tedious and troublesome. The difficulty of cart transport was greatly augmented by the absence of bridges on the roads.

In the case of the survey of Gorakhpur town, about half the plotted trijunctions could not be found. A great deal of plane-table traversing had therefore to be done and supplementary points fixed. Every effort was made to identify and fix bench-marks shown and described on a map of the "City, Civil Station and Cantonment of Gorakhpur" on the scale of 440 feet to one inch, lent by the Collector of Gorakhpur, but not a single one could be traced. Information obtained locally pointed to the fact that they had either been built over or destroyed. It seems a pity that marks such as these, which cost a good deal of money to fix, should not be preserved, as such preservation would cost a fraction of that originally required to fix them.

Inspections.—The party was inspected by the Surveyor General and the Superintendent, Northern Circle.

SIND-SAGAR PARTY (PUNJAB).

BY MAJOR H. L. CROSTHWAIT, R. E.

PERSONNEL.

Imperial Officer.

Major H. L. Crosthwait, R. E., in charge.

Provincial Officers.

Mr. J. C. C. Lears.
,, F. J. Grice.

Upper Subordinate Service.

Mr. Mohammad Husain Khan.
,, Nabidad Khan.

Lower Subordinate Service.

18 Surveyors, etc.

This party was inaugurated on the 15th June for the purpose of carrying out the rectangulation in the Sind-Sāgar *Doāb*, lying between the Indus and the Jhelum rivers, to the south of the Salt Range, in connection with a large canal and colonization scheme which the Punjab Government propose to carry out in this area.

During the recess the surveyors, who are to be engaged in this work, were especially trained in triangulation and traversing both in the field work and computations connected with these operations. The party will take the field for the first time in October 1917.

The total expenditure of the party from 15th June to 30th September 1917 has been Rs. 16,419. As in the case of the Riverain Detachment, this cost is to be a charge against Punjab provincial revenues.

RIVERAIN DETACHMENT.

By Maya Das Puri, Rai Sahib.

PERSONNEL.

Provincial Officer.

Mr. Maya Das Puri, R. S., in charge.

Upper Subordinate Service.

Mr. Paras Ram.
,, Jamna Prasad, R. S., from 1st October 1916 to 15th July 1917.
,, Mahomed Lutf Ali from 10th November 1916.
,, Lakshmi Dutt Joshi.
,, Vidya Dhor Chopra.

Lower Subordinate Service.

74 Surveyors, Traversers, etc.
1 *Nāib Tahsildār* and 5 *Kānungos* (Settlement establishment).

The field operations were commenced on the 1st October 1916, and were brought to a close on the 31st May 1917. One Upper Subordinate with one traverser continued the Kāngra road survey till the 13th July 1917, when it was finished. The office of the detachment remained at Campbellpore all through the year.

The detachment was divided into several camps and sections:—

Mr. Paras Ram looked after the plotting section and the Kāngra road survey.

Mr. Jamna Prasad, R. S. assisted in computations and in starting main circuits along the Indus in the Dera Ghāzi Khān *tahsil.*

Mr. Mahomed Lutf Ali was put on minor traversing for about 3 months, after which he returned to office due to ill health, and later proceeded on long leave on medical certificate.

Messrs. Lakshmi Dutt Joshi and Vidya Dhor Chopra were employed on main circuits and detail traversing along the Indus, Rāvi and the Chenāb in the field, and on computations in recess. They also supervised several traversers for some months.

Munshi Ganda Singh, *Nāib Tahsildār,* remained in charge of a camp during the field season, and did miscellaneous work in office.

The detachment continued the work of traversing, and laying down base lines. 977 linear, and 1,796 square miles of main circuits; and 2,246 linear, and 421 square miles of minor traverses were run; and 1,359 theodolite stations of the former and 8,535 of the latter, were fixed in the area under water action of the rivers Indus, Chenāb, Rāvi and Jumna in districts Dera Ghāzi Khān, Muzaffargarh, Multān, Ambāla and Sahāranpur. 537 corners of 179 squares were demarcated with permanent mark-stones in an area of 748 square miles on both banks of the Indus and the Jumna in districts Dera Ghāzi Khān, Muzaffargarh, Ambāla and Sahāranpur. This demarcation is to serve as a basis for the future survey and demarcation of boundaries and fields in the beds of the rivers. 1,231 plotted, and 355 boundary *masāvis* (settlement mapping sheets) on the scales of 1/2,640 (Dera Ghāzi Khān) and 1/2,280 (Ambāla) and 31 four-inch sheets were traced and supplied to the Settlement Officers. Besides these, 191 miscellaneous traces were prepared and all the traverse stations marked during the year were plotted on 30 four-inch sheets. 5 riverain boundary sheets (scale 4 inches to a mile) of the Beās river (districts Kāngra and Hoshiārpur) were typed and finally examined; the computation volumes yet remain to be completed. Much trouble was experienced for want of *khalāsis* as they could not be had in sufficient numbers locally, due to military recruitment, and consequently had to be imported from Hazāribāgh; this delayed the work nearly a month. Several traversers had also to waste a good deal of time in crossing the Indus for throwing out points on isolated islands and cutting the heavy jungle along boundaries situated in the bed of the river. There was also some waste of time on account of the uncertainty of the settlement demands during the middle of the season.

The following tables give full details of the riverain work completed during the year:—

(1) Field work.

Names of Rivers, Districts and Scales.	Straight length in miles.	Main-circuit.			Minor Traverse for Detail Survey.				Base Lines.			Remarks.
		Number of square miles.	Number of linear miles.	Number of theodolite stations.	Number of square miles.	Number of linear miles.	Number of theodolite stations.	Number of villages.	Number of corners.	Number of squares.	Area in square miles.	
Indus River. Districts Dera Ghāzi Khān and Muzaffargarh. Scale 220 feet = 1 inch.	143	1,410	612	805	338	1,799	6,626	92	318	106	665	
Chenāb and Rāvi Rivers. District Multān	78	386	365	554	...	...	...	...	...	...	...	
Jumna River. Districts Ambāla and Sahāranpur. Scale 190 feet = 1 inch.	...	...	...	...	83	447	1,909	37	*219	73	83	* In addition to these 12 wooden pegs were replaced by stones.
Total	221	1,796	977	1,359	421	2,246	8,535	129	537	179	748	

(2) OFFICE WORK DONE FOR THE CADASTRAL SURVEYS OF RIVERAIN ESTATES.

Name of river.	Name of district.	Scale of *masāvis*.	Number of plotted *masāvis* showing traversed points.	Number of compiled *masāvis* showing riverain boundaries.	Number of sheets traced for the use of Settlement Officers on scale 4 inches to a mile.	Number of 4-inch sheets on which new work was plotted.
Jumna ...	Ambāla ...	2,280 inches = one inch.	293	81	5	5
Indus ...	Dera Ghāzi Khān	2,640 inches = one inch.	938	274	26	25
	Total	...	1,231	355	31	30

Besides these 191 miscellaneous traces were prepared.

(3) OFFICE WORK DONE FOR THE 4-INCH COMPILATION OF RIVERAIN BOUNDARIES.

Name of river.	Name of series.	Number of sheets typed.	Number of sheets finally examined and completed
Beās ...	Kāngra / Hoshiārpur	5	5

The remaining work in the Kāngra district was continued during the year. 414 traverse stations were computed, and plotted on 2 four-inch sheets; and the computation volumes of Pālampur, Kāngra, and Nūrpur have to a great extent been completed. 1,187 plotted *masāvis* of 59 *tikās* (sub-villages), and 102 enlarged boundary *masāvis* of 32 villages of the Beās, on the scale 20 and 40 *karms* (one *karm* = 57·5 inches) to an inch, and 18 traces of 18 sheets, on the scale 4 inches to a mile, were supplied to the Settlement Officer, Kāngra. Besides these 10 miscellaneous traces were prepared.

The computation volumes of the Simla district were completed during the year.

The Kāngra Road Survey was carried on in continuation of the last year's programme with the object of avoiding boundary discrepancies as compared with the settlement maps. 43·30 miles of road, from mile No. 48 to 53·28, from mile No. 94 to 91·72, and from mile No. 89 to 53·26 were surveyed. 840 points were fixed with theodolite, and 55 linear miles traversed. 29 sheets (scale 200 feet to an inch) of the main road, and 23 sheets (scale 50 feet to an inch) of 20 *bāzārs*, surveyed last year, were plotted, typed, examined, and supplied to the Executive Engineer, Provincial Division, Kāngra, together with copies of *Khasrās* (records of rights) relating to the same. 27 sheets (scale 200 feet to an inch) of the main road, and 5 sheets (scale 50 feet to an inch) of 5 *bāzārs*, surveyed this year, are also almost ready and will be supplied to the Executive Engineer early during next winter. Besides these 7 indexes of the last year's and 5 of this year's work were prepared on the scale of 4 inches to a mile.

At the end of August 1917 necessary traversing was undertaken for a 3-inch military survey close to Hatti in the Attock *tahsil*. 18 linear miles were traversed, sufficient theodolite stations were made in suitable places, and their heights taken.

The riverain area was generally broken, full of swamps, scrub, high grass and sand. The Indus was cut into several small streams and creeks besides the main channel. Large isolated plots in the beds of the rivers and portions of villages above the banks were open, flat, well cultivated, and in places wooded.

The health of the detachment was on the whole satisfactory all through the year. Several men working on the Indus suffered badly from malaria in the early part of the season. 5 *khalāsis* died of fever.

The Indus main circuits were connected with Khandī Kot T. S. CX, Nāzichand T. S. CIX, Ilwālā T. S. CI, Naharwālā T. S. XCVIII, Jhakar T. S. XCV, Dalurā T. S. XCIII, Abrīn T. S. XCVII, Mārā T. S. CII, Khemwālā T. S. CIV, Mohānā T. S. CV, Tounsā T. S. CXIV, Guhman T. S. CVI, Tūrī T. S. CXIII, Chūnī T. S. CXXIV, Rākwā T. S. CXXIII, Tibbī Platform Station CXIX, Langāwālā T. S. CXVI, Farowālā T. S. CXVII, Dago T. S. LXXVI, Gapolā T. S. LXXX, Thal Megrāj T. S. LXXXVII, and Ganghā T. S. LXXXV, and those of the Rāvi and Chenāb with Abdul Hakim, Tulumba, Channu, and Tarkhana mark-stones of the Jāderin Traverse, and with Multān Fort.

Work on the Jumna was based on the main circuits run in season 1910-11.

The Hatti traverse was connected with Kālu or South-West End Station XIII and Kāmra Hill Mark.

The average errors in the various classes of work were as follows:—

Riverain Surveys:—(*a*) Base-lines 1·02 feet per corner when compared with the theoretical values.

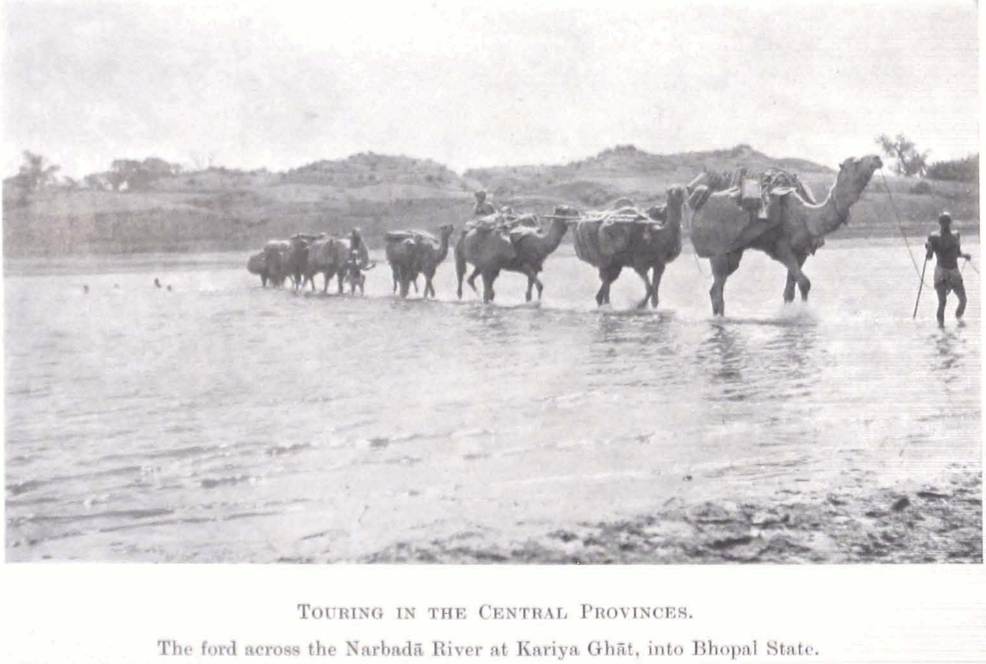
	Angular error per station in seconds.	Linear error in links per ten chains.
(*b*) Main circuits Indus	3·06	0·05
Rāvi and Chenāb ...	4·08	0·09
(*c*) Minor traverse Indus	4·69	0·38
Jumna	10·30	0·58

The total expenditure of the detachment from the 1st October 1916 to 30th September 1917 was Rs. 91,060 as detailed below:—

Riverain Survey including Hatti traversing	Rs.	77,947
Kāngra District Survey	„	8,106
Simla Survey	„	1,326
Kāngra Road Survey	„	3,681

The detachment was inspected by the Superintendent, Northern Circle, on the 13th November 1916.

A temple on the bank of the Lotus tank, Jubbulpore, C.P.



Touring in the Central Provinces.

The ford across the Narbadā River at Kariya Ghāt, into Bhopal State.

From photographs by Lieut.-Colonel C. L. Robertson, C.M.G., R.E.

SOUTHERN CIRCLE.

(*Vide* Index Maps 2, 5 and 9).

Summary.— This Circle was under the superintendence of Colonel T. F. B. Renny-Tailyour, C. S. I., R. E. throughout the year and comprised Nos. 5, 6, 7 and 8 Parties, No. 4 Drawing Office and the Training Section. No. 20 Party was transferred from the Northern to the Southern Circle with effect from the 1st April 1917.

During the year Nos. 5, 6, 7 and 8 Parties completed 11,769 square miles of detail survey, 22,316 square miles of triangulation and 390 linear miles of theodolite traversing.

The detail survey consisted of :—

5,045 square miles of	½-inch original survey.
5,532 " " "	1-inch original survey.
557 " " "	1-inch revision survey.
24 " " "	1-inch supplementary survey.
431 " " "	1½-inch resurvey.
65 " " "	2-inch original survey.
115 " " "	4-inch original survey.

No. 20 Party surveyed an area of 24,489 acres in cantonments and military stations.

Owing to the shortage of supervising officers on account of the war, the detail survey was considerably curtailed. Nos. 6 and 7 Parties took the field with a full strength of surveyors but the majority, including the head-quarters, of Nos. 5 and 8 Parties remained at Bangalore throughout the year and were principally employed on the fair-mapping of ½-inch sheets compiled from published sheets of the 1-inch map.

The Training Section carried out detail survey on the 1½-inch scale in sheet 57 $\frac{G}{8}$, 3 probationers of the Upper Subordinate Service and 10 pupil surveyors, etc. received instruction in topographical surveying.

The following work was undertaken in the Photo.-Zinco. Section of No. 4 Drawing Office :—

Reproductions	40
Enlargements	113
Reductions	140
Sheets vandyked	168
Copies printed	5,552

No. 5 PARTY (BERĀR, CENTRAL INDIA AND CENTRAL PROVINCES).

By P. R. Anderson.

PERSONNEL.

Provincial Officers.

Mr. P. R. Anderson in charge.
" C. West to 12th April 1917.
" Haji Abdul Rahim, K. B.
" F. H. Grant from 28th March 1917.

Upper Subordinate Service.

Mr. Damodar Khadilkar.

Lower Subordinate Service.

22 Surveyors, etc.

This party took the field in reduced strength and completed the detail survey on the 1-inch scale of sheets 55 $\frac{G}{2,3,4}$. The party also completed the triangulation of sheets 55 $\frac{F}{13,14}$.

The general nature of the country is highly cultivated, well-wooded plains and intricate jungle-clad hills.

The field season opened on the 12th November 1916 and closed on the 20th April 1917. The head-quarters of the party remained at Bangalore throughout the year.

The health of the party in the field was not good. The members suffered very much from fever. The Melghāt, where they were employed for the greater part of the field season, is a notoriously malarious locality, and an abnormal monsoon made it more feverish than usual. There were no deaths.

Plane-tabling.—The nature of the country surveyed is varied. The 1-inch original survey covered the monotonous and well cultivated plains of the Pāyānghāt in sheet 55 $\frac{G}{4}$ and the intricate and hilly country along the north bank of the Tāpti river in sheet 55 $\frac{G}{2}$. The 1-inch revision survey was confined entirely to the picturesque and intricate Melghāt hills with their abrupt scarpy summits, densely wooded slopes and steep ravines in sheets 55 $\frac{G}{2,3}$; these hills rise suddenly to their greatest height along their southern-most range, which immediately overlooks the Pāyānghāt, and decrease in height, as they stretch away northwards towards the Tāpti river.

The survey was done by 5 surveyors under Mr. Damodar Khadilkar. Mr. Damodar Khadilkar also *partāled* the 2-inch survey of the previous season.

The country covered by the 1-inch original survey is not favourable to rapid plane-tabling. As the greater portion of it is a gently sloping plain dappled over by large trees, interpolation was impossible without an unusual number of auxiliary points which the plane-tabler had to cut in for himself. The 1-inch revision survey gave little trouble, as it was carried out on vandyked blue prints on Bristol board of photographic reductions of previous 4-inch surveys which proved to be very reliable.

The full programme, amounting to 831 square miles, was completed. The total out-turn of 1-inch original survey and of 1-inch revision survey was 274 and 557 square miles respectively, the average monthly out-turn per man was 28·0 and 43·7 square miles respectively, and the cost-rate per square mile was Rs. 13·4 and Rs. 12·1 respectively.

Triangulation.—The nature of the country is a well-wooded, highly cultivated and gently undulating plain. It lies along the Narbadā valley and falls in the lower half of sheet $55\frac{F}{13}$ and the whole of sheet $55\frac{F}{14}$.

Mr. Anderson completed an area of 412 square miles in sheets $55\frac{F}{13, 14}$, and the cost-rate per square mile was Rs. 3·2.

Recess Duties.—(*a*) The fair-mapping was divided between two sections as follows:—

No. 1 Section, which worked throughout the year, under Mr. Haji Abdul Rahim, ½-inch sheets (compiled from 1-inch published sheets) $47\frac{M}{S. W.}$, $54\frac{L}{S. W.}$, $54\frac{P}{S. W., S. E.}$, $55\frac{D}{N. W., S. W., N. E., S. E.}$, $55\frac{G}{N. E., S. E.}$, $55\frac{I}{S. W., S. E.}$, $55\frac{K}{N. W., S. W., N. E., S. E.}$, $64\frac{A}{N. E.}$. This section also completed a considerable number of sheets, which were left unfinished by No. 6 Party at the end of the previous recess season.

No. 2 Section, which worked throughout the recess only, under Mr. Damodar Khadilkar, 1-inch sheets $55\frac{G}{2, 3, 4}$.

All No. 6 Party's work has been completed and submitted. Of the ½-inch sheets compiled from published sheets, $54\frac{L}{S. W.}$, $54\frac{P}{S. W., S. E.}$, $55\frac{I}{S. W., S. E.}$, $55\frac{K}{S. E.}$, $64\frac{A}{N. E.}$ have been submitted for publication, $55\frac{D}{N. W., S. W., N. E., S. E.}$, $55\frac{G}{N. E., S. E.}$, $55\frac{K}{N. W., S. W., N. E.}$ are well in hand and $47\frac{M}{S. W.}$ has been commenced. Sheets $55\frac{G}{2, 3, 4}$ are completed and will be submitted by the end of the recess season.

The party has completed 11, 060 square miles of fair-mapping for the ½-inch scale from published sheets and 831 square miles for the 1-inch scale, at a cost-rate of Rs. 1·2 and Rs. 3·3 per square mile respectively.

(*b*) For want of computers, the computations have not been completed, but it is hoped that all arrears will be wiped out by the end of next year.

The preparation of the data for the triangulation pamphlets was under Mr. West; on transfer to Calcutta he was relieved by Mr. Grant. Sheets 46 K, 48 P, 55 P, 56 I, 56 M and 57 P have been completed, sheets 46 O, 46 P, 54 L, 55 G and 55 I are in hand, and sheets 55 C, 55 F and 55 N will be put in hand when the areas they cover have been plane-tabled.

Miscellaneous.—The communications throughout the Melghāt, considering the hilly nature of the country, are good. A *pakka* road with bridges runs from Akola to Selu, and from there a well planned forest road to Harisāl on the Burhānpur-Ellichpur road. This road is practicable for motors. Branching away from this main route are many well-kept cart tracks, which work their way into all parts of the hills. Local labour is scarce and the country is unhealthy, so it is advisable to have squads at full strength and a reserve of *khalāsis* at camp head-quarters to supplement casualties. Supplies are only to be had at the *bāzār* villages in the Pāyānghāt or along the Burhānpur road.

The most convenient form of transport is camels for camp officers and triangulators, and carts for plane-tablers. Hardā is the most convenient centre for camels; carts can be had locally, whenever needed.

No. 6 PARTY (BOMBAY, HYDERĀBĀD AND MADRAS).

By J. O'B. Donaghey.

This party completed the detail survey on the ½-inch scale of sheets $56\frac{C}{1,5}$, $56\frac{K}{1 \text{ to } 16}$ and on the 1-inch scale of sheets $56\frac{C}{2,3,4,6,7,8}$ except that the area of Bombay in sheet $56\frac{C}{1}$ and the areas of Secunderābād Cantonment and of Hyderābād City in sheets $56\frac{K}{7,10,11}$ were surveyed on the 1-inch scale. An area of 97 square miles in sheets $56\frac{F}{15,16}$ was also surveyed on the ½-inch scale; this area, which was surveyed but rejected last year, was not included in the areas entered in the General Report and Records for 1915-16. Scattered areas of reserved forests in Hyderābād were surveyed on the 1½-inch scale in sheets $46\frac{P}{3,4,6,7,8,10,11,12,14,16}$, $47\frac{M}{1,5,9,10,13,14}$, $55\frac{D}{2}$, $56\frac{A}{14}$; as these areas had been previously surveyed on the ½-inch or 1-inch scale, they are not included in the out-turn for the current year in Table II of the General Report for 1916-17. The party also undertook the triangulation for the ½-inch, 1-inch and 1½-inch scales in sheets $56\frac{D}{1 \text{ to } 16}$, $56\frac{G}{11,15}$, $56\frac{H}{2,3,4,7 \text{ to } 16}$, $56\frac{L}{1 \text{ to } 8}$, $57\frac{A}{1,2,5,6,9,10,13,14}$.

PERSONNEL.

Provincial Officers.

Mr. J. O'B. Donaghey in charge.
" E. A. Meyer.
" F. C. Pilcher to 19th June 1917.
" Munshi Lal, B.A.
" F. W. Smith from 11th December 1916.
" M. S. Ganesa Aiyar.
" K. S. Gopalachari, B.A.

Upper Subordinate Service.

Mr. Eknath Battu.
" Ram Narayan Hastir.
" Nabidad Khan to 7th January 1917.
" Masud Khan.

Lower Subordinate Service

38 Surveyors, etc.

The general nature of the country is undulating and highly cultivated to the east and south with scattered rocky hills in the southern portion, the remaining area being mostly hilly with undulating portions consisting of cultivation and scattered areas of scrub and open jungle.

The field season opened on the 23rd October 1916 and closed on the 30th April 1917. Owing to abnormal and heavy rain, very little field work could be done before the 15th November 1916. The field head-quarters was at Secunderābād and the recess head-quarters at Bangalore.

The health of the party was on the whole fair; notwithstanding a severe outbreak of plague which was prevalent during the earlier part of the field season throughout the area under survey, only one menial of the party was attacked by and died from this disease. There were four deaths among the menials from cholera. The camp which was employed on the reserved forest survey suffered a good deal from malaria.

Plane-tabling.—The nature of the country surveyed in sheets $56\frac{C}{1 \text{ to } 8}$ is undulating and highly cultivated with low hills in the north-eastern portion; in sheets $56\frac{K}{1 \text{ to } 16}$ the country is mostly hilly,—a conspicuous feature being isolated granite hills and boulders,—interspersed with undulating areas of cultivation, patches of low scrubby jungle and in the north-western portion numerous tanks used for irrigation purposes. The reserved forest areas consist of wooded steep hills and flat-topped hills characteristic of the geological formation known as the "Deccan trap".

The work was divided among three camps as follows:—

No. 1 Camp.—Under Mr. Meyer with Messrs. Nabidad Khan and Masud Khan and 16 surveyors completed the original survey of sheets $56\frac{C}{1 \text{ to } 8}$.

No. 2 Camp.—Under Mr. Pilcher with 15 surveyors completed the original survey of sheets $56\frac{F}{15,16}$, $56\frac{K}{1 \text{ to } 16}$.

No. 3 Camp.—Under Mr. Munshi Lal with 6 surveyors was employed on the special resurvey of scattered reserved forests of the Hyderābād State in sheets $46\frac{P}{3,4,6,7,8,10,11,12,14,16}$, $47\frac{M}{1,5,9,10,13,14}$, $55\frac{D}{2}$, $56\frac{A}{14}$.

A total area, amounting to 7,333 square miles, was completed. The out-turn of the ½-inch, 1-inch and 1½-inch detail survey was 5,045, 1,857 and 431 square miles respectively, the average monthly out-turn per man was 74·3, 26·9 and 13·5 square miles respectively and the cost-rate per square mile was Rs. 4·4, Rs. 10·3 and Rs. 30·6 respectively. Areas of 5,045, 788 and 431 square miles of ½-inch, 1-inch and 1½-inch survey respectively were in Hyderābād.

Triangulation.—The nature of the country was on the whole easy for triangulation consisting of open cultivated areas with commanding hills which are for the most part bare and rocky or lightly wooded. In sheets 56 $\frac{G}{11, 15}$ portions of the country consist of forest-clad hilly areas somewhat difficult for triangulation, and it will be necessary to provide extra points by means of traversing.

Mr. Smith completed an area of 504 square miles in sheets 56 $\frac{G}{11, 15}$, Mr. Ganesa Aiyar completed an area of 3,485 square miles in sheets 56 $\frac{H}{2, 3, 4, 7 \text{ to } 16}$, Mr. Gopalachari completed an area of 1,542 square miles in sheets 57 $\frac{A}{1, 2, 5, 6, 10, 13, 14}$, Mr. Eknath Battu completed an area of 2,220 square miles in sheets 56 $\frac{L}{1 \text{ to } 8}$, Mr. Ram Narayan Hastir completed an area of 3,246 square miles in sheets 56 $\frac{D}{1, 2, 5, 6, 9, 10, 13, 14}$, 56 $\frac{H}{2}$, 57 $\frac{A}{9, 10, 13}$ and surveyor Dharmaji Narsu completed an area of 2,283 square miles in sheets 56 $\frac{D}{3, 4, 7, 8, 11, 12, 15, 16}$.

The total out-turn was 13,280 square miles and the cost-rate per square mile was Rs. 2·8. An area of 11,335 square miles is in Hyderābād of which an area of 350 square miles was triangulated for the 1½-inch scale.

Recess Duties.—(*a*) The fair-mapping was divided among three sections as follows:—

No. 1 Section.—Under Mr. Meyer, ½-inch sheet 56 $\frac{C}{N.W.}$ and 1-inch sheets 56 $\frac{C}{1 \text{ to } 4, 6, 7, 8}$.

No. 2 Section.—Under Mr. Pilcher, ½-inch sheets 56 $\frac{K}{N.W., N.E., S.W., S.E.}$. On the transfer of Mr. Pilcher to the Basrah Survey Party, this section was taken over by Mr. Meyer.

No. 3 Section.—Under Mr. Munshi Lal, nineteen 2-inch sheets of reserved forests in the Hyderābād State.

All the above sheets should be completed by the end of 1917. The fair-mapping remaining at the end of the recess season will be completed by No. 5 Party and No. 4 Drawing Office.

The area of 97 square miles, which was surveyed in sheets 56 $\frac{F}{15, 16}$ and is in Hyderābād, was fair-mapped by No. 5 Party.

The total out-turn of fair-mapping was 7,840 square miles (5,670 square miles for the ½-inch scale, 1,739 square miles for the 1-inch scale and 431 square miles for the 2-inch scale), and the cost-rate per square mile was Rs. 1·8 for the ½-inch scale, Rs. 2·0 for the 1-inch scale and Rs. 8·0 for the 2-inch scale. An area of 604 square miles was fair-mapped for both the ½-inch and 1-inch scales.

The areas fair-mapped by Nos. 5 and 6 Parties in Hyderābād were 5,163 square miles for the ½-inch scale, 484 square miles for the 1-inch scale, 186 square miles for both the ½-inch and 1-inch scales and 431 square miles for the 2-inch scale.

(*b*) The computations of the triangulation have not been completed but it is intended that they shall be completed during the coming field season.

No. 7 PARTY (MADRAS).

By W. M. Gorman.

PERSONNEL.

Provincial Officers.

Mr. W.M. Gorman in charge.
" H.B. Simons to 30th June 1917.
" V.W. Morton.
" H.H.P. Butterfield to 9th May 1917.
" B.T. Wyatt.
" N.S. Harihara Iyer.

Upper Subordinate Service.

Mr. Abdul Hakk, K. S.
" K. Mandanna.
" P.S. Vengusvami.
" Shib Lal.
" H. Narasimhamurti Rao.
" Shaikh Muhammad Salik.
" E.N. Natesan, B.A.
" P.B. Roy.
" J.M. Mukerji.

Lower Subordinate Service.

89 Surveyors, etc.

This party completed the 1-inch detail survey of sheets 57 $\frac{N}{11, 12, 15, 16}$, 57 $\frac{O}{9, 10, 13, 14}$, 66 $\frac{B}{3, 4}$, 66 $\frac{C}{1, 2, 5, 6}$ with the exception of some reserved forests falling in sheets 57 $\frac{N}{11, 12, 15, 16}$ surveyed on the 2-inch scale and the special forest survey on the 4-inch scale of Rāpūr Velikonda Block A and Extensions, Rāpūr Velikonda Block B and Extensions and Udayagiri Velikonda Block B and Extensions falling in sheets 57 $\frac{N}{2, 6, 7, 8}$. The party also completed the triangulation of sheets 56 $\frac{P}{2, 3, 4, 6, 7, 8, 10, 11, 12, 14, 15, 16}$, 56 $\frac{L}{8, 12}$ up to the Kistna river which is the limit of the Madras Presidency and of sheets 56 $\frac{I}{1 \text{ to } 12, 14, 15, 16}$, and theodolite traversing for the special forest survey falling in sheets 57 $\frac{N}{1, 2, 5, 6, 7, 8, 11}$.

With the exception of the special reserved forests situated on the eastern slopes of the Eastern Ghāts, the country surveyed extends, in an undulating expanse of wooded and cultivated lands broken at long intervals by detached knolls, from the foot of these Ghāts to the sea coast.

The field season opened on the 1st December 1916 at Gūdūr which was the field head-quarters and closed on the 12th May 1917, except for the triangulators who finished work on the 23rd June 1917. The party recessed at Bangalore.

There were several cases of malaria among the men of the triangulation section from March onwards while working in the Nallamalais. Six *khalāsis* died during the field season, two from fever, two from forest fires and two from other causes not contracted in the field. One surveyor died during recess while on leave, from natural causes. The health of the party working in the low ground, with the exception of one Upper Subordinate and one surveyor who contracted malaria and were obliged to go on leave, was good.

Plane-tabling.—The country surveyed on the 4-inch scale embraces the fairly open flat crest and eastern precipitous slopes of the Velikonda range, of an average width of from one to two miles, with low-lying and undulating ground densely covered with forest, starting from the foot hills eastwards, containing numerous small channels hardly discernible although well defined as main hill streams as far as the foot of the hills. The 2-inch and 1-inch survey stretched from the foot of the Eastern Ghāts on the west in an undulating expanse of wooded and cultivated land to the sea coast, varied at long intervals by the inclusion of a detached knoll, bounded on the north by the Penner river and on the south by the detached ranges of the Nagari and Nāgalāpuram hills, offshoots of the Eastern Ghāts, thickly forest-clad, steep, intricate, and standing out boldly from the plains. Main metalled roads throughout the low country are fairly numerous and well distributed, and cart tracks help to span the country where deficient in the former. Similarly the Buckingham Canal along the sea coast supplies a need when both are wanting. Two railways, one on the standard, and the other on the metre gauge, traverse the work, from north to south and from west to east respectively. The chief rivers falling in the work are the Penner, Swarnamukhi, and Kandleru. Of these the only one perennial is the Penner and helps to irrigate a large area. Numerous tanks which generally dry up form a feature of the country. The country, as seen from the vast area of low scrub jungle prevailing which is mostly reserved by the Forest Department for fuel purposes, owing to its stony soil and absence of perennial water, is poor and unproductive. The country east of the Pulicat lake contains little or no cultivation, is considered very malarious and elephantiasis is very common. The noted temple of Siva in Kālahasti town attracts thousands of worshippers from all over India during the ten days' festival held yearly in February.

The work was divided among three camps as follows :—

No. 1 Camp, under Mr. Morton with Mr. Wyatt for three months and an average of 7 surveyors, carried out the original survey on the 4-inch scale of 115 square miles of special reserved forests in sheets $57\frac{N}{2, 6, 7, 8}$.

No. 2 Camp, under Mr. Butterfield assisted by surveyor Mansab Khan with Mr. Wyatt and 15 surveyors, carried out the original survey of 65 square miles of reserved forests on the 2-inch scale and the original survey on the 1-inch scale of 1,435 square miles in sheets $57\frac{N}{11, 12, 15, 16}$, $66\frac{B}{3, 4}$.

No. 3 Camp, under Mr. Abdul Hakk with 12 surveyors, carried out the original survey on the 1-inch scale of 1,673 square miles and the supplementary survey on the 1-inch scale of 24 square miles in sheets $57\frac{O}{9, 10, 13, 14}$, $66\frac{C}{1, 2, 5, 6}$.

The reserved forests, for survey on the 4-inch scale, lie scattered throughout several sheets with an equal number of blocks north and south of the Penner river, and presented no difficulty in the high ground, it being poorly forest clad with bold outstanding features and detail well defined. In the low ground, covered with a dense growth of trees, plane-table traversing was resorted to in order to pick up the numerous detail contained therein, this and the scarcity of water in the area, compelling the surveyors to encamp on the outskirts of the reserves or near villages, meant much loss of time and out-turn of work. With the exception of about a mile of disputed boundary of the Udayagiri Velikonda Block B and Extensions Reserved Forest, all boundaries were cleared. The disputed portion was surveyed as pointed out by the Deputy Ranger of Gudigunta. No cairns with numbers, as stated in the notifications of these forests, were found.

The twenty reserved forests, surveyed on the 2-inch scale, consist of small trees and shrubs of a thorny growth forming what is called scrub jungle and are located in undulating ground varied at times by the inclusion of a detached knoll; the forests were surveyed mostly by plane-table traversing and by interpolation. Forest plans, supplied by the forest authorities for these reserves, were utilised in checking boundaries and for locality names.

Direct blue prints on Bristol boards of certain 1-inch prints of maps by the Madras Revenue Survey, containing much detail, were obtained from that Department and from the Southern Circle Office. The remaining 1-inch prints were transferred in blue by surveyors as the work progressed. The work of the Madras Revenue Survey was found accurate and satisfactory and considerably helped the work. *Zamīndāri* areas in the 1-inch prints supplied by the Madras Revenue Survey contained very meagre detail which was generally incorrect and only useful as a guide. Trijunctions of the Madras Revenue Survey in the coast sheets were utilised and were very helpful where trigonometrical points were few and far between. All work was gone over and checked as rigorously as if 1-inch original work.

2-inch plots on tracing cloth of the Tungabhadra irrigation project with contours at 20 feet intervals, containing ground level heights at distances of 330 to 660 feet along cross sections from 1 to 2½ miles apart and referred to G.T.S. Bench Mark data, fell in the work and were applied for from the Chief Engineer for Irrigation, Madras. The data were inserted proportionately on the 1-inch prints of the Madras Revenue Survey, and utilised as a check on heights and contouring.

The only reserved forest previously published on the 4-inch scale and falling in the work was reduced to the 1½-inch scale in blue, which was inked up in detail and hill features and again reduced to the 1-inch scale and transferred on the plane-table in position by common trigonometrical points. This was rigorously gone over, supplemented, brought up to date, contoured, and was found correct.

The total out-turn of survey on all scales was 3,312 square miles. The out-turn of the 4-inch original survey, of the 2-inch original survey, of the 1-inch original survey and of the 1-inch supplementary survey was 115 square miles, 65 square miles, 3,108 square miles and 24 square miles respectively, the average out-turn per man per month was 3·5, 12·4, 28·9 and 48·3 square miles respectively, and the cost-rate per square mile as mentioned in the above order is Rs. 93·6, Rs. 34·6, Rs. 7·4, and Rs. 2·3.

Triangulation.—The country triangulated embraces the Nallamalai hills, with its outliers to the east merging into the plains, the flat open and cultivated valley of Nandyāl in the centre and the Erramala hills further west; the Kistna river, both narrow and swift, bounds it on the north. The general run of the Nallamalais is from south to north as far as the Kistna river from whence it takes a bend to the east and consists of a series of hill peaks and small irregular ranges with several plateaux, the whole covered with unbroken forest and a heavy under-growth of high grass, mostly reserved forest. As this area was previously triangulated for the 4-inch scale, the former work was only supplemented. The Erramala hills, mostly reserved forest, rise up gradually into a series of flat-topped plateaux generally bare, but with their slopes clothed with stunted trees and shrubs, and presented a difficulty to the triangulators in fixing points. The country generally is deficient in main roads, the hilly area being especially ill supplied. The Kurnool-Cuddapah Canal runs through the Nandyāl valley from north to south and is navigable throughout the year. The Madras and Southern Mahratta Railway (metre gauge) crosses the area from west to east with a branch-line from Dronachellam to Kurnool. Malarial fever is very prevalent almost everywhere, especially in the Nallamalais. Guinea-worm, due to the impurity of water, also prevails. Great difficulty in procuring supplies and labour in the Nallamalai tract was experienced, as villages are few and far apart. Work in this area was carried out by assistance rendered by the forest authorities, who employ largely a forest tribe called the Chenchus. Scarcity of water also prevails during the hot months and can only be obtained at certain halting places.

The total out-turn of triangulation by the party for 2-inch and 1-inch surveys was 6,994 square miles and as detailed below was completed by :—

Mr. Simons, area 1,081 square miles, in sheets 57 $\frac{I}{14}$, 56 $\frac{P}{14, 15, 16}$ to the Kistna river.

Mr. Harihara Iyer, area 1,850 square miles, in sheets 57 $\frac{I}{1, 2, 5, 6, 9, 10}$, 56 $\frac{L}{8, 12}$ to the Kistna river.

Mr. Shib Lal, area 1,296 square miles, in sheets 57 $\frac{I}{15, 16}$, 56 $\frac{P}{2, 3, 6, 7, 8}$ to the Kistna river.

Mr. Shaikh Muhammad Salik, area 1,334 square miles, in sheets] 57 $\frac{I}{11, 12}$, 56 $\frac{P}{10, 11, 12}$ to the Kistna river.

Surveyor Jagan Nath, area 1,433 square miles, in sheets 57 $\frac{I}{3,4,7,8}$, 56 $\frac{P}{4}$ to the Kistna river.

The above was based on the Great Arc Meridional and the Madras Meridional and Coast series, but as the area between these series contained no geodetic or minor triangulation, a small secondary series, the stations of which are built of *pakka* material, was run from the base Katomoraj-Kerebelagal of the former series to provide data for adjoining triangulators. Observations were taken on five zeros on a 6-inch micrometer theodolite by Messrs. Troughton and Simms. Two stations of the series, *viz.* Gurimānikonda and Gummankonda, were handed over to the local authorities and the remaining stations will be similarly dealt with during the coming field season. In addition to the points now fixed there are about 1,064 points fixed by previous triangulation carried out for reserved forests surveyed on the 4-inch scale. Charts on the ¼-inch scale embracing the area triangulated, showing the principal traverse stations and village trijunctions of the Madras Revenue Survey and all geodetic triangulation on which their work was based, were obtained for the use of the triangulators to enable them to fix the same and so check the accuracy of the revenue work. 28 trijunctions were fixed in the area completed.

The cost-rate per square mile was Rs. 5·3.

Traversing.— Theodolite traversing of the boundaries of the special forests, was started at the end of October 1916 in advance of the detail survey to supply data for the same and as a theodolite traverse for 4-inch plots. Those boundaries, of which no Madras Revenue Survey traverse data or no previous surveys by the Survey of India adjoining these forests existed, were traversed. Fourteen 4-inch traverse plots on drawing paper, showing all existing data of the Madras Revenue Survey connected with and adjoining these forests, were supplied by the Madras Revenue Survey.

132 linear miles of boundaries for special forest survey on the 4-inch scale in sheets 57 $\frac{N}{1,2,5,6,7,8}$ for the following reserved forests:—

Rāpūr Velikonda Block A & Extensions
" " " B & "
Udayagiri Velikonda Block A & Extensions
" " " B & "
Gundlakonda

were traversed and connected with 18 trigonometrical stations and 22 azimuths were observed by Mr. Narasimhamurti Rao and a surveyor.

The total out-turn was 132 linear miles and the cost-rate per linear mile was Rs. 28·0.

Recess Duties.— (*a*) Two sections were engaged in the fair-mapping of the survey completed during 1916-17.

No. 1 Section, under Mr. Morton, sheets 57 $\frac{N}{11,12,15,16}$, 66 $\frac{B}{3,4}$.

No. 2 Section, under Mr. Abdul Hakk, and while on leave by the officer in charge assisted by Mr. Vengusvami, sheets 57 $\frac{O}{9,10,13,14}$, 66 $\frac{C}{1,2,5,6}$.

It is expected that the fair-mapping of these sheets will be completed before the party leaves for the field.

The total out-turn of fair-mapping is 3,197 square miles and the cost-rate is Rs. 8·8 per square mile.

(*b*) Arrears of the computations of degree sheet 57 M from last recess, together with current work, are in hand. It is expected that the former, partly completed during the field season together with 56 P will be ready by the end of this recess, leaving as arrears 57 I and 56 L the base work of which has only been completed. The error disclosed on comparison, of trijunctions fixed by party triangulation with their values as supplied by the Madras Revenue Survey on reduction from rectangular to spherical co-ordinates, is 0·58 seconds in latitude and in longitude.

Triangulation charts were under Mr. Simons, and on his transfer were handed over to Mr. Wyatt. Very little progress has been made in the preparation of triangulation charts and pamphlets owing to the further issue of instructions on the subject whereby charts 48 L and 57 L completed last year were returned and are being brought up to date. Besides the above, chart 66 D is well in hand and is expected to be completed soon. With the assistance of No. 5 Party, charts 48 P and 57 P were completed.

No. 8 PARTY (MADRAS).

By W. F. E. Adams.

The head-quarters and the bulk of the party remained in Bangalore throughout the year and continued the fair-mapping of ½-inch sheets compiled from 1-inch published sheets. The portion of the party that took the field consisted of a plane-tabling section working in sheet 58 $\frac{G}{4}$, a triangulator who worked in sheets 58 $\frac{G}{9, 10, 13, 14}$, 58 $\frac{K}{1, 2, 5}$ and a traverser who worked in sheets 58 $\frac{H}{11, 13, 14, 15}$, 58 $\frac{L}{1, 2, 3}$.

Personnel.

Provincial Officers.

Mr. W.F.E. Adams in charge.
,, M. Mahadeva Mudaliar, M.A.

Upper Subordinate Service.

Mr. Anantarao Dhondiba Mandhre, R.S. to 15th August 1917.
,, K. Narayanasvami Chetti.

Lower Subordinate Service.

26 Surveyors, etc.

The country under survey comprises the high wooded hills in sheet 58 $\frac{G}{4}$, the high open hills in sheets 58 $\frac{G}{9, 10}$ and the flat plains in sheets 58 $\frac{G}{13, 14}$, 58 $\frac{K}{1, 2, 5}$.

The plane-tabling section, triangulator and theodolite traverser left Bangalore on the 3rd December 1916 and returned to Bangalore on the 3rd, 26th and 29th May 1917 respectively.

The health of the surveyors in the plane-tabling section was fairly good, while among the *khalāsis* there were a great number of cases of fever and guinea-worm. The menials with the triangulator and the traverser kept good health throughout the field season.

Plane-tabling.—Sheet 58 $\frac{G}{4}$ is a very difficult one for survey, half the area is unexplored. The hills vary from 150 to 6,300 feet in height and are clothed with heavy forests, swarming with wild elephants and leeches.

The 1-inch original survey was completed by six surveyors under the supervision of Mr. Mahadeva Mudaliar.

The total area plane-tabled was 293 square miles, the average monthly out-turn per man was 12·8 square miles and the cost-rate per square mile was Rs. 62·2.

Triangulation.—The country is fairly favourable for triangulation, consisting of the high ranges of Sadragiri and Kudiramalai and the flat plains of the Madura district which are interspersed with a few rocky isolated low hills.

The total area triangulated was 1,630 square miles and the cost-rate per square mile was Rs. 4·4.

Traversing.—The country traversed is dead flat consisting of black cotton soil inland, succeeded by deep sand near the coast.

One surveyor traversed 255 linear miles at a cost-rate per linear mile of Rs. 9·6.

In addition to the above Mr. Mahadeva Mudaliar traversed Section IX (about 3 linear miles) of the Tinnevelly-Travancore boundary.

Recess Duties.—(*a*) The fair-mapping of ½-inch sheets, compiled from 1-inch published sheets, was under Mr. Anantarao Dhondiba Mandhre until he retired on the 16th August 1917 and was afterwards under Mr. Narayanasvami Chetti. Sheets 48 $\frac{L}{N.E., S.E.}$, 58 $\frac{B}{N.W., N.E., S.E.}$, 58 $\frac{C}{N.W.}$, 58 $\frac{D}{S.E.}$ were completed and submitted for publication, sheets 48 $\frac{K}{N.E., S.E.}$, 58 $\frac{B}{S.W.}$, 58 $\frac{C}{N.E., S.E.}$ are well in hand and sheets 57 $\frac{P}{N.W., S.W., N.E., S.E.}$, 58 $\frac{D}{N.E.}$, 66 $\frac{D}{N.W., S.W.}$ have been commenced.

Mr. Mahadeva Mudaliar was in charge of the fair-mapping of sheet 58 $\frac{G}{4}$.

A total area of 5,751 square miles has been fair-mapped at a cost-rate of Rs. 3·9 per square mile.

(*b*) The computations were undertaken under Mr. Mahadeva Mudaliar.

The material for the triangulation pamphlet sheet 58 D was completed, and the material for the pamphlets sheets 58 A, 58 B and 58 C should be completed by the end of November 1917.

Miscellaneous.—For the survey of sheet 58 $\frac{G}{4}$, local labour and transport were not procurable and had to be imported from other districts.

No. 20 PARTY (CANTONMENT).

BY A. EWING.

PERSONNEL.

Provincial Officers.

Mr. A. Ewing in charge.
" O. D. Jackson.

Upper Subordinate Service.

Mr. Dharmu.

Lower Subordinate Service.

25 Surveyors, etc.

During the year under report, the party was employed on the survey of the cantonments and military stations of Rāwalpindi, Chitrāl, Drosh, Ghairat, Jhelum, Siālkot, Topa, Dharmsāla, Chaman, Jhānsi, Deoli, Neemuch, Nasīrābād, Ahmadnagar, Drazinda, Jandola, Jatta and Zām on the scale of 16 inches to a mile, and on the bāzārs of Rāwalpindi, Jhelum, Siālkot, Topa, Jhānsi, Deoli, Neemuch, Nasīrābād and Ahmadnagar on the scale of 64 inches to a mile. The triangulation and traversing of Chitrāl, Drosh, Ghairat, Dharmsāla, Jhānsi, Deoli, Nasīrābād, Ahmadnagar, Drazinda, Jandola, Jatta and Zām were completed during the year. Twenty-six fair sheets have been submitted for publication, eleven have been completed but have not as yet been submitted for publication, sixteen are in hand and thirty-eight are remaining to be fair-mapped. These sixty-five fair sheets will be submited for publication by July 1918.

The field season commenced in Rāwalpindi, Jhelum, Siālkot, Topa and Neemuch on 1st October 1916 and closed in Drosh, Chaman, Jhānsi and Ahmadnagar on 30th September 1917. The head-quarters of the party was at Rāwalpindi until the beginning of May 1917, and at Poona for the remainder of the year.

The health of the party was good during the year, but some of the draftsmen and menials in Rāwalpindi suffered from malarial fever.

Plane-tabling.—Mr. Ewing was in charge of the survey of Rāwalpindi, Jhelum, Siālkot and Ahmadnagar, Mr. Jackson was in charge of the surveyors employed on the survey of Chaman, Deoli, Neemuch and Nasīrābād, and Mr. Dharmu was in charge of the survey of Chitrāl, Drosh, Ghairat, and of the four small military out-posts of Drazinda, Jandola, Jatta and Zām. There is an increase of 4, 901 acres on the scale of 16 inches to a mile and of 287 acres on the scale of 64 inches to a mile to what was previously surveyed during season 1915-16.

The accuracy of the survey done during the year was tested by Messrs. Ewing, Jackson and Dharmu by 30 linear miles, 69 linear miles and 21 linear miles of test lines respectively.

The total areas plane-tabled on the 16-inch and 64-inch scales were 23, 859 and 630 acres respectively, the average monthly out-turn per man was 295·9 and 21·6 acres respectively and the cost-rate per acre was Rs. 1·1 and Rs. 10·1 respectively.

Triangulation.—A sufficient number of stations and intersected points were fixed from the nearest Great Trigonometrical Series in Chitrāl, Drosh, Ghairat, Jhānsi, Deoli, Nasīrābād, Drazinda, Jandola, Jatta and Zām for the connection of theodolite traversing done in these cantonments. Messrs. Jackson and Dharmu and two surveyors were employed on the triangulation.

The total area triangulated was 518 square miles and the cost-rate per square mile was Rs. 9·9.

Traversing.—During the year the traversing of Chitrāl, Drosh, Ghairat, Dharmsāla, Jhānsi, Deoli, Nasīrābād, Ahmadnagar, Drazinda, Jandola, Jatta and Zām was completed by Messrs. Jackson and Dharmu and four surveyors.

The theodolite traversing done during the year is very good both in angular observations and in chaining. 294 linear miles were traversed at a cost-rate per linear mile of Rs. 29·4.

Levelling.—A few miles of levelling were done in Chaman, Jhānsi, Deoli, Neemuch, Nasīrābād and Ahmadnagar. From five to ten bench-marks were fixed in each cantonment at a cost of Rs. 326.

Recess Duties.—Twenty-six fair sheets have been submitted to Dehra Dūn for publication. Eleven fair sheets of Rāwalpindi have been completed but have not been finally examined, these sheets will be submitted for publication in October 1917. Sixteen fair sheets of Jhelum, Siālkot and Topa are in hand and thirty-eight sheets are remaining to be fair-mapped. Out of the thirty-eight sheets remaining eight were completed during September 1917 and five are very small sheets. The fair-mapping is about four months in arrears owing to some of the draftsmen being sick with malarial fever when the head-quarters of the party was in Rāwalpindi. As the field work of this party is increasing every year the number of draftsmen will also have to be increased. The fair-mapping was done under the supervision of Mr. Ewing.

The total areas fair-mapped on the 16-inch and 64-inch scales were 20, 277 and 435 acres respectively and the cost-rate per acre was Re. 0·3 and Rs. 3·2 respectively.

EASTERN CIRCLE.

(*Vide* Index Maps 3 and 6.)

Summary.—The Circle was under the superintendence of Lieutenant-Colonel R. T. Crichton, C. I. E., I. A., throughout the year and consisted of Nos. 9, 10, 11 and 12 Parties and No. 5 Drawing Office.

During the year 9,723 square miles of detail survey and 9, 405 square miles of triangulation were completed.

The detail survey consists of :—

2,140	square miles of	¼-inch original survey.
6,879	do.	1-inch original survey.
334	do.	1-inch revision survey.
370	do.	2-inch original survey.

A section of No. 9 Party was employed on half-inch mapping during the year.

No. 9 PARTY (BENGAL AND BIHAR AND ORISSA).

By J. Smith.

This party, which took the field in reduced strength, completed the detail survey on the 1-inch scale of sheets $79\frac{A}{1, 2, 5, 6, 9}$, also of portions of sheets $72\frac{L}{5, 6, 9, 10}$.

PERSONNEL.

Provincial Officers.

Mr. J. Smith in charge.
" Dhani Ram Verma, to 10th April 1917.
" A. B. Hunter, from 3rd May 1917.
" B. C. Newland.
" Amar Krishna Mitra.

Upper Subordinate Service.

Mr. Ram Singh, to 6th June 1917.
" Amulya Charan Ghosh.
" Gopal Lal Mitra.

Lower Subordinate Service.

27 Surveyors, etc.

The country in Bengal is flat and featureless, and being widely cultivated was easy to survey. In Bihār hilly portions were selected as the survey was intended more for instructional purposes than for mapping.

The party office, except for the ½-inch mapping, was closed at Shillong on the 3rd November 1916, and re-opened at Deoghar on the 10th idem. The camp for detail survey in Bengal under Mr. Dhani Ram Verma assembled at Beldanga on the same date. The field season closed on the 3rd May and office re-opened at Shillong on the 10th May 1917.

The health of the party throughout the field season was good. There was only one serious case of fever amongst the surveyors in Bihār, but the man was brought into Deoghar for treatment and soon recovered. One khalasi attached to a surveyor's camp in Bengal was badly bitten by a dog, believed to be mad, and the man was sent up to Shillong for treatment at the Pasteur Institute at Government expense.

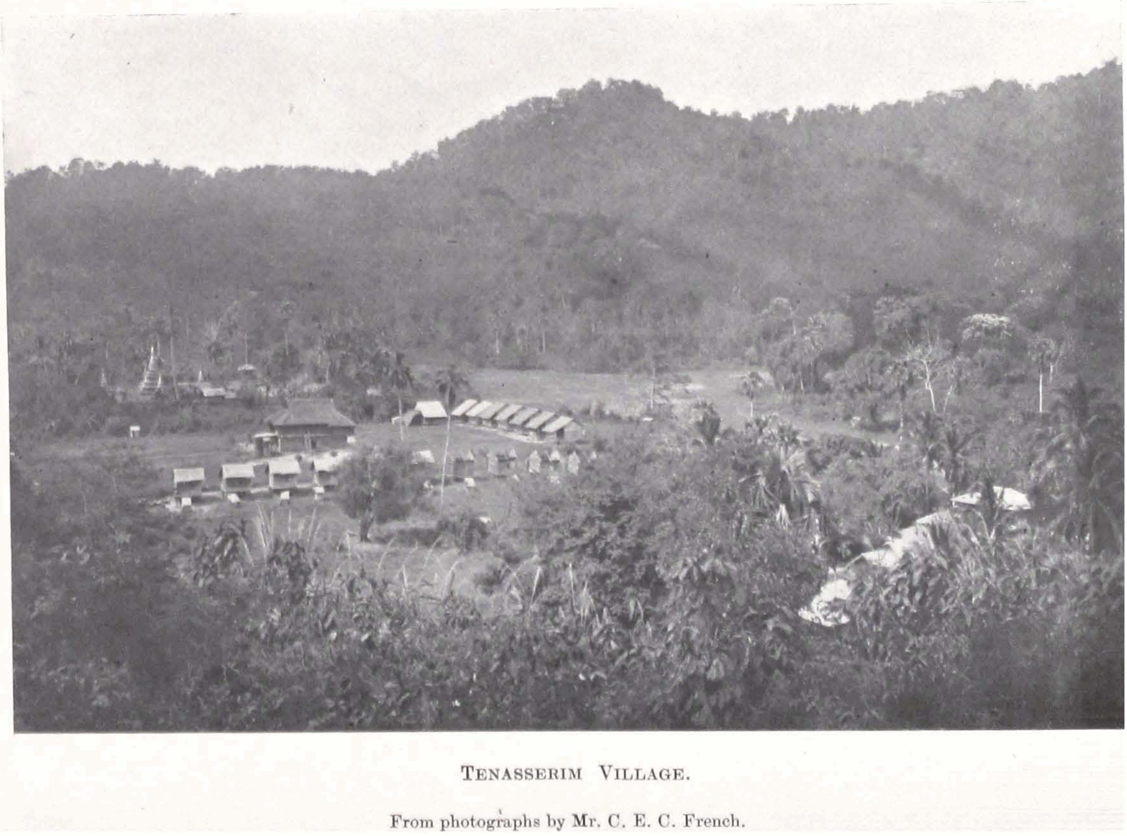
Plane-tabling.—In Bengal the area surveyed comprises portions of the Murshidābād, Nadiā and Burdwān districts. The Bhāgīrathi river which, further south, is known as the Hooghly, divides the first named district into almost two equal parts, but forms the boundary between the other two districts. Two lines of railway traverse the area from north to south, one on each side of the river, and there are, besides, numerous cart tracks and a few good feeder roads to the railway. The river is crossed by ferries when the water is high *i.e.* between the commencement of the monsoon and November. For the rest of the year it is fordable by carts as well as people. The general level of the country is about 30 feet above mean sea-level.

One camp under Mr. Dhani Ram Verma with 8 surveyors completed the detail survey of the whole of the area in Bengal. Owing to his transfer to the Simla Drawing Office in April, Mr. Amar Krishna Mitra had to be brought down from Shillong to take over charge of the camp.

Very few of the intersected points which had been fixed in previous seasons from a theodolite traverse were found to be incorrect, and the work was principally done from "in situ" fixings, plane-table traverses being only resorted to in surveying the interior of the village-sites and the banks of the rivers.

In Bihār, as already stated, the country surveyed being selected mainly for instructional purposes, is hilly, the general level is about 500 feet and the highest point in the hills about 1,600 feet above sea-level. The camp, made up of 2 Upper Subordinates and 4 pupil surveyors, was placed under the charge of Mr. Ram Singh with surveyor Ghulam Haidar to help in the training of the pupils who were absolutely raw and did not even know the use of their instruments.

TENASSERIM HILL.



TENASSERIM VILLAGE.

From photographs by Mr. C. E. C. French.

The out-turn of plane-tabling was 1,362 square miles in Bengal and 319 square miles in Bihār.

Cost-rates work out as follows:—

1-inch detail survey in Bengal	...	Rs. 11·4	per square mile.
1-inch detail survey in Bihār and Orissa		" 34·6	do.
½-inch fair-mapping	... ...	" 1·3	do.
1-inch fair-mapping	... ...	" 4·7	do.

The total cost of the party was Rs. 63,568.

Recess Duties.—(*a*) Mr. Newland, with Mr. Mitra helping in the examination of maps up to the end of March 1917, held charge of the ½-inch mapping section throughout the year. The following sheets have been completed and submitted for publication since the last report—72 $\frac{L}{S.W.}$, 73 $\frac{B}{N.W.}$, 78 $\frac{O}{S.W.}$, 78 $\frac{P}{N.E.}$, 83 $\frac{D}{N.W., N.E.}$, 83 $\frac{F}{S.W.}$, 84 $\frac{K}{N.W., S.W.}$, 94 $\frac{E}{S.E.}$ and 94 $\frac{F}{N.W., N.E., S.W., S.E.}$. The following sheets are nearing completion:—94 $\frac{E}{N.W., N.E., S.W.}$; two others 94 $\frac{B}{S.E.}$ and 94 $\frac{C}{N.E.}$ have been recently put in hand.

The fair-mapping of the 1-inch sheets was supervised by Mr. Amar Krishna Mitra and will be completed before the party takes the field except in regard to the district boundaries which have been referred to the Collectors for verification; this may delay the publication of the sheets.

(*b*) Mr. Hunter was entrusted with the preparation of the triangulation charts and lists for pamphlets of all the triangulation done by the party, since its transfer to the Eastern Circle, and the correction of all volumes in terms of the latest value of data supplied by the Superintendent of the Trigonometrical Survey. Charts for degree sheets 72 L and 72 P will be completed before the party takes the field; two others 73 B and 73 F are nearing completion.

Miscellaneous.—The area surveyed in Bihār, although previously done cadastrally and ordinarily should only have had to be supplemented by the topographical survey, was executed as original survey, as it was considered inadvisable to allow the plane-tablers access to the old maps, seeing that they were under instruction. This area has not been mapped but the work will be incorporated at some future date when the supplementary survey of these sheets is being undertaken.

With regard to the anticipated delay in the publication of the Bengal sheets, it should be stated that the physiographical changes in the country have been so great that the district boundaries, as defined and mapped from surveys executed between 1853 to 1870, cannot now be delineated on the ground. The matter has been referred to the Collectors of districts concerned.

Inspections.—The Superintendent, Eastern Circle inspected a portion of the party in the field in January 1917, and on several occasions during recess.

No. 10 PARTY (UPPER BURMA).

BY M. C. PETTERS.

PERSONNEL.

Imperial Officer.

Major E. T. Rich, R. E., in charge to 23rd October 1916.

Provincial Officers.

Mr. M. C. Petters in charge from 5th November 1916.
" W. G. Jarbo, in charge from 24th October to 4th November 1916.
" H. H. Creed, from 11th October 1916.
" A. V. Dickson.
" D. N. Banerjee, L. C. E.

Upper Subordinate Service.

Mr. Hayat Muhammad, K. S.
" Maung Kyaw Nyein.
" Dhirendra Nath Saha.
" Ram Prasad, R. S.

Lower Subordinate Service.

23 Surveyors, etc.

This party continued detail survey in Myitkyinā and Putao districts, the area surveyed extending over sheets 92 $\frac{C}{7, 10, 11, 12, 16}$, 92 $\frac{F}{N.W., S.W., N.E., S.E.}$ and 92 $\frac{G}{1, 5}$ with small areas of revision in sheets 92 $\frac{C}{8}$ and 92 $\frac{G}{6}$. The triangulation in advance for survey on the one-inch and half-inch scales embraced sheets 92 $\frac{A}{14, 15}$, 92 $\frac{C}{1, 2, 5, 6}$ and 92 $\frac{E}{1 \text{ to } 16}$.

The country under survey ranged in altitude from 600 feet in the valley of the Mali Hka to 11,300 feet above sea-level in the Kumon Bum, which here forms the watershed between the Mali Hka and Chindwin rivers and the boundary between Putao district and the rich unadministered tract of the Hukawng valley. Below 7,000 feet the area is covered with dense forest growth, and heavy jungle clearing was necessary at suitable sites to allow of surveyors fixing the positions and heights of surrounding detail. Work was retarded in the early months of the season by a heavy mist which obscured trigonometrical points and made plane-table fixings by interpolation impossible before 10 A.M. Kachin coolies were employed for transport of equipment and rations over large areas on the eastern slopes of the Kumon Bum which are uninhabited and without communications.

The field season opened on 26th October 1916 and closed on different dates between 21st May and 10th June 1917. The field head-quarters was at Myitkyinā.

The health of the party was only fair. A large number of men suffered from malaria and ulcers due to leech-bites and the stings of a variety of poisonous flies. Pupil surveyor Maung Hla Pe was drowned while bathing in the Mogaung chaung. Two surveyors, as a result of malaria, had to stop their field work and proceed on long leave. The head clerk who had been suffering from asthma from the commencement of the field season also proceeded on medical leave before the close of field work. Three khalāsis died in the field, one of whom was killed by a tiger.

Plane-tabling.— The programme of detail survey was completed and an area of 94 square miles, in addition, was surveyed on the one-inch scale. The work was divided into 3 camps under Messrs. M. C. Petters, W. G. Jarbo and D. N. Banerjee, whilst Mr. Maung Kyaw Nyein was in charge of a camp of instruction.

No. 1 Camp.— Under Mr. M. C. Petters with 3 surveyors completed an area of 322 square miles on the one-inch scale in sheets $92\frac{G}{1, 5}$. This camp also revised 8 square miles of faulty work in sheet $92\frac{G}{6}$. An escort of 12 rifles was provided by the military police for the survey of a portion of the Sana tract lying in the southern half of sheet $92\frac{G}{1}$.

No. 2 Camp.—Under Mr. W. G. Jarbo completed an area of 44 square miles on the one-inch scale in sheet $92\frac{F}{8}$ and 2,140 square miles on the half-inch scale in sheets $92\frac{F}{N.W., N.E., S.W., S.E.}$. The camp was originally composed of Messrs. H. H. Creed and A.V. Dickson and 8 surveyors. Two surveyors, however, developed a severe type of malaria early in the season and were obliged to proceed on long leave; their departure necessitated a re-adjustment of work to complete the season's programme, one surveyor was transferred from No. 1 Camp and another from No. 3 Camp. Messrs. Hayat Muhammad, K.S. and Ram Prasad, R.S., on finishing their triangulation also helped to complete the detail survey. As the average distance of this camp was 12 marches from Myitkyinā a good deal of time was spent on the road by surveyors despatched to reinforce it. Heavy and continuous rain in April also delayed the completion of the work. The camp returned to Myitkyinā between the 1st and 8th June 1917. The survey was confined to the administered tract lying between the Mali Hka on the east and the Kumon range on the west. Messrs. Creed and Dickson, in addition to plane-tabling on the one-inch and half-inch scales, assisted the officers in charge of Nos. 1 and 2 Camps in testing the work of surveyors.

No. 3 Camp.—Under Mr. D. N. Banerjee with 8 surveyors completed an area of 60 square miles of reserved forest on the two-inch scale in sheets $92\frac{C}{11, 12}$, 702 square miles on the one-inch scale in sheets $92\frac{C}{7, 11, 15}$ and a revision of 8 square miles on the one-inch scale of country surveyed during the previous season in sheet $92\frac{C}{8}$.

Mr. Maung Kyaw Nyein in addition to plane-tabling himself was in charge of a camp of instruction composed of 10 pupils of whom 4 were attached from No. 11 Party for training. The pupils had acquired sufficient experience for independent work by the end of March and were given small areas to survey in the valley of the Namkawng chaung which is waterlogged for 9 months in the year, April and May being the only months in which this tract can be conveniently and accurately surveyed. Mr. Maung Kyaw Nyein personally surveyed an area of 76 square miles in sheet $92\frac{C}{15}$ on the one-inch scale and the pupils 94 square miles on the same scale in sheet $92\frac{C}{10}$.

Out-turns and cost-rates are as follows :—

½-inch original survey,	2,140	square miles at	Rs.	19·6	per square mile.
1-inch ,, ,,	1,068	do.	Rs.	39·0	do.
1-inch revision ,,	16	do.	Rs.	21·2	do.
2-inch original ,,	60	do.	Rs.	101·0	do.

The out-turn and cost-rate of survey on the one-inch scale by the instruction camp are not included in the above.

Triangulation.—Mr. Hayat Muhammad, K. S., triangulated an area of 1,080 square miles for detail survey on the one-inch scale in sheets $92\frac{C}{1, 2, 5, 6}$.

Mr. Ram Prasad, R. S., triangulated an area of 3,672 square miles for plane-table survey on the half-inch scale in sheets $92\frac{A}{14, 15}$ and $92\frac{F}{1 \text{ to } 16}$. Great credit is due to Mr. Ram Prasad, whose work lay at an average distance of 20 marches from Myitkyinā. There are few roads in the area he triangulated and his arrangements for coolie transport and provisions for his squad were made entirely by himself.

Out-turns and cost-rates are as given below :—

Triangulation for half-inch original survey, 3,672 square miles at Rs. 2·2 per square mile.

Triangulation for one-inch original survey, 1,080 square miles at Rs. 6·4 per square mile.

The cost-rate for half-inch triangulation is Rs. 4·0 less than that of last year.

Recess Duties.—(*a*) The fair-mapping of the season's detail survey, consisting of four half-inch sheets, five one-inch sheets and two sheets containing small areas of revision on the one-inch scale, has progressed very satisfactorily. All the sheets will be submitted for publication before the party moves into the field.

The system of direct-mapping, which appears particularly suitable for parties recessing in Burma, was tried this year with success. Plane-table sections of complete sheets were despatched from the field to the Superintendent of Map Publication for enlargement to the scale of drawing. A copy of each of these enlargements on Hollingworth paper was then cut and pasted together in position, in Calcutta, on sheets projected to the scale of drawing, all distortion in graticule being eliminated by sub-dividing the enlargements, when necessary, into 5 minute or 10 minute squares. These compiled sheets were then treated as originals and reproduced by photography and 2 drawing blue prints obtained, one for the outline and the other for the contour original. By this method, not only was the time saved, which is usually spent in the middle of the recess season when fair outline sheets are sent to Calcutta for vandyke prints for contour originals but, it enabled work on the fair outline and contour sheets to be carried out concurrently and the heavier sheets to be drawn in double shifts from the beginning of the recess season.

The fair-mapping was divided into 3 sections as follows :—

No. 1 Section.—Under Mr. W.G. Jarbo, sheets 92 $\frac{F}{N.E., S.W., S.E.}$ and 92 $\frac{G}{1}$.

No. 2 Section.—Under Mr. H.H. Creed, sheets 92 $\frac{C}{7, 11, 15}$ and the outline of sheet 92 $\frac{F}{N.W.}$.

No. 3 Section.—Under Mr. A.V. Dickson, sheet 92 $\frac{G}{5}$ and the contours of sheet 92 $\frac{F}{N.W.}$. In addition, Mr. Dickson personally drew the greater portion of the areas in sheets 92 $\frac{C}{12}$ and 92 $\frac{G}{6}$ which were resurveyed on the two-inch and revised on the one-inch scales respectively.

The areas of fair-mapping in square miles on the half-inch and one-inch scales were 2,340 and 1,441 and their cost-rates per square mile Rs. 3·8 and Rs. 7·6 respectively.

(*b*) The computation of the season's triangulation was completed by Mr. Ram Prasad assisted by three computers.

Inspections.—The Superintendent, Eastern Circle inspected the party in the field in February 1917.

No. 11 Party.

By J.O. Greiff.

During field season 1916-17 the party was employed in the district of Mergui, Lower Burma, and the districts of Mandalay and Kyaukse, and the Northern Shan States, Upper Burma. The classes of survey were original and revision on the 1-inch scale, and original 2-inch of part of the reserved forest of Yeyaman.

PERSONNEL.

Provincial Officers.

Mr. J.O. Greiff in charge.
" C.E.C. French from 25th October 1916.
" O.J.H. Hart.
" T.P. Dewar from 9th February 1917.
" C.O. Picard.

Upper Subordinate Service.

Mr. Lachman Daji Jadu, B.B.
" Dalbir Rai from 17th October 1916.
" P.C. Sen Gupta, B. Sc.

Lower Subordinate Service.

30 Surveyors, etc.

The total area surveyed was 2,709 square miles, distributed as follows :—

Original 1-inch, 2,213 square miles in sheets 95 $\frac{K}{16 \text{ (part)}}$, 95 $\frac{L}{6, 7, 11, 12, 13 \text{ (part)}, 14 \text{ (part)}, 15 \text{ (part)}, 16 \text{ (part)}}$ and 95 $\frac{P}{1 \text{ (part)}, 2 \text{ (part)}, 3 \text{ (part)}, 4 \text{ (part)}, 6 \text{ (part)}, 7}$.

Revision 1-inch, 74 square miles in sheets 95 $\frac{L}{16}$, 95 $\frac{P}{2, 4}$ and 244 square miles in sheets 93 $\frac{B}{8, 12}$.

Original 2-inch, 178 square miles in sheets 93 $\frac{B}{16}$ and 93 $\frac{C}{10, 13, 14}$.

The recess office was closed at Maymyo on the 25th October 1916, and the field office opened at Mergui on the 6th November 1916.

The field office was closed at Mergui on the 5th June 1917, and the recess office opened at Maymyo on the 11th June 1917, where it remained for the rest of the year.

The country surveyed in Upper Burma was densely wooded with a heavy undergrowth of grass jungle. The area enclosed by the Yeyaman forest reserve is known as the "Yeyaman Hill Tract". The main watershed, rising to over 5,000 feet, and limiting the eastern boundary of the forest reserve, is also the boundary between the district of Kyaukse and the Southern Shan States. A single, and fairly good, mule track runs through the reserve from Yeyaman village in the south-west to Kyawkku in the north-east, in the Southern Shan States. In Mergui the survey extended over parts of the valleys of the Tenasserim and the Little Tenasserim rivers, the seaboard area enclosed by the mouths of the former, and King Island, the largest island in the Mergui Archipelago. Inland the country consists of a succession of rugged steep hills and valleys running north and south almost parallel to the Tenasserim, and rising to elevations of over 4,000 feet on the main watershed, which forms the administrative boundary between the district and Siam. The almost primeval forest growth, the size and height of the trees, and the undergrowth of cane and bamboo, with which these hills are covered was again a serious obstacle to progress. An attempt was made to work from platforms raised several feet above the ground, but even from these the view was so confined, that the idea had to be abandoned, and plane-table and prismatic compass traversing resorted to. Sheet 95 $\frac{P}{7}$ is practically unknown land, borne out by the fact, that within the whole area not a single local name was available for any of the main streams and hills. In the early mornings, until dried by the sun, the whole country is enveloped in fog, the vegetation dripping with moisture, as though it had just ceased to rain. The thick vegetable matter under foot harbours all kinds of objectionable insects, and during this season, in addition to leeches and ticks, swarms of bees and large horseflies had to be contended against. The state of some of the *khalāsis* at the close of the field season was pitiable. The seaboard area consisted of low hills fringed with broad stretches of mangrove swamps, broken up by numerous creeks and inlets. The sea coast of the main land, and even of the islands in the Archipelago have hardly any beach to speak of, the foreshore consisting of soft mud flats or rock and shingle.

As regards roads they were conspicuous by their absence; communications except by boat do not exist. Mule-tracks and paths had to be cut and cleared to all camps, some of which were six to eight days' march from the nearest village.

Local supplies were altogether wanting. Four supply depôts were established throughout the area. The main depôt was at Mergui, from where supplies were regularly sent up to the sub-depôts, whence they were conveyed by mules or coolies to the several camps. Coolie transport, always a disadvantage, was particularly so this year, from the inability of the men to carry much more food than they required for themselves over long marches.

The party was divided into four camps as follows:—

No. 1 Camp.—Four surveyors, under the personal supervision of the executive officer, completed the survey of sheets 95 $\frac{L}{6, 7, 11}$. In March the charge of the camp was transferred to Mr. Lachman Daji Jadu, R.B.

No. 2 Camp.—Mr. Lachman Daji Jadu, R.B. in charge, and eight surveyors, completed the survey of sheets 95 $\frac{L}{12, 15 \text{ (part)}, 16 \text{ (part)}}$ and 95 $\frac{P}{4 \text{ (part)}}$. Mr. French took charge of the camp at the end of February.

No. 3 Camp.—Mr. Picard in charge with Mr. Gupta and seven surveyors, completed the survey of sheets 95 $\frac{L}{13 \text{ (part)}}$ and 95 $\frac{P}{2 \text{ (part)}, 6 \text{ (part)}, 7}$.

No. 4 Camp.—Mr. Dewar in charge and 3 surveyors, completed the revision survey in sheets 93 $\frac{B}{8, 12}$, and the 2-inch forest survey in sheets 93 $\frac{B}{16}$ and 93 $\frac{C}{10, 13}$. Mr. French was in charge till the end of January.

The cost-rates for the different classes of survey are, original 1-inch Rs. 47·3 per square mile, revision 1-inch Rs. 18·8 per square mile, and original 2-inch Rs. 52·7 per square mile. They show an appreciable decrease on those of last year.

Triangulation.—New triangulation was completed over an area of 4,075 square miles in sheets 95 $\frac{P}{8, 12}$, 96 $\frac{I}{1, 2, 3 \text{ (part)}, 5, 6, 7 \text{ (part)}, 9, 10, 11 \text{ (part)}, 13, 14, 15 \text{ (part)}}$, 96 $\frac{M}{1, 2, 3 \text{ (part)}, 5, 6 \text{ (part)}, 7 \text{ (part)}, 9 \text{ (part)}}$. The triangulation in the Mergui Archipelago was carried out by Mr. Dalbir Rai, that inland by surveyor Muhammad Yusuf Khan. The country was difficult to triangulate owing to the density of the forest growth, and the almost entire lack of habitations and communications. The supply of labour for hill clearing was a constant source of trouble and anxiety. In the Archipelago the conditions were even worse; the islands, but for a few fishing villages, are uninhabited except by *Salōns*, an aboriginal tribe of sea gipsies, said to be of Malay descent, but whose language is said to be akin to the Cham of Cambodia. They are in a very low state of civilization, and on the islands go about in an almost nude condition. They are expert divers and weather prophets, and live by bartering shells, fish, *bôche-de-mer*, wax, honey, etc. with traders. They are extremely timid, and on the approach of strangers disappear and hide, until confidence is restored. When I visited the Pickwick group of islands, a whole family on the beach disappeared, and defied all my efforts to trace and photograph the group. The consequence was that progress in the Archipelago was extremely trying and slow. Another source of endless delay was the use of a sea-going boat instead of a launch. The Archipelago is frequently subject to rough weather and contrary winds, and sailing boats are consequently held up days at a time. The difficulties for a triangulator and his helio-men under such conditions are easier imagined than described. In addition, the haze over the Archipelago during the early part of the season was so dense, that a 6-inch helio would not show up at a distance of 15 miles. The results of the triangulation in the Archipelago are not very good, but considering all the circumstances under which the work was carried out, it would be unfair to find fault.

The cost-rate for triangulation is Rs. 5·0 per square mile.

The Mergui Archipelago is extremely pretty, and the Fell Passage along the east coast of King Island is said to be one of the prettiest sights in the Archipelago. It is a rich pearling ground, and its islands are the home of the esculent swift, whose nests are extremely valuable and are exported in large quantities for the delectation of the Chinese. The nest is pure white in the shape of the half of a small cup, and is built up of the saliva of the bird.

Recess Duties.—(*a*) During recess the party was divided into four sections :—

No. 1 Section.—Under Mr. C. E. C. French completed the fair-mapping of sheets 95 $\frac{L}{12,\ 16}$ and 95 $\frac{P}{4,\ 7}$. At the beginning of the year Mr. French was attached to the drawing office, to dispose of the final examination and despatch of the half-inch and quarter-inch sheets. Half-inch sheets 84 $\frac{M}{NE,\ SW,\ SE.}$, 92 $\frac{G}{SW.}$, 92 $\frac{L}{SW,\ SE,}$ and 93 $\frac{I}{NE}$ and quarter-inch sheets 84 N and 93 I were completed and sent for publication by the end of January 1917.

No. 2 Section.—The Maymyo drawing office under Mr. O. J. H. Hart completed the fair-mapping of one-inch sheets 93 $\frac{B}{8,\ 12}$, 93 $\frac{C}{5,\ 9}$, 95 $\frac{F}{13}$, 95 $\frac{J}{6}$, 95 $\frac{K}{11}$ (contour sheet only), 95 $\frac{L}{7,\ 10,\ 13\ (part),\ 14}$ and 95 $\frac{P}{3}$, also 2,000 square miles of mapping in quarter-inch sheets 93 E and 93 J and 1,100 square miles of half-inch mapping in sheets 93 $\frac{E}{SW}$ and 93 $\frac{I}{NW}$. The out-turn of fair-mapping completed by this section is most creditable, considering the strength of the staff and the troublesome nature of the work. The original survey of most of these sheets was carried out in bits, thereby permitting of very little direct mapping and necessitating a vast amount of adjustments, corrections, etc. The maps of Maymyo and environs were particularly troublesome; large areas in them had to be compiled from original surveys done on the 2-inch, 4-inch and 16-inch scales. Moreover, owing to serious discrepancies between the different classes of survey, a large area of the revision survey done in the recess of 1913-14 had to be re-checked on the ground. The mapping had practically been completed when the errors were discovered, and consequently about 300 square miles of mapping had to be scrapped.

No. 3 Section.—Under Mr. Dewar completed the fair-mapping of sheets 95 $\frac{L}{6,\ 11,\ 15}$ and 95 $\frac{P}{2\ (part)}$.

(*b*) *No. 4 Section.*—In charge of Mr. Picard was employed on the computations of the triangulation. Owing to the small staff available, it has not been possible to complete all the computations, or to take in hand the preparation of any of the fair degree charts.

The total amount of one-inch mapping completed by the end of the survey year was 3,550 square miles, at a cost of Rs. 6 per square mile, showing a decrease of Rs. 2·6 on that of last year.

Miscellaneous.—All mangrove swamps were surveyed by means of prismatic compass traverses, being the quickest and most economical method of surveying large valueless areas of ground, featureless but for creeks and inlets. In running these traverses three boats were used, one for the surveyor and back chain man, one for the forward chain man, and one for the flagman. Cane or fishing line lengths, on account of their buoyancy, of five to twenty chains, with detachable plumbs, were used for measurements. Each traverse was started from and closed on a fixed or interpolated point. The procedure was as follows:—The flagman went out in the direction the traverse was to run, and anchored on the spot he was ordered to. The bearing to his flag was then read and recorded, and the forward chain man went out the full length of his chain, cast anchor at the spot arrived at and dropped his plumb. He was followed by the third boat, the chain being reeled in as the boat proceeded. On arriving at the spot where the plumb had been dropped the third boat cast anchor, and on went the forward chain man on his second lap, the process being repeated, till the forward station was reached. All readings and distances were recorded in the ordinary field traverse book form, in which was also kept up a rough sketch of the banks, as well as bearings to important features, and check bearings to any known fixed points that were visible. At the close of the day's work, these traverses were plotted on a bank post sheet of form 28 Trav., on which the graticule of the plane-table and the known fixed points had been pricked off; the detail was then entered and inked up. If the traverse closed fairly well between its starting and closing point, the material was transferred on to the plane-table, otherwise it was adjusted between its limits on the principle for adjusting a plane-table traverse. The method may appear to be a rough and ready one, but it was the most suitable for the ground to be covered.

The work of the party during the year under report was very heavy and trying. There was only one clerk in the party, and for a month and a half, towards the end, he was on leave; the consequence being prolonged office hours for the executive officer throughout the year.

The experiences of the party with the local inhabitants of Mergui can be said to have been anything but pleasant. The people appear to be an independent fractious lot, not amenable to orders and, living as they are in a fair state of competence, were strongly averse to leaving their homes and submitting to the hardships and discomforts of survey life. Surveyor Abdul Majid was cruelly done to death by a villager from a cut with a *dā* on the head. The case has been committed to the Sessions, and is to be tried next November. From the evidence to hand there appears to have been no reasonable provocation for so grave an act, and it can only be attributed to the instinctive propensity of the Burman to use his *dā* for little or no cause. The surveyor's death was a great loss to the party, he was an all round good man and a most promising lad. Four surveyors were also robbed of their belongings and of Rs. 272 odd Government money. It is difficult to understand how acts of this nature are possible, in and around villages, and the perpetrators able to escape the penalty of the law and leave no clue behind. There was a great deal of sickness in the way of fever and dysentery, of which two *khalāsis* died. One was also killed by a falling tree.

The district of Mergui is full of interest and presents a surprising variety of most pleasing scenery. The landscape of parts of the Tenasserim valley is pretty and impressive and the harbour quite picturesque. The main part of the town is on a ridge that commands a lovely view of the Archipelago. The modern town of Mergui and the village of Tenasserim, built on the ruins of the old fort at the confluence of the Tenasserim and the Little Tenasserim rivers, are of ancient and historical interest; particularly the latter, which was the more important of the two and, as far back as the 13th century, the principal port on the west coast of the Siamese kingdom. It derived its great importance from the circumstance, that it was the starting point of a good overland route to the capital of Siam and a port at which vessels of light draft could discharge their cargoes and so avoid the long and dangerous passage round the limits of the peninsula. The larger and more commodious harbour of Mergui affords anchorage for large vessels. The Survey Camp at Tenasserim was pitched on the site of the old elephant mart. Dr. J. Anderson in his book "English Intercourse with Siam in the XVII Century" Trubner's Oriental Series, speaks of three overland routes to Siam and places the starting point at *Jelinga* seventy miles up the big Tenasserim. From the map accompanying his book, the position of *Jelinga* was plotted on to the old 1-inch map and every endeavour was made to locate it and the route across to Siam, but without success. The oldest inhabitants having no knowledge of such a route, it is more likely that the main route was up the Little Tenasserim, the starting point being somewhere near the present village of *Thein-Khwon*. At this place, it is said, there still exist relics of ancient buildings on a large scale, and through it passes a well recognised bridle-path to Siam from Tenasserim. This is the route along which Mr. Leal, interpreter to Captain Burney's Mission to Bangkok, travelled in 1825-26 and the Jesuit Bishop of Trabaca from Siam also speaks of having travelled along this route in 1761 in chariots. It is certain that such a route did exist and was a good military road. The route falls in sheets 96 $\frac{M}{1,5,9}$, and it would be most interesting, when the survey of these sheets is undertaken for an endeavour to be made to verify the identity of the route. It is a pity, as Dr. Anderson remarks, that during our occupation of the ancient province of Tenasserim no effort has been made to re-establish and maintain these ancient and valuable routes of commerce with the rich kingdom of Siam. In the village of Tenasserim stands a covered-over stone obelisk, erected by the Burman king Alaungpayā to celebrate his victory over Siam in 1759. The story connected with it is, that it was erected over the grave of a woman who was buried alive in a state of pregnancy as a sacrifice. To this day, on certain days of the year, the obelisk is visited by the women of the village and covered over with gold leaf. Still standing on the ruins of old Tenasserim is the *Wottsheng* pagoda, built in 1380, in a wonderful state of preservation as also are the baked bricks in the wall of the old fort, which are of a very large size measuring 16″ × 8½″ and unaffected by time. In front of the main jetty at Mergui stands a solid stone pillar set up in concrete, recording the death of Samuel White, the *Shahbander* or Principal Port Officer of the Province of Tenasserim under the Siamese Government. He escaped to England in the massacre of the English that took place at Mergui in 1687. Dr. Anderson has recorded, that he traced the death of Samuel White, from one of the parish registers in England, to have taken place in England in 1689. It is now generally believed that the stone commemorates the death of his wife, who is said to have died in 1682 at Mergui. But the inscription on the stone begins "*Ego resurgam*"; it may be that Samuel White particularly fancied this epitaph and anticipated the manufacture of his own tombstone, for it is hardly likely that such an inscription would have been adopted by him for his wife's grave. In a certain sense the prediction may be said to have been fulfilled, for the stone stands at the entrance to the town, and, by the researches of Dr. Anderson, he has been called forth from the mists of the forgotten past. The stone was found only in 1905 at the *Kangyi* lake and was being used by the dhobies of the town to beat out old rags on. *Sic transit gloria mundi.*

Inspections.— The Superintendent, Eastern Circle inspected the party in the field in January 1917.

No. 12 PARTY (ASSAM).

BY H. W. BIGGIE.

PERSONNEL.

Imperial Officer.

Lieutenant-Colonel A. Mears, I. A., in charge up to 14th April 1917.

Provincial Officers.

Mr. H. W. Biggie in charge from 15th April 1917.
Mr. E. G. Hardinge.
" Pramadaranjan Ray, R. S.
" E. M. Kenny.
" P. C. Mitra, B. A., during the field season only.

Upper Subordinate Service.

Mr. Girija Sonker Bagchi.

Lower Subordinate Service.

35 Surveyors, etc.

The party continued topographical operations in the Lakhimpur and Sibsāgar districts and North-East Frontier Tract, Central and Eastern Sections, which included a stretch of the Brahmaputra river and the country to the south, the northern bank of the former being the limit of the season's operations in sheets 83$\frac{L}{2}$ and 83 $\frac{M}{8, 11, 14}$. In these sheets a narrow strip about 2 miles in width was surveyed beyond the high bank to ensure a satisfactory common margin when the balance of these sheets come under survey, the banks of the Brahmaputra being subject to considerable erosion. An area of about 55 square miles on the north bank of the river in 83 $\frac{I}{12, 15}$ was also surveyed to complete these sheets.

The field season extended over a period of five months, from November to April, with the party head-quarters at Dibrugarh.

The surveyors and menials working to the south of the Disāng river in No. 1 Camp suffered a good deal from malarial fever; the health of the rest of the party was on the whole satisfactory.

Plane-tabling.— A great portion of the country that came under survey is covered with very dense forest, consisting of trees with an under-growth of cane and thorny creepers. It is generally flat with the exception of a range of hills rising to 1,800 feet, lying within and along the southern limit of the area of survey, and low hills rising to 800 feet which are the main features of the Abhaipur reserved forest. In the vicinity of the tea gardens, which are numerous, there are good winter roads, and second class roads maintained by Government agency traverse the more open parts of the area at convenient intervals. Besides the Brahmaputra, which flows in a southwesterly direction, the Burhi Dihing, Dibru and Disāng are the only other rivers of any importance; their general direction is east to west and they are navigable by small country boats. A broad belt of jungle parallel to the Brahmaputra lies in the centre of the area and extends across the south bank of the Burhi Dihing river; here villages are scarce and means of communication very poor and labour could not be obtained at all. Generally speaking little or no labour for line-clearing could be obtained locally. Another difficulty was means of transport; carts were procurable only in the vicinity of police stations. The party's elephants were invaluable in enabling inspecting officers to visit and thoroughly check the work of the surveyors in the jungle-clad country.

The detail work in the field was divided into three camps as follows:—No. 1 Camp under Mr. Pramadaranjan Ray, R. S., with one Sub-Assistant Superintendent for two months, eight surveyors and one pupil surveyor surveyed 542 square miles on the one-inch scale and 49 square miles on the two-inch scale in sheets $83\frac{I}{16}$, $\frac{J}{13}$, $\frac{M}{4}$ and $\frac{N}{1}$; No. 2 Camp under Mr. E. M. Kenny, with one Provincial Officer for two months, six surveyors and one pupil surveyor surveyed 529 square miles on the one-inch scale in sheets $83\frac{M}{2, 3, 4}$, and 16 square miles on the two-inch scale in sheet $83\frac{M}{2}$; No. 3 Camp under Mr. P. C. Mitra, with nine surveyors and one pupil surveyor surveyed 676 square miles on the one-inch scale and 67 square miles on the two-inch scale in sheets $83\frac{I}{8, 11, 12, 14, 15}$; the total results thus achieved being 1,747 square miles on the one-inch scale and 132 square miles on the two-inch scale, the latter area consisting of reserved forests only.

The cost-rates per square mile for one-inch and two-inch plane-tabling are Rs. 25·8 and Rs. 97·1 respectively. The combined cost-rate per square mile for both scales of survey is Rs. 30·8.

Triangulation.—A little supplementary triangulation was carried out by Mr. Pramadaranjan Ray, R. S. to provide points for the connection of traverses. Six stations were observed at and four new stations fixed. No area can be given. The cost is Rs. 1,722.

Traversing.—More than three-fourths of the area traversed is low-lying and very densely wooded, the remaining portion consisting of cultivation and tea gardens. The work was under Mr. E. G. Hardinge with one Sub-Assistant Superintendent, for three months, seven traversers and covered an area of 1, 111 square miles in sheets $83\frac{M}{6, 7, 10, 11}$ and portions of sheets $83\frac{M}{5, 8, 9}$ in which detail survey will be carried out in the winter of 1917-18. A total of 466 linear miles was traversed of which 38 linear miles consisted of the traversing of artificial boundaries of reserved forests. 4, 680 traverse stations were fixed of which 86 selected stations such as bench-marks, bridges, mile and revenue stones were permanently marked, in addition 175 zinc cylinders were embedded. The cost-rate per linear mile for 428 linear miles of traversing for one-inch survey and 38 linear miles of traversing of artificial boundaries is Rs. 73·8 and Rs. 64·7 respectively. The combined cost-rate per linear mile is Rs. 73·1. These abnormal cost-rates are due to the nature of the country traversed and to the fact that a senior Provincial officer was in charge of the traverse and computing sections. The cost-rate per square mile for 1, 111 square miles traversed is Rs. 30·7.

Recess Duties.—(*a*) The fair-mapping was divided into three sections as follows:—No. 1 Section under Mr. Pramadaranjan Ray, R. S., with one Sub-Assistant Superintendent, for three months, seven surveyors and one pupil surveyor carried out the fair-mapping of sheets $83\frac{I}{16}$, $\frac{J}{13}$, $\frac{M}{4}$ and $\frac{N}{1}$ for publication on the one-inch scale and of a portion of sheet $83\frac{F}{N. E}$ for publication on the half-inch scale; No. 2 Section under Mr. E. M. Kenny with six surveyors and one pupil surveyor fair-mapped sheets $83\frac{M}{2, 3}$ for publication on the one-inch scale and portions of sheets $84\frac{O}{N. W., N. E.}$ for publication on the half-inch scale; the work of this section was taken over by Mr. E. G. Hardinge on the 1st September 1917, when Mr. E. M. Kenny proceeded on privilege leave for 21 days on the expiration of which he was transferred to the office of the Superintendent, Eastern Circle for recruitment duty at Hazāribāgh; No. 3 Section under Mr. P. C. Mitra with four surveyors and one pupil surveyor was allotted the fair-mapping of sheets $83\frac{I}{15, 16}$ for publication on the one-inch scale, but, owing to the necessity of his having to proceed on privilege leave very early in the recess season, the work of this section was taken over in April and supervised by Mr. Pramadaranjan Ray, R. S. in addition to his own duties. Mr. P. C. Mitra was again with the party for one week after his return from privilege leave, and was then transferred to No. 5 Drawing Office where he remained until the end of the survey year.

With the exception of 21 square miles surveyed on the one-inch scale in sheet 83 $\frac{N}{1}$, and 132 square miles surveyed on the two-inch scale which were transferred to the fair sheets from enlarged and reduced traces on the scale of 1½ inches to 1 mile, the fair-drawing was done on blue prints for direct mapping.

The out-turn of fair-mapping for publication on the one-inch scale comprises sheets 83 $\frac{I}{12, 15, 16}$, $\frac{J}{13}$, $\frac{M}{2, 3, 4}$; of these, sheets 83 $\frac{I}{15, 16}$, $\frac{M}{4}$ were submitted for publication before the close of the survey year and the remaining sheets will be completed before the party takes the field. In addition to the above, sheets 83 $\frac{J}{2, 5, 6, 9}$ of the previous season have been submitted for publication during the year under report.

For publication on the half-inch scale the fair-mapping of portions of sheets 83 $\frac{F}{N. E.}$, 84 $\frac{O}{N. W., N. E.}$ is in hand at the end of the survey year and of which a proportion has been estimated for purposes of out-turn in square miles. The total area fair-mapped is 4,253 square miles, consisting of 2,731 square miles for publication on the one-inch scale and 1,522 square miles for publication on the half-inch scale at a cost per square mile of Rs. 8·7 and Rs. 1·6 respectively. The combined cost-rate of fair-mapping per square mile for both scales is Rs. 6·2.

Sheets 83 $\frac{I}{8, 11, 14}$, which were only surveyed in part during the year under report were not fair-drawn during this recess. The survey of these three sheets will be completed in the winter of 1918-19, and the fair-mapping taken up during the following recess.

(*b*). Mr. E. G. Hardinge with one Sub-Assistant Superintendent, for three months, and six traversers and computers completed the computations of advance traversing for detail survey in 1917-18 and the preparation of four-inch plots of traverses of artificial boundaries of reserved forests which have been supplied to the Forest Department.

Miscellaneous.—A question affecting the fair-mapping of the recess season was the unsettled condition of most of the administrative boundaries dealt with during the year under report. These are under reference to the local authorities and decisions are expected in all cases at an early date. Existing notifications and rulings are often conflicting and cannot be followed out as against the detail given in modern surveys due to their having been based on older surveys and maps. Owing to the difficulty referred to, steps are being taken to have all boundaries coming under survey in the future finally settled in the field. This will save delay and trouble in recess in dealing with the boundaries when they are being fair-drawn.

Inspections.— The Superintendent, Eastern Circle inspected the party in the field in March 1917 and several times during recess.

TABLE I.

OUT-TURNS OF PLANE-TABLING 1916-17.

Scale.	Class of Survey	Circle.	Party.	Locality.	Out-turn, square miles. Total.	Out-turn, square miles. Average per man per month of 24 working days.	Average number of fixings per square mile. In situ (by resection).	Average number of fixings per square mile. Plane-table traverse.
½-inch .	Original Survey .	N	No. 2	Rājputāna ...	1,622	84·0	6·0	
		S	No. 6	Hyderābād ...	5,045	74·3	5·2	
		E	No. 10	Upper Burma ...	2,140	39·9	1·6	1·3
1-inch .	Original Survey .	N	No. 1	Jammu and Chamba States ...	2,677	28·3	7·0	
		N	No. 2	Punjab & Rājputāna	1,092	42·0	13·0	
		N	Tank Det.	Wazīristān ...	297	93·0	5·2	
		S	No. 5	Berār and Central Provinces ...	274	28·0	9·6	
		S	No. 6	Bombay and Hyderābād ...	1,857	26·9	10·1	
		S	No. 7	Madras ...	3,108	28·9	8·4	2·7
		S	No. 8	Madras ...	293	12·8	4·1	9·2
		E	No. 9	Bengal ...	1,362	30·4	10·2	8·0
				Bihār and Orissa	319	10·5	17·8	6·0
		E	No. 10	Upper Burma ...	1,238	13·9	2·6	12·8
		E	No 11	Lower Burma ...	2,213	20·2	2·2	8·0
		E	No. 12	Assam ...	1,747	22·3	0·4	17·0
1-inch .	Resurvey .	N	No. 1	Punjab ...	1,056	29·1	16·0	
		N	No. 3	United Provinces and Punjab ...	2,619	28·1	16·0	
		N	No. 4	United Provinces ...	1,329	25·6	9·8	16·1
1-inch .	Revision Survey .	N	No. 2	Punjab & Rājputāna	199	32·0	14·0	
		S	No. 5	Berār ...	557	43·7	3·2	
		E	No. 10	Upper Burma ...	16	19·2	1·3	2·7
		E	No. 11	Lower and Upper Burma ...	318	25·1	3·1	7·5
1-inch .	Supplementary Survey .	N	No. 1	Punjab ...	278	25·5	10·0	
		S	No. 7	Madras ...	24	48·3	6·8	
1½-inch .	Original Survey .	N	No. 2	Rājputāna ...	4	12·0	26·0	
1½-inch .	Resurvey .	S	No. 6	Hyderābād ...	431	13·5	15·0	2·4

TABLE 1.—*Concluded.*

OUT-TURNS OF PLANE-TABLING 1916-17.—*Concluded.*

Scale.	Class of Survey.	Circle.	Party.	Locality.	Out-turn, square miles. Total.	Out-turn, square miles. Average per man per month of 24 working days.	Average number of fixings per square mile. *In situ* (by resection).	Average number of fixings per square mile. Plane-table traverse.
2-inch .	Original Survey .	N	No. 3	United Provinces ...	11	8·2	14·0	
		S	No. 7	Madras ...	65	12·4	29·5	
		E	No. 10	Upper Burma ...	60	5·5	3·9	19·8
		E	No. 11	Upper Burma ...	178	14·0	9·1	7·4
		E	No. 12	Assam ...	132	6·3	...	58·3
3-inch .	Original Survey .	N	No. 3	Punjab ...	56	6·7	67·0	
3-inch .	Supplementary Survey .	N	No. 3	Punjab ...	56	39·4	10·0	
4-inch .	Original Survey .	S	No. 7	Madras ...	115	3·5	19·3	77·1
4-inch .	Original Survey (Military)	N	No. 1	North-west Frontier Province ...	208	6·7	63·0	
4-inch .	Original Survey (Special Forest) .	N	No. 3	United Provinces ...	118	3·6	65·0	
4-inch .	Revision Survey .	N	No. 2	Delhi Province ...	64	6·0	75·0	
4-inch .	Supplementary Survey (Special Forest) .	N	No. 3	United Provinces ...	3	6·0	39·0	
16-inch.	Original Survey .	S	No. 20	Chitrāl, Drosh, Ghairat, Chaman, Deoli, Draginda, Jandola, Jatta and Zām Cantonments ...	acres 23,859 (16-inch, both entries)	acres. 295·9 (16-inch, both entries)		
16-inch.	Resurvey	S	No. 20	Rāwalpindi, Jhelum, Siālkot, Topa, Dharmsāla, Jhānsi, Neemuch, Nasirābād and Ahmadnagar Cantonments				
64-inch.	Original Survey .	S	No. 20	Deoli Cantonment	630 (64-inch, both entries)	21·6 (64-inch, both entries)		
64-inch.	Resurvey .	S	No. 20	Rāwalpindi, Jhelum, Siālkot, Topa, Jhānsi, Neemuch, Narsirābād and Ahmadnagar Cantonments ...				

TABLE II.

DETAILS OF TRIANGULATION AND TRAVERSING, 1916-17.

Scale.	Class of Survey.	Circle.	Party.	Locality.	TRIANGULATION									TRAVERSING				
									Stations.			Intersected Points.						
					Diameter of theodolite in inches.	Area in square miles.	Number of square miles to each point trigonometrically fixed.	Number of square miles to each height.	Number of stations fixed.	Triangular error in seconds.	Linear error per mile in feet.	Number of intersected points fixed.	Linear error per mile in feet.	Area in square miles.	Linear miles chaining.	Number of stations at which theodolite was set up.	Angular error per station in seconds.	Linear error per 1,000.
4-inch	Military Survey	N	No. 1	North-West Frontier Province	6	20	0·8	0·8	3	4	0·04	21	3·20	150	66	182	16	1·8
½-inch	Original Survey	N	No. 2	Bharatpur and Alwar States	6 & 5	...	...	...	...	...	...	...	...	...	131	495	3·6	·96
½-inch	Ditto	N	No. 2	Jaipur and Alwar States	6	830	7·0	7·2	15	6·1	·4	103	·77	...	...	...	...	...
1-inch	Original Survey and Revision Survey.	N	No. 2	Patiāla and Alwar States	6	120	7·1	7·1	2	15·5	·11	15	·45	...	...	...	...	...
4-inch	Imperial Delhi Revision Survey.	N	No. 2	Delhi Province	5	...	...	...	...	...	...	...	...	...	59	174	1·7	·83
1-inch	Resurvey	N	No. 3	United Provinces	5	...	...	...	...	...	...	...	...	...	235	931	3·9	2·8
2-inch	Original Survey	N	No. 3	Ditto.	6 & 5	1,493	0·7(a)	0·7(a)	79	8·1	0·23	1,940	0·45	...	...	...	...	...
4-inch	Special Forest Survey	N	No. 3	Ditto.	6	95	0·3	0·3	29	10·0	0·21	300	1·70	...	...	...	...	...
4-inch	Ditto	N	No. 3	Ditto.	5	...	...	...	...	...	...	...	...	...	353	5,255	5·4	6·7
1-inch	Original Survey	S	No. 5	Central India and Central Provinces	6	412	12·5 (a)	12·5 (a)	4	5·0	0·06	29	(b)	...	...	...	...	...

(a) Additional points previously fixed will also be used in this area.
(b) Computations not completed.

TABLE II.—*Concluded.*

DETAILS OF TRIANGULATION AND TRAVERSING, 1916-17.—*Concluded.*

Scale.	Class of Survey.	Circle.	Party.	Locality.	TRIANGULATION.									TRAVERSING.				
					Diameter of theodolite in inches.	Area in square miles.	Number of square miles to each point trigonometrically fixed.	Number of square miles to each height.	STATIONS.			INTERSECTED POINTS.		Area in square miles.	Linear miles chaining.	Number of stations at which theodolite was set up.	Angular error per station in seconds.	Linear error per 1,000.
									Number of stations fixed.	Triangular error in seconds.	Linear error per mile in feet.	Number of intersected points fixed.	Linear error per mile in feet.					
½-inch, 1-inch and 1½-inch.	Original Survey .	S	No. 6	Bombay, Hyderābād and Madras.	5 & 6	13,280	(*b*)	(*b*)	(*b*)	(*b*)	(*b*)	(*b*)	(*b*)	...	...	...	...	...
1-inch and 2-inch.	Ditto .	S	No. 7	Madras .	6	6,994	(*b*)	(*b*)	130	7·2	0·17	(*b*)	(*b*)	...	132	911	3·5	1·2
1-inch .	Ditto .	S	No. 8	Do. .	6	1,630	8·3(*a*)	8·3(*a*)	47	5·7	0·10	150	0·40	928	258	867	4·2	1·0
16-inch .	Original Survey and Resurvey	S	No. 20	Rāwalpindi, Chitrāl, Drosh, Ghairat, Dharmsāla, Jhānsi, Deoli, Nasīrābād, Ahmadnagar, Drazinda, Jandola, Jatta and Zām Cantonments.	6	518	23·6	23·6	18	9·0	0·28	4	0·40	31	294	2,626	7·5	1·0
½-inch .	Original Survey .	E	No. 10	Upper Burma .	6	3,672	12·0	12·2	13	7·3	0·16	341	0·48	...	...	...	...	...
1-inch .	Ditto .	E	No. 10	Ditto .	6	1,080	9·2	9·3	8	8·0	0·14	109	0·41	...	...	...	...	...
1-inch .	Ditto .	E	No. 11	Lower Burma .	6	4,075	7·6	7·9	24	19·6	0·29	511	0·72	...	...	...	..	...
1-inch and 2-inch .	Triangulation .	E	No. 12	Assam .	6	not available	...	...	4	6	·03	...	...	...	...	...	...	...
1-inch and 2-inch.	Traversing .	E	No. 12	Ditto .	5 & 6	...	..	...	...	...	...	...	...	1,111	466	4,680	2·4	1·9

(*a*) Additional points, previously fixed, will also be used in this area.
(*b*) Computations not completed.

TABLE III.

COST-RATES OF SURVEY 1916-17.

rty.	Locality.	COST-RATES, RUPEES, PLANE-TABLING, PER SQUARE MILE.														COST-RATES, RUPEES.				Total plane-tabling out-turns on all scales, square miles.	Total cost of party.	Remarks.
		¼-inch original survey.	1-inch original survey.	1-inch resurvey.	1-inch revision survey.	1-inch supplementary survey.	1½-inch original survey.	1½-inch resurvey.	2-inch original survey.	3-inch original and supplementary survey.	4-inch original survey.	4-inch original and supplementary survey.	4-inch revision survey.	16-inch original survey.	64-inch original survey.	Triangulation per square mile.	Traversing per linear mile. Topographical.	Traversing per linear mile. Forest boundary.	Fair-mapping, per square mile.		Rs.	
o. 1	Kashmir, Jammu and Chamba States, Punjab and N.W.F. Province.	...	23·5	5·6	...	13·7	...	...	...	...	62·9	...	...	...	...	27·1	15·5	...	6·0(*a*)	4,219	1,02,700(*b*)	(*a*) Represents average on all scales. (*b*) Excludes Rs. 158 debited to Tharoch State.
o. 2	Punjab and Rājputāna	6·5	10·4	...	14·0	...	13·0	...	...	...	...	...	108·6	...	...	5·7	22·3	20·3(*c*)	5·4(*a*)	2,981	67,568(*d*)	(*c*) Work done on Imperial Delhi 4″ boundary. (*d*) Excludes Rs. 85 debited to the Executive Engineer Lower Bari Doab Canal.
o. 3	United Provinces and Punjab.	...	...	13·8	...	...	...	...	14·0	14·1	...	80·6	...	...	...	14·4(*e*)	17·8	37·9	16·8(*a*)	2,863	84,020(*f*)	(*e*) Additional points previously fixed will also be used. (*f*) Excludes a sum of Rs. 25,170 debited to Forest Department and Rs. 1,969 debited to the Settlement Officer, Gorakhpur.
o. 4	United Provinces ...	...	...	11·9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2·4(*g*)	1,329	41,987	(*g*) Based on mapping for publication on 1″ and ½″ scales and on compilation of village boundary editions.
ānk Dett.	Wazīristān ...	...	22·7	...	...	...	...	...	...	...	...	...	...	...	..	..	...	...	...	297	6,745	
o. 5	Berār, Central India and Central Provinces.	...	13·4	...	12·1	...	...	...	...	...	...	...	...	...	...	3·2(*e*)	...	...	1·2(*h*) 3·3(*i*)	831	39,082	(*h*) For ½-inch. (*i*) For 1-inch.
o. 6	Bombay, Hyderābād and Madras	4·4	10·3	...	...	...	...	30·6	...	...	...	...	...	...	...	2·8	...	...	1·8(*j*) 2·0(*k*) 8·0(*l*)	7,333	1,08,784	(*j*) For ½-inch. (*k*) For 1-inch. (*l*) For 2-inch.

TABLE III.—*Concluded.*

COST-RATES OF SURVEY 1916-17.—*Concluded.*

COST-RATES, RUPEES, PLANE-TABLING, PER SQUARE MILE.														COST-RATES, RUPEES.						
															TRAVERSING PER LINEAR MILE.					
½-inch original survey.	1-inch original survey.	1-inch resurvey.	1-inch revision survey.	1-inch supplementary survey.	1½-inch original survey.	1½-inch resurvey.	2-inch original survey.	3-inch original and supplementary survey.	4-inch original survey.	4-inch original and supplementary survey.	4-inch revision survey.	16-inch original survey.	64-inch original survey.	Triangulation per square mile.	Topographical.	Forest boundary.	Fair-mapping, per square mile.	Total plane-tabling out-turns on all scales, square miles.	Total cost of party. Rs.	REMARKS.
...	7·4	...	...	2·3	...	...	34·6	...	93·6	...	...	...	...	5·3*	...	28·0	8·8	3,312	1,05,009	
...	62·2	...	...	...	...	...	...	...	...	...	...	...	...	4·4*	9·6	...	3·9	293	50,105	
...	...	...	...	...	...	...	...	...	...	...	...	1·1(*m*)	10·1 (*m*)	9·9	29·4	...	0·3(*n*) 3·2(*o*)	24,489 (*m*)	53,809	(*m*) These entries refer to acres. (*n*) Per acre for 16-inch. (*o*) Per acre for 64-inch.
...	15·8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4·7	1,681	63,568	The area surveyed in Bihar and Orissa has not been mapped.
19·6	39·0	...	21·2	...	...	...	101·0	...	...	...	...	...	...	2·2(*p*) 6·4(*q*)	...	...	3·8(*p*) 7·6(*q*)	3,454	1,36,499	(*p*) For ½-inch. (*q*) For 1-inch.
...	47·3	...	18·8	...	...	...	52·7	...	...	...	...	...	...	5·0	...	...	6·0(*r*) 1·8(*s*) 1·2(*t*)	2,709	1,72,244	(*r*) For 1-inch. (*s*) For ½-inch. (*t*) For ¼-inch.
...	25·8	...	...	...	...	...	97·1	...	...	...	...	...	...	(*u*)	73·8	64·7	6·2	1.879	1,19,919 (*v*)	(*u*) Total cost Rs. 1,722 of supplementary triangulation for which no area can be given. (*v*) Does not include Rs. 1,548 being cost of 430 blankets purchased in 1916-17 but for use in 1917-18.

* Additional points, previously fixed, will also be used.

PART II.—GEODETIC AND SCIENTIFIC OPERATIONS.

TRIGONOMETRICAL SURVEY.

ASTRONOMICAL LATITUDES

PERSONNEL of No. 13 PARTY.

Imperial Officers.

Major H. H. Turner, R. E., in charge 1st October to 9th November 1916.

Major H. McC. Cowie, R. E., in charge 10th November 1916 to 23rd February 1917 and 18th August to 30th September 1917.

From 24th February to 17th August 1917, the Superintendent of the Trigonometrical Survey held charge in addition to his other duties.

Lower Subordinate Service.

2 Computers.

As war conditions still prevailed during the year under report, no Latitude operations were undertaken and the personnel of the party was employed in the Head Quarters Offices.

The work of marking the Longitude Stations by inscribed tablets, which had been commenced in the previous year, was continued. Up to date, tablets have been placed in position at Agra, Akyab, Amritsar, Bangalore, Bellary, Bombay, Chittagong, Deesa, Fyzabad, Jalpaiguri, Jubbulpore, Karāchi, Mangalore, Multān and Nāgarkoil.

PENDULUM OPERATIONS.

PERSONNEL of No. 14 PARTY.

Imperial Officers.

Major H. McC. Cowie, R. E., in charge 10th November 1916 to 23rd February 1917 and 18th August to 30th September 1917.

From 1st October to 9th November 1916 and 24th February to 17th August 1917, the Superintendent of the Trigonometrical Survey held charge in addition to his other duties.

Lower Subordinate Service.

2 Computers.

As no officer was available during the year, pendulum operations were in abeyance and the personnel of the party was employed in the Head Quarters Offices.

TRIANGULATION.

By H. G. Shaw.

Personnel of No. 15 Party.

Imperial Officer.

J. de Graaff Hunter, Esq., M. A. in charge till 31st August 1917.

Provincial Officers.

Mr. H. G. Shaw, in charge from 1st September 1917.
„ L. Williams.
„ R. B. Mathur, B. A.

Upper Subordinate Service.

Mr. Jugal Behari Lal.

Lower Subordinate Service.

9 Computers, etc.

The programme of field work, (*vide Index Map No. 14*), during season 1916-17 consisted of:—

(1) The completion of the observations of the Madura Series.

(2) The reconnaissance, building and observation of a new series called the Bāgalkot Series.

(3) The reconnaissance and building of secondary stations of a new series called the Sind-Sāgar Doāb Series. The observations of the Madura Series were carried out by the officer in charge of the party and Mr. L. Williams, and it was arranged that Mr. Jugal Behari Lal, with a small detachment should reconnoitre and build the Bāgalkot Series, while the observations of the Madura Series were being completed.

Particulars of Triangulation out-turn during the Year.

		Madura Series.	Bāgalkot Series.
Number of stations observed at		12	14
„ „ „ newly fixed		8	10
„ „ „ „ built		...	10
Length of triangulation completed in miles		68	102
„ „ „ remaining to be done		...	...
Area of triangulation in square miles		781	1400
Number of triangles observed		10	13
„ „ astronomical azimuths observed		...	...
Maximum triangular error		4″·68	2″·17
Average „ „		1″·53	1″·02
Mean errors in closing on the South-East Coast Series and the Naldrug Series respectively.	in latitude	+0″·01	−0″·06
	„ longitude	−0″·09	−0″·09
	„ height	...	−0·5 foot
	„ azimuth	+3″·2	−1″·13
	„ log. side, the unit being the seventh place of decimals.	−205	−68
Value of m*		1·148	0·701
„ of M		1·53	0·83
Theodolite used		T. and S. 8-inch Micr. Nos. 1055 & 1311	T. and S. 8-inch Micr. No. 1311

The Madura Series (*96*).—The reconnaissance and building of this series, which connects the Great Arc and the South-East Coast Series, a little north of parallel of latitude 10°, had been completed in season 1911-12 (*vide* "Records" for that year).

The observations could not be taken up earlier as the stations at the eastern end of the series had to be built in the low-lying country near the coast and the whole area was covered with groves of palms and other large trees, which necessitated the use of special apparatus for raising the theodolite and also for signals over the station marks before the observations could be secured.

* *Vide* "Records of the Survey of India", Vol. IX, p. 137.

This apparatus, which consisted of a trestle by means of which the theodolite could be raised to a height of 65 feet, and four masts, each 100 feet high, was designed by Mr. J. de Graaff Hunter. The trestle and one mast had been made in anticipation of the present work. They are illustrated in "Records of the Survey of India" Volumes VII and V respectively. Another illustration showing the trestle and one mast in use at Kulamangalam station will be found facing page 47. Four masts were needed and the remaining three were constructed last year in the Trigonometrical Survey workshops at Dehra. The following account of the work in connection with the trestle and masts is taken *verbatim* from a report by Mr. J. de Graaff Hunter:—

"It was intended to make all observations at night on lamps, as opaque signals are not satisfactory at ranges over five miles: and for this purpose incandescent petrol lamps, nominally 70 C. P., were obtained, and arrangements made for hauling these up to the top of the masts. The possibility of fairly high winds had been overlooked in the preliminary trials at Dehra, where there is usually very little wind; and where the lamps were found to be sufficiently powerful to be picked up from ten miles distance with the unaided eye. The case, however, was very different at all the mast stations of the Madura Series, and very great difficulty was encountered in seeing the lamps even with the theodolite. Wind up to 30 miles an hour was the rule, and the lamps, which were not specially meant for outside work in the first place became extinguished: and later, with such protecting covers as could be contrived at short notice in the field, only showed a feeble light. As time progressed matters became worse rather than better, and it was found that ordinary hurricane lanterns gave better visibility during the later work. These were not nearly so bright as was desirable and difficulties of seeing were throughout very great. The masts themselves were found visible at times during daylight, but a good deal depended on the relative position of the sun, some showing up better in the evening and some better in the morning. One of the most important additions to the equipment is a lamp of some 30 C. P. which will burn satisfactorily in all weather likely to be experienced. An electric lamp would offer many advantages, as being reliable in these respects: but this would involve accumulators and a charging dynamo.

The stability of the masts in the wind was satisfactory and no serious changes of position were detected, though several check measurements were made in each case. The actual measurements of the relative positions of mast, lamp and station were troublesome, and indicate the desirability of (1) a satisfactory lamp which will not usually necessitate any day observations, (2) a fine adjustment for bringing the lamp precisely over the station mark—the only means available in the apparatus under discussion being the slacking of the several drums on the central main drum, which would not admit of a setting to nearer than a couple of inches; (3) an arrangement for the lamp to be on the axis of the mast, so that the mast would also be central over the station, in case observations were made to it. This would easily be managed with an electric lamp which would be fixed to the topmost section. An attempt was made to swing the petrol lamps into position vertically above the mast: but the swinging yard employed was difficult to manipulate—impossible for an ordinary lampman—and had to be abandoned in the field: and (4) some suitable attachment for day observations of vertical angles.

The wind also gave some trouble and anxiety as regards the trestle. As a result of this it was first deemed inadvisable to put up the *kanats* of the observatory tent because of the surface they would present to the wind. Later on confidence in the strength of the trestle to resist this pressure was established. It was found that the wind acting on the *kanats* caused less disturbance to the instrument than when the *kanats* were removed and the wind had access to the instrument and observer though the trestle was subjected to less disturbance. The stabilising arrangements proved on the whole satisfactory and the level of the instrument was fairly well maintained. A gust of wind would cause the whole trestle and with it the instrument to shudder but the instrument rapidly returned to rest and proved by its readings that it had not been disturbed. It would be quite easy to choose a time of freedom from tremor and make a good intersection if a clearly visible signal was observed. In the actual case, often the signal was changing from what could be just seen to what was too faint to see: and between the two observation was extremely difficult, and the illumination of the field had to be constantly varied. This latter was arranged by an electric torch held by the observer at varying distances from the transit axis of the instrument. Vertical angles can be observed satisfactorily by using the bent eyepiece, when the level readings can be made without changing position, immediately after the observation. The masts however were not suitable objects for intersection and were rarely visible at midday.

As regards the mechanical questions of erecting masts and trestle, no difficulties arose. Mr. Williams witnessed and assisted at the erection of the first mast at Pallathivayal and then proceeded to the other stations and erected the masts at each without any mishap. The erection of the trestle is a larger business, but with practice the khalāsis got to know their work and at the end of the time a mast could be erected to 100 feet in three hours from reaching the site and taken down and packed up in one and a half hours. The trestle took some six or seven hours to erect and three or four hours to take down and pack up. On one occasion it was successfully taken down at night: but it is much harder to keep an eye on all that needs attention at night.

For the work of erecting and dismantling masts and trestle one fitter and three carpenters were taken with the detachment: and a carpenter was usually left at each mast station when neither Mr. Williams nor myself was there.

No attempt was made to centre the masts or trestle precisely over the station marks. It would be undoubtedly convenient to have the mast over the station mark but no means of accurately doing so were available. It is probably best to set up the trestle at any conveniently adjacent point and so not to have to remove the mast and reerect after finishing observations. The correction for satellite stations is easy enough to make, though the details of the necessary measurements might be improved. It is to be observed that when one is on the trestle, points near the base of the trestle cannot conveniently be viewed by the telescope as the structure of the trestle and the observatory tent block the view. Something was done by removing some of the floor boards and looking through these spaces. Again when observing on ground level no station from which to take the azimuth is visible. The plan generally adopted was to put in two pegs on the direction of each of the stations, these pegs being upwards of 100 feet distant from the trestle on both sides, and so visible without much preliminary difficulty from the instrument. The length of the perpendiculars from the station mark on the lines joining the two pegs was then measured by tape.

The masts and lamps were transferred to ground level by means of 3-inch theodolites set up in two positions nearly at right angles. This was found to be a tedious business: and though perfectly straightforward, was often made troublesome owing to rays near the ground being obscured by small bushes etc.

The original trestle was made for a 12-inch theodolite, and to adapt it for an 8-inch theodolite the table had to be raised. This was done by placing on it the top of a theodolite stand fitted with three short feet, making the height some 4 inches greater. Little thought was given to this, which was done at the last moment before leaving for the field. When the results of the measurements of the angles in the field were obtained, and three triangles as well as measures of compound angles became available, it was found that a systematic negative error existed in all the angles. Luckily this was noticed before the work at the last station was completed: and its cause was attributed to this rather unsatisfactory means of raising the instrument. Accordingly the theodolite table and this addition were set up at ground level and a set of measurements made to determine whether there was any yielding in this member. The results showed that there undoubtedly was, and gave a measure of its amount. This can easily be avoided in future work and certainly should be.

Owing to the difficulties of observation it was customary to observe as follows:—

(1). Intersect first station A with tangent screw.
(2). Unclamp and swing round.
(3). Clamp and use slow motion to intersect B.
(4). Without unclamping make a second setting on B.
(5). Unclamp and swing round.
(6). Clamp and intersect A.

It will be seen that in processes (2) and (5) some force was applied (depending on the stiffness of the instrument on its vertical axis) which tended to pull the stand round. Under this force it would swing by say a'' of arc. Process (3) would not interfere with this and so the angle (1) (3) would be too small by a''. Similarly the angle (4) (6), for the force is always in the direction to reduce the angle. If, however, a second angle B C was measured, it is presumed that no further twist will take place. But on swinging back the error would occur in CB but not in BA. Accordingly the correction for all angles measured singly is $+ a''$ and for all angles measured in pairs the mean correction is $\frac{a''}{2}$: and so on. This correction was duly applied. In addition the angles had to be corrected for the distances of the masts and trestle from the stations. Finally the following results were obtained:—

Triangle.		Final value of observed angle.			Prob. error of each angle.	Triangular error.
		°	′	″	″	″
Puram	Trs. S.	58	34	29·27	±0·70	− 1·54
Annavasal	H. S.	36	18	38·85	±0·58	
Chettyapatty	Trs. S.	85	6	51·18	±1·39	
Puram	Trs. S.	68	39	58·21	±0·95	−4·68
Chettyapatty	Trs. S.	61	52	16·10	±1·30	
Kulamangalam	Trs. S.	49	27	41·63	±1·63	
Puram	Trs. S.	42	40	45·70	±0·66	+ 2·15
Kulamangalam	Trs. S.	79	11	8·14	±1·27	
Pallathivayal	Trs. S.	58	8	8·93	±0·62	

The probable errors were worked out for each angle and are given above. They lead to probable triangular errors less than those actually obtained, and perhaps some further mechanical source of systematic error is still undetected. The experience gained encourages confidence in the stability of the masts. In the light of the experience gained in the five weeks of observation, several simple improvements in the system can be made. The closing errors of the circuits have already been given".

During the month of December Mr. Williams was employed in helping with the erection of the masts at the various stations. As soon as the four eastern stations, at which the trestle and masts were used, were observed, Mr. Williams continued the observations at the remaining stations of the Series. Owing to a good deal of rainy weather which interfered with the helios, resort had to be made in many cases to observation on lamps but the work was carried on expeditiously to its junction with the Great Arc by the first week of February 1917.

The final connection proved very satisfactory and the triangular and linear errors of the work, including that done at the stations where the trestle and masts were used, proved no larger than the average for this class of work. A satisfactory connection for the heights was not, however, made, as the observations of the vertical angles at two or three of the eastern stations of the series gave discrepant results, due, most probably, to the indistinctness of the masts during the hours at which vertical angles are observed. It has been proposed that some supplementary levelling between Pallathivayal and Puram Stations should be carried out at a future date to establish the connection for the heights and throw some light on the discrepancies found.

The Bāgalkot Series (97).— This series connects the Mangalore Meridional with the Naldrug Series and is on the parallel 16°.

The building of the stations had been completed early in February. Mr. Williams reached Bāgalkot, from Madura, by the 15th of that month, but owing to the unavoidable delay in getting up the equipment by rail, he was not able to start work before the 22nd February. From this date, however, the observations were pushed on rapidly and the series carried to its junction with the Naldrug Series by the 3rd April 1917.

The final connection and the general accuracy of the work proved very satisfactory. The mean triangular errors of this series and of that portion of the Madura Series which was independent of the trestle stations were 1″·03 and 0″·99 respectively: proving the observation work in both cases to be of a high order of excellence, in consideration of the facts that an 8-inch theodolite was used and that the programme was arranged as for secondary triangulation, and the work carried out with corresponding despatch. The values of M obtained place the series between 38 and 39 in order of merit in the series of the Indian triangulations.

Astronomical Latitude of Robat.—During the recess the observations for Latitude taken at Robat S. of the *Kalāt Longitudinal Series* in 1907-08 were reduced. The observations were carried out with T. and S. 12-inch theodolite No. II and the latitude was computed from the observed circum-meridian zenith distances.

The results proved very satisfactory, the probable error of the mean being 0″·142 and that of a single observation 2″·18. The final value of the latitude shows a southerly deflection of 10″·41. The result is of especial value owing to the fact that no other values of the deflection in the meridian in this neighbourhood have been determined. This is an example of the value of astronomical observations by the triangulation party in outlying districts where the astronomical party is unlikely to follow for many years. Such results, while slightly inferior in probable accuracy to those obtained with the zenith telescope using the Talcott method, are accurate enough for most geodetic uses to which they can at present be put. Observations of this kind, even with a curtailed programme, may be most useful and it is much to be regretted that they have not been made more frequently.

The Sind-Sāgar Doāb Series.— Mr. Mathur was in charge of No. 1 and Mr. Abdul Karim of No. 2 detachment.

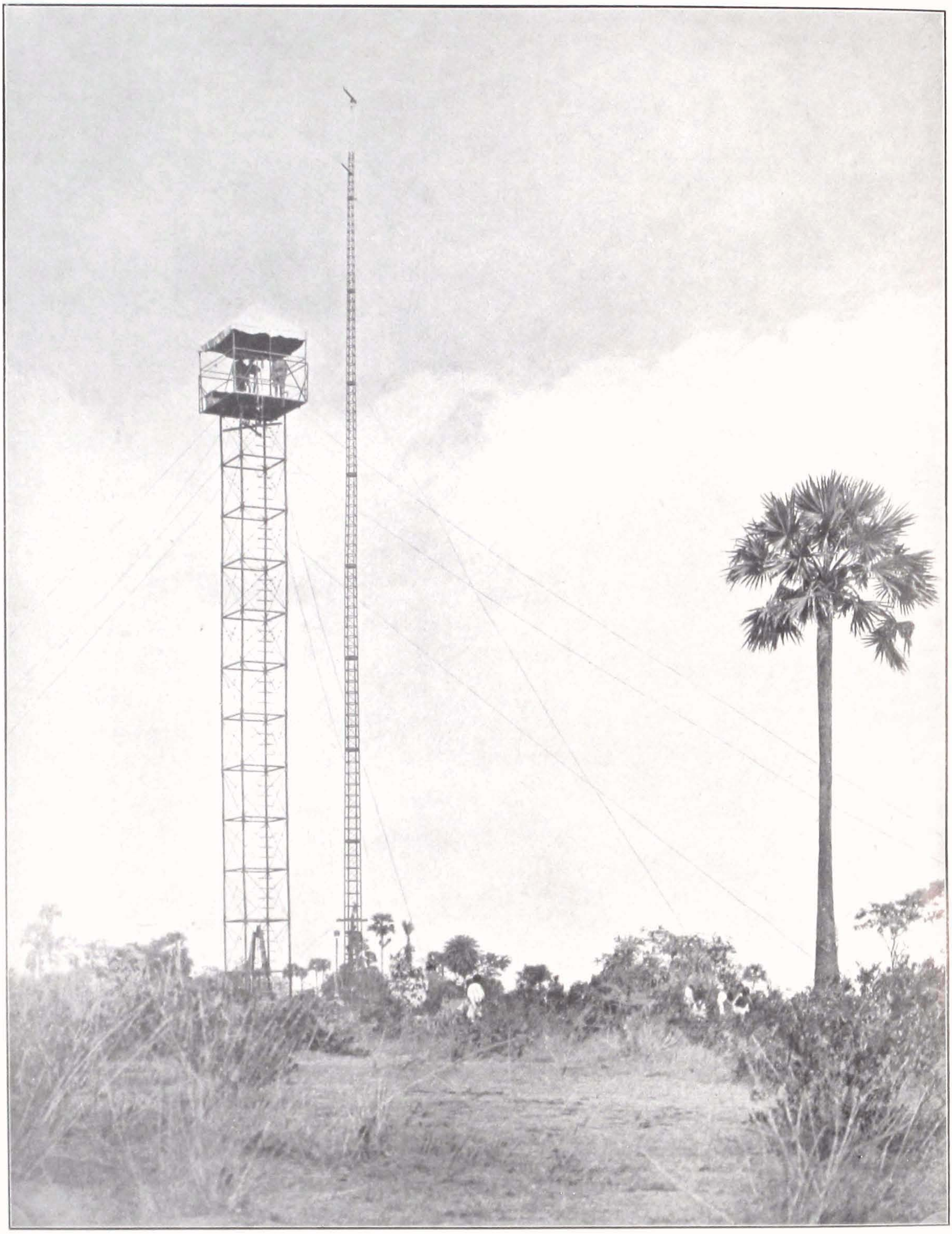
The detachments left for the field on the 13th January 1917 and started work on the 23rd of that month from Bhakkar, a *tahsīl* in Miānwāli district. As the time at disposal was very limited, no observations were undertaken and the work was confined to reconnaissance and pillar-building. Fifty-one secondary stations were prepared, and 6 tower stations, having connection with the extension of the work, were thoroughly repaired. The side Ahmad Sindi T. S. — Miāni T. S. of the Great Indus Series was made the starting point of the triangulation. From this base the series was run for a distance of about 30 miles towards the east, whence it branched off into two arms one running towards Miānwāli and the other towards Khushāb. The portion to Miānwāli traversed a distance of about 50 miles and the one to Khushāb about 45 miles. After the completion of these two portions, the work was continued S. W. towards Leiah, and joined on to the base Muhammad Shāh T. S. — Shāhpur T.S. of the Great Indus Series. The length of this extended portion is about 70 miles.

The work kept the detachment engaged till the 17th April 1917, when it closed field work at Leiah and returned to Dehra Dūn. The work was greatly hampered by sudden and violent sand storms.

The secondary stations are built of *pakka* brick masonry, they are 3 feet 4 inches square, and from 1½ to 3 feet deep, only 6 inches being above the ground surface. Brick slabs 9 inches square, and bearing the inscription G.T.S. ⊙, which were specially made before the detachments left Dehra Dūn, have been embedded in each of these pillars, one at the bottom and the other at the top. The stations are about 7 miles apart on an average, and as the tract is almost flat, it will be necessary next year to use sufficiently tall signals while observations are being taken.

The area within the above reconnaissance is sandy, thinly populated, with scanty supplies, gram being its chief product. Its climate is fairly good. It is almost treeless except near the railway line in the S. W. where wells are numerous. Portions of the tract interspersed with groups of such wells are locally termed *daggar*. Owing to the abundance of high trees near these wells, great difficulty was experienced in effecting a connection to the tower stations, otherwise very little ray-clearing had to be resorted to. The main transport is by camels, but occasionally donkeys and bullocks are available. The people generally are willing and helpful. The water is brackish to a certain extent.

No. 19 Party was also employed on triangulation. Particulars will be found on p. 85.



Kulamangalam Station, Madura Series, 1916-17.

Height of instrument 67 feet. Height of signal 100 feet.

From a photograph taken by J.de Graaff Hunter, M.A.

TIDAL OPERATIONS.

BY SYED ZILLE HASNAIN.

PERSONNEL OF NO. 16 PARTY.

Provincial Officers.

Mr. Syed Aulad Hossein, K. B., in charge till 8th November 1916.
" O. C. Ollenbach, in charge from 9th November 1916 to 10th September 1917.
" Syed Zille Hasnain, in charge from 11th September 1917.

Lower Subordinate Service.

20 Computers, etc.

During the year under report the registration of the tides by self-registering tide-gauges was carried out at the ports of Aden, Karāchi, Appollo Bandar (Bombay), Prince's Dock (Bombay), Madras, Kidderpore, Rangoon, Moulmein and Port Blair*. These operations were conducted under the direction of this department, the immediate control of all the tidal observatories being entrusted to the local officers of the ports concerned.

In addition to the above work, the predictions of the high and low water for the year 1916 at Bhaunagar, Chittagong and Akyab were compared against actual readings of the high and low water supplied by the Port Officers concerned. These readings were taken during day-light on tide-poles throughout the year. The object of the above comparisons was to see whether the predictions which were based on tidal observations taken some years ago still maintained the required degree of accuracy.

TIDAL OBSERVATIONS AT BASRAH.

An ordinary wooden tide-gauge was erected by the military authorities on the Shatt-al-Arab river at Basrah in connection with their own requirements. During the year 1915 readings of high and low water taken on this gauge daily, were supplied to this department by the General Staff, Basrah. The observations consisted of the heights of high and low water only, the times at which they were observed were not recorded. It was also not known whether the observations were taken during day-light only, or whether they were the highest and the lowest readings for the 24 hours. The observations, as they stood, were not of any practical use to this department. The matter was brought to the notice of the Chief of the General Staff, Basrah and it was suggested that if hourly readings of the tide-gauge were taken day and night continuously, it might be possible to discover something of the law of the tides at Basrah. This proposal was accepted and, in compliance therewith, hourly readings of the tide-gauge were regularly supplied to this department by the Director of Inland Water Transport, Basrah from the beginning of March 1916.

As soon as the readings for a whole year were available, they were reduced in the office of 16 Party (Tidal) at Dehra Dūn by the method of harmonic analysis and the constants thus deduced were used in the computation of data for a set of tide-tables for Basrah for 1917-18. These data were forwarded in April 1917 to the National Physical Laboratory Teddington, England, where tidal predictions were made from them with the aid of the tide-predicting machine lodged there. A set of the predictions were received from the Laboratory on 6th August 1917. With this material, tide-tables for Basrah from 1st September 1917 to end of December 1918 were printed at the office of the Trigonometrical Survey, Dehra Dūn and a supply of the same was despatched to the Director, Inland Water Transport, Basrah on 3rd September 1917.

LIST OF TIDAL STATIONS.

The following is a complete list of the ports at which tidal observations have been carried out from the commencement of the tidal operations in 1874 up to the present time. The permanent stations are shown in italics; the others are minor stations which were closed on the completion of the requisite registrations.

* *Vide* Index Map No. 14.

List of Tidal Stations.

Serial No.	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	1903	7	
2	Perim	„	1898	1902	5	
3	*Aden*	„	1879	Still Working	38	
4	Maskat	„	1893	1898	5	
5	Bushire	„	1892	1901	8	
6	*Karāchi*	„	{ 1868 { 1881	1880 Still Working	*13 } 37 } 50	* Small tide-gauge working.
7	Hanstal	„	1874	1875	1 }	Tide tables not published.
8	Navānar	„	1874	1875	1 }	
9	Okha Point ...	„	{ 1874 { Restarted { 1904	1875 1906	1 } } 2 1 }	Year 1904-05 is excluded.
10	Porbandar... ...	Personal	1893	1894	2	
10A	Porbandar... ...	Automatic	1898	1902	2	Years 1898, 1899 & 1902 are excluded.
11	Port Albert Victor ... (Kāthiāwār).	Personal	1881	1882	1	
11A	Port Albert Victor (Kāthiāwār).	Automatic	1900	1903	4	
12	Bhaunagar ...	„	1889	1894	5	
13	*Bombay (Apollo Bandar)*	„	1878	Still Working	39	
14	*Bombay (Prince's Dock)*	„	1888	„	29	
15	Marmagao (Goa) ...	„	1884	1889	5	
16	Kārwār	„	1878	1883	5	
17	Beypore	„	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	Pāmban Pass ...	„	1878	1882	4	
25	Negapatam ...	„	1881	1888	5	Years 1883 to 1885 are excluded
26	*Madras*	„	{ 1880 { Restarted { 1895	1890 Still Working	10 } } 32 22 }	
27	Cocanāda	„	1886	1891	5	
28	Vizagapatam ...	„	1879	1885	6	
29	False Point ...	„	1881	1885	4	
30	Dublat (Sāgar Island)...	„	1881	1886	5	
31	Diamond Harbour ...	„	1881	1886	5	
32	*Kidderpore* ...	„	1881	Still Working	36	
33	Chittagong ...	„	1886	1891	5	
34	Akyab	„	1887	1892	5	
35	Diamond Island ...	„	1895	1899	5	
36	Bassein (Burma) ...	„	1902	1903	2	
37	Elephant Point ...	„	{ 1880 { Restarted { 1884	1881 } } 1888 }	5	Year 1880-81 is excluded.
38	*Rangoon*	„	1880	Still Working	37	
39	Amherst	„	1880	1886	6	
40	*Moulmein*... ...	„	{ 1880 { Restarted { 1909	1886 Still Working	6 } } 14 8 }	
41	Mergui	„	1889	1894	5	
42	*Port Blair* ...	„	1880	Still Working	37	

Working of the Observatories.

The tidal observatories at Kidderpore, Rangoon, Moulmein, Port Blair and Madras were inspected by Mr. O. C. Ollenbach.

Mr. Syed Zille Hasnain inspected the Observatories at Karāchi, Bombay (Apollo Bandar), Bombay (Prince's Dock) and Aden. He also inspected the Kidderpore Observatory again when he went there to transfer the tide-gauge to the new observatory.

The inspection of each observatory was carried out rigorously, special attention being paid to the following points:—

(*a*) Checking the working zero of the tide-gauge and comparison of the same with the true zero.

(*b*) Testing the stability of the tide-gauge by check levelling between its bed plate and the bench-mark of reference.

(*c*) Testing the zero of the graduated staff with reference to the zero of the tide-gauge.

(*d*) Thoroughly cleaning and overhauling all the instruments and putting them in perfect working order.

(*e*) Final adjustment of the tide-gauge and the working zero after cleaning the whole apparatus.

(*f*) Examination and cleaning of the observatory well and the inlet holes and securing free communication between the sea and the well.

(*g*) General examination of the observatory cabin with the object of getting any repairs done, if necessary.

The following remarks regarding the working of each observatory may be added:—

Aden.—The working of this observatory has been far from satisfactory during the year under report. The tidal registrations were interrupted 25 times, for a few hours each time, owing to the stoppage of the driving clock, chiefly during bad weather.

The observatory clerks have been changed no less than five times during the year and on this account the work of the observatory has suffered a good deal. There have been frequent delays in the despatch of the tidal diagrams and daily reports to the office of the Tidal Party at Dehra Dūn. On one occasion no reports of any kind were received from the observatory for nearly three months and the enquiries made from the Chief Engineer of the port elicited no satisfactory explanation. When the inspecting officer visited the observatory in the middle of February 1917, he found all the tidal diagrams and reports from 16th November 1916 onwards lying there in an incomplete state. The matter was brought to the notice of the Chief Engineer who promised to make better arrangements for the working of the observatory in future. Detailed instructions to the observatory clerk regarding the completion and despatch of the reports and diagrams to Dehra Dūn were drawn up by the inspecting officer in consultation with the Chief Engineer. These documents have since been received with fair regularity, but errors and omissions have been found every now and again in the tidal diagrams, the correction and completion of which have thrown a good deal of extra work on the office of the Tidal Party.

Karāchi.—The tidal registrations of this observatory have been frequently disturbed during the past year owing to the communication between the sea and the tide-gauge well being wholly or partially blocked. These disturbances were very frequent between the beginning of December 1916 and the end of February 1917, having occurred 35 times during this period.

The inspecting officer visited the observatory early in March 1917 and on investigating the cause of the above defect, he found that a great deal of mud had accumulated both outside and inside of the well and this, combined with the small size of the inlet hole (½ inch in diameter), was the main cause of the trouble. The mud outside the well had come up to within an inch or two of the inlet hole, while inside the well it was more than 6 inches deep. The matter was at once reported to the Chief Engineer of the port who had the well thoroughly cleared of mud both from the inside and outside. The size of the inlet hole was increased from ½ to ¾ inch in diameter. Arrangements were also made to have the mud from outside of the well removed by a diver every two months in future, so that a clearance of about 3 feet between the bed of the sea and the level of the inlet hole may be constantly maintained. It was also arranged that the inlet hole should be examined and cleaned at least twice a week to guard against anything temporarily sticking in it. The tide-gauge has worked satisfactorily since the last inspection.

Bombay (Apollo Bandar).—This observatory has worked very well and no break has occurred in the registration of the tides during the past year.

Bombay (Prince's Dock).—During the past year there has been a marked improvement in the working of this observatory. The tidal registrations were stopped only twice, for a few hours each time, owing to the recording pencil having stuck in its slide. The improvement appears to be chiefly due to the care and attention paid to the tide-gauge by the new clerk who took charge of this observatory in October 1916.

Madras.—The tide-gauge at this observatory has worked well during the year under report. At the time of the inspection of the observatory it was found that water had got into the float. Similar defects were found in this float on previous inspections. It was therefore rejected and a new float of the old pattern was put in its place. The inlet hole in the cylinder was found to have been enlarged by action of the sea. It was reduced to its original size.

Kidderpore.—The work at this observatory has been carried out very satisfactorily during the past year. As mentioned in last year's report, the port authorities had decided to abandon the old observatory and build a new one in deeper water. The new observatory was expected to be ready in January 1917, but when the inspecting officer passed through Calcutta on his return from Rangoon on the 20th of that month, the building had hardly been commenced. The Deputy Conservator of the port reported in the middle of April 1917 that the new observatory was ready and he proposed that the tide-gauge should be shifted to it as soon as possible, owing to the possibility of a collapse of the old observatory during the coming freshets. Mr. Syed Zille Hasnain therefore went to Calcutta at once. He arrived there on 21st April 1917 and found that the new observatory was practically ready, but the float cylinder from the old observatory had to be removed and fixed in the new one before the tide-gauge could be installed. This was done and the tidal registrations were started in the new observatory on the afternoon of 24th April 1917.

The new observatory has been built about 30 feet N.E. of the old observatory, alongside of the iron jetty, 2½ feet away from the jetty and connected with it by means of a swing gangway. It is larger and in every way much better than the old building.

The new graduated staff has been fixed on one of the iron piles of the jetty on the east side of the observatory in such a position that it can be easily read from inside the cabin.

Rangoon.—The tide-gauge at this observatory has, as usual, worked very satisfactorily during the past year. At the time of the inspection the supporting piles on the south side of the cabin were found to need attention and the chain on either side of the bridge required to be lifted up. The Deputy Conservator of the port was requested to do the needful.

Moulmein.—There have been six minor interruptions of a few hours each in the tidal registration at this observatory owing to the stoppage of the recording pencil. The tidal diagrams of this observatory showed signs of carelessness on the part of the observatory clerk: the curves were badly inked, the colouring was faulty and the general appearance of the diagrams was untidy. The clerk was warned by the inspecting officer to be more careful in the discharge of his duties in future.

Port Blair.—No breaks have occurred in the tidal registrations at this observatory and all details of the work have been carefully and satisfactorily carried out.

Computations and Reduction of Observations.

All the computations pertaining to the past year's work have been completed and there are no arrears. The tidal observations at the nine working stations for the year 1916 have been reduced by harmonic analysis. In addition, the readings taken at Basrah from March 1916 to March 1917, on a tide-gauge erected by the military authorities which were supplied to this department have been similarly treated.

The tidal constants deduced from the above reductions are shown in the attached tables.

These tables give the amplitudes (R) and the epochs (ξ) at the various stations; they also give the values of H and K which are connected with R and ξ through the various astronomical quantities involved in the positions of the sun and the moon, in such a way that if the tidal observations were consistent from year to year H and K would come out the same from each year's reductions.

1916

Tide symbol	ADEN				KARACHI				BOMBAY (Apollo Bandar)			
	$A_0 = 5·904$				$A_0 = 7·374$				$A_0 = 10·345$			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period		°		°		°		°		°		°
S_1	0·132	167·49	0·132	167·49	0·116	181·93	0·116	181·93	0·097	181·90	0·097	181·90
S_2	0·673	248·27	0·673	248·27	0·975	323·45	0·975	323·45	1·574	4·31	1·574	4·31
S_4	0·004	295·41	0·004	295·41	0·005	344·06	0·005	344·06	0·023	211·05	0·023	211·05
S_6	0·005	217·09	0·005	217·09	0·008	289·60	0·008	289·60	0·006	145·24	0·006	145·24
S_8	0·001	333·44	0·001	333·44	0·001	32·47	0·001	32·47	0·002	352·57	0·002	352·57
M_1	0·098	111·31	0·071	23·36	0·098	129·21	0·072	41·99	0·094	137.64	0·068	50·62
M_2	1·525	132·51	1·554	230·46	2·570	194·97	2·618	294·41	3·924	231·49	3·998	331·32
M_3	0·020	61·58	0·020	208·50	0·036	177·88	0·037	327·03	0·061	235·64	0·063	25·39
M_4	0·007	106·78	0·007	302·68	0·023	131·48	0·024	330·35	0·095	114·98	0·098	314·64
M_6	0·007	64·20	0·008	358·05	0·042	265·90	0·044	204·21	0·019	107·68	0·020	47·18
M_8	0·001	238·00	0·001	269·79	0·006	234·21	0·007	271·95	0·009	311·26	0·010	350·59
O_1	0·733	140·56	0·661	38·75	0·745	147·01	0·672	46·74	0·731	148·75	0·659	48·90
K_1	1·392	199·31	1·304	36·09	1·420	209·39	1·330	46·11	1·492	209·21	1·398	45·91
K_2	0·198	28·01	0·170	242·14	0·284	103·00	0·244	317·02	0·453	139·14	0·389	353·12
P_1	0·404	218·14	0·404	28·45	0·400	229·39	0·400	39·75	0·412	230·73	0·412	411·12
J_1	0·147	255·48	0·133	61·53	0·139	267·72	0·126	72·91	0·157	269·45	0·143	74·41
Q_1	0·191	108·19	0·172	40·09	0.188	114·04	0·170	48·28	0·186	118·82	0·168	53·69
L_2	0·049	331·75	0·042	227·78	0·084	35·16	0·072	291·88	0·118	43·36	0·100	300·27
N_2	0·412	94·81	0·419	226·46	0·585	145·40	0·596	279·34	0·916	182·66	0·934	317·22
ν_2	0·049	135·76	0·050	296·08	0·065	173·28	0·066	335·78	0.098	224·21	0·100	27·29
μ_2	0·069	6·49	0·072	202·39	0·074	66·79	0·077	265·66	0·212	106·16	0·220	305·83
T_2	0·049	202·40	0·049	204·21	0·047	261·19	0·047	263·05	0·063	327·71	0·063	329·59
$(MS)_4$	0·003	65·23	0·003	163·17	0·032	219·88	0·033	319·31	0·087	294·01	0·089	33·84
$(2SM)_2$	0·028	209·36	0·028	111·41	0·023	185·38	0·023	85·95	0·035	198.75	0·036	98·92
$2N_2$	0·100	36·92	0·102	202·28	0·127	74·61	0·130	243·05	0·171	101·16	0·174	270·44
$(M_2N)_4$	0·012	12·64	0·012	242·25	0·025	121·00	0·026	354·38	0·005	13·74	0·005	248·12
$(M_2K_1)_3$	0·034	46·36	0·032	341·09	0·061	100·46	0·058	36·61	0·044	168·43	0·042	104·96
$(2M_2K_1)_3$	0·012	13·68	0·012	12·80	0·013	28·93	0·013	31·08	0·045	79·30	0·044	82·26
Long Period		°		°		°		°		°		°
Mm	0·028	36·52	0·030	2·81	0·045	317·68	0·048	283·18	0·057	276·46	0·061	241·74
Mf	0·055	248·06	0·044	9·63	0·038	214·43	0·030	334·39	0·032	224·82	0·026	344·35
MSf	0·024	267·06	0·024	169·11	0·061	286·37	0·062	186·94	0·044	222.87	0·045	123·04
Sa	0·433	65·92	0·433	345·61	0·157	195·22	0·157	114·85	0·032	294·62	0·032	214·24
Ssa	0·160	292·21	0·160	131·60	0·142	349·16	0·142	188·43	0·161	11·70	0·161	210·93

1916.

Tide symbol	BOMBAY (Prince's Dock)				MADRAS				KIDDERPORE			
	A_0 = 8·404				A_0 = 2·401				A_0 = 10·804			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period		°		°		°		°		°		°
S_1	0·111	185·31	0·111	185·31	0·035	81·32	0·035	81·32	0·106	196·39	0·106	196·39
S_2	1·604	4·82	1·604	4·82	0·457	267·12	0·457	267·12	1·591	95·53	1·591	95·53
S_4	0·024	208·87	0·024	208·87	0·003	145·18	0·003	145·18	0·095	110·86	0·095	110·86
S_6	0·006	201·99	0·006	201·99	0·003	119·25	0·003	119·25	0·005	22·01	0·005	22·01
S_8	0·002	125·22	0·002	125·22	0·002	93·58	0·002	93·58	0·007	304·92	0·007	304·92
M_1	0·095	137·65	0·069	50·63	0·016	90·37	0·011	3·60	0·041	225·60	0·030	139·10
M_2	4·010	231·49	4·086	331·32	1·081	137·30	1·102	237·64	3·777	313·20	3·848	54·08
M_3	0·059	232·45	0·061	22·20	0·003	292·62	0·003	83·13	0·037	120·18	0·038	271·50
M_4	0·107	139·41	0·111	339·07	0·007	342·70	0·007	183·38	0·721	186·89	0·749	28·65
M_6	0·008	222·61	0·008	162·12	0·006	159·44	0·006	100·46	0·155	9·06	0·163	311·70
M_8	0·003	45·00	0·003	84·34	0·002	241·70	0·002	283·05	0·063	223·52	0·068	267·05
O_1	0·734	147·76	0·662	47·91	0·104	65·56	0·094	326·23	0·226	118·99	0·203	20·24
K_1	1·496	209·00	1·402	45·70	0·320	139·29	0·299	335·97	0·436	216·86	0·409	53·52
K_2	0·436	139·88	0·374	353·86	0·133	48·45	0·114	262·39	0·522	233·19	0·448	87·08
P_1	0·408	230·25	0·408	40·63	0·097	166·24	0·097	336·64	0·142	234·34	0·142	44·77
J_1	0·156	269·52	0·141	74·48	0·022	170·45	0·020	335·12	0·017	245·42	0·015	49·77
Q_1	0·189	118·42	0·170	53·29	0·004	231·55	0·004	167·22	0·030	58·36	0·027	354·88
L_2	0·141	47·04	0·120	303·95	0·019	342·23	0·016	239·37	0·190	166·69	0·163	64·08
N_2	0·945	183·55	0·962	318·10	0·236	98·77	0·240	234·10	0·649	269·63	0·662	45·80
ν_2	0·098	228·34	0·100	31·43	0·022	125·10	0·022	288·93	0·138	221·56	0·141	26·18
μ_2	0·221	111·94	0·229	311·61	0·033	336·55	0·035	177·23	0·295	337·33	0·306	179·10
T_2	0·036	341·86	0·036	343·74	0·026	212·13	0·026	214·03	0·036	132·40	0·036	134·33
$(MS)_4$	0·122	303·23	0·124	43·06	0·004	133·88	0·004	234·22	0·679	328·38	0·692	69·26
$(2SM)_2$	0·055	203·70	0·056	103·86	0·013	308·45	0·013	208·12	0·072	73·64	0·073	332·76
$2N_2$	0·176	96·26	0·180	265·53	0·050	50·31	0·051	220·63	0·234	215·60	0·238	27·04
$(MN)_4$	0·014	170·19	0·015	44·58	0·001	95·19	0·001	330·86	0·281	141·38	0·292	18·43
$(M_2K_1)_3$	0·067	178·78	0·064	115·32	0·016	51·16	0·015	318·18	0·102	107·26	0·098	44·80
$(2M_2K_1)_1$	0·058	89·70	0·056	92·66	0·003	289·18	0·002	293·17	0·037	336·18	0·036	341·28
Long Period		°		°		°		°		°		°
Mm	0·060	284·93	0·064	250·21	0·032	302·03	0·034	267·04	0·377	31·19	0·403	355·91
Mf	0·060	244·42	0·048	3·94	0·045	240·35	0·036	359·31	0·300	259·05	0·240	17·45
MSf	0·054	214·47	0·055	114·63	0·021	295·72	0·021	195·38	0·907	146·28	0·924	45·40
Sa	0·112	333·91	0·112	253·53	0·404	271·32	0·404	190·92	2·782	241·00	2·782	160·57
Ssa	0·192	356·75	0·192	195·99	0·354	280·04	0·354	119·23	0·963	163·45	0·963	5·60

1916

Tide symbol	RANGOON				MOULMEIN				PORT BLAIR			
	A_0 = 10·294				A_0 = 8·232				A_0 = 4·895			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period		°		°		°		°		°		°
S_1	0·111	135·98	0·111	135·98	0·097	139·21	0·097	139·21	0 032	98·61	0·032	98·61
S_2	2·187	166·16	2·187	166·16	1·545	144·15	1·545	144·15	0·973	314·46	0·973	314·46
S_4	0·084	263·41	0·084	263·41	0·067	221·80	0·067	221·80	0·001	143·13	0·001	143·13
S_6	0·015	29·51	0·015	29·51	0·007	197·61	0·007	197·61	0·002	352·88	0·002	352·88
S_8	0·001	345·96	0·001	345·96	0·004	157·89	0·004	157·89	0·004	77·13	0·004	77·13
M_1	0·039	249·30	0·028	163·06	0·037	227·10	0·027	140·90	0·014	65·39	0·011	339·03
M_2	5·820	27·74	5·929	129·16	4·257	7·39	4·337	108·90	1·970	178·89	2·007	280·07
M_3	0·015	96·78	0·015	248·90	0·026	104·15	0·026	256·42	0·007	212·35	0·008	4·12
M_4	0·475	319·49	0·493	162·32	0·948	317·27	0·984	160·29	0·008	270·80	0·008	113·16
M_6	0·248	144·87	0·262	89·11	0·050	225·98	0·053	170·52	0·002	92·60	0·003	36·15
M_8	0·077	54·58	0·082	100·23	0·050	46·28	0·054	92·33	0·002	327·53	0·002	12·26
O_1	0·327	122·12	0·295	23·92	0·279	138·56	0·251	40·46	0·172	42·63	0·155	304·19
K_1	0·725	196·49	0·679	33·13	0·498	199·79	0·466	36·42	0·427	130·17	0·400	326·82
K_2	0·720	311·08	0·618	164·93	0·466	290·19	0·400	144·04	0·292	95·56	0·251	309·44
P_1	0·162	245·30	0·162	55·74	0·131	245·59	0·131	56·04	0·140	150·71	0·140	321·15
J_1	0·068	267·64	0·062	71·69	0·042	278·81	0·038	82·80	0·040	158·94	0·036	323·13
Q_1	0·035	80·46	0·032	17·82	0·040	111·14	0·036	48·66	0·021	309·21	0·019	246·21
L_2	0·289	251·51	0·247	149·15	0·245	234·70	0·209	132·38	0·062	10·50	0·053	268·03
N_2	0·973	339·42	0·991	116·41	0·692	320·05	0·705	97·18	0·383	139·88	0·390	276·50
ν_2	0·148	313·45	0·151	118·85	0·119	284·71	0·121	90·25	0·033	173·64	0·034	338·70
μ_2	0·541	89·36	0·561	292·19	0·408	66·19	0·424	269·22	0·086	95·04	0·090	297·41
T_2	0·168	109·95	0·168	111·89	0·132	99·72	0·132	101·67	0·056	271·25	0·056	273·19
$(MS)_4$	0·439	105·75	0·447	207·17	0·779	98·42	0·793	199·93	0·007	63·02	0·007	164·20
$(2SM)_2$	0·158	152·27	0·162	50·86	0·151	124·04	0·154	22·53	0·021	239·23	0·021	138·04
$2N_2$	0·360	303·54	0·367	116·09	0·263	276·07	0·268	88·82	0·080	69·68	0·081	241·75
$(M_2N)_4$	0·183	281·58	0·189	159·98	0·362	267·61	0·376	146·26	0·004	123·69	0·004	1·50
$(M_2K_1)_3$	0·089	145·50	0·085	83·56	0·160	152·41	0·152	90·56	0·023	79·29	0·022	17·12
$(2M_2K_1)_3$	0·129	43·77	0·125	49·96	0·129	43·51	0·125	49·90	0·012	201·28	0·012	206·99
Long Period		°		°		°		°		°		°
Mm	0·132	56·79	0·141	21·22	0·453	45·89	0·485	10·27	0·020	26·49	0·021	351·04
Mf	0·101	291·16	0·081	48·98	0·331	285·57	0·264	43·28	0·076	248·31	0·061	6·38
MSf	0·470	147·80	0·479	46·39	1·209	144·20	1·232	42·69	0·010	77·72	0·010	336·54
Sa	1·223	232·58	1·223	152·14	2·045	228·45	2·045	148·00	0·244	239·91	0·244	159·47
Ssa	0·158	204·91	0·158	44·02	0·372	112·40	0·372	311·50	0·096	311·74	0·096	150·87

1916-17.

Tide symbol	BASRAH											
	$A_0 = 6 \cdot 905$				$A_0=$				$A_0=$			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period		°		°								
S_1	0·230	201·56	0·230	201·56								
S_2												
S_4												
S_6												
S_8												
M_1												
M_2												
M_3												
M_4												
M_6												
M_8												
O_1	0·416	48·45	0·378	356·12								
K_1	0·697	126·23	0·657	31·32								
K_2												
P_1	0·102	254·25	0·102	356·55								
J_1	0·026	216·03	0·024	271·91								
Q_1	0·058	205·68	0·053	5·68								
L_2												
N_2												
ν_2												
μ_2												
T_2												
$(MS)_4$												
$(2SM)_2$												
$2N_2$												
$(M_2N)_4$												
$(M_2K_1)_3$	0·196	285·64	0·188	46·59								
$(2M_2K_1)_3$	0·179	207·67	0·174	14·33								
Long Period												
Mm												
Mf												
MSf												
Sa												
Ssa												

Data forwarded to England.

The following data were prepared and supplied to the Director, National Physical Laboratory, Teddington, England during the year under report :—

(*a*) Values of the tidal constants for 40 ports for the tide-tables for 1920, ready for use for the tide-predicting machine.

(*b*) Values of the tidal constants for the tide-tables for Basrah from 1st September 1917 to 31st December 1918.

(*c*) Actual values of high and low water during 1915 at 12 stations. These include nine stations at which regular tidal observations by self-registering tide-gauges were carried out and three stations at which high and low water readings were taken during day-light on tide-poles.

(*d*) Comparison of the above with predicted values for 1915, the errors being tabulated in such a form as to be of use in improving the predictions, if possible.

Errors in Predictions.

The predicted times and heights of high and low water for the year 1916, as given in the tide-tables, have been compared against the actual values obtained from tidal observations at the nine stations now working and at three other stations where tidal registrations by self-registering tide-gauges have ceased but where the times and heights of high and low water are still read on the tide-poles.

The errors of the predictions thus determined are tabulated in the five tables herewith appended.

No. 1.

Percentages and amounts of the errors in the predicted times of high water at the various tidal stations for the year 1916.

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
Aden ...	Auto.	667	32	46	11	8	3
Karāchi ...	"	696	30	43	12	10	5
Bhaunagar ...	T. P.	366	67	33	0	0	0
Bombay (Apollo Bandar)	Auto.	705	48	42	5	4	1
Bombay (Prince's Dock)	"	697	40	41	9	8	2
Madras ...	"	707	33	45	11	9	2
Kidderpore ...	"	707	30	42	12	10	6
Chittagong ...	T. P.	366	35	45	9	6	5
Akyab ...	"	365	94	4	1	1	0
Rangoon ...	Auto.	708	56	30	6	4	4
Moulmein ...	"	706	42	42	9	5	2
Port Blair ...	"	707	46	42	8	4	0

No. 2.

Percentages and amounts of the errors in the predicted times of low water at the various tidal stations for the year 1916.

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
Aden ...		Auto.	660	33	44	11	8	4
Karāchi ...		"	707	35	37	10	13	5
Bhaunagar ...		T. P.	366	70	30	0	0	0
Bombay	(Apollo Bandar)	Auto.	706	41	48	6	4	1
	(Prince's Dock)	"	696	35	42	11	9	3
Madras ...		"	707	42	45	7	4	2
Kidderpore ...		"	707	30	40	11	11	8
Chittagong ...		T. P.	366	33	40	9	12	6
Akyab ...		"	366	96	2	1	1	0
Rangoon ...		Auto.	707	29	41	10	12	8
Moulmein ...		"	706	23	42	13	11	11
Port Blair ...		"	706	50	41	4	3	2

No. 3.

Percentages and amounts of the errors in the predicted heights of high water at the various tidal stations for the year 1916.

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
Aden ...		Auto.	667	6·7	92	8	0	0
Karāchi ...		"	696	9·3	55	40	5	0
Bhaunagar ...		T. P.	366	31·4	67	30	3	0
Bombay	(Apollo Bandar)	Auto.	705	13·9	71	25	4	0
	(Prince's Dock)	"	697	13·9	56	33	9	2
Madras ...		"	707	3·5	74	24	2	0
Kidderpore ...		"	707	11·7	47	25	11	17
Chittagong ...		T. P.	366	13·3	48	26	10	16
Akyab ...		"	365	8·3	83	15	1	1
Rangoon ...		Auto.	708	16·4	52	30	12	6
Moulmein ...		"	706	12·7	38	26	17	19
Port Blair ...		"	707	6·6	87	13	0	0

No. 4.

Percentages and amounts of the errors in the predicted heights of low water at the various tidal stations for the year 1916.

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
Aden ...	Auto.	660	6·7	92	8	0	0
Karāchi ...	"	707	9·3	79	19	2	0
Bhaunagar ...	T. P.	366	31·4	65	30	5	0
Bombay (Apollo Bandar)	Auto.	706	13·9	64	31	5	0
Bombay (Prince's Dock)	"	696	13·9	60	31	8	1
Madras ...	"	707	3·5	91	9	0	0
Kidderpore ...	"	707	11·7	46	24	14	16
Chittagong ...	T. P.	366	13·3	30	28	18	24
Akyab ..	"	366	8·3	82	16	2	0
Rangoon ...	Auto.	707	16·4	32	27	22	19
Moulmein ...	"	706	12·7	36	21	13	30
Port Blair ...	"	706	6·6	93	7	0	0

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 1916.

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.								
Aden	Auto.	6·7	11	11	0·025	0·025	2	2
Karāchi	"	9·3	12	12	·036	·027	4	3
Bhaunagar	T.P.	31·4	5	5	·011	·011	4	4
Bombay (Apollo Bandar)	Auto.	13·9	7	8	·018	·024	3	4
Bombay (Prince's Dock)	"	13·9	9	10	·024	·024	4	4
Madras	"	3·5	10	9	·071	·048	3	2
Akyab	T.P.	8·3	1	1	·030	·030	3	3
Port Blair...	Auto.	6·6	8	7	·038	·025	3	2
General Mean	...	...	8	8	·032	·027	3	3
Riverain.								
Kidderpore	Auto.	11·7	12	13	·050	·050	7	7
Chittagong	T.P.	13·3	10	12	·044	·069	7	11
Rangoon	Auto.	16·4	8	13	·025	·041	5	8
Moulmein...	"	12 7	9	15	·046	·072	7	11
General Mean	...	...	10	13	·041	·058	7	9

Summary for 1916.

Number of stations.	Predictions tested by	Percentage of Predictions, at high and low water within					
		15 minutes of actuals.		8 inches of actuals.		one-tenth of mean range	
		High.	Low.	High.	Low.	High.	Low.
6 Open coast	S.R. Tide-gauge	81	82	96	97	96	99
2 „	Tide-pole	99	99	98	97	100	100
3 Riverain	S.R. Tide-gauge	81	68	73	62	93	87
1 „	Tide-pole	80	73	74	58	92	82

COMPARISONS OF THE PREDICTIONS FOR THE YEAR 1916 WITH THOSE FOR THE PREVIOUS YEAR.

The predictions of the heights of high and low water for the year 1916 were practically of the same degree of accuracy as those for the previous year for all the nine working stations. The predictions of times for 1916 were worse for Aden and Madras and better for Karāchi, Bombay (Apollo Bandar), Moulmein and Port Blair than the predictions for 1915.

The greatest differences between the actual and predicted heights of low water for 1916 at the riverain ports were as follows:—

Kidderpore ... 4 feet 1 inch on 6th October 1916, actuals being higher.
Rangoon ... 2 feet 3 inches on 3rd September 1916, actuals being lower.
Moulmein ... 3 feet 8 inches on 28th July 1916, actuals being lower.

TIDE-TABLES.

The tide-tables for the year 1918 were despatched from England in two consignments on 25th June and 25th July 1917. The first lot arrived at Dehra Dūn on the 19th of September. No intimation of the arrival of the second consignment at Karāchi had been received up to 30th September. They will be distributed to the various officers concerned as soon as the whole supply is received. The tide-tables for Basrah from 1st September 1917 to 31st December 1918 were printed at the office of the Trigonometrical Survey at Dehra Dūn and a supply of the same was despatched to the Director, Inland Water Transport, Basrah on 3rd September 1917.

The amount realized on the sale of tide-tables during the year ending 30th September 1917 was Rs. 1,179-3.

PROGRAMME FOR SEASON 1917-18.

Tidal observations during the coming year will be continued at the 9 observatories now working.

LEVELLING

By H. G. Shaw.

Personnel of No. 17 Party.

Provincial Officers.

Mr. H. G. Shaw in charge. Retired: in temporary employ from 21st February 1917.
" D. H. Luxa.
" R. B. Mathur, B. A.
" G. A. Norman.
" Abdul Karim, B. A.
" F. J. Grice.
" N. N. Chuckerbutty, L. C. E.

Upper Subordinate Service.

Mr. Satish Chandra Mukerji.

Lower Subordinate Service.

4 Computers.
7 Recorders.
1 Clerk.

Four detachments were employed on levelling operations during the past field season (*vide* Index Map No. 14). The out-turn amounted to 540 miles of "fore and back double levelling of precision" in Bengal, and in Bihār and Orissa, in course of which the heights of 4 principal stations of triangulation, 9 primary and 627 secondary bench-marks were determined. Full details of this out-turn of work are given in Table I attached.

The health of the detachments was on the whole not good during the field season, as there were numerous cases of malaria and dysentery. One khalāsi died of colic.

The country through which the lines of levels were carried was varied in nature, flat in Bengal, and undulating and hilly in Bihār and Orissa.

Levelling operations.—The work was divided among the four detachments as follows; each detachment consisted of one levelling officer, 2 recorders and 19 menials:—

Nos. 1 (A) and 1 (B) Detachments.

Mr. Chuckerbutty was in charge of No. 1 (A) and Mr. Mukerji of No. 1 (B) detachment. These two detachments working in opposite directions levelled (*a*) from Aurangābād *via* Daltonganj to Rānchī along the main roads, and (*b*) from Barhī *via* Hazāribāgh to Rānchī along the P. W. D. road. These are new lines of levels and complete the circuit Aurangābād-Rānchī-Barhī-Aurangābād, the closing error being −0·089 of a foot in a distance of 321 miles as shown below:—

Circuit A.

Lines. From	Lines. To	Distance in miles.	Unadjusted dynamic difference of height in feet.	Year.
Embedded B. M. at Aurangābād.	Standard B. M. at Rānchī.	163·8	+1779·307	1916-17
Standard B. M. at Rānchī.	Embedded B. M. near Barhī.	83·8	− 920·191	1916-17
Embedded B. M. near Barhī.	Embedded B. M. at Aurangābād.	73·1	− 859·205	1914-15
	Total ...	320·7	− 0·089	

Nos. 2 and 3 Detachments.

Mr. Luxa was in charge of No. 2 and Mr. Norman of No. 3 detachment. These two detachments worked in opposite directions. Levelled (*a*) from Barākar to Burdwān along the Grand Trunk Road, and (*b*) from Rānchī *via* Purūlia to Barākar along the main road. These are new lines.

Revised from Chāmpdāni to Burdwān along the Grand Trunk Road. This line was originally levelled in 1862-63.

The line Rānchī *via* Purūlia to Barākar closes the circuit Rānchī-Barākar-Barhī-Rānchī with an error of −0·989 of a foot in a distance of 312 miles as shown below:—

Circuit B.

Lines.		Distance in miles.	Unadjusted dynamic difference of height in feet.	Year.
From	To			
Standard B.M. at Rānchī.	Embedded B.M. at Barākar.	122·5	−1774·060	1916-17
Embedded B.M. at Barākar.	Embedded B.M. near Barhī.	106·0	+ 852·880	1914-15
Embedded B.M. near Barhī.	Standard B.M. at Rānchī.	83·8	+ 920·191	1916-17
	Total ...	312·3	− 0·989	

The difference between the published dynamic heights of the Standard bench-mark at Benares, $\frac{\text{B.M.96}}{\text{63 K}}$, and Barhāni T.S., $\frac{\text{B.M.58}}{\text{63 O}}$, and also that between Howrah Botanical Gardens, $\frac{\text{B.M.264}}{\text{79 B}}$, and Niāl T.S., $\frac{\text{B.M.3}}{\text{79 A}}$, agree with the unadjusted differences of the dynamic heights obtained by the new levelling; but there is a discrepancy of −1·619 feet between Barhāni T.S. and Niāl T.S. *via* Aurangābād, Barhī and Barākar, a distance of 363 miles, (*vide* diagram). This large discrepancy is difficult to explain as all the precautions, necessary to guard against errors in levelling of precision, were taken when these lines were levelled; moreover the difference between the two levellers from Barhāni T.S. to Niāl T.S. amounts to 0·180 of a foot, which is very small in comparison with the large discrepancy mentioned above.

The portions from Karamnāsā (the point from which the branch-line to Barhāni T. S. emanated in 1914-15) to Aurangābād, a distance of 73 miles, and from Barākar to Niāl T. S., a distance of 106 miles, cannot at present be discussed because they do not form part of the Circuits A and B; and if there be any discrepancy in either of these portions it will be disclosed on the revision of one or both.

Again the discrepancy between Barhāni T.S. and Niāl T. S. *via* Aurangābād, Rānchī and Barākar is −2·697 feet in a distance of 470 miles, *i.e.*, a further increase of −1·078 feet.

Since Circuit A closes well, it may be taken for granted that the lines forming it, of which Aurangābād to Rānchī is one, are probably above suspicion; also there being an error of −0·989 of a foot in Circuit B, the evidence is strong that the line Rānchī to Barākar, which forms part of Circuit B, is probably burdened with a large error. The revision of this line will clear all doubts on this portion.

GENERAL NOTES.

Standard Steel Tapes.—During the past field season standard steel tapes were introduced and used for determining week by week, the changes in the lengths of the staves. These tapes were compared at a tension of 10 lbs. with a Base Line Standard Bar, and the length of their edges A and B determined, at the Head Quarters of the Trigonometrical Survey, Dehra Dūn. All these tapes are of the same pattern, so that the following description of Tape No. 2 will apply to all:—

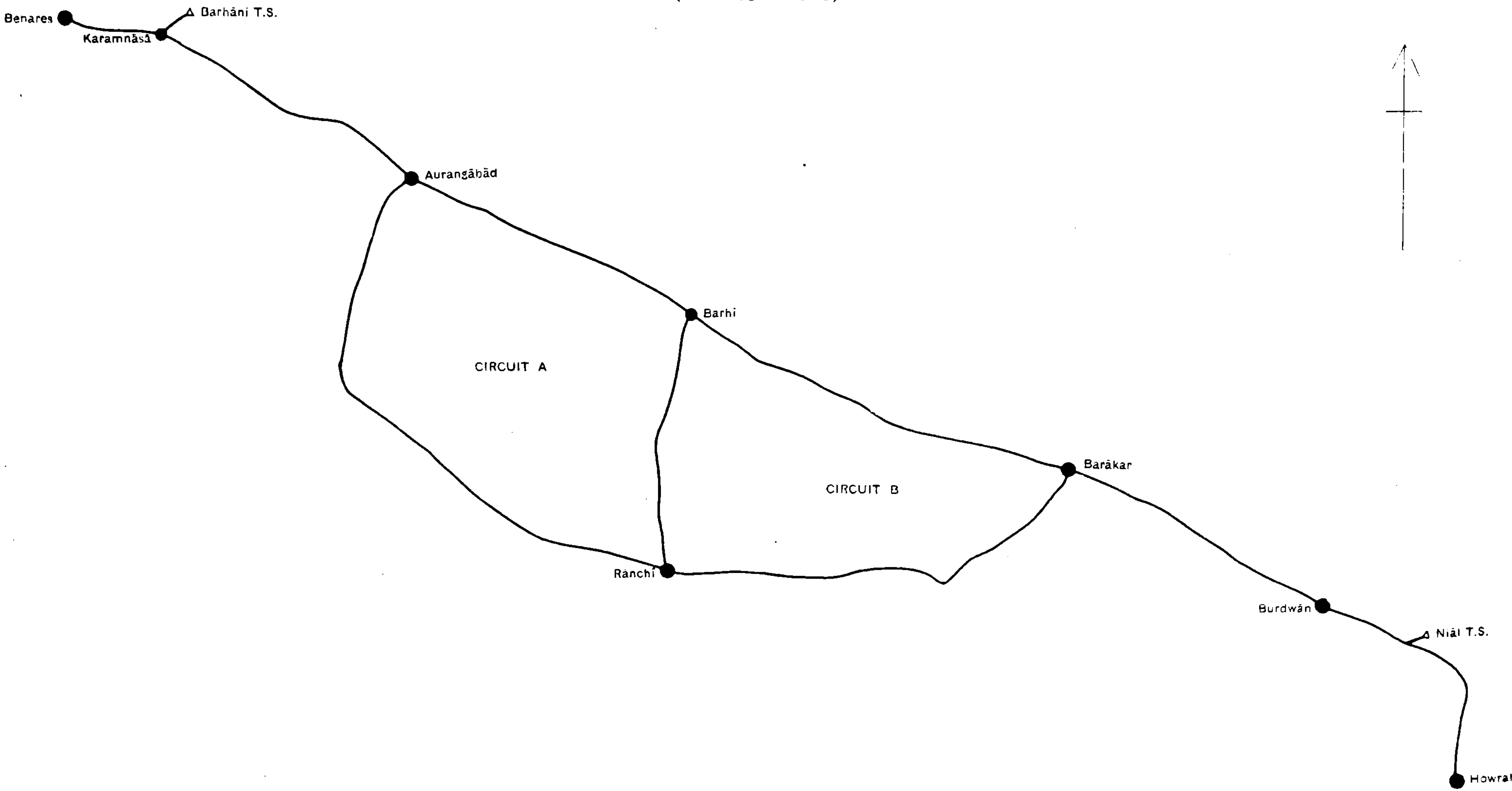
Field Standard Tape No. 2 consists of a ¼-inch wide Chesterman steel band, and is 10 feet 3½ inches in length. The zero and 10-foot points are marked by fine lines having the figures 0 and 10 engraved at their centres, a finely graduated scale, each division being 0·002 of a foot, is engraved at both edges of the tape for a distance of 0·3 of an inch on either side of the 0 and 10-foot lines. The intermediate feet are shown by fine lines, but without numbers.

The tape is wound round a metal reel and packed in a wooden box to protect it from injury in transit. The number on the tape is engraved on it and the two edges are marked A and B. These tapes were manufactured in the M.I.O., Calcutta.

The tape when used for the comparison of a staff is unwound, stretched along the centre of the graduated face of the staff, and fixed at the zero end by means of a screw which fits into the brass shoe of the staff: a wire attached to the 10-foot end of the tape is stretched over a pulley by means of a 10 lbs. weight suspended from it.

ROUGH DIAGRAM OF LEVELLING

(Not to Scale)



Hitherto Field Standard Steel Bars were used, but have now been discontinued as the tapes are far more convenient to carry about.

A description of one of the Standard Bars, which will practically answer for all others, is given below for future reference in case they are used again.

Field Standard Bar No. 4 is made of steel and is 10 feet 1 inch in length, 1·4 inches in width, and $\frac{3}{16}$th inch in thickness. It is bevelled at the two edges for the first foot at both ends. The 10-foot length is marked by dots on silver let into the bar at each end. Through these dots crosses or zero lines are cut to the extreme edges of the bar: the ends of these lines are marked by arrows. A finely graduated scale, of which each division is 0·002 of a foot, is engraved at both edges of the bar for about half an inch on either side of the zero lines. A detachable slow-motion screw is provided with the bar to facilitate the zero lines on the bar being made to coincide with the zero line on a levelling staff when compared with the bar in the field. The bar is usually carried on a wooden support, rectangular in section, and is held on it by means of screws passing through holes made in the bar at a distance of 1 foot apart. These holes are a little too large for the screws, so that the bar is just held on the wooden support without being strained. The bar with the wooden support is packed in a wooden box, which is well padded and lined with cloth, to protect it from injury in transit.

The number of the bar is engraved on it and the two edges are marked A and B.

Identity of bench-marks.—On revisionary levelling, in order to decide when a difference between two values of the height of a bench-mark should be looked on as real and when as a mere error of observation, the following formula will serve as a useful guide. Let $x = \sqrt{16(y^2+y^{12})M+(0\cdot003)^2M^2}$, where y is the probable accidental error per mile in the old levelling, y^1 is the probable accidental error per mile in the revision, and M the distance in miles from the last undisturbed common point.

If the difference between the heights as obtained in the old and new works exceeds x, the bench-marks should be considered to have been disturbed and new values assigned to them, otherwise the difference may be ascribed to error of observation and the old values retained.

A detachment working under the Officer in charge No. 17 Party (Levelling) went to the Sind-Sāgar Doāb for reconnaissance work and building of secondary triangulation stations. Full details of the work done are given under the heading "Triangulation" in this volume.

TABLE I.—*Tabular statement of out-turn of work, season 1916-17.*

Detachment Nos.	Lines.	Months.	Mean distance levelled in both directions. Main Line.	Extras and branch-lines.	Total.	Relevelled.	Total number of feet (Mean of both directions). Rises.	Falls.	Mean number of stations at which the instruments were set up in both the directions.	Number of Bench-marks connected. Primary. Rock-cut. Old.	Rock-cut. New.	Protected. Old.	Protected. New.	Standard. Old.	Standard. New.	Principal stations of triangulation. Old.	Principal stations of triangulation. New.	Secondary. Embedded. Old.	Embedded. New.	Rock-cut. Old.	Rock-cut. New.	Inscribed. Old.	Inscribed. New.	P.W.D. Old.	P.W.D. New.	Railway. Old.	Railway. New.
			Mls.Chs.Lks.	Mls.Chs.Lks.	Mls.Chs.Lks.	Mls.Chs.Lks.																					
1 (A) and 1 (B)	Aurangābād to Rānchī	November 1916	34 08 68	...	34 08 68	...	1095·603	873·592	514	...	...	...	1	...	2	1	14	...	38	4	81	...	...	...	...
		December „	35 70 51	11 12 73	47 03 24	2 27 50	3427·086	1463·143	969																
		January 1917	55 34 91	1 03 55	56 38 46	6 65 45	1524·007	1316·245	863																
		February „	38 26 94	8 23 18	46 50 12	0 32 56	1334·707	740·745	606																
		Totals	163 61 04	20 39 46	184 20 50	9 45 51	7381·403	4393·725	2952	...	...	...	1	...	2	1	14	...	38	4	81	...	...	...	...
	Barhī to Rānchī	March 1917	56 23 02	2 31 07	58 54 09	...	2810·815	2302·317	883	...	...	1	...	...	1	1	9	1	17	4	43	...	..	...	...
		April „	27 38 12	2 33 58	29 71 70	6 51 53	1882·085	632·004	581																
		Totals	83 61 14	4 64 65	88 45 79	6 51 53	4692·900	2934·321	1464	...	...	1	...	...	1	1	9	1	17	4	43	...	...	...	...
		Grand Totals	247 42 18	25 24 11	272 66 29	16 17 04	12074·303	7328·046	4416	...	...	1	1	...	3	2	23	1	55	8	124	...	...	...	...
2 and 3	Chāmpdāni to Burdwān	November 1916	25 46 47	5 35 22	31 01 69	6 76 93	229·528	209·422	513	...	...	1	...	...	1	3	7	...	...	17	87	...	1	...	...
		December „	29 63 99	2 04 25	31 68 24	18 19 05	246·633	190·878	390																
		Totals	55 30 46	7 39 47	62 69 93	25 15 98	476·161	400·300	903	...	...	1	...	...	1	3	7	...	...	17	87	...	1	...	...
	Barākar to Burdwān	December 1916	24 16 59	0 70 60	25 07 19	...	353·150	417·204	309	...	...	1	...	...	...	1	7	2	11	6	103	...	3	...	...
		January 1917	52 35 40	4 29 64	56 65 04	12 65 27	780 085	982·932	665																
		Totals	76 51 99	5 20 24	81 72 23	12 65 27	1133·235	1400·136	974	...	...	1	...	...	...	1	7	2	11	6	103	...	3	...	...
	Rānchī to Barākar	January 1917	2 23 88	...	2 23 88	...	105·070	92·250	34	...	7	...	1	...	...	1	9	...	94	1	101	...	2	...	...
		February „	64 51 31	...	64 51 31	1 09 56	1331·718	2257·943	858																
		March „	48 34 53	...	48 34 53	9 16 93	1032·783	1846·560	652																
		April „	7 09 71	...	7 09 71	1 63 11	153·048	223·525	85																
		Totals	122 39 43	...	122 39 43	12 09 60	2622·619	4420·278	1629	...	7	...	1	...	...	1	9	...	94	1	101	...	2	...	...
		Grand Totals	254 41 88	12 59 71	267 21 59	50 10 85	4232·015	6220·714	3506	...	7	2	1	...	1	5	23	2	105	24	291	...	6	...	...

TABLE II—Check-Levelling.

Discrepancies between the old and new heights of bench-marks.

Bench-marks of the original levelling that were connected for check-levelling. Number.	Degree sheet.	Description.	Distance from starting bench-mark.	Observed height above (+) or below (−) starting bench-mark as determined by: Original levelling.	Date.	Check-levelling, 1916-17.	Difference (check-original). The sign + denotes that the height was greater, and the sign − less in 1916-17 than when originally levelled.
			Miles.	Feet.		Feet.	Feet.
		Check-Levelling at Aurangābād.					
106*	72 D	Embedded, Aurangābād	0·0	0·000	1914-15	0·000	0·000
107*	„	Bridge No. 211 ...	0·7	+ 16·409	„	+ 16·373	− 0·036
108*	„	Mile-stone No. 320	1·1	+ 14·087	„	+ 14·101	+ 0·014
105*	„	Tree ...	0·6	− 1·940	„	− 1·967	− 0·027
		Check-Levelling at Barhī.					
176*	72 H	Embedded, Barhī ...	0·0	0·000	1914-15	0·000	0·000
2/176*	„	Barākar bridge ...	0·7	+ 8·835	„	+ 8·830	− 0·005
1/176*	„	Rock *in situ* ...	0·9	− 7·608	„	− 7·616	− 0·008
177*	„	Mile-stone No. 249 ...	1·5	+ 45·754	„	+ 45·768	+ 0·014
178*	„	Subdivisional office ...	3·1	+ 69·523	„	+ 69·546	+ 0·023
179*	„	Inspection bungalow ...	3·6	+ 87·391	„	+ 87·404	+ 0·013
		Check-Levelling at Chāmpdāni.					
32†	79 B	Embedded, Chāmpdāni ...	0·0	0·000	1913-14	0·000	0·000
34†	„	Bridge No. 15 B.B. ...	0·1	− 2·462	„	− 2·469	− 0·007
35†	„	Tree ...	0·2	+ 2·057	„	+ 2·047	− 0·010
36†	„	Bridge No. 13 B.B. ...	0·3	+ 2·830	„	+ 2·821	− 0·009
		Check-Levelling at Burdwān.					
1/6‡	73 M	Standard bench-mark, Burdwān ...	0·0	0·000	1909-10	0·000	0·000
6‡	„	Pillar ...	0·4	+ 2·513	„	+ 2·543	+ 0·030
14‡	79 A	Wheel-guard stone ...	15·8	− 33·522	„	− 33·562	− 0·040
15‡	„	Memāri Railway Station	16·4	− 26·962	„	− 26·978	− 0·016
16‡	„	Mile-stone ...	18·4	− 34·166	„	− 34·194	− 0·028
18‡	„	Bridge ...	22·0	− 41·300	„	− 41·335	− 0·035
19‡	„	Tank ...	22·6	− 43·292	„	− 43·356	− 0·064
21‡	„	Well ...	25·7	− 47·765	„	− 47·792	− 0·027
1‡	73 M	Temple ...	5·0	+ 14·684	„	+ 14·738	+ 0·054
		Check-Levelling at Barākar.					
270*	73 I	Embedded, Barākar ...	0·0	0·000	1914-15	0·000	0·000
269*	„	Bridge over Barākar river	0·1	+ 3·033	„	+ 3·022	− 0·011
268*	„	„ „ „ „	0·6	+ 7·547	„	+ 7·558	+ 0·011
267*	„	Rock ...	1·8	+ 30·378	„	+ 30·384	+ 0·006
271*	„	Stone pillar ...	0·0	+ 5·998	„	+ 6·017	+ 0·019
272*	„	Zinc plate ...	0·0	+ 2·963	„	+ 2·971	+ 0·008
274*	„	Rock ..	1·0	+ 42·762	„	+ 42·801	+ 0·039
275*	„	Pillar ...	1·2	+ 12·827	„	+ 12·857	+ 0·030

* Temporary line form numbers, not published, of Line 70 A (Benares-Barākar).
† „ „ „ „ „ of revision (Howrah-Chāmpdāni).
‡ „ „ „ „ „ in connection of Burdwān Standard bench-mark.

TABLE III.—Revision Levelling.

Discrepancies between the old and new heights of bench-marks.

Bench-marks of the original levelling that were connected during the revisionary operations.			Distance from starting bench-mark.	Difference of orthometric heights, above (+) or below (−) the starting bench-mark.			Difference (Revision—Original). The sign + denotes that the height was greater and the sign − less in 1916-17 than when originally levelled.
Number.	Degree sheet.	Description.		From published heights.	Date of original levelling.	From revision, 1916-17 (unadjusted).	
			Miles	Feet.		Feet.	Feet.
		Revision of part of line No. 75 B (Howrah-Nadiā).					
264	79 B	Botanical gardens ...	0·0	0·000	1881-82 & 1882-83	0·000	0·000
337	„	Platform ...	25·1	+ 11·651	1887-88	+ 11·708	+ 0·057
344	„	Embedded, Chinsura ...	31·1	+ 12·399	„	+ 12·431	+ 0·032
342	„	Step ...	31·3	+ 13·767	„	+ 13·740	− 0·027
346	„	Plinth ...	32·4	+ 13·611	„	+ 13·452	− 0·159*
347	„	Plinth ...	32·6	+ 15·877	„	+ 15·931	+ 0·054
348	„	Step ...	32·9	+ 18·805	„	+ 18·820	+ 0·015
352	„	Embedded, Tribenī ...	40·8	+ 11·721	„	+ 11·869	+ 0·148
351	„	Step ...	41·0	+ 22·837	„	+ 22·910	+ 0·073
350	„	Tablet (stone) ...	42·4	+ 17·582	„	+ 17·676	+ 0·094
3†	79 A	Niāl T. S. (ground mark)	56·5	+ 22·197	1862-63	+ 22·375	+ 0·178

* Worn out, inscription newly cut.

† This bench-mark is in line No. 74.

MAGNETIC SURVEY.

By E. C. J. BOND.

PERSONNEL of No. 18 PARTY.

Provincial Officers.

Mr. E. C. J. Bond, in charge.
" R. P. Ray, B. A.
" N. R. Mazumdar.
" R. B. Mathur, B. A.

Upper Subordinate Service.

Mr. K. K. Das, B. A. attached from 1st October 1916.
" B. B. Shome.

Lower Subordinate Service.

2 Magnetic observers.
12 Computers, etc.

The present report on the work of the magnetic party in 1916-17 comprises:—

I.—An account of the work during the field and recess seasons.

II.—A note on each of the observatories*.

III.—Tables of the mean values of the magnetic elements, dates of magnetic disturbances and hourly means and diurnal inequality of the magnetic elements at observatories in 1916.

I.—WORK DURING THE FIELD AND RECESS SEASONS.

1. *Work during the field season.*—The observatories at Dehra Dūn and Toungoo were inspected by the officer in charge during two months of the field season and a complete set of observations were taken at each for the comparison of instruments.

The Alibāg and Kodaikānal observatories, under the Meteorological Department, were also visited for the same purpose.

No field work was undertaken during the year. When observations are taken again at the repeat stations in the field season of 1919-20 for determining the secular change for the period 1915 to 1920, the magnetic elements and the isomagnetic charts which will be published shortly for the epoch 1909 will be revised for 1920. The revision will be particularly needed in the case of the Declination which is given in all the published maps of the Survey of India.

The staff of the party was chiefly employed on the reduction of the final results of the magnetic elements at field stations to the selected epoch, 1st January 1909.

The officer in charge, in addition to his duties in the magnetic party held charge of No. 19 Party which he visited in the field when it was employed on triangulation in Delhi and its vicinity.

2. *Work during the recess.*—The computation of the comparative observations taken at the observatories, and the computation and tabulation of the Declination, Dip, Horizontal Force and Vertical Force for the three observatories (Dehra Dūn, Toungoo and Kodaikānal) for 1916 have been completed. The mean values of these elements for the year 1916 derived from measurement of traces of all available days, excluding those of great disturbance, are given in the table at the end of the report.

The reduction of the magnetic elements to the selected epoch, at the 74 repeat stations in India and Burma and the 1351 field stations in India, Burma and Ceylon will very shortly be completed. The Declination and Horizontal Force data are ready for publication but as the reduction of the Dip is very near completion it is considered desirable to publish it with the other two elements and also to include the rectangular components of the force so that the publication may form a complete record of the results of the magnetic survey of India from 1901 to 1915. With the published values of these elements will be given the average annual change of each element at the field and repeat stations for each of the two periods 1901 to 1909·0 and 1909·0 to 1914. There will also be issued the monthly mean values of the elements at the observatories and a set of isomagnetic charts, as well as a set of charts showing graphically the monthly mean values and annual change of each element at the observatories from 1901 to 1909·0 and 1909·0 to 1914, *i. e.*, the average annual change will be given separately for each of the periods preceding and following the beginning of January 1909, the selected epoch of the survey, which is the date nearest to the point where an appreciable change is indicated in the curve of secular variation: the sections of the curve, appertaining respectively to the two periods 1901 to 1909·0 and 1909·0 to 1914, are approximately straight lines, representing an almost uniform change.

* *Vide* Index Map No. 16.

The 50 field stations, selected in 1910 as repeat stations and permanently marked in 1915, have now been numbered in Roman numerals on the magnetic chart in this report, in continuation of the numbers of the former 23 repeat stations.

The thin phosphor-bronze ribbon which was used formerly for the suspension in the Declination magnetograph and the galvanometer are not procurable now and fine tungsten wires, ·03 and ·015 millimetres in thickness, were recommended by the Director General of Stores as substitutes. Samples of the wires were received and an experiment was made with the finer of the two for the suspension of a galvanometer magnet. The wire was found to be very suitable for the galvanometer suspension. There is every hope that the thicker of the two wires, which is finer and as strong as the phosphor-bronze ribbon, will prove quite successful should the necessity arise for renewing the suspension in any of the Declination or the Horizontal Force magnetographs.

3. *Programme for 1917-18.*—The three base stations (Dehra Dūn, Toungoo and Kodaikānal) will continue in operation. These observatories will be visited by the officer in charge during the field season for the comparison of instruments.

Two or three of the field stations will also be visited and will be permanently marked with a view of using them as extra repeat stations: this is desirable for obtaining further data for the determination of the true course of the lines of secular change to the south of Lower Burma and in Ceylon.

II.—The Observatories in 1916-17.

Dehra Dun Observatory.

1. The Declination, Horizontal Force and Vertical Force magnetographs worked satisfactorily during the year, except that the magnet system of the latter, for a short time, was not moving freely. The photographic trace showed almost a straight line instead of a curve: this defect was probably due to some obstruction, such as the presence of tiny insects. The magnet system was removed, the agate plane cleaned and the magnet replaced and its balance adjusted.

During the rainy season last year when the underground observatory was inundated it was noticed that there was an outflow of water from the pipe leading from the observatory passage to the masonry well, although the mouth of the pipe at the passage was closed: from this it appeared that the earthenware pipe was broken and that the subsoil water was entering it and flowing into the well. It was then decided to excavate and expose the pipe, from the wall of the observatory up to the well, before the rains commenced this season, to ascertain whether the pipe was broken and also whether the boulder trench served its purpose in collecting the subsoil water. The surmise regarding the pipe was correct, and during the rains this season the subsoil water was found to trickle from the exposed portions of the boulder trench at the excavation. The conclusion arrived at was that the undersoil water entered the pit and boulder trench at the same time and from the latter percolated through the outer walls of the observatory into the passage. The water level in the passage was found by spirit-levelling to be slightly higher than that in the pit; this is probably due to the fact that the natural slope of the ground is from the observatory to the pit. The average rate of accumulation of water in the passage was about 20 cubic feet per hour when the water in the pit was 2 feet above the level of the passage floor, but this rate increased if the water in the pit continued to rise. At the suggestion of the Superintendent of the Trigonometrical Survey a metal pipe was fitted to connect the passage in the observatory to a pump at ground level outside the observatory, any water that entered the passage could be discharged by this pump at a rate of 100 cubic feet per hour or from four to five times as fast as it collected in the passage, so that the passage can always be emptied before too much water accumulates and there is now less risk of the magnetograph room being flooded.

The base line values of the Declination and Horizontal Force magnetographs have been affected slightly by the introduction of the galvanized iron pipe although the mouth of the pipe is some distance away from the instruments.

2. *Mean values of the Declination and H. F. constants.*—The table below gives the mean monthly values of magnetic collimation, the distribution constants $P_{1\cdot2}$ and $P_{2\cdot3}$, and the accepted values of p and q used in determining the values of the revised distribution factor (*vide* the last para in page 61 of "Records", Volume X). The values of m are also given, as determined with the revised distribution factor and moment of inertia used for the computations in 1915. The values of m in the table are all derived from the vibration observations as determined with the chronograph.

Mean values of the constants of magnet No. 17 in 1916.

Months.		Declination constants.	H. F. constants.					
			Distribution Factors.				Mean values of m.	
		Mean magnetic collimation.	$P_{1\cdot2}$	$P_{2\cdot3}$	Accepted values. p	Accepted values. q	Monthly means.	Accepted m.
		′ ″						
January	...	− 6 58	5·92	6·52			808·73	
February	...	− 6 55	5·89	6·50			808·71	808·63
March	...	− 6 56	5·89	6·30			808 72	
April	...	− 7 5	5·97	5·99			806·53	
May	...	− 7 12	6·02	6·15			806·89	
June	...	− 7 8	5·98	6·48	7·30	− 382	806·80	
July	...	− 7 5	5·98	6·20				
August	...	− 7 8	6·09	6·09			806 80	806·80
September	...	− 7 4	6·10	6·16			806·73	
October	...	− 7 7	6·03	6·31			806·86	
November	...	− 7 5	6·09	6·41			806·96	
December	...	− 7 5	6·15	6·29			806·79	

3. *Mean base line values.*—The table below gives the mean monthly observed and accepted values of the Declination and Horizontal Force base lines: the accepted values have been used to compute the values of these elements for 1916. The H. F. base line values have been derived from H as determined with the revised values of the moment of inertia and distribution coefficient used in the computations for 1915.

Base line values of magnetographs in 1916.

Months.		Declination.			Horizontal Force.		
		Mean value of Base line.	Base line accepted.	Remarks.	Mean value of Base line.	Base line accepted.	Remarks.
		° ′	° ′		C. G. S.	C. G. S.	
January	...	1 30·9	1 30 9		·32792	·32792	
February	...	1 30·9	1 30·9		·32792	·32792	
March	...	1 30·9	1 30·9		·32792	·32792	
April	...	1 31·1	1 31·1		·32791	·32791	
May	...	1 31·0	1 31·0		·32791	·32791	
June	...	1 30·5	1 30 5		·32792	·32792	
July	...	1 30·7	1 30·7		·32791	·32791	
August	...	1 30·7	1 30·7	Up to 12 h. on 28th August	·32787	·32789 ·32784	Up to 12 h. on 28th August. From 13 h. on „ „
September	...	1 28·6	1 28·6	From 13 h. on 28th August	·32783	·32783	
October	...	1 28·8	1 28·8		·32777	·32779 ·32777	Up to 20th October. From 21st „
November	...	1 28·5	1 28·5		·32766	·32766	
December	...	1 28·3	1 28·3		·32761	·32767 ·32757	Up to 13th December. From 14th „

4. *Mean scale values and temperature range.*—The mean scale values for 1916 for an ordinate of 1/25 inch are:— Horizontal Force 4·42 gammas.
Declination 1·03 minutes.
Vertical Force 5·13 to 7·92 gammas.

The mean temperature throughout the year was 27°·0 C. The temperature of reduction is 27°·0 C.

5. ***Mean monthly values and annual changes.***—The following table shows the monthly mean values of the magnetic elements for 1915 and 1916 and the annual changes for that period: these annual changes are deduced from the values of H as corrected for the moment of inertia and the revised distribution factor used in the computations for 1915.

Annual changes at Dehra Dūn in 1915-16.

Months.	Horizontal Force ·33000 C. G. S. +			Declination E. 2° +			Dip N. 44° +			Vertical Force ·32000 C. G. S. +		
	1915.	1916.	Annual change.	1915.	1916.	Annual change.	1915.	1916.	Annual change.	1915.	1916.	Annual change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January ...	105	63	−42	17·1	13·2	−3·9	26·8	34·9	+8·1	471	583	+112
February ...	103	72	−31	16·9	12·8	−4·1	27·6	34·7	+7·1	484	589	+105
March ...	101	52	−49	16·7	12·7	−4·0	28·2	36·3	+8·1	493	599	+106
April ...	97	61	−36	16·4	12·2	−4·2	28·8	36·2	+7·4	501	606	+105
May ...	93	57	−36	15·8	11·8	−4·0	29·3	36·9	+7·6	507	616	+109
June ...	80	64	−16	15·7	10·9	−4·8	30·4	37·0	+6·6	515	625	+110
July ...	86	53	−33	15·3	10·9	−4·4	30·9	38·0	+7·1	531	632	+101
August ...	80	48	−32	15·0	10·6	−4·4	31·6	38·5	+6·9	538	637	+ 99
September ...	72	38	−34	14·7	10·0	−4·7	32·1	39·4	+7·3	540	644	+104
October ...	63	34	−29	14·5	9·7	−4·8	33·1	40·3	+7·2	549	658	+109
November ...	52	28	−24	13·9	9·0	−4·9	34·4	41·1	+6·7	563	666	+103
December ...	63	25	−38	13·5	8·6	−4·9	34·4	41·3	+6·9	574	667	+ 93
Means ...	83	50	−33	15·5	11·0	−4·5	30·6	37·9	+7·3	522	627	+105

Toungoo Observatory.

1. The Declination, H. F. and V. F. magnetographs have worked well throughout the year.

2. ***Mean values of the Declination and H. F. constants.***—The table below gives the mean monthly values of magnetic collimation, revised distribution constants and moment "m" as determined with the revised distribution factor and moment of inertia used for the computations in 1915.

Mean values of the constants of magnet No. 194 in 1916.

Months.	Declination constants. Mean magnetic collimation.	H. F. constants. Distribution Factors. $P_{1·2}$	$P_{2·3}$	Accepted values p	q	Mean values of m. Monthly means.	Accepted m.	Remarks.
	′ ″							
January ...	−10 0	8·25	8·85	10·19	·546	875·95	875·95	To 15th Jan.
						875·79	875·79	From 18th Jan. to 10th Feb.
February ...	−10 6	8·44	8·80			875·54	875·54	From 15th Feb.
	−11 24							
March ...	−11 21	8·46	8·72			875·51	875·51	1st to 11th Mar.
April ...	−11 21	8·53	8·90			875·38	875·38	From 14th Mar. to end of Apr.
May ...	−11 26	8·48	8·85			875·15	875·15	
June ...	−11 31	8·39	8·84			875·04	875·04	
July ...	−11 29	8·43	8·91					
August ...	−11 26	8·43	8·84			874·86	874·86	
September ...	−11 30	8·38	8·89					
October ...	−11 33	8·47	8·93			874·77	874·77	
November ...	−11 29	8·48	8·83					
December ...	−11 31	8·37	8·79			874·29	874·29	

3. *Mean base line values.*—The following table gives the mean monthly observed and accepted base line values of the Declination and H. F. magnetographs: the accepted values have been used to compute the values of these elements for 1916.

The H. F. base lines are derived from H as determined with the revised values of the moment of inertia and distribution coefficient used in the computations for 1915.

Base line values of magnetographs in 1916.

Months.	Declination. Mean value of Base line.	Declination. Base line accepted.	Remarks.	Horizontal Force. Mean value of Base line.	Horizontal Force. Base line accepted.
	° ′	° ′		C. G. S.	C. G. S
January ...	0 53·0	0 53·0	h m To 0-12 on 1st May	·38611	·38611
February ...	0 52·8			·38605	·38606
March ...	0 53·1			·38601	·38601
April ...	0 53 2			·38603	·38603
May ...	0 51·6	0 51·6	h m From 0-13 on 1st May	·38599	·38599
June ...	0 51·5	0 51·5		·38597	·38597
July ...	0 51·9	0 51·9		·38599	·38599
August ...	0 52·0	0 52·0		·38597	·38597
September ...	0 52·1	0 52·1		·38592	·38592
October ...	0 52·1	0 52·1		·38591	·38591
November ...	0 52·3	0 52·3		·38594	·38594
December ...	0 51·9	0 51·9		·38584	·38584

4. *Mean scale values and temperature range.*—The mean scale values for 1916 for an ordinate of 1/25 inch are:—

Horizontal Force	5·40 gammas.
Declination	1·04 minutes.
Vertical Force	5·72 to 6·13 gammas.

The mean temperature for the year was 89°·2 Fahr. with maximum and minimum monthly values of 89°·7 Fahr. and 89°·0 Fahr. The temperature of reduction is 89°·0 Fahr.

5. *Mean monthly values and annual changes.*—The table below gives the mean monthly values of the magnetic elements for 1915 and 1916 and the annual changes for that period: these annual change values are deduced from the values of H as corrected for changes in the moment of inertia and the revised distribution factor used in the computations for 1915.

Annual changes at Toungoo in 1915-16.

Months.	Horizontal Force ·38000 C. G. S. +			Declination W. 0° +			Dip N. 23° +			Vertical Force ·16000 C. G. S. +		
	1915	1916	Annual change.	1915	1916	Annual change.	1915	1916	Annual change.	1915	1916	Annual change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January ...	1000	1013	+13	0·5	6·3	+5·8	6·7	7·3	+0 6	644	658	+14
February ...	1003	1022	19	1·0	6·6	5·6	6·8	7·7	0·9	647	667	20
March ...	1004	1004	0	1·3	6·9	5·6	6·9	8·6	1·7	648	671	23
April ...	1002	1021	19	1·6	7·5	5·9	7·0	8·3	1·3	648	675	27
May ...	1009	1015	6	2·1	8·0	5·9	6·8	8·6	1·8	649	676	27
June ...	1003	1026	23	2·4	8·2	5·8	7·7	8·5	0·8	659	679	20
July ...	1005	1021	16	3·0	8·8	5·8	7·2	9·0	1·8	653	684	31
August ...	1005	1020	15	3·9	9·0	5·1	7·2	9·0	1·8	653	684	31
September ...	1010	1014	4	4·5	9·5	5·0	7·1	9·2	2·1	654	684	30
October ...	1006	1017	11	5·1	9·7	4·6	7·6	8·6	1·0	659	677	18
November ...	999	1025	26	5·4	10·3	4·9	8·1	8·7	0·6	663	681	18
December ...	1010	1019	9	6·0	10·5	4·5	7·7	8·8	1·1	662	681	19
Means ...	1005	1018	+13	3·1	8·4	+5·3	7·2	8·5	+1·3	653	676	+23

Kodaikanal Observatory.

1. The Kodaikānal observatory is now under the control of the Meteorological Department (*vide* " Records ", Volume X), but the absolute observations and the records of the self-registering instruments are forwarded periodically by the Director of the Kodaikānal observatory for computation and for record in the party.

Thanks are due to the Director for cordial assistance in all matters connected with the magnetic work.

2. ***Mean values of Declination and H. F. constants.***—The table below gives the mean monthly values of the magnetic collimation, revised distribution constants and moment "m" as determined with the revised distribution factor and moment of inertia used for the computations in 1915. The values of m in the table are all derived from the vibration observation as determined with the chronograph.

Mean values of the constants of magnet No. 16 in 1916.

Months.	Declination constants.	H. F. constants.					
	Mean magnetic collimation.	Distribution factors.				Mean values of m.	
		$P_{1\cdot2}$	$P_{2\cdot3}$	Accepted values. p	Accepted values. q	Monthly means.	Accepted m.
	' "						
January ...	− 3 26	5·86	8·49			883·18	
February ...	− 3 27	5 84	8·67			883·08	
March ...	− 3 26	5 83	8·66			883·04	
April ...	− 3 27	5·78	8·60			883·10	
May ...	− 3 23	5·83	8·34			883·01	
June ...	− 3 25	5·77	8·61	11·39	—1621	882·98	882·77
July ...	− 3 23	5·79	8·63			883·01	
August ...	− 3 24	5·89	8·31			882 93	
September ...	− 3 23	5·95	8·29			882·97	
October ...	− 3 23	5·89	8 66			882·92	
November ...	− 3 22	5·88	8 49			882·93	
December ...	− 3 24	5 97	8·18			883·07	

3. ***Mean base line values.***— The following table gives the mean monthly observed and accepted values of the Declination and Horizontal Force base lines: the accepted values have been used to compute the values of these elements for 1916. The H.F. base line values have been derived from H as determined with the revised values of the moment of inertia and distribution coefficients used in the computations for 1915.

Base line values of magnetographs in 1916.

Months.	Declination. Mean value of Base line.	Declination. Base line accepted.	Horizontal force. Mean value of Base line.	Horizontal force. Base line accepted.	Months.	Declination. Mean value of Base line.	Declination. Base line accepted.	Horizontal force. Mean value of Base line.	Horizontal force. Base line accepted.
	° '	° '	C.G.S.	C.G.S.		° '	° '	C.G.S.	C.G.S.
January ...	1 57·4	1 57·4	·87357	·37357	July ...	2 33 7	2 33·7	·37359	·37359
February	1 57·2	1 57·2	·37356	·37356	August ...	2 34 0	2 34·0	·37358	·37358
March ...	...	...	·37361	·37361	September	2 33·9	2 33·9	·37349	·37349
April ...	2 33·5	2 33·5	·37363	·37363	October ...	2 34·0	2 34·0	·37348	·37348
May ...	2 34·2	2 34·2	·37363	·37363	November	2 33·8	2 33·8	·37348	·37348
June ...	2 34·0	2 34·0	·37358	·37358	December	2 34·0	2 34·0	·37343	·37343

4. ***Mean scale values and temperature range.***—The mean scale values for 1916 for an ordinate of 1/25 inch are :—

Horizontal Force	5·90 gammas.
Declination	1·03 minutes.
Vertical Force	5·14 to 6·46 gammas.

The mean temperature for the year was 18°·1 C. with maximum and minimum monthly values of 18°·9 C. and 17°·4 C. The temperature of reduction is 19°·0 C.

5. *Mean monthly values and annual changes.*—The table below gives the mean monthly values of the magnetic elements for 1915 and 1916 and the annual changes for that period : these annual change values are deduced from the values of H as corrected for the moment of inertia and the revised distribution factor used in the computations for 1915.

Annual changes at Kodaikānal in 1915-16.

Months.	Horizontal Force ·37000 C.G.S. +			Declination W. 1° +			Dip N. 4° +			Vertical Force. ·02000 C.G.S. +		
	1915.	1916.	Annual change.	1915.	1916.	Annual change.	1915.	1916.	Annual change.	1915.	1916.	Annual change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January ...	608	623	+ 15	19·8	25·5	+ 5·7	13·7	19·0	+ 5·3	781	839	+ 58
February ...	606	630	+ 24	20·3	25·6	+ 5·3	15 0	20·4	+ 5·4	794	855	+ 61
March ...	611	622	+ 11	20·6	...	...	15·8	20·6	+ 4·8	804	858	+ 54
April ...	617	637	+ 20	21·0	26·4	+ 5·4	15·9	21·0	+ 5·1	805	862	+ 57
May ...	618	634	+ 16	21·6	26·9	+ 5·3	16·7	21·7	+ 5·0	814	871	+ 57
June ...	610	638	+ 28	22·2	27·2	+ 5·0	17·2	22·4	+ 5·2	818	879	+ 61
July ...	610	635	+ 25	22·6	27·5	+ 4·9	17·9	22·9	+ 5·0	827	884	+ 57
August ...	619	635	+ 16	23·0	28·4	+ 5·4	17·2	23·5	+ 6·3	820	890	+ 70
September ...	623	630	+ 7	23·4	28·9	+ 5·5	17 9	23 3	+ 5·4	827	888	+ 61
October ...	620	636	+ 16	23·8	29·5	+ 5·7	18·1	23·8	+ 5·7	829	894	+ 65
November ...	609	637	+ 28	24·2	29·9	+ 5·7	19·2	24·6	+ 5·4	841	903	+ 62
December ...	620	636	+ 16	25·0	30·6	+ 5·6	19·1	25·1	+ 6·0	841	908	+ 67
Means ...	614	633	+ 19	22·3	...	+ 5·4	17·0	22·4	+ 5·4	817	878	+ 61

III.—Tables of Results.

Mean values of the magnetic elements at observatories in 1916.

Observatory.	Latitude and Longitude.	Dip.	Declination.	H. F.	V. F.
	° ′ ″	° ′	° ′	C. G. S.	C. G. S.
Dehra Dūn ...	30 19 19 N 78 3 19 E	N. 44 37·9	E. 2 11·0	·33050	·32627
Toungoo ...	18 55 45 N 96 27 3 E	N. 23 8·5	W. 0 8·4	·39018	·16677
Kodaikānal ...	10 13 50 N 77 27 46 E	N. 4 22·4	W. 1 27·9	·37633	·02878

D = Dehra Dūn ... Lat. 30° 19′ 19″ N. Long. 78° 3′ 19″ E.

T = Toungoo ... Lat. 18° 55′ 45″ N. Long. 96° 27′ 3″ E.

K = Kodaikānal ... Lat. 10° 13′ 50″ N. Long. 77° 27′ 46″ E.

Classification of curves and dates of Magnetic disturbances in 1916.

Dates.		January.			February.			March.			April.			May.			June.			July.			August.			September.			October.			November.			December.		
1916		D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K
1	...	C	C	C	C	C	C	C	C	C	S	S	S	S	S	S	S	S	S	M	M	M	C	C	C	C	C	C	M	S	M	C	C	C	M	M	M
2	...	C	C	C	C	C	C	C	C	C	C	C	C	S	S	S	C	C	C	S	S	M	M	M	M	C	C	C	S	S	S	C	C	C	M	M	M
3	...	C	C	C	C	C	C	S	S	S	C	C	C	S	S	S	C	C	C	S	S	S	S	S	S	S	S	S	S	C	S	M	M	M	S	S	S
4	...	S	S	S	S	S	C	S	S	S	C	C	C	S	S	S	C	C	C	S	S	S	C	C	C	S	S	S	C	C	C	S	S	S	S	S	S
5	...	C	C	C	S	S	S	S	S	C	C	C	C	S	S	S	C	C	C	S	S	S	S	S	S	S	—	S	S	C	S	M	S	S	C	C	C
6	...	S	S	S	C	C	C	S	S	S	S	C	S	S	S	S	S	S	S	S	S	S	M	M	M	S	C	C	M	M	M	S	S	S	C	C	C
7	...	S	S	C	C	C	C	S	S	S	S	S	S	S	S	S	S	S	S	C	C	C	S	S	S	S	S	S	G	G	G	S	S	S	C	C	C
8	...	C	C	C	S	S	S	V.G.	V.G.	V.G.	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	M	S	M	S	S	S	C	C	C
9	...	S	S	S	S	S	S	G	G	G	S	S	S	S	S	S	S	S	S	M	S	S	S	S	S	C	C	C	M	S	S	S	C	C	C	C	C
10	...	S	S	S	S	S	S	G	G	G	C	C	C	S	S	S	C	C	C	S	S	S	S	S	S	S	S	S	S	S	S	C	C	C	C	C	C
11	...	G	G	G	C	C	C	S	S	S	C	C	C	S	S	S	C	C	C	S	S	S	C	C	C	S	S	S	S	S	S	C	C	C	C	C	C
12	..	G	G	G	S	S	S	S	S	S	C	C	C	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	G	G	G	S	S	S
13	...	S	S	S	S	S	S	C	C	C	C	C	C	S	C	C	S	S	S	S	S	S	S	S	S	S	S	S	—	S	S	G	G	G	S	S	S
14	...	S	C	C	S	S	S	C	C	C	C	C	C	C	C	C	S	S	S	S	S	S	S	S	S	S	C	C	—	S	M	C	C	C	S	S	S
15	...	C	C	C	S	S	S	C	C	C	S	S	S	C	C	—	C	C	C	C	C	C	C	C	C	S	S	S	C	C	C	S	S	S	M	M	S
16	...	S	C	C	C	•C	C	C	C	C	S	S	S	S	S	—	C	C	C	C	C	C	C	C	C	S	S	S	C	C	C	S	C	C	M	S	S
17	...	C	C	C	S	S	S	M	M	M	C	C	C	S	S	S	S	S	S	S	S	S	C	C	C	S	S	S	C	C	C	S	C	C	S	C	C
18	...	C	C	C	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	—	S	C	S	—	S	C	C	C	S	S	S	C	C	C
19	...	C	C	C	S	S	S	S	S	S	S	S	S	C	C	C	S	S	S	S	S	S	—	S	S	C	—	C	C	C	C	S	S	S	C	C	C
20	...	M	M	M	S	S	S	S	S	S	S	S	S	C	C	S	S	S	S	C	C	S	—	S	S	C	C	C	S	C	S	C	—	C	C	C	C
21	...	S	S	S	C	C	C	S	S	S	S	S	S	M	M	—	S	S	S	C	C	C	S	S	S	C	C	C	S	S	S	C	—	C	C	C	C
22	...	S	S	S	S	S	S	C	C	C	S	S	S	G	G	—	S	S	S	C	C	C	S	S	S	S	S	S	S	S	S	S	S	S	C	C	C
23	...	S	S	S	S	C	C	C	C	C	S	C	C	M	S	S	S	S	S	S	S	S	G	M	S	S	S	S	S	C	S	S	S	C	C	C	C
24	...	S	S	S	C	S	S	M	M	M	C	C	S	S	S	S	C	C	C	S	S	S	M	M	S	S	S	S	S	S	S	C	C	C	C	C	S
25	...	M	M	M	C	C	C	S	S	S	M	M	M	S	S	S	S	S	S	C	C	C	C	C	C	S	S	S	S	C	S	C	—	C	S	S	C
26	...	S	S	S	S	S	S	S	S	S	G	G	G	C	C	C	S	S	S	C	C	C	C	C	C	S	S	S	C	C	C	S	S	S	S	S	C
27	...	C	C	C	S	S	S	C	C	C	M	S	S	C	C	C	S	S	S	C	C	C	G	G	G	S	S	S	C	C	C	S	S	S	S	S	S
28	...	C	C	C	S	S	S	S	S	C	G	M	S	C	C	C	S	S	S	C	C	C	S	S	S	C	C	C	C	C	C	S	S	S	S	S	S
29	...	S	S	S	C	C	C	G	G	G	G	G	G	S	S	S	S	S	C	C	C	C	S	S	S	C	C	C	S	C	S	S	S	S	S	S	S
30	...	C	C	C	...	...	...	M	M	M	S	S	S	M	M	S	S	S	S	C	C	C	S	S	S	S	—	S	S	S	S	S	S	S	S	S	S
31	...	C	C	C	...	...	...	S	S	S	...	...	...	M	M	S	...	...	...	C	C	C	S	S	S	...	...	...	C	C	C	...	...	...	S	S	S
C	...	13	15	16	11	11	12	9	9	11	11	13	11	7	8	6	9	9	10	13	13	12	8	8	9	8	9	10	10	15	10	9	9	13	14	15	16
S	...	14	12	11	18	18	17	15	15	13	14	13	16	19	19	21	21	21	20	16	17	17	15	18	19	22	17	20	14	14	16	17	15	14	13	13	13
M	...	2	2	2	...	...	...	3	3	3	2	2	1	4	3	...	...	...	...	2	1	2	3	4	2	..	...	...	4	1	4	2	1	1	4	3	2
G	...	2	2	2	...	...	...	3	3	3	3	2	2	1	1	...	...	...	...	...	...	...	2	1	1	...	...	...	1	1	1	2	2	2	...	...	...
V.G.	...	...	...	...	...	...	...	1	1	1	...	...	...	...	...	...	...	...	...	...	...	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Trace lost	...	...	...	...	...	...	...	...	..	...	...	...	...	...	...	4	...	...	...	...	...	...	...	...	...	...	4	...	2	...	...	...	3	...	...	...	...

C = Calm. S = Slight. M = Moderate. G = Great. V.G. = Very Great. — = Trace lost.

Hourly Means of the Declination at Dehra Dun in 1916, determined from all available days. Declination = E. 2° + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter. Jan.	13·3	13·2	13·2	13·1	13·0	12·9	12·9	13·0	14·0	14·8	14·5	12·9	11·8	11·8	12·3	13·1	13·7	13·5	13·3	13·3	13·5	13·3	13·3	13·2	13·3	13·2
Feb.	13·3	13·1	13·1	12·9	12·6	12·4	12·8	12·4	13·0	13·7	14·0	13·5	12·7	12·1	11·9	12·1	12·4	12·7	12·7	12·8	12·9	12·9	13·1	13·1	13·3	12·8
Mar.	13·0	13·0	12·8	12·6	12·7	12·8	13·0	13·7	14·9	15·2	14·4	12·8	11·2	10·3	10·5	11·4	12·4	12·8	12·5	12·3	12·3	12·5	12·7	12·9	12·9	12·7
Oct.	10·1	10·0	10·0	9·8	9·5	9·5	9·7	10·6	11·5	11·3	10·3	9·3	8·1	7·6	8·2	9·1	9·7	9·6	9·5	9·6	9·6	9·7	9·9	10·0	10·0	9·7
Nov.	9·3	9·5	9·4	9·1	8·8	8·5	8·5	8·6	9·2	9·5	9·3	8·5	8·0	8·4	8·9	9·1	9·1	9·0	9·0	9·1	9·1	9·3	9·3	9·3	9·3	9·0
Dec.	8·8	8·7	8·7	8·5	8·4	8·1	7·9	7·8	8·3	8·9	9·0	8·0	7·7	8·1	8·8	9·0	8·9	8·8	8·8	8·9	8·8	8·8	8·9	8·7	8·7	8·6
Means	11·3	11·3	11·2	11·0	10·8	10·7	10·7	11·0	11·8	12·2	11·9	10·8	9·9	9·7	10·1	10·6	11·0	11·1	11·0	11·0	11·0	11·1	11·2	11·2	11·3	11·0
Summer. April	12·6	12·7	12·7	12·6	12·4	12·3	13·0	14·4	15·7	15·9	14·6	12·0	9·7	8·8	8·3	9·8	10·9	11·8	12·2	12·0	12·1	12·1	12·3	12·5	12·6	12·2
May	12·1	12·1	12·1	12·2	12·3	12·6	14·2	15·2	15·3	14·3	12·3	10·2	8·7	8·3	8·7	9·8	10·9	11·8	12·0	11·7	11·6	11·7	11·9	12·0	12·1	11·8
June	11·1	11·5	11·5	11·5	11·5	11·9	13·3	14·5	14·7	13·7	11·8	9·6	8·2	7·6	7·7	8·2	9·2	10·2	10·8	10·7	10·7	10·7	10·9	11·0	11·1	10·9
July	11·1	11·2	11·3	11·4	11·3	11·7	13·2	14·4	14·6	13·8	12·1	9·9	8·5	7·5	7·3	8·0	9·1	10·1	11·0	10·7	10·5	10·6	10·6	10·7	11·0	10·9
Aug.	10·8	10·9	10·9	11·0	11·1	11·4	13·0	14·0	14·2	12·8	10·6	8·8	7·5	7·0	7·5	8·7	9·7	10·6	11·1	10·6	10·5	10·4	10·5	10·6	10·7	10·6
Sep.	10·1	10·2	10·2	10·1	10·3	10·5	11·3	12·6	13·0	11·9	9·8	7·9	6·5	6·5	7·4	8·8	10·1	10·6	10·4	10·2	10·0	10·2	10·1	10·1	10·1	10·0
Means	11·3	11·4	11·5	11·5	11·5	11·7	13·0	14·2	14·6	13·7	11·9	9·7	8·2	7·6	7·9	8·9	10·0	10·9	11·3	11·0	10·9	11·0	11·1	11·2	11·3	11·1

Diurnal Inequality of the Declination at Dehra Dun in 1916, deduced from the above Table.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.
Winter. Jan.	+0·1	0·0	0·0	−0·1	−0·2	−0·3	−0·3	−0·2	+0·8	+1·6	+1·3	−0·3	−1·4	−1·4	−0·9	−0·1	+0·5	+0·3	+0·1	+0·1	+0·3	+0·1	+0·1	0·0	+0·1
Feb.	+0·5	+0·3	+0·3	+0·1	−0·2	−0·4	−0·5	−0·4	+0·2	+0·9	+1·2	+0·7	−0·1	−0·7	−0·9	−0·7	−0·4	−0·1	−0·1	0·0	+0·1	+0·1	+0·3	+0·3	+0·5
Mar.	+0·3	+0·3	+0·1	−0·1	0·0	+0·1	+0·3	+1·0	+2·2	+2·5	+1·7	+0·1	−1·5	−2·4	−2·2	−1·3	−0·3	+0·1	−0·2	−0·4	−0·4	−0·2	+0·0	+0·2	+0·2
Oct.	+0·4	+0·3	+0·3	+0·1	−0·2	−0·2	0·0	+0·9	+1·8	+1·6	+0·6	−0·4	−1·6	−2·1	−1·5	−0·6	0·0	−0·1	−0·2	−0·1	−0·1	0·0	+0·2	+0·3	+0·3
Nov.	+0·3	+0·5	+0·4	+0·1	−0·2	−0·5	−0·5	−0·4	+0·2	+0·5	+0·3	−0·5	−1·0	−0·6	−0·1	+0·1	+0·1	0·0	0·0	+0·1	+0·1	+0·3	+0·3	+0·3	+0·3
Dec.	+0·2	+0·1	+0·1	−0·1	−0·2	−0·5	−0·7	−0·8	−0·3	+0·3	+0·4	−0·6	−0·9	−0·5	+0·2	+0·4	+0·3	+0·2	+0·2	+0·3	+0·2	+0·2	+0·3	+0·1	+0·1
Means	+0·3	+0·3	+0·2	0·0	−0·2	−0·3	−0·3	0·0	+0·8	+1·2	+0·9	−0·2	−1·1	−1·3	−0·9	−0·4	0·0	+0·1	0·0	0·0	0·0	+0·1	+0·2	+0·2	+0·3
Summer. April	+0·4	+0·5	+0·5	+0·4	+0·2	+0·1	+0·8	+2·2	+3·5	+3·7	+2·4	−0·2	−2·5	−3·4	−3·4	−2·4	−1·3	−0·4	0·0	−0·2	−0·1	−0·1	+0·1	+0·3	+0·4
May	+0·3	+0·3	+0·3	+0·4	+0·5	+0·8	+2·4	+3·4	+3·5	+2·5	+0·5	−1·6	−3·1	−3·5	−3·1	−2·0	−0·9	0·0	+0·2	−0·1	−0·2	−0·1	+0·1	+0·2	+0·3
June	+0·2	+0·6	+0·6	+0·6	+0·6	+1·0	+2·4	+3·6	+3·8	+2·8	+0·9	−1·3	−2·7	−3·3	−3·2	−2·7	−1·7	−0·7	−0·1	−0·2	−0·2	−0·2	0·0	+0·1	+0·2
July	+0·2	+0·3	+0·4	+0·5	+0·4	+0·8	+2·3	+3·5	+3·7	+2·9	+1·2	−1·0	−2·4	−3·4	−3·6	−2·9	−1·8	−0·8	+0·1	−0·2	−0·4	−0·3	−0·3	−0·2	+0·1
Aug.	+0·2	+0·3	+0·3	+0·4	+0·5	+0·8	+2·4	+3·4	+3·6	+2·2	0·0	−1·8	−3·1	−3·6	−3·1	−1·9	−0·9	0·0	+0·5	0·0	−0·1	−0·2	−0·1	0·0	+0·1
Sep.	+0·1	+0·2	+0·2	+0·1	+0·3	+0·5	+1·3	+2·6	+3·0	+1·9	−0·2	−2·1	−3·5	−3·5	−2·6	−1·2	+0·1	+0·6	+0·4	+0·2	0·0	+0·2	+0·1	+0·1	+0·1
Means	+0·2	+0·3	+0·4	+0·4	+0·4	+0·6	+1·9	+3·1	+3·5	+2·6	+0·8	−1·4	−2·9	−3·5	−3·2	−2·2	−1·1	−0·2	+0·2	−0·1	−0·2	−0·1	0·0	+0·1	+0·2

NOTE.—When the sign is + the magnet points to the East, and when − to the West of the mean position.

Hourly Means of Horizontal Force in C.G.S. units (corrected for temperature) at Dehra Dun in 1916, from all available days. ***Horizontal Force = ·83000 C.G.S. + tabular quantity.***

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ		γ	γ	γ	γ	γ	γ	γ	γ	γ	
Winter.	Jan.	61	60	62	63	64	66	68	67	67	61	54	57	63	68	68	69	63	64	61	58	58	58	58	62	61	63
	Feb.	63	67	66	66	67	69	72	74	77	82	84	85	86	84	78	73	70	69	66	65	66	64	66	64	68	72
	Mar.	46	49	49	52	51	48	48	46	47	51	58	67	70	68	67	61	54	48	44	46	48	46	45	50	49	52
	Oct.	32	34	31	33	33	33	33	34	32	31	32	40	46	49	46	37	32	27	30	30	33	28	31	32	35	34
	Nov.	29	27	26	28	29	29	30	31	35	38	37	39	41	37	28	25	21	16	21	19	19	21	23	25	28	28
	Dec.	22	22	24	24	23	25	27	30	32	33	30	33	35	34	28	22	20	18	19	20	20	21	20	22	23	25
	Means	42	43	43	44	45	45	46	47	48	49	49	54	57	57	53	48	44	40	40	40	41	40	41	43	43	46
Summer.	April	56	56	54	55	58	59	58	58	57	62	68	73	79	80	77	70	61	56	52	54	52	55	57	57	58	61
	May	55	54	55	56	56	56	56	52	50	51	57	68	76	76	69	64	57	51	47	47	51	50	52	54	56	57
	June	62	61	62	63	62	63	65	64	61	61	64	69	74	79	79	76	67	60	56	55	60	59	62	62	62	64
	July	54	54	54	53	52	55	55	54	47	44	47	51	56	60	62	60	55	50	48	47	48	51	54	55	54	53
	Aug.	47	48	49	48	49	48	48	46	41	42	45	47	57	60	56	50	49	46	42	41	43	46	49	51	51	48
	Sep.	38	41	41	43	41	42	38	32	26	26	31	37	46	48	46	44	37	34	33	34	34	36	39	40	38	38
	Means	52	52	53	53	53	54	53	51	47	48	52	58	65	67	65	61	54	50	46	46	48	50	52	53	53	54

Diurnal Inequality of the Horizontal Force at Dehra Dun in 1916, deduced from the above Table.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
Winter.	Jan.	− 2	− 3	− 1	0	+ 1	+ 3	+ 5	+ 4	+ 4	− 2	− 9	− 6	0	+ 5	+ 5	+ 6	+ 5	+ 1	− 2	− 5	− 5	− 5	− 5	− 1	− 2	
	Feb.	− 9	− 5	− 6	− 6	− 5	− 3	0	+ 2	+ 5	+10	+12	+13	+14	+12	+ 6	+ 1	− 2	− 3	− 6	− 7	− 6	− 8	− 6	− 8	− 9	
	Mar.	− 6	− 3	− 3	0	− 1	− 4	− 4	− 6	− 5	− 1	+ 6	+15	+18	+16	+15	+ 9	+ 2	− 4	− 8	− 6	− 4	− 6	− 7	− 2	− 3	
	Oct.	− 2	0	− 3	− 1	− 1	− 1	− 1	0	− 2	− 3	− 2	+ 6	+12	+15	+12	+ 3	− 2	− 7	− 4	− 4	− 1	− 6	− 3	− 2	+ 1	
	Nov.	+ 1	− 1	− 2	0	+ 1	+ 1	+ 2	+ 3	+ 7	+10	+ 9	+11	+13	+ 9	0	− 3	− 7	−12	− 7	− 9	− 9	− 7	− 5	− 3	0	
	Dec.	− 3	− 3	− 1	− 1	− 2	0	+ 2	+ 5	+ 7	+ 8	+ 5	+ 8	+10	+ 9	+ 3	− 3	− 5	− 7	− 6	− 5	− 5	− 4	− 5	− 3	− 2	
	Means	− 4	− 3	− 3	− 2	− 1	− 1	0	+ 1	+ 2	+ 3	+ 3	+ 8	+11	+11	+ 7	+ 2	− 2	− 6	− 6	− 6	− 5	− 6	− 5	− 3	− 3	
Summer.	April	− 5	− 5	− 7	− 6	− 3	− 2	− 3	− 3	− 4	+ 1	+ 7	+12	+18	+19	+16	+ 9	0	− 5	− 9	− 7	− 9	− 6	− 4	− 4	− 3	
	May	− 2	− 3	− 2	− 1	− 1	− 1	− 1	− 5	− 7	− 6	0	+11	+19	+19	+12	+ 7	0	− 6	−10	−10	− 6	− 7	− 5	− 3	− 1	
	June	− 2	− 3	− 2	− 1	− 2	− 1	+ 1	0	− 3	− 3	0	+ 5	+10	+15	+15	+12	+ 3	− 4	− 8	− 9	− 4	− 5	− 2	− 2	− 2	
	July	+ 1	+ 1	+ 1	0	− 1	+ 2	+ 2	+ 1	− 6	− 9	− 6	− 2	+ 3	+ 7	+ 9	+ 7	+ 2	− 3	− 5	− 6	− 5	− 2	+ 1	+ 2	+ 1	
	Aug.	− 1	0	+ 1	0	+ 1	0	0	− 2	− 7	− 6	− 3	− 1	+ 9	+12	+ 8	+ 2	+ 1	− 2	− 6	− 7	− 5	− 2	+ 1	+ 3	+ 3	
	Sep.	0	+ 3	+ 3	+ 5	+ 3	+ 4	0	− 6	−12	−12	− 7	− 1	+ 8	+10	+ 8	+ 6	− 1	− 4	− 5	− 4	− 4	− 2	+ 1	+ 2	0	
	Means	− 2	− 2	− 1	− 1	− 1	0	− 1	− 3	− 7	− 6	− 2	+ 4	+11	+13	+11	+ 7	0	− 4	− 8	− 8	− 6	− 4	− 2	− 1	− 1	

NOTE.—When the sign is + the H.F. is greater, and when − it is less than the mean.

Hourly Means of Vertical Force in C. G. S. units (corrected for temperature) at Dehra Dun in 1916, from all available days. Vertical Force = ·32000 C. G. S. + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter. Jan.	583	583	583	583	583	584	584	584	586	583	577	574	575	579	582	584	584	583	583	583	585	585	585	586	585	583
Feb.	592	592	591	591	590	591	590	591	592	592	588	585	582	581	583	586	589	590	589	590	591	590	592	591	591	589
Mar.	602	604	603	603	603	603	603	606	605	594	591	585	583	586	592	597	599	600	600	602	604	603	604	606	605	599
Oct.	662	662	662	662	662	662	662	664	663	658	652	647	644	646	650	654	656	657	659	659	661	660	661	661	661	658
Nov.	667	666	666	667	666	666	666	667	667	663	661	658	660	662	664	665	667	667	669	669	669	669	669	669	669	666
Dec.	668	668	668	668	667	668	667	667	669	668	663	660	661	664	665	665	666	667	669	668	668	669	668	668	668	667
Means	629	629	629	629	629	629	629	630	630	626	622	618	618	620	623	625	627	627	628	629	630	629	630	630	630	627
Summer. April	612	612	611	612	612	612	614	616	613	606	596	585	585	590	596	602	606	608	608	609	610	611	612	612	612	606
May	620	620	620	620	620	621	624	622	615	608	601	600	602	606	610	616	619	620	618	618	620	620	622	622	622	616
June	629	629	629	629	629	631	635	633	627	619	612	606	608	611	616	620	623	627	629	629	630	630	631	631	631	625
July	635	636	635	636	636	638	642	640	634	626	619	613	614	617	621	627	633	636	637	635	636	638	638	638	638	632
Aug.	642	642	642	642	642	642	646	644	638	632	625	619	621	626	631	635	639	641	641	640	642	642	643	642	642	637
Sep.	644	646	645	645	645	646	647	648	646	641	635	631	632	636	640	646	646	647	646	648	649	650	650	650	649	644
Means	630	631	630	631	631	632	685	634	629	622	615	609	610	614	619	624	628	630	630	630	631	632	633	633	632	627

Diurnal Inequality of the Vertical Force at Dehra Dun in 1916, deduced from the above Table.

	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
Winter. Jan.	0	0	0	0	0	+ 1	+ 1	+ 1	+ 3	0	− 6	− 9	− 8	− 4	− 1	+ 1	+ 1	0	0	0	+ 2	+ 2	+ 2	+ 3	+ 2	
Feb.	+ 3	+ 3	+ 2	+ 2	+ 1	+ 2	+ 1	+ 2	+ 3	+ 3	− 1	− 4	− 7	− 8	− 6	− 3	0	+ 1	0	+ 1	+ 2	+ 1	+ 3	+ 2	+ 2	
Mar.	+ 3	+ 5	+ 4	+ 4	+ 4	+ 4	+ 4	+ 7	+ 6	− 5	− 8	−14	−16	−13	− 7	− 2	0	+ 1	+ 1	+ 3	+ 5	+ 4	+ 5	+ 7	+ 6	
Oct.	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	+ 6	+ 5	0	− 6	−11	−14	−12	− 8	− 4	− 2	− 1	+ 1	+ 1	+ 3	+ 2	+ 3	+ 3	+ 3	
Nov.	+ 1	0	0	+ 1	0	0	0	+ 1	+ 1	− 3	− 5	− 8	− 6	− 4	− 2	− 1	+ 1	+ 1	+ 3	+ 3	+ 3	+ 3	+ 3	+ 3	+ 3	
Dec.	+ 1	+ 1	+ 1	+ 1	0	+ 1	0	0	+ 2	+ 1	− 4	− 7	− 6	− 3	− 2	− 2	− 1	0	+ 2	+ 1	+ 1	+ 2	+ 1	+ 1	+ 1	
Means	+ 2	+ 2	+ 2	+ 2	+ 2	+ 2	+ 2	+ 3	+ 3	− 1	− 5	− 9	− 9	− 7	− 4	− 2	0	0	+ 1	+ 2	+ 3	+ 2	+ 3	+ 3	+ 3	
Summer. April	+ 6	+ 6	+ 5	+ 6	+ 6	+ 6	+ 8	+10	+ 7	0	−10	−21	−21	−16	−10	− 4	0	+ 2	+ 2	+ 3	+ 4	+ 5	+ 6	+ 6	+ 6	
May	+ 4	+ 4	+ 4	+ 4	+ 4	+ 5	+ 8	+ 6	− 1	− 8	−15	−16	−14	−10	− 6	0	+ 3	+ 4	+ 2	+ 2	+ 4	+ 4	+ 6	+ 6	+ 6	
June	+ 4	+ 4	+ 4	+ 4	+ 4	+ 6	+10	+ 8	+ 2	− 6	−13	−19	−17	−14	− 9	− 5	− 2	+ 2	+ 4	+ 4	+ 5	+ 5	+ 6	+ 6	+ 6	
July	+ 3	+ 4	+ 3	+ 4	+ 4	+ 6	+10	+ 8	+ 2	− 6	−13	−19	−18	−15	−11	− 5	+ 1	+ 4	+ 5	+ 3	+ 4	+ 6	+ 6	+ 6	+ 6	
Aug.	+ 5	+ 5	+ 5	+ 5	+ 5	+ 5	+ 9	+ 7	+ 1	− 5	−12	−18	−16	−11	− 6	− 2	+ 2	+ 4	+ 4	+ 3	+ 5	+ 5	+ 6	+ 5	+ 5	
Sep.	0	+ 2	+ 1	+ 1	+ 1	+ 2	+ 3	+ 4	+ 2	− 3	− 9	−13	−12	− 8	− 4	+ 2	+ 2	+ 3	+ 2	+ 4	+ 5	+ 6	+ 6	+ 6	+ 5	
Means	+ 8	+ 4	+ 3	+ 4	+ 4	+ 5	+ 8	+ 7	+ 2	− 5	−12	−18	−17	−13	− 8	− 3	+ 1	+ 3	+ 3	+ 3	+ 4	+ 5	+ 6	+ 6	+ 5	

NOTE.—When the sign is + the V. F. is greater, and when − it is less than the mean.

Hourly Means of the Dip at Dehra Dun in 1916, determined from all available days. Dip = N. 41° + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter. Jan.	35′·0	35′·0	34′·9	34′·9	34′·8	34′·8	34′·6	34′·7	34′·8	35′·0	35′·0	34′·7	34′·4	34′·4	34′·6	34′·6	34′·6	34′·8	35′·0	35′·1	35′·2	35′·2	35′·2	35′·1	35′·1	34′·9
Feb.	35·4	35·2	35·2	35·2	35·0	35·0	34·8	34·7	34·6	34·4	34·0	33·8	33·7	33·7	34·1	34·5	34·8	34·9	35·0	35·1	35·2	35·2	35·2	35·2	35·3	34·7
Mar.	36·7	36·7	36·7	36·5	36·6	36·7	36·7	37·0	36·9	36·1	35·5	34·8	34·5	34·8	35·2	35·7	36·2	36·5	36·8	36·7	36·7	36·8	36·9	36·8	36·7	36·3
Oct.	40·7	40·5	40·7	40·6	40·6	40·6	40·6	40·7	40·7	40·5	40·1	39·4	39·0	38·9	39·3	40·0	40·3	40·7	40·6	40·6	40·5	40·8	40·7	40·6	40·5	40·3
Nov.	41·1	41·1	41·2	41·1	41·0	41·0	41·0	41·0	40·8	40·4	40·3	40·1	40·1	40·4	41·0	41·2	41·5	41·8	41·6	41·7	41·7	41·6	41·5	41·4	41·2	41·1
Dec.	41·5	41·5	41·4	41·4	41·4	41·3	41·2	41·0	41·1	40·9	40·8	40·5	40·5	40·7	41·0	41·3	41·5	41·6	41·7	41·6	41·6	41·6	41·6	41·5	41·4	41·3
Means	38·4	38·3	38·4	38·3	38·2	38·2	38·2	38·2	38·2	37·9	37·6	37·2	37·0	37·2	37·5	37·9	38·2	38·4	38·5	38·5	38·5	38·5	38·5	38·4	38·4	38·1
Summer. April	36·8	36·8	36·8	36·8	36·7	36·6	36·7	36·9	36·8	36·1	35·3	34·5	34·2	34·3	34·8	35·5	36·2	36·5	36·7	36·7	36·9	36·7	36·7	36·7	36·7	36·2
May	37·2	37·3	37·2	37·2	37·2	37·3	37·4	37·5	37·3	36·8	36·1	35·5	35·2	35·4	36·0	36·5	37·1	37·4	37·6	37·6	37·4	37·5	37·5	37·4	37·3	36·9
June	37·3	37·4	37·3	37·3	37·3	37·4	37·5	37·4	37·3	36·9	36·3	35·8	35·6	35·5	35·8	36·1	36·8	37·4	37·6	37·7	37·5	37·6	37·4	37·4	37·4	37·0
July	38·1	38·2	38·1	38·2	38·2	38·2	38·4	38·4	38·4	38·1	37·6	37·1	36·9	36·8	36·9	37·4	37·9	38·4	38·5	38·4	38·4	38·4	38·2	38·2	38·2	38·0
Aug.	38·8	38·8	38·7	38·8	38·7	38·8	39·0	39·0	38·9	38·5	38·0	37·6	37·2	37·3	37·8	38·3	38·6	38·8	39·0	39·0	39·0	38·9	38·8	38·6	38·6	38·5
Sep.	39·4	39·3	39·3	39·2	39·3	39·3	39·5	39·9	40·1	39·8	39·3	38·8	38·3	38·4	38·8	39·2	39·5	39·7	39·7	39·8	39·9	39·8	39·6	39·6	39·7	39·4
Means	37·9	38·0	37·9	37·9	37·9	37·9	38·1	38·2	38·1	37·7	37·1	36·6	36·2	36·3	36·7	37·2	37·7	38·0	38·2	38·2	38·2	38·2	38·0	38·0	38·0	37·7

Diurnal Inequality of the Dip at Dehra Dun in 1916, deduced from the above Table.

	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	
Winter. Jan.	+0′·1	+0′·1	0′·0	0′·0	−0′·1	−0′·1	−0′·3	−0′·2	−0′·1	+0′·1	+0′·1	−0′·2	−0′·5	−0′·5	−0′·3	−0′·3	−0′·3	−0′·1	+0′·1	+0′·2	+0′·3	+0′·3	+0′·3	+0′·2	+0′·2	
Feb.	+0·7	+0·5	+0·5	+0·5	+0·3	+0·3	+0·1	0·0	−0·1	−0·3	−0·7	−0·9	−1·0	−1·0	−0·6	−0·2	+0·1	+0·2	+0·3	+0·4	+0·5	+0·5	+0·5	+0·5	+0·6	
Mar.	+0·4	+0·4	+0·4	+0·2	+0·3	+0·4	+0·4	+0·7	+0·6	−0·2	−0·8	−1·5	−1·8	−1·5	−1·1	−0·6	−0·1	+0·2	+0·5	+0·4	+0·4	+0·5	+0·6	+0·5	+0·4	
Oct.	+0·4	+0·2	+0·4	+0·3	+0·3	+0·3	+0·3	+0·4	+0·4	+0·2	−0·2	−0·9	−1·3	−1·4	−1·0	−0·3	0·0	+0·4	+0·3	+0·3	+0·2	+0·5	+0·4	+0·3	+0·2	
Nov.	0·0	0·0	+0·1	0·0	−0·1	−0·1	−0·1	−0·1	−0·3	−0·7	−0·8	−1·0	−1·0	−0·7	−0·1	+0·1	+0·4	+0·7	+0·5	+0·6	+0·6	+0·5	+0·4	+0·3	+0·1	
Dec.	+0·2	+0·2	+0·1	+0·1	+0·1	0·0	−0·1	−0·3	−0·2	−0·4	−0·5	−0·8	−0·8	−0·6	−0·3	0·0	+0·2	+0·3	+0·4	+0·3	+0·3	+0·3	+0·3	+0·2	+0·1	
Means	+0·3	+0·2	+0·3	+0·2	+0·1	+0·1	+0·1	+0·1	+0·1	−0·2	−0·5	−0·9	−1·1	−0·9	−0·6	−0·2	+0·1	+0·3	+0·4	+0·4	+0·4	+0·4	+0·4	+0·3	+0·3	
Summer. April	+0·6	+0·6	+0·6	+0·6	+0·5	+0·4	+0·5	+0·7	+0·6	−0·1	−0·9	−1·7	−2·0	−1·9	−1·4	−0·7	0·0	+0·3	+0·5	+0·5	+0·7	+0·5	+0·5	+0·5	+0·5	
May	+0·3	+0·4	+0·3	+0·3	+0·3	+0·4	+0·5	+0·6	+0·4	−0·1	−0·8	−1·4	−1·7	−1·5	−0·9	−0·4	+0·2	+0·5	+0·7	+0·7	+0·5	+0·6	+0·6	+0·5	+0·4	
June	+0·3	+0·4	+0·3	+0·3	+0·3	+0·4	+0·5	+0·4	+0·3	−0·1	−0·7	−1·2	−1·4	−1·5	−1·2	−0·9	−0·2	+0·4	+0·6	+0·7	+0·5	+0·6	+0·4	+0·4	+0·4	
July	+0·1	+0·2	+0·1	+0·2	+0·2	+0·2	+0·4	+0·4	+0·4	+0·1	−0·4	−0·9	−1·1	−1·2	−1·1	−0·6	−0·1	+0·4	+0·5	+0·4	+0·4	+0·4	+0·2	+0·2	+0·2	
Aug.	+0·3	+0·3	+0·2	+0·3	+0·2	+0·3	+0·5	+0·5	+0·4	0·0	−0·5	−0·9	−1·3	−1·2	−0·7	−0·2	+0·1	+0·3	+0·5	+0·5	+0·5	+0·4	+0·3	+0·1	+0·1	
Sep.	0·0	−0·1	−0·1	−0·2	−0·1	−0·1	+0·1	+0·5	+0·7	+0·4	−0·1	−0·6	−1·1	−1·0	−0·6	−0·2	+0·1	+0·3	+0·3	+0·4	+0·5	+0·4	+0·2	+0·2	+0·3	
Means	+0·2	+0·3	+0·2	+0·2	+0·2	+0·2	+0·4	+0·5	+0·4	0·0	−0·6	−1·1	−1·5	−1·4	−1·0	−0·5	0·0	+0·3	+0·5	+0·5	+0·5	+0·5	+0·3	+0·3	+0·3	

NOTE.—When the sign is + the Dip is greater, and when − it is less than the mean.

Hourly Means of the Declination at Toungoo in 1916, determined from all available days. Declination = W. 0° + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter. Jan.	6·3	6·3	6·4	6·4	6·5	6·6	6·8	6·6	5·8	4·9	5·3	6·6	7·3	7·2	7·0	6·2	5·6	5·8	6·2	6·1	6·2	6·1	6·3	6·3	6·3	6·3
Feb.	6·5	6·5	6·5	6·7	6·9	7·1	7·3	7·4	6·9	6·2	5·7	5·8	6·4	6·7	6·9	7·0	6·7	6·5	6·7	6·6	6·5	6·6	6·7	6·7	6·5	6·6
Mar.	7·0	6·9	6·9	7·0	7·2	7·2	7·0	6·3	5·7	5·3	5·7	6·5	7·7	8·4	8·2	7·4	6·8	6·6	7·1	7·0	7·0	7·1	7·1	7·0	7·0	6·9
Oct.	9·7	9·6	9·6	9·5	9·7	9·9	9·8	9·1	8·4	8·6	9·4	10·0	10·8	10·8	10·5	9·8	9·4	9·4	10·0	9·7	9·7	9·9	9·9	9·7	9·7	9·7
Nov.	10·2	10·2	10·0	10·2	10·5	10·7	10·9	10·9	10·3	9·8	9·8	10·1	10·2	10·1	10·1	10·1	10·0	10·2	10·4	10·0	10·2	10·5	10·4	10·3	10·2	10·3
Dec.	10·5	10·5	10·5	10·6	10·7	10·9	11·1	11·3	10·7	10·0	10·2	10·7	10·8	10·6	10·2	10·1	10·0	10·1	10·3	10·1	10·3	10·4	10·5	10·5	10·6	10·5
Means	8·4	8·3	8·3	8·4	8·6	8·7	8·8	8·6	8·0	7·5	7·7	8·3	8·9	9·0	8·8	8·4	8·1	8·1	8·5	8·3	8·3	8·4	8·5	8·4	8·4	8·4
Summer. April	7·4	7·2	7·2	7·3	7·5	7·6	7·1	6·2	5·5	5·4	6·2	7·7	9·2	9·7	9·4	8·6	7·8	7·2	7·3	7·5	7·6	7·7	7·7	7·6	7·4	7·5
May	8·0	7·9	7·8	7·8	7·8	7·7	6·5	5·4	5·4	6·3	7·7	9·0	9·9	10·1	9·7	9·0	8·3	7·7	7·7	8·0	8·3	8·4	8·3	8·1	8·0	8·0
June	8·1	7·9	7·7	7·7	7·7	7·6	6·5	5·5	5·4	6·3	7·7	9·3	10·3	10·5	10·1	9·7	9·0	8·4	8·1	8·4	8·6	8·6	8·5	8·3	8·1	8·2
July	9·1	8·8	8·6	8·6	8·6	8·3	7·1	6·0	5·8	6·7	8·2	9·7	10·7	10·9	10·7	10·3	9·4	8·8	8·7	8·9	9·2	9·3	9·2	9·1	9·1	8·8
Aug.	9·3	9·3	8·9	8·9	8·7	8·4	7·2	6·0	6·0	7·3	9·0	10·3	10·9	11·1	10·8	10·0	9·1	8·7	8·8	9·2	9·3	9·3	9·3	9·3	9·3	9·0
Sep.	9·6	9·6	9·4	9·4	9·4	9·2	8·2	7·0	7·1	8·1	9·6	11·0	11·8	11·8	11·1	9·9	9·0	8·8	9·3	9·5	9·5	9·6	9·6	9·7	9·6	9·5
Means	8·6	8·4	8·3	8·3	8·3	8·1	7·1	6·0	5·9	6·7	8·1	9·5	10·5	10·7	10·3	9·6	8·8	8·3	8·3	8·6	8·8	8·8	8·8	8·7	8·6	8·5

Diurnal Inequality of the Declination at Toungoo in 1916, deduced from the above Table.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	
Winter. Jan.	0·0	0·0	−0·1	−0·1	−0·2	−0·3	−0·5	−0·3	+0·5	+1·4	+1·0	−0·3	−1·0	−0·9	−0·7	+0·1	+0·7	+0·5	+0·1	+0·2	+0·1	+0·2	0·0	0·0	0·0	
Feb.	+0·1	+0·1	+0·1	−0·1	−0·3	−0·5	−0·7	−0·8	−0·3	+0·4	+0·9	+0·8	+0·2	−0·1	−0·3	−0·4	−0·1	+0·1	−0·1	0·0	+0·1	0·0	−0·1	−0·1	+0·1	
Mar.	−0·1	0·0	0·0	−0·1	−0·3	−0·3	−0·1	+0·6	+1·2	+1·6	+1·2	+0·4	−0·8	−1·5	−1·3	−0·5	+0·1	+0·3	−0·2	−0·1	−0·1	−0·2	−0·2	−0·1	−0·1	
Oct.	0·0	+0·1	+0·1	+0·2	0·0	−0·2	−0·1	+0·6	+1·3	+1·1	+0·3	−0·3	−1·1	−1·1	−0·8	−0·1	+0·3	+0·3	−0·3	0·0	0·0	−0·2	−0·2	0·0	0·0	
Nov.	+0·1	+0·1	+0·3	+0·1	−0·2	−0·4	−0·6	−0·6	0·0	+0·5	+0·5	+0·2	+0·1	+0·2	+0·2	+0·2	+0·3	+0·1	−0·1	+0·3	+0·1	−0·2	−0·1	0·0	+0·1	
Dec.	0·0	0·0	0·0	−0·1	−0·2	−0·4	−0·6	−0·8	−0·2	+0·5	+0·3	−0·2	−0·3	−0·1	+0·3	+0·4	+0·5	+0·4	+0·2	+0·4	+0·2	+0·1	0·0	0·0	−0·1	
Means	0·0	+0·1	+0·1	0·0	−0·2	−0·3	−0·4	−0·2	+0·4	+0·9	+0·7	+0·1	−0·5	−0·6	−0·4	0·0	+0·3	+0·3	−0·1	+0·1	+0·1	0·0	−0·1	0·0	0·0	
Summer. April	+0·1	+0·3	+0·3	+0·2	0·0	−0·1	+0·4	+1·3	+2·0	+2·1	+1·3	−0·2	−1·7	−2·2	−1·9	−1·1	−0·3	+0·3	+0·2	0·0	−0·1	−0·2	−0·2	−0·1	+0·1	
May	0·0	+0·1	+0·2	+0·2	+0·2	+0·3	+1·5	+2·6	+2·6	+1·7	+0·3	−1·0	−1·9	−2·1	−1·7	−1·0	−0·3	+0·3	+0·3	0·0	−0·3	−0·4	−0·3	−0·1	0·0	
June	+0·1	+0·3	+0·5	+0·5	+0·5	+0·6	+1·7	+2·7	+2·8	+1·9	+0·5	−1·1	−2·1	−2·3	−1·9	−1·5	−0·8	−0·2	+0·1	−0·2	−0·4	−0·4	−0·3	−0·1	+0·1	
July	−0·3	0·0	+0·2	+0·2	+0·2	+0·5	+1·7	+2·8	+3·0	+2·1	+0·6	−0·9	−1·9	−2·1	−1·9	−1·5	−0·6	0·0	+0·1	−0·1	−0·4	−0·5	−0·4	−0·3	−0·3	
Aug.	−0·3	−0·3	+0·1	+0·1	+0·3	+0·6	+1·8	+3·0	+3·0	+1·7	0·0	−1·3	−1·9	−2·1	−1·8	−1·0	−0·1	+0·3	+0·2	−0·2	−0·3	−0·3	−0·3	−0·3	−0·3	
Sep.	−0·1	−0·1	+0·1	+0·1	+0·1	+0·3	+1·3	+2·5	+2·4	+1·4	−0·1	−1·5	−2·3	−2·3	−1·6	−0·4	+0·5	+0·7	+0·2	0·0	0·0	−0·1	−0·1	−0·2	−0·1	
Means	−0·1	+0·1	+0·2	+0·2	+0·2	+0·4	+1·4	+2·5	+2·6	+1·8	+0·4	−1·0	−2·0	−2·2	−1·8	−1·1	−0·3	+0·2	+0·2	−0·1	−0·3	−0·3	−0·3	−0·2	−0·1	

NOTE.—When the sign is + the magnet points to the East, and when − to the West of the mean position.

Hourly Means of Horizontal Force in C.G.S. units (corrected for temperature) at Toungoo in 1916, from all available days. Horizontal Force = ·38000 C.G.S. + tabular quantity.

Hours		Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter.	Jan.	1005	1007	1005	1007	1008	1010	1013	1017	1021	1026	1029	1032	1033	1028	1023	1017	1012	1008	1007	1006	1001	1001	1003	1002	1006	1013
	Feb.	1010	1008	1010	1013	1013	1014	1016	1020	1028	1036	1045	1050	1051	1044	1034	1025	1020	1016	1014	1013	1009	1009	1009	1010	1010	1022
	Mar.	992	991	990	993	998	994	992	993	999	1014	1030	1040	1045	1037	1023	1012	1004	999	995	992	994	993	992	990	992	1004
	Oct.	1008	1006	1010	1007	1009	1010	1009	1009	1015	1025	1037	1047	1051	1044	1033	1021	1011	1007	1007	1008	1007	1008	1006	1009	1010	1017
	Nov.	1017	1018	1019	1018	1018	1021	1023	1026	1033	1044	1063	1055	1052	1044	1035	1026	1019	1018	1010	1011	1012	1011	1013	1015	1016	1025
	Dec.	1010	1012	1012	1014	1015	1015	1018	1021	1027	1033	1040	1043	1049	1035	1028	1021	1013	1009	1008	1008	1006	1008	1010	1010	1011	1019
Means		1007	1007	1008	1009	1009	1011	1012	1014	1021	1030	1039	1045	1045	1039	1029	1020	1013	1009	1007	1006	1005	1005	1006	1006	1008	1017
Summer.	April	1004	1004	1005	1004	1005	1006	1007	1009	1022	1041	1061	1071	1069	1060	1045	1033	1019	1009	1006	1005	1004	1003	1004	1007	1006	1021
	May	1003	1004	1004	1005	1007	1008	1009	1012	1022	1035	1045	1048	1045	1041	1031	1017	1008	999	1001	1001	1000	1003	1001	1002	1002	1015
	June	1012	1013	1014	1016	1016	1014	1017	1023	1032	1043	1054	1061	1061	1055	1045	1033	1022	1013	1011	1011	1012	1013	1013	1013	1012	1026
	July	1012	1011	1010	1013	1013	1012	1015	1018	1027	1034	1045	1052	1054	1051	1042	1029	1015	1006	1004	1009	1009	1008	1008	1011	1013	1021
	Aug.	1012	1013	1011	1013	1011	1014	1014	1016	1023	1031	1040	1046	1049	1047	1038	1027	1015	1009	1008	1009	1008	1007	1010	1012	1014	1020
	Sep.	1010	1007	1006	1009	1011	1011	1010	1003	1002	1013	1027	1035	1039	1038	1030	1017	1010	1005	1009	1010	1008	1005	1004	1006	1010	1014
Means		1009	1009	1008	1010	1011	1011	1012	1014	1021	1033	1045	1052	1053	1049	1039	1026	1015	1007	1007	1008	1007	1007	1007	1009	1010	1020

Diurnal Inequality of the Horizontal Force at Toungoo in 1916, deduced from the above Table.

Hours		Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter.	Jan.	− 8	− 6	− 8	− 6	− 5	− 3	0	+ 4	+ 8	+13	+16	+19	+20	+15	+10	+ 4	− 1	− 5	− 6	− 7	−12	−12	−10	−11	− 7
	Feb.	−12	−14	−12	− 9	− 9	− 8	− 6	− 2	+ 6	+14	+23	+28	+29	+22	+12	+ 3	− 2	− 6	− 8	− 9	−13	−13	−13	−12	−12
	Mar.	−12	−13	−14	−11	−11	−10	−12	−11	− 5	+10	+26	+36	+41	+33	+19	+ 8	0	− 5	− 9	−12	−10	−11	−12	−14	−12
	Oct.	− 9	−11	− 7	−10	− 8	− 7	− 8	− 8	− 2	+ 8	+20	+30	+34	+27	+16	+ 4	− 6	−10	−10	− 9	−10	− 9	−11	− 8	− 7
	Nov.	− 8	− 7	− 6	− 7	− 7	− 4	− 2	+ 1	+ 8	+19	+28	+30	+27	+19	+10	0	− 6	−12	−15	−14	−13	−14	−12	−10	− 9
	Dec.	− 9	− 7	− 7	− 5	− 4	− 4	− 1	+ 2	+ 8	+14	+21	+24	+21	+16	+ 9	+ 2	− 6	−10	−11	−11	−13	−11	− 9	− 9	− 8
Means		−10	−10	− 9	− 8	− 8	− 6	− 5	− 3	+ 4	+13	+22	+28	+28	+22	+12	+ 3	− 4	− 8	−10	−11	−12	−12	−11	−11	− 9
Summer.	April	−17	−17	−16	−17	−16	−15	−14	−12	+ 1	+20	+40	+50	+48	+39	+24	+12	− 2	−12	−15	−16	−17	−18	−17	−14	−15
	May	−12	−11	−11	−10	− 8	− 7	− 6	− 3	+ 7	+20	+30	+33	+30	+26	+16	+ 2	− 7	−16	−14	−14	−15	−12	−14	−13	−13
	June	−14	−13	−12	−10	−10	−12	− 9	− 3	+ 6	+17	+28	+35	+35	+29	+19	+ 7	− 4	−13	−15	−15	−14	−13	−13	−13	−14
	July	− 9	−10	−11	− 8	− 8	− 9	− 6	− 3	+ 6	+13	+24	+31	+33	+30	+21	+ 8	− 6	−15	−17	−12	−12	−13	−13	−10	− 8
	Aug.	− 8	− 7	− 9	− 7	− 9	− 6	− 6	− 4	+ 3	+11	+20	+26	+29	+27	+18	+ 7	− 5	−11	−12	−11	−12	−13	−10	− 8	− 6
	Sep.	− 4	− 7	− 8	− 5	− 3	− 3	− 4	−11	−12	− 1	+13	+21	+25	+24	+16	+ 3	− 4	− 9	− 5	− 4	− 6	− 9	−10	− 8	− 4
Means		−11	−11	−12	−10	− 9	− 9	− 8	− 6	+ 1	+13	+25	+32	+33	+29	+19	+ 6	− 5	−13	−13	−12	−13	−13	−13	−11	−10

NOTE.—When the sign is + the H.F. is greater, and when − it is less than the mean.

Hourly Means of Vertical Force in C. G. S. units (corrected for temperature) at Toungoo in 1916, from all available days. Vertical Force = ·16000 C. G. S. + tabular quantity.

Hours		Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter.	Jan.	663	663	663	663	663	663	663	663	**664**	658	645	**640**	641	647	654	660	662	659	659	661	661	662	662	663	663	658
	Feb.	671	671	**671**	671	671	671	670	670	670	667	662	657	**656**	658	660	662	666	667	667	669	669	669	670	671	671	667
	Mar.	676	676	677	676	676	676	676	**677**	673	666	659	656	**656**	661	669	673	673	670	673	672	673	673	674	675	675	671
	Oct.	681	682	682	682	682	682	684	**684**	679	670	664	**661**	662	668	674	676	677	674	676	678	678	679	681	681	681	677
	Nov.	684	685	685	685	684	685	685	**685**	684	680	676	**673**	674	676	676	677	678	679	680	683	682	684	684	685	685	681
	Dec.	683	684	684	684	684	684	684	683	683	679	673	**670**	673	677	680	681	680	679	681	682	682	682	683	684	**684**	681
Means		676	677	**677**	677	677	677	677	677	676	670	663	**660**	660	665	669	672	673	671	673	674	674	675	676	677	677	673
Summer.	April	681	681	681	681	680	680	**683**	682	676	667	657	**652**	656	664	672	679	681	679	676	677	678	679	680	681	682	675
	May	681	682	681	681	681	682	**686**	681	674	665	660	**658**	661	667	674	680	682	681	678	677	678	679	680	681	682	676
	June	684	684	684	684	684	686	**689**	686	679	669	663	**661**	664	670	675	678	682	682	680	679	681	681	681	683	684	679
	July	689	689	689	689	689	690	**694**	692	686	675	669	**668**	669	675	680	685	687	687	686	684	686	687	688	689	689	684
	Aug.	688	688	689	689	689	690	**694**	691	684	673	**668**	669	670	675	680	685	688	687	685	685	686	687	688	688	689	684
	Sep.	687	688	689	689	689	689	**693**	691	681	671	665	**663**	667	676	684	690	690	687	684	686	686	687	688	688	689	684
Means		685	685	686	686	635	686	**690**	687	680	670	664	**662**	664	671	678	683	685	684	682	681	683	683	684	685	686	680

Diurnal Inequality of the Vertical Force at Toungoo in 1916, deduced from the above Table.

Hours		Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
Winter.	Jan.	+ 5	+ 5	+ 5	+ 5	+ 5	+ 5	+ 5	÷ 5	+ 6	0	− 13	− 18	− 17	− 11	− 4	+ 2	+ 4	+ 1	+ 1	+ 3	+ 3	+ 4	+ 4	+ 5	+ 5	
	Feb.	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	+ 3	+ 3	+ 3	0	− 5	− 10	− 11	− 9	− 7	− 5	− 1	0	0	+ 2	+ 2	+ 2	+ 3	+ 4	+ 4	
	Mar.	+ 5	+ 5	+ 6	+ 5	+ 5	+ 5	+ 5	+ 6	+ 2	− 5	− 12	− 15	− 15	− 10	− 2	+ 2	+ 2	− 1	+ 2	+ 1	+ 2	+ 2	+ 3	+ 4	+ 4	
	Oct.	+ 4	+ 5	+ 5	+ 5	+ 5	+ 5	+ 7	+ 7	+ 2	− 7	− 13	− 16	− 15	− 9	− 3	− 1	0	− 3	− 1	+ 1	+ 1	+ 2	+ 4	+ 4	+ 4	
	Nov.	+ 3	+ 4	+ 4	+ 4	+ 3	+ 4	+ 4	+ 4	+ 3	− 1	− 5	− 8	− 7	− 5	− 5	− 4	− 3	− 2	− 1	+ 2	+ 1	+ 3	+ 3	+ 4	+ 4	
	Dec.	+ 2	+ 3	+ 3	+ 3	+ 3	+ 3	+ 3	+ 2	+ 2	− 2	− 8	− 11	− 8	− 4	− 1	0	− 1	− 2	0	+ 1	+ 1	+ 1	+ 2	+ 3	+ 3	
Means		+ 3	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	+ 3	− 3	− 10	− 13	− 13	− 8	− 4	− 1	0	− 2	0	+ 1	+ 1	+ 2	+ 3	+ 4	+ 4	
Summer.	April	+ 6	+ 6	+ 6	+ 6	+ 5	+ 5	+ 8	+ 7	+ 1	− 8	− 18	− 23	− 20	− 11	− 3	+ 4	+ 6	+ 4	+ 1	+ 2	+ 3	+ 4	+ 5	+ 6	+ 7	
	May	+ 5	+ 6	+ 5	+ 5	+ 5	+ 6	+ 10	+ 5	− 2	− 11	− 16	− 18	− 15	− 9	− 2	+ 4	+ 6	+ 5	+ 2	+ 1	+ 2	+ 3	+ 4	+ 5	+ 6	
	June	+ 5	+ 5	+ 5	+ 5	+ 5	+ 7	+ 10	+ 7	0	− 10	− 16	− 18	− 15	− 9	− 4	− 1	+ 3	+ 3	+ 1	0	+ 2	+ 2	+ 2	+ 4	+ 5	
	July	+ 5	+ 5	+ 5	+ 5	+ 5	+ 6	+ 10	+ 8	+ 2	− 9	− 15	− 16	− 15	− 9	− 4	+ 1	+ 3	+ 3	+ 2	0	+ 2	+ 3	+ 4	+ 5	+ 5	
	Aug.	+ 4	+ 4	+ 5	+ 5	+ 5	+ 6	+ 10	+ 7	0	− 11	− 16	− 15	− 14	− 9	− 4	+ 1	+ 4	+ 3	+ 1	+ 1	+ 2	+ 3	+ 4	+ 4	+ 5	
	Sep.	+ 3	+ 4	+ 5	+ 5	+ 5	+ 5	+ 9	+ 7	− 3	− 13	− 19	− 21	− 17	− 8	0	+ 6	+ 6	+ 3	0	+ 2	+ 2	+ 3	+ 4	+ 4	+ 5	
Means		+ 5	+ 5	+ 6	+ 6	+ 5	+ 6	+ 10	+ 7	0	− 10	− 16	− 18	− 16	− 9	− 2	+ 3	+ 5	+ 4	+ 2	+ 1	+ 3	+ 3	+ 4	+ 5	+ 6	

NOTE.—When the sign is + the V. F. is greater, and when − it is less than the mean.

Hourly Means of the Dip at Toungoo in 1916, determined from all available days. Dip = N. 23° + tabular quantity.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter.	Jan	7′·9	7′·9	7′·9	7′·9	7′·8	7′·8	7′·7	7′·6	7′·5	6′·9	5′·8	5′·4	6′·4	6′·0	6′·7	7′·4	7′·6	7′·6	7′·6	7′·8	7′·9	8′·0	7′·9	8′·0	7′·9	7′·8
	Feb	8·4	8·5	8·4	8·3	8·3	8·2	8·1	8·0	7·7	7·2	6·6	6·1	6·0	6·3	6·8	7·2	7·7	7·9	8·0	8·1	8·3	8·3	8·4	8·4	8·4	7·7
	Mar.	9·3	9·4	9·5	9·3	9·3	9·3	9·3	9·4	8·9	7·9	6·8	6·3	6·1	6·8	7·8	8·5	8·7	8·7	9·0	9·0	9·0	9·1	9·2	9·8	9·3	8·6
	Oct.	9·2	9·3	9·2	9·3	9·3	9·2	9·4	9·4	8·8	7·8	7·0	6·4	6·4	7·1	7·9	8·4	8·8	8·7	8·9	9·0	9·0	9·1	9·3	9·2	9·1	8·6
	Nov	9·1	9·2	9·1	9·2	9·1	9·1	9·0	8·9	8·6	8·0	7·4	7·1	7·3	7·7	8·0	8·4	8·6	8·9	9·1	9·2	9·1	9·3	9·3	9·3	9·3	8·7
	Dec	9·3	9·3	9·3	9·2	9·2	9·2	9·1	8·9	8·7	8·2	7·6	7·3	7·6	8·0	8·5	8·8	9·0	9·0	9·2	9·3	9·3	9·3	9·3	9·3	9·3	8·8
	Means	8·9	8·9	8·9	8·9	8·8	8·8	8·8	8·7	8·4	7·7	6·9	6·4	6·5	7·0	7·6	8·1	8·4	8·5	8·6	8·7	8·8	8·9	8·9	8·9	8·9	8·3
Summer.	April	9·3	9·3	9·3	9·3	9·2	9·2	9·4	9·3	8·4	7·1	5·7	5·0	5·3	6·3	7·3	8·2	8·8	9·0	8·9	9·0	9·1	9·2	9·3	9·2	9·3	8·3
	May	9·3	9·4	9·3	9·3	9·2	9·3	9·5	9·1	8·2	7·2	6·4	6·2	6·5	7·1	7·9	8·9	9·3	9·5	9·2	9·1	9·2	9·2	9·3	9·4	9·5	8·6
	June	9·3	9·3	9·2	9·2	9·2	9·4	9·5	9·1	8·3	7·2	6·4	6·0	6·2	6·9	7·6	8·2	8·8	9·1	9·0	8·9	9·1	9·0	9·0	9·2	9·3	8·5
	July	9·7	9·7	9·7	9·6	9·6	9·7	9·9	9·7	8·9	7·9	7·1	6·8	6·8	7·4	8·0	8·8	9·4	9·7	9·7	9·4	9·5	9·7	9·7	9·7	9·6	9·0
	Aug.	9·6	9·5	9·7	9·6	9·7	9·7	10·0	9·7	8·9	7·8	7·2	7·1	7·1	7·5	8·2	8·9	9·5	9·6	9·5	9·5	9·6	9·7	9·6	9·6	9·6	9·0
	Sep.	9·6	9·7	9·9	9·8	9·7	9·7	10·0	10·1	9·4	8·3	7·4	7·0	7·2	7·8	8·7	9·6	9·8	9·7	9·4	9·5	9·6	9·7	9·8	9·8	9·7	9·2
	Means	9·5	9·5	9·5	9·5	9·4	9·5	9·7	9·5	8·7	7·6	6·7	6·4	6·5	7·2	8·0	8·8	9·3	9·4	9·3	9·2	9·4	9·4	9·5	9·5	9·5	8·8

Diurnal Inequality of the Dip at Toungoo in 1916, deduced from the above Table.

Winter.	Jan.	+0′·6	+0′·6	+0′·6	+0′·6	+0′·5	+0′·5	+0′·4	+0′·3	+0′·2	−0′·4	−1′·5	−1′·9	−1′·9	−1′·3	−0′·6	+0′·1	+0′·3	+0′·3	+0′·3	+0′·5	+0′·6	+0′·7	+0′·6	+0′·7	+0′·6
	Feb.	+0·7	+0·8	+0·7	+0·6	+0·6	+0·5	+0·4	+0·3	0·0	−0·5	−1·1	−1·6	−1·7	−1·4	−0·9	−0·5	0·0	+0·2	+0·3	+0·4	+0·6	+0·6	+0·7	+0·7	+0·7
	Mar.	+0·7	+0·8	+0·9	+0·7	+0·7	+0·7	+0·7	+0·8	+0·3	−0·7	−1·8	−2·3	−2·5	−1·8	−0·8	−0·1	+0·1	+0·1	+0·4	+0·4	+0·4	+0·5	+0·6	+0·7	+0·7
	Oct.	+0·6	+0·7	+0·6	+0·7	+0·7	+0·6	+0·8	+0·8	+0·2	−0·8	−1·6	−2·2	−2·2	−1·5	−0·7	−0·2	+0·2	+0·1	+0·3	+0·4	+0·4	+0·5	+0·7	+0·6	+0·5
	Nov.	+0·4	+0·5	+0·4	+0·5	+0·4	+0·4	+0·3	+0·2	−0·1	−0·7	−1·3	−1·6	−1·4	−1·0	−0·7	−0·3	−0·1	+0·2	+0·4	+0·5	+0·4	+0·6	+0·6	+0·6	+0·6
	Dec.	+0·5	+0·5	+0·5	+0·4	+0·4	+0·4	+0·3	+0·1	−0·1	−0·6	−1·2	−1·5	−1·2	−0·8	−0·3	0·0	+0·2	+0·2	+0·4	+0·5	+0·5	+0·5	+0·5	+0·5	+0·5
	Means	+0·6	+0·6	+0·6	+0·6	+0·5	+0·5	+0·5	+0·4	+0·1	−0·6	−1·4	−1·9	−1·8	−1·3	−0·7	−0·2	+0·1	+0·2	+0·3	+0·4	+0·5	+0·6	+0·6	+0·6	+0·6
Summer.	April	+1·0	+1·0	+1·0	+1·0	+0·9	+0·9	+1·1	+1·0	+0·1	−1·2	−2·6	−3·3	−3·0	−2·0	−1·0	−0·1	+0·5	+0·7	+0·6	+0·7	+0·8	+0·9	+1·0	+0·9	+1·0
	May	+0·7	+0·8	+0·7	+0·7	+0·6	+0·7	+0·9	+0·5	−0·4	−1·4	−2·2	−2·4	−2·1	−1·5	−0·7	+0·3	+0·7	+0·9	+0·6	+0·5	+0·6	+0·6	+0·7	+0·8	+0·9
	June	+0·8	+0·8	+0·7	+0·7	+0·7	+0·9	+1·0	+0·6	−0·2	−1·3	−2·1	−2·5	−2·3	−1·6	−0·9	−0·3	+0·3	+0·6	+0·5	+0·4	+0·6	+0·5	+0·5	+0·7	+0·8
	July	+0·7	+0·7	+0·7	+0·6	+0·6	+0·7	+0·9	+0·7	−0·1	−1·1	−1·9	−2·2	−2·2	−1·6	−1·0	−0·2	+0·4	+0·7	+0·7	+0·4	+0·5	+0·7	+0·7	+0·7	+0·6
	Aug.	+0·6	+0·5	+0·7	+0·6	+0·7	+0·7	+1·0	+0·7	−0·1	−1·2	−1·8	−1·9	−1·9	−1·5	−0·8	−0·1	+0·5	+0·6	+0·5	+0·5	+0·6	+0·7	+0·6	+0·6	+0·6
	Sep.	+0·4	+0·5	+0·7	+0·6	+0·5	+0·5	+0·8	+0·9	+0·2	−0·9	−1·8	−2·2	−2·0	−1·4	−0·5	+0·4	+0·6	+0·5	+0·2	+0·3	+0·4	+0·5	+0·6	+0·6	+0·5
	Means	+0·7	+0·7	+0·7	+0·7	+0·6	+0·7	+0·9	+0·7	−0·1	−1·2	−2·1	−2·4	−2·3	−1·6	−0·8	0·0	+0·5	+0·6	+0·5	+0·4	+0·6	+0·6	+0·7	+0·7	+0·7

NOTE.—When the sign is + the Dip is greater, and when − it is less than the mean.

Hourly Means of the Declination at Kodaikanal in 1916, determined from all available days. Declination = W. 1° + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter. Jan.	25·5	25·5	25·6	25·6	25·7	25·9	26·0	25·9	25·5	**24·8**	25·1	25·9	**26·3**	26·0	25·8	25·4	**24·8**	25·0	25·5	25·3	25·3	25·4	25·5	25·5	25·5	25·5
Winter. Feb.	25·4	25·3	25·4	25·6	25·9	26·1	26·2	**26·4**	26·2	25·6	**25·2**	25·3	25·5	25·4	25·6	25·7	25·6	25·5	25·5	25·4	25·4	25·4	25·3	25·4	25·4	25·6
Winter. Mar.																										
Winter. Oct.	29·4	29·4	29·4	29·4	29·5	29·7	29·5	29·1	**28·8**	28·9	29·4	30·2	**30·4**	30·0	29·6	29·2	28·9	29·3	29·5	29·4	29·5	29·5	29·5	29·5	29·4	29·5
Winter. Nov.	29·8	29·7	29·7	29·9	30·0	30·3	30·5	**30·9**	30·6	30·3	30·3	30·2	30·1	29·4	**29·1**	29·1	29·3	29·5	29·7	29·7	29·7	29·8	29·8	29·8	29·8	29·9
Winter. Dec.	30·6	30·6	30·7	30·7	30·8	31·0	31·3	**31·7**	31·3	31·0	31·0	31·1	31·0	30·4	30·0	29·8	**29·8**	30·2	30·4	30·1	30·3	30·5	30·5	30·7	30·7	30·6
Means																										
Summer. April	26·3	26·3	26·2	26·2	26·3	26·4	26·1	25·2	**25·1**	25·4	25·9	26·5	27·9	**28·1**	27·9	27·3	26·6	26·2	26·2	26·3	26·5	26·5	26·5	26·4	26·3	26·4
Summer. May	26·8	26·8	26·6	26·5	26·4	26·3	25·7	**25·1**	25·3	26·1	27·2	28·0	28·7	**28·8**	28·1	27·6	26·9	26·4	26·4	27·0	27·0	27·0	27·0	26·9	26·8	26·9
Summer. June	27·2	27·0	27·0	26·9	26·9	26·7	26·1	25·3	**25·3**	26·1	27·3	28·3	29·0	**29·1**	28·5	27·9	27·4	27·2	27·3	27·5	27·5	27·5	27·4	27·3	27·2	27·2
Summer. July	27·5	27·4	27·3	27·2	27·2	27·1	26·3	25·4	**25·4**	26·4	27·7	28·7	**29·5**	29·4	29·0	28·4	27·6	27·3	27·2	27·7	27·8	27·7	27·7	27·7	27·5	27·5
Summer. Aug.	28·5	28·4	28·2	28·2	28·1	28·0	27·0	**26·2**	26·3	27·5	28·8	30·0	**30·5**	30·4	29·9	29·1	28·4	27·9	28·0	28·5	28·7	28·7	28·7	28·6	28·5	28·4
Summer. Sep.	29·0	28·9	28·9	28·9	28·8	28·7	27·8	**26·8**	26·9	28·0	29·4	30·4	**31·2**	31·1	30·3	29·2	28·5	28·2	28·6	28·8	28·9	29·0	29·0	29·0	29·0	28·9
Means	27·6	27·5	27·4	27·3	27·3	27·2	26·5	**25·7**	25·7	26·6	27·7	28·7	29·5	**29·5**	29·0	28·3	27·6	27·2	27·3	27·6	27·7	27·7	27·7	27·7	27·6	27·6

Diurnal Inequality of the Declination at Kodaikanal in 1916, deduced from the above Table.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.
Winter. Jan.	0·0	0·0	−0·1	−0·1	−0·2	−0·4	−0·5	−0·4	0·0	+0·7	+0·4	−0·4	−0·8	−0·5	−0·3	+0·1	+0·7	+0·5	0·0	+0·2	+0·2	+0·1	0·0	0·0	0·0
Winter. Feb.	+0·2	+0·3	+0·2	0·0	−0·3	−0·5	−0·6	−0·8	−0·6	0·0	+0·4	+0·3	+0·1	+0·2	0·0	−0·1	0·0	+0·1	+0·1	+0·2	+0·2	+0·2	+0·3	+0·2	+0·2
Winter. Mar.																									
Winter. Oct.	+0·1	+0·1	+0·1	+0·1	0·0	−0·2	0·0	+0·4	+0·7	+0·6	+0·1	−0·7	−0·9	−0·5	−0·1	+0·3	+0·6	+0·2	0·0	+0·1	0·0	0·0	0·0	0·0	+0·1
Winter. Nov.	+0·1	+0·2	+0·2	0·0	−0·1	−0·4	−0·6	−1·0	−0·7	−0·4	−0·4	−0·3	−0·2	+0·5	+0·8	+0·8	+0·6	+0·4	+0·2	+0·2	+0·2	+0·1	+0·1	+0·1	+0·1
Winter. Dec.	0·0	0·0	−0·1	−0·1	−0·2	−0·4	−0·7	−1·1	−0·7	−0·4	−0·4	−0·5	−0·4	+0·2	+0·6	+0·8	+0·8	+0·4	+0·2	+0·5	+0·3	+0·1	+0·1	−0·1	−0·1
Means																									
Summer. April	+0·1	+0·1	+0·2	+0·2	+0·1	0·0	+0·3	+1·2	+1·3	+1·0	+0·5	−0·1	−1·5	−1·7	−1·5	−0·9	−0·2	+0·2	+0·2	+0·1	−0·1	−0·1	−0·1	0·0	+0·1
Summer. May	+0·1	+0·1	+0·3	+0·4	+0·5	+0·6	+1·2	+1·8	+1·6	+0·8	−0·3	−1·1	−1·8	−1·9	−1·2	−0·7	0·0	+0·5	+0·5	−0·1	−0·1	−0·1	−0·1	0·0	+0·1
Summer. June	0·0	+0·2	+0·2	+0·3	+0·3	+0·5	+1·1	+1·9	+1·9	+1·1	−0·1	−1·1	−1·8	−1·9	−1·3	−0·7	−0·2	0·0	−0·1	−0·3	−0·3	−0·3	−0·2	−0·1	0·0
Summer. July	0·0	+0·1	+0·2	+0·3	+0·3	+0·4	+1·2	+2·1	+2·1	+1·1	−0·2	−1·2	−2·0	−1·9	−1·5	−0·9	−0·1	+0·2	+0·3	−0·2	−0·3	−0·2	−0·2	−0·2	0·0
Summer. Aug.	−0·1	0·0	+0·2	+0·2	+0·3	+0·4	+1·4	+2·2	+2·1	+0·9	−0·4	−1·6	−2·1	−2·0	−1·5	−0·7	0·0	+0·5	+0·4	−0·1	−0·3	−0·3	−0·3	−0·2	−0·1
Summer. Sep.	−0·1	0·0	0·0	0·0	+0·1	+0·2	+1·1	+2·1	+2·0	+0·9	−0·5	−1·5	−2·3	−2·2	−1·4	−0·3	+0·4	+0·7	+0·3	+0·1	0·0	−0·1	−0·1	−0·1	−0·1
Means	0·0	+0·1	+0·2	+0·3	+0·3	+0·4	+1·1	+1·9	+1·9	+1·0	−0·1	−1·1	−1·9	−1·9	−1·4	−0·7	0·0	+0·4	+0·3	0·0	−0·1	−0·1	−0·1	−0·1	0·0

NOTE.—When the sign is + the magnet points to the East, and when − to the West of the mean position.

Hourly Means of Horizontal Force in C.G.S. units (corrected for temperature) at Kodaikanal in 1916, from all available days. Horizontal Force = ·37000 C.G.S. + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter. Jan.	605	605	606	607	608	608	610	613	629	652	672	**685**	678	660	634	617	614	615	611	606	605	603	**602**	605	605	623
Feb.	608	612	611	613	614	614	616	621	635	654	671	**680**	679	666	652	641	632	625	619	615	614	612	613	610	**608**	630
Mar.	**597**	599	600	604	604	602	600	605	628	661	690	**699**	690	659	635	620	615	613	609	605	603	600	598	600	599	622
Oct.	614	617	616	618	619	617	617	624	647	676	697	**703**	691	669	650	634	628	624	621	617	618	**613**	613	614	616	636
Nov.	622	622	622	624	624	624	625	635	652	670	683	**685**	678	665	651	642	633	625	623	618	**616**	617	617	618	622	637
Dec.	621	622	623	625	623	624	625	634	647	666	**677**	675	668	656	647	637	633	628	624	623	621	**620**	620	621	622	636
Means	611	613	613	615	615	615	616	622	640	663	682	**688**	681	663	645	632	626	622	618	614	613	611	**611**	611	612	631
Summer. April	**609**	610	610	611	613	613	612	623	648	689	718	**730**	712	687	656	632	620	620	619	615	611	611	611	610	611	637
May	613	614	616	617	617	616	619	629	652	676	691	**696**	688	671	645	629	619	618	617	615	614	612	**611**	613	614	634
June	620	620	622	624	621	621	626	633	648	671	685	**695**	689	673	655	637	621	621	620	620	620	**618**	619	619	620	638
July	619	620	622	622	622	622	625	632	646	665	681	**689**	682	667	646	629	619	**617**	620	620	617	618	620	620	620	635
Aug.	621	621	622	623	624	623	627	630	645	666	679	**683**	676	665	649	630	623	621	621	618	**618**	620	622	622	624	635
Sep.	613	615	616	618	617	617	615	622	645	671	**693**	692	677	653	630	619	615	618	618	614	**610**	611	612	613	613	630
Means	616	617	618	619	619	619	621	628	647	674	691	**698**	687	669	647	629	620	619	619	617	**615**	615	616	616	617	635

Diurnal Inequality of the Horizontal Force at Kodaikanal in 1916, deduced from the above Table.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
Winter. Jan.	−18	−18	−17	−16	−15	−15	−13	−10	+6	+29	+49	+62	+55	+37	+11	−6	−9	−8	−12	−17	−18	−20	−21	−18	−18	
Feb.	−22	−18	−19	−17	−16	−16	−14	−9	+5	+24	+41	+50	+49	+36	+22	+11	+2	−5	−11	−15	−16	−18	−17	−20	−22	
Mar.	−25	−23	−22	−18	−18	−20	−22	−17	+6	+39	+68	+77	+68	+37	+13	−2	−7	−9	−13	−17	−19	−22	−24	−22	−23	
Oct.	−22	−19	−20	−18	−17	−19	−19	−12	+11	+40	+61	+67	+55	+33	+14	−2	−8	−12	−15	−19	−18	−23	−23	−22	−20	
Nov.	−15	−15	−15	−13	−13	−13	−12	−2	+15	+33	+46	+48	+41	+28	+14	+5	−4	−12	−14	−19	−21	−20	−20	−19	−15	
Dec.	−15	−14	−13	−11	−13	−12	−11	−2	+11	+30	+41	+39	+32	+20	+11	+1	−3	−8	−12	−13	−15	−16	−16	−15	−14	
Means	−20	−18	−18	−16	−16	−16	−15	−9	+9	+32	+51	+57	+50	+32	+14	+1	−5	−9	−13	−17	−18	−20	−20	−20	−19	
Summer. April	−28	−27	−27	−26	−24	−24	−25	−14	+11	+52	+81	+93	+75	+50	+19	−5	−17	−17	−18	−22	−26	−26	−26	−27	−26	
May	−21	−20	−18	−17	−17	−18	−15	−5	+18	+42	+57	+62	+54	+37	+11	−5	−15	−16	−17	−19	−20	−22	−23	−21	−20	
June	−18	−18	−16	−14	−17	−17	−12	−5	+10	+33	+47	+57	+51	+35	+17	−1	−14	−17	−18	−18	−18	−20	−19	−19	−18	
July	−16	−15	−13	−13	−13	−13	−10	−3	+11	+30	+46	+54	+47	+32	+11	−6	−16	−18	−15	−15	−18	−17	−15	−15	−15	
Aug.	−14	−14	−13	−12	−11	−12	−8	−5	+10	+31	+44	+48	+41	+30	+14	−5	−12	−14	−14	−17	−17	−15	−13	−13	−11	
Sep.	−17	−15	−14	−12	−13	−13	−15	−8	+15	+44	+63	+62	+47	+23	0	−11	−15	−12	−12	−16	−20	−19	−18	−17	−17	
Means	−19	−18	−17	−16	−16	−16	−14	−7	+12	+39	+56	+63	+52	+34	+12	−6	−15	−16	−16	−18	−20	−20	−19	−19	−18	

NOTE.—When the sign is + the H.F. is greater, and when − it is less than the mean.

Hourly Means of Vertical Force in C. G. S. units (corrected for temperature) at Kodaikanal in 1916, from all available days. Vertical Force= ·02000 C.G.S.+tabular quantity.

Hours		Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter.	Jan.	847	847	848	847	848	848	**849**	848	845	836	826	819	**816**	818	825	837	842	839	841	842	813	844	845	847	847	839
	Feb.	860	**862**	861	861	861	861	862	859	860	857	853	849	846	815	**843**	844	846	851	854	857	859	858	860	859	860	855
	Mar.	864	866	866	867	865	865	**867**	866	864	856	847	836	**833**	838	847	854	857	857	857	860	862	862	862	865	865	858
	Oct.	901	902	901	901	901	901	**903**	902	899	892	883	**877**	881	881	883	885	887	888	893	895	897	896	899	900	901	894
	Nov.	910	909	908	909	909	909	909	907	906	902	898	895	896	894	**892**	893	894	896	903	904	905	906	908	909	**910**	903
	Dec.	914	913	913	914	913	914	**914**	913	911	905	899	**898**	901	901	900	901	903	904	908	910	910	911	913	914	914	908
Means		883	883	883	883	883	883	**884**	883	881	875	868	862	862	863	865	869	872	873	876	878	879	880	881	882	883	876
Summer.	April	872	872	871	871	872	873	876	**878**	871	863	849	836	**832**	836	843	853	862	864	864	865	866	868	870	871	871	862
	May	879	879	879	880	880	881	**885**	883	875	864	854	849	**847**	818	854	861	869	873	874	873	875	876	878	879	880	871
	June	884	884	884	884	884	886	891	**892**	888	878	868	862	**859**	863	869	875	877	878	877	877	880	881	883	883	884	879
	July	888	889	889	888	888	891	**895**	893	887	878	874	868	**868**	871	877	883	888	888	885	883	884	886	888	888	888	884
	Aug.	894	895	896	896	896	897	**900**	900	893	886	878	**875**	876	880	884	889	894	893	889	888	891	892	894	894	895	890
	Sep.	896	898	898	898	898	899	**902**	896	885	873	865	**861**	864	870	881	889	891	890	889	891	892	894	896	896	897	888
Means		886	886	886	886	886	888	**892**	890	883	874	865	859	**858**	861	868	875	880	881	880	880	881	883	885	885	886	879

Diurnal Inequality of the Vertical Force at Kodaikanal in 1916, deduced from the above Table.

Hours		Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
Winter.	Jan.	+ 8	+ 8	+ 9	+ 8	+ 9	+ 9	+10	+ 9	+ 6	− 3	−13	−20	−23	−21	−14	− 2	+ 3	0	+ 2	+ 3	+ 4	+ 5	+ 6	+ 8	+ 8	
	Feb.	+ 5	+ 7	+ 6	+ 6	+ 6	+ 6	+ 7	+ 4	+ 5	+ 2	− 2	− 6	− 9	−10	−12	−11	− 9	− 4	− 1	+ 2	+ 4	+ 3	+ 5	+ 4	+ 5	
	Mar.	+ 6	+ 8	+ 8	+ 9	+ 7	+ 7	+ 9	+ 8	+ 6	− 2	−11	−22	−25	−20	−11	− 4	− 1	− 1	− 1	+ 2	+ 4	+ 4	+ 4	+ 7	+ 7	
	Oct.	+ 7	+ 8	+ 7	+ 7	+ 7	+ 7	+ 9	+ 8	+ 5	− 2	−11	−17	−13	−13	−11	− 9	− 7	− 6	− 1	+ 1	+ 3	+ 2	+ 5	+ 6	+ 7	
	Nov.	+ 7	+ 6	+ 5	+ 6	+ 6	+ 6	+ 6	+ 4	+ 3	− 1	− 5	− 8	− 7	− 9	−11	−10	− 9	− 7	0	+ 1	+ 2	+ 3	+ 5	+ 6	+ 7	
	Dec.	+ 6	+ 5	+ 5	+ 6	+ 5	+ 6	+ 6	+ 5	+ 3	− 3	− 9	−10	− 7	− 7	− 8	− 7	− 5	− 4	0	+ 2	+ 2	+ 3	+ 5	+ 6	+ 6	
Means		+ 7	+ 7	+ 7	+ 7	+ 7	+ 7	+ 8	+ 7	+ 5	− 1	− 8	−14	−14	−13	−11	− 7	− 4	− 3	0	+ 2	+ 3	+ 4	+ 5	+ 6	+ 7	
Summer.	April	+10	+10	+ 9	+ 9	+10	+11	+14	+16	+ 9	+ 1	−13	−26	−30	−26	−19	− 9	0	+ 2	+ 2	+ 3	+ 4	+ 6	+ 8	+ 9	+ 9	
	May	+ 8	+ 8	+ 8	+ 9	+ 9	+10	+14	+12	+ 4	− 7	−17	−22	−24	−23	−17	−10	− 2	+ 2	+ 3	+ 2	+ 4	+ 5	+ 7	+ 8	+ 9	
	June	+ 5	+ 5	+ 5	+ 5	+ 5	+ 7	+12	+13	+ 9	− 1	−11	−17	−20	−16	−10	− 4	− 2	− 1	− 2	− 2	+ 1	+ 2	+ 4	+ 4	+ 5	
	July	+ 4	+ 5	+ 5	+ 4	+ 4	+ 7	+11	+ 9	+ 3	− 6	−10	−16	−16	−13	− 7	− 1	+ 4	+ 4	+ 1	− 1	0	+ 2	+ 4	+ 4	+ 4	
	Aug.	+ 4	+ 5	+ 6	+ 6	+ 6	+ 7	+10	+10	+ 3	− 4	−12	−15	−14	−10	− 6	− 1	+ 4	+ 3	− 1	− 2	+ 1	+ 2	+ 4	+ 4	+ 5	
	Sep.	+ 8	+10	+10	+10	+10	+11	+14	+ 8	− 3	−15	−23	−27	−24	−18	− 7	+ 1	+ 3	+ 2	+ 1	+ 3	+ 4	+ 6	+ 8	+ 8	+ 9	
Means		+ 7	+ 7	+ 7	+ 7	+ 7	+ 9	+13	+11	+ 4	− 5	−14	−20	−21	−18	−11	− 4	+ 1	+ 2	+ 1	+ 1	+ 2	+ 4	+ 6	+ 6	+ 7	

NOTE.—When the sign is + the V. F. is greater, and when − it is less than the mean.

Hourly Means of the Dip at Kodaikanal in 1916, determined from all available days. Dip = N. 4° + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter. Jan.	19′8	19′8	19′9	19′8	19′8	19′8	19′9	19′8	19′4	18′5	17′4	16′7	16′5	16′8	17′6	18′8	19′3	19′0	19′2	19′3	19′4	19′5	19′6	19′8	19′6	19′0
Winter. Feb.	20·9	21·1	21·0	21·0	21·0	21·0	21·1	20·8	20·8	20·3	19·9	19·4	19·2	19·2	19·1	19·3	19·5	20·0	20·3	20·6	20·8	20·7	20·9	20·8	20·9	20·4
Winter. Mar.	21·4	21·5	21·5	21·6	21·4	21·4	21·6	21·5	21·2	20·2	19·2	18·1	17·9	18·6	19·6	20·3	20·6	20·6	20·7	21·0	21·2	21·2	21·2	21·4	21·5	20·6
Winter. Oct.	24·6	24·7	24·6	24·6	24·6	24·6	24·8	24·6	24·2	23·4	22·4	21·8	22·3	22·4	22·7	23·0	23·3	23·4	23·8	24·1	24·2	24·2	24·4	24·5	24·6	23·8
Winter. Nov.	25·4	25·3	25·2	25·3	25·3	25·3	25·3	25·0	24·8	24·3	23·9	23·6	23·7	23·6	23·5	23·7	23·9	24·1	24·7	24·9	25·0	25·1	25·2	25·3	25·4	24·6
Winter. Dec.	25·8	25·7	25·7	25·7	25·7	25·7	25·7	25·6	25·3	24·6	24·0	23·9	24·2	24·3	24·3	24·5	24·7	24·8	25·2	25·4	25·4	25·5	25·7	25·8	25·7	25·1
Means	23·0	23·0	23·0	23·0	23·0	23·0	23·1	22·9	22·6	21·9	21·1	20·6	20·6	20·8	21·1	21·6	21·9	22·0	22·3	22·6	22·7	22·7	22·8	22·9	23·0	22·3
Summer. April	22·0	22·0	21·9	21·9	22·0	22·1	22·4	22·5	21·7	20·7	19·2	17·9	17·7	18·2	19·1	20·1	21·0	21·2	21·2	21·3	21·5	21·6	21·8	21·9	21·9	21·0
Summer. May	22·6	22·6	22·6	22·7	22·7	22·8	23·1	22·9	22·0	20·8	19·8	19·3	19·2	19·4	20·1	20·9	21·7	22·1	22·2	22·1	22·3	22·4	22·6	22·6	22·7	21·7
Summer. June	23·0	23·0	23·0	23·0	23·0	23·2	23·6	23·7	23·2	22·1	21·1	20·5	20·3	20·8	21·4	22·1	22·4	22·5	22·4	22·4	22·7	22·8	22·9	22·9	23·0	22·4
Summer. July	23·4	23·5	23·5	23·4	23·4	23·7	24·0	23·8	23·1	22·2	21·7	21·1	21·2	21·5	22·2	22·9	23·4	23·4	23·1	22·9	23·1	23·2	23·4	23·4	23·4	22·9
Summer. Aug.	23·9	24·0	24·1	24·1	24·1	24·2	24·4	24·4	23·7	22·9	22·1	21·8	21·9	22·4	22·8	23·4	23·9	23·8	23·5	23·4	23·7	23·8	23·9	23·9	24·0	23·5
Summer. Sep.	24·2	24·3	24·3	24·3	24·3	24·4	24·7	24·1	23·0	21·7	20·8	20·5	20·8	21·5	22·7	23·5	23·7	23·6	23·5	23·7	23·8	24·0	24·2	24·2	24·3	23·3
Means	23·2	23·2	23·2	23·2	23·3	23·4	23·7	23·6	22·8	21·7	20·8	20·2	20·2	20·6	21·4	22·2	22·7	22·8	22·7	22·6	22·9	23·0	23·1	23·2	23·2	22·5

Diurnal Inequality of the Dip at Kodaikanal in 1916, deduced from the above Table.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter. Jan.	+0′8	+0′8	+0′9	+0′8	+0′8	+0′8	+0′9	+0′8	+0′4	−0′5	−1′6	−2′3	−2′5	−2·2	−1′4	−0′2	+0′3	0′0	+0′2	+0′3	+0′4	+0′5	+0′6	+0′8	+0′8	
Winter. Feb.	+0·5	+0·7	+0·6	+0·6	+0·6	+0·6	+0·7	+0·4	+0·4	−0·1	−0·5	−1·0	−1·2	−1·2	−1·3	−1·1	−0·9	−0·4	−0·1	+0·2	+0·4	+0·3	+0·5	+0·4	+0·5	
Winter. Mar.	+0·8	+0·9	+0·9	+1·0	+0·8	+0·8	+1·0	+0·9	+0·6	−0·4	−1·4	−2·5	−2·7	−2·0	−1·0	−0·3	0·0	0·0	+0·1	+0·4	+0·6	+0·6	+0·6	+0·8	+0·9	
Winter. Oct.	+0·8	+0·9	+0·8	+0·8	+0·8	+0·8	+1·0	+0·8	+0·4	−0·4	−1·4	−2·0	−1·5	−1·4	−1·1	−0·8	−0·5	−0·4	0·0	+0·3	+0·4	+0·4	+0·6	+0·7	+0·8	
Winter. Nov.	+0·8	+0·7	+0·6	+0·7	+0·7	+0·7	+0·7	+0·4	+0·2	−0·3	−0·7	−1·0	−0·9	−1·0	−1·1	−0·9	−0·7	−0·5	+0·1	+0·3	+0·4	+0·5	+0·6	+0·7	+0·8	
Winter. Dec.	+0·7	+0·6	+0·6	+0·6	+0·6	+0·6	+0·6	+0·5	+0·2	−0·5	−1·1	−1·2	−0·9	−0·8	−0·8	−0·6	−0·4	−0·3	+0·1	+0·3	+0·3	+0·4	+0·6	+0·7	+0·6	
Means	+0·7	+0·7	+0·7	+0·7	+0·7	+0·7	+0·8	+0·6	+0·3	−0·4	−1·2	−1·7	−1·7	−1·5	−1·2	−0·7	−0·4	−0·3	0·0	+0·3	+0·4	+0·4	+0·5	+0·6	+0·7	
Summer. April	+1·0	+1·0	+0·9	+0·9	+1·0	+1·1	+1·4	+1·5	+0·7	−0·3	−1·8	−3·1	−3·3	−2·8	−1·9	−0·9	0·0	+0·2	+0·2	+0·3	+0·5	+0·6	+0·8	+0·9	+0·9	
Summer. May	+0·9	+0·9	+0·9	+1·0	+1·0	+1·1	+1·4	+1·2	+0·3	−0·9	−1·9	−2·4	−2·5	−2·3	−1·6	−0·8	0·0	+0·4	+0·5	+0·4	+0·6	+0·7	+0·9	+0·9	+1·0	
Summer. June	+0·6	+0·6	+0·6	+0·6	+0·6	+0·8	+1·2	+1·3	+0·8	−0·3	−1·3	−1·9	−2·1	−1·6	−1·0	−0·3	0·0	+0·1	0·0	0·0	+0·3	+0·4	+0·5	+0·5	+0·6	
Summer. July	+0·5	+0·6	+0·6	+0·5	+0·5	+0·8	+1·1	+0·9	+0·2	−0·7	−1·2	−1·8	−1·7	−1·4	−0·7	0·0	+0·5	+0·5	+0·2	0·0	+0·2	+0·3	+0·5	+0·5	+0·5	
Summer. Aug.	+0·4	+0·5	+0·6	+0·6	+0·6	+0·7	+0·9	+0·9	+0·2	−0·6	−1·4	−1·7	−1·6	−1·1	−0·7	−0·1	+0·4	+0·3	0·0	−0·1	+0·2	+0·3	+0·4	+0·4	+0·5	
Summer. Sep.	+0·9	+1·0	+1·0	+1·0	+1·0	+1·1	+1·4	+0·8	−0·3	−1·6	−2·5	−2·8	−2·5	−1·8	−0·6	+0·2	+0·4	+0·3	+0·2	+0·4	+0·5	+0·7	+0·9	+0·9	+1·0	
Means	+0·7	+0·7	+0·7	+0·7	+0·8	+0·9	+1·2	+1·1	+0·3	−0·8	−1·7	−2·3	−2·3	−1·9	−1·1	−0·3	+0·2	+0·3	+0·2	+0·1	+0·4	+0·5	+0·6	+0·7	+0·7	

NOTE.—When the sign is + the Dip is greater, and when − it is less than the mean.

BASE LINE.

By E. C. J. Bond.

Personnel of No. 19 Party.

Provincial Officers.

Mr. E. C. J. Bond in charge.
„ O. N. Pushong.

Lower Subordinate Service.

3 Computers, etc.

No base-line work was practicable during the year, owing to the deficiency of officers.

The detachment of 19 Party formed in the previous season to run the traverse of the Imperial Delhi Area was employed this season in carrying out a network of minor triangulation to provide points for the revision of the 4-inch maps of Delhi and its Vicinity.

The area embraced by the triangulation includes the city and old cantonments of Delhi in the centre, Imperial Delhi to the south of the city, and the New Cantonment 3 miles south-west of the city. The country is open and undulating and is well cultivated. A sandstone ridge runs north-east and south-west through the middle of the area, varying in height from 50 to 100 feet above the general level of the country. Many isolated hillocks and mounds are interspersed over the area. In the north-western portion of the work a good part is covered with large trees which caused some difficulty with the extension of the triangulation in that direction. The Jumna River enters the area 4 miles due north of Delhi, skirts the city on the east and flows in a south-easterly direction.

The triangulation covers an area of 324 square miles within Latitudes 28° 30′ and 28° 47′ and Longitudes 77° 0′ and 77° 20′. It is based on the side Pirghaib T.S.—Tālkatora h.s. of the Great Arc Meridional Series. The sides of the triangles are from 3 to 5 miles in length.

The rectangular co-ordinates of the stations and points were computed in chains from the meridian of origin Nigdhu s. (Latitude 29° 50′ 23″·50, Longitude 76° 44′ 19″·34) of the Rōhan Meridional Series: this was necessary for the revisionary survey of Delhi and its Vicinity, as the 4-inch maps of the area were originally constructed on the system of rectangular co-ordinates in chains in terms of the origin Nigdhu s.

Computations were carried on in the field as the work advanced. When a sufficient number of observations became available these were computed and the values of successive groups of stations and intersected points were supplied during the progress of the triangulation to the Officer in charge of No. 2 Party to enable his plane-tablers to proceed with the revisionary survey.

The stations of the triangulation executed in season 1915-16 to fix points for the control of the boundary traverse of the Imperial Delhi Area were connected and now form part of the present triangulation.

The results of the triangulation, and also of the traverse of the Imperial Delhi Area boundary executed last season by the party, will be published in an addendum to "Triangulation of India and Adjacent Countries—Sheet No. 53 H".

Detail of triangulation in Delhi and its Vicinity.

Theodolite used	Troughton and Simms 6″ Vernier, No. 1397.
Area in square miles	324
Square miles to each point fixed	1·3
Square miles to each height	1·3
Stations fixed	36
Number of triangles	52
Average triangular error in seconds	5″·2
Maximum do. do.	16″
Linear error per mile in feet	0·30
Intersected points: number of points fixed	215
Intersected points: linear error per mile in feet	0·58

THE COMPUTING OFFICE.

By Major H. McC. Cowie, R. E.

Personnel.

Imperial Officers.

J. de Graaff Hunter, Esq., M. A. in charge (till 17th Septr. 1917)

Major H. McC. Cowie, R. E. (from 18th Septr. 1917)

Provincial Officer.

Mr. Hanuman Prasad.

Computing Office.

Rai Sahib Ishan Chandra Deva, B. A., and 11 Computers; 4 Computers attached (7 Computers from field parties worked for a portion of the year in Computing Office) and 11 book-binders.

Printing Office.

Mr. Sarat Kumar Mukerji, Sub-Asstt. Supdt. 21 Compositors & 4 Printers.

Workshops.

1 Head Artificer, fitters and carpenters.

Adjustment of triangulation.—The simultaneous reduction of the Burma Quadrilateral, commenced last year, was completed. It included the consideration of the Burma Coast Series, the Mandalay Meridional, the Mandalay Longitudinal, the Manipur Meridional and the Manipur Longitudinal Series.

The quadrilateral provided three circuits giving twelve equations of condition involving twenty unknowns. Other series dependent on this quadrilateral, *viz*:—the Assam Valley, the Kohīma, the Cāchār, the Nāga Hills, the Gāro Hills, and the Khāsi & Jaintiā Hills Series, were afterwards finally adjusted.

The Great Salween and the Upper Irrawaddy Series being still incomplete, no final adjustment is yet possible. A preliminary adjustment, however, has been made by means of empirical formulæ derived from the results given by the reduction of the Burma Quadrilateral.

Miscellaneous computations.—For the purposes of Professional Paper No. 16,—*The Earth's Axes and Triangulation,* fairly heavy computations had to be dealt with in deducing the probable errors of circuit, base-line, and Laplace closures of the Indian Triangulation. Summaries of all Plumb-line deflections, referred to the Helmert spheroid have been compiled. Deflections observed in Turkistān by Russian officers and originally referred to the Bessel spheroid and to the Tashkent vertical have been reduced to terms of the Helmert spheroid and the Kaliānpur vertical.

Levelling.—The dynamic and orthometric heights of bench-marks on the four lines Benares to Barākar, Bāgalkot to Bijāpur, Howrah to Chāmpdāni and Bankipore to Bihta, were computed. In compliance with Trigonometrical Survey Office Order No. 214 of 23rd July 1917, computations in connection with lines of levelling will in future be carried out by No. 17 Party, the Computing Office giving assistance only in cases of emergency.

The heights of bench-marks on lines of levelling in Burma have been revised and reduced to the new datum of mean sea-level at Amherst and the publication of a new edition of the levelling pamphlets is in hand and well advanced. One-half of the complete edition has been published and it is hoped that the other half will be accomplished in the course of the next year.

Triangulation Pamphlets.—Great progress has been made in the collection of G.T. data for the triangulation pamphlets, 121 of which were compiled and compared during the year.

Printing Section.—The year's work included the publication of 90 Triangulation pamphlets, Volume X of the Records of the Survey of India, Tide Tables for the Port of Basrah and Levelling pamphlets. Professional Paper No. 16 and Part II of the new edition of the Auxiliary Tables are now in hand and it is hoped will soon be published. The efficiency of the section has been increased by the provision of new furniture in the Composing room. New frames and cases have assisted largely towards the attainment of cleanliness and method.

The strength of the section will shortly be increased by the addition of two machines for the accommodation of which the building has been slightly extended.

In the book-binding section the work dealt with comprised 350 copies of Volume X of the Records of the Survey of India, 4100 copies of Triangulation and Levelling pamphlets, 900 volumes of old Triangulation records, 200 copies of the Basrah Tide Tables and 1760 miscellaneous volumes.

Workshops.—The main work of the year consisted in the making of equipment for the Sind-Sāgar Party and additions and alterations to the office buildings. A light pattern of telescope designed for the observation of æroplanes was made experimentally but has not yet been put through any field tests.

Miscellaneous.—The Omori Seismograph has been in operation throughout the year and the usual meteorological observations continued as in past years. The following statements show the earthquakes recorded and the number of days on which Solar photographs were taken.

List of earthquakes, 1916-17.

Serial No.	Month and Date.	Time of beginning (corrected) Dehra.	Simla (From W.R.)	Duration	Distance of Epicentre in miles. Dehra	Simla (From W.R.)	Intensity
		Hrs. Mts.	Hrs. Mts.	Minutes.	Miles.	Miles.	
1	2-10-16	0 4	0 4	...	...	...	very slight (local shock)
2	15-10-16	1 17¼	1 19	16	210	200 to 300	slight
3	22-10-16	1 1	1 1	19	1,820	2,000	moderate
4	1-11-16	21 12	21 12	40	5,320	6,000	,,
5	1-12-16	13 45	...	8	350	...	slight
6	4-12-16	14 9	14 8	11	175	150	...
7	25-12-16	13 24½	13 24	30	140	150	...
8	21- 1-17	4 50	4 50	67	3,290	5,000	great intensity
9	30- 1-17	8 28½	8 26	99	4,340	4,000	very great
10	21- 2-17	1 28	...	90	8,890	...	moderate
11	21- 4-17	6 22	6 22	36	630	350	...
12	2- 5-17	0 16	0 13	155	2,800	2,500	considerable
13	9- 5-17	21 35½	21 35	75	4,200	6,000	great
14	10- 5-17	3 15½	3 16	32	350	120	slight
15	1- 6-17	14 27	14 29	80	4,790	7,500	moderate
16	26- 6-17	11 38½	12 39	130	5,320	9,500	great
17	4- 7-17	6 14	6 16	34	2,800	3,500	moderate

SOLAR PHOTOGRAPHY.

Statement showing the number of days on which Solar Photographs were taken during the year 1916-17.

Month.	No. of days.	8″ Negts. Good.	8″ Negts. Bad.	12″ Negts. Good.	12″ Negts. Bad.	No. of days on which Sun was invisible.	Month.	No. of days.	8″ Negts. Good.	8″ Negts. Bad.	12″ Negts. Good.	12″ Negts. Bad.	No. of days on which Sun was invisible.
October 1916	29	52	5	...	...	2	April 1917	27	42	3	2	...	3
November ,,	30	55	4	3	1	...	May ,,	25	42	3	1	...	6
December ,,	31	57	4	3	...	...	June ,,	28	43	4	3	...	2
January 1917	28	51	3	2	...	3	July ,,	25	35	2	...	...	6
February ,,	26	47	3	3	...	2	August ,,	24	37	4	2	...	7
March ,,	30	54	4	3	...	1	September ,,	19	30	2	...	...	11
							Totals ...	322	545	41	22	1	43

Specimen of reproduction by the three-colour process from a water colour sketch.

PART III.—SPECIAL REPORTS.

PHOTO.-LITHO. OFFICE, CALCUTTA.

By Captain F. J. M. King, R.E.

No special report on the work of the Photo.-Litho. Office has appeared in the Records Volume since 1913-14.

The most noteworthy feature of the year under report is the large increase in out-turn as compared with previous years. Departmental work showed a considerable decrease owing to survey operations being curtailed on account of the war. The decrease in departmental work is however much more than counterbalanced by the phenomenal increase in extra-departmental work due to great demands for maps for the various field forces and for other military purposes. In consequence of the large and urgent demands by the military authorities the publication of some of our ordinary departmental maps has had to be delayed at times: this delay was purely of a temporary nature and the office has always been able to work off the arrears thus caused and so keep its head above water. To cope with the great increase of work it has been necessary to employ a good deal of overtime, which, if continued for long periods without a break, undoubtedly causes a good deal of strain on the staff.

During the latter part of the period under report the Stores Section has been reorganised owing to the anything but satisfactory way in which it was working. This section is still very cramped for room, but it is hoped that this defect can be remedied to some extent by getting rid of stocks of old paper, which, though still serviceable, is not now used for our work.

Mr. Vandyke proceeded to Mesopotamia in October 1916 returning to Calcutta in December 1916. While in Mesopotamia Mr. Vandyke visited Basrah and the Tigris Corps Head Quarters and put the Vandyke Printing Section of the Basrah Survey Party on a sound working footing, and was able to overcome the difficulties which this section had previously experienced.

Fixing of Stump Shaded Originals.—All stump shaded originals on receipt in the Photo.-Litho. office are now "fixed" by spraying a solution of gelatine over them. This, it is hoped, will prevent these originals from having the chalk rubbed off them and so losing their depth of tone, and will obviate the necessity of touching them up in case a reprint is called for.

Levy Acid-Blast Etching Machine.—The etching machine mentioned in the Records Volume of 1913-14 as having been ordered went down in a ship which was sunk by the Emden and a new one was ordered. The new one arrived here towards the end of 1916 but with parts of it badly broken. Temporary repairs were effected here and the machine was taken into use for etching line-blocks. It is not used for etching half-tone blocks owing to the time necessary to empty out the acid used for etching the line blocks and re-filling with the perchloride of iron with which half-tone blocks are etched. It is therefore recommended that another machine of the same type but of a smaller size be ordered as soon as possible after the war so as to enable one machine always to be used with acid and the other with perchloride of iron.

Special Lens for correcting distortion.—No further experiments have been carried out in connection with this lens since Captain Hamilton left the office in 1914 owing to the difficulty of getting any apparatus made since the war broke out.

The Powder Process.—It seems likely that there will be occasion to take up again the use of what is known as the " Powder Process" by means of which any number of reversed duplicates can be made of a negative. If this process were taken into use it would only be necessary to make one negative in the camera of the outline of every sheet, as many reversed duplicates as required being made of this negative in a printing frame by this " Powder Process". The process would also be useful for making the negatives for the layer plates of layered maps. The advantages of this method are its cheapness and the fact that no prism need be used in making the original negative in the camera, a shorter exposure being therefore necessary. The adoption of this process would lighten the work of the negative section enormously and would do away with the present congestion of the studio. A considerable saving in the cost of chemicals would also result. This process was used in former years for the purpose of making reversed negatives for preparing the "dust on" blue prints used for hill shading before the present method of preparing these blue prints was worked out. Experiments have been made during 1916-17 to determine the feasibility of adopting this process, and the results obtained seem to be in no way inferior to results obtained by the ordinary method. The only thing against using the process at present is lack of space: it is hoped that by re-arranging the accommodation used for storing negatives and glass, that room will be found in which to work the process.

New Formulæ.—The use of gall nuts obtained from England for etching helio plates has been discontinued, and a local nut, *Myrobolans*, (Hindi :—Bara Harre) is now being used instead at a considerable saving of expense.

The use of Photopake for duffing will be discontinued on the exhaustion of our present stock firstly on account of the difficulty of obtaining stores from England and secondly because it does not appear to be superior in lasting quality to the duffing medium made up here, the formula for which is :—

Indian ink	...	16 cakes.
Carbolic acid	...	1 oz.
Decoction of ox-gall		½ oz.
Water	up to	80 oz.

NEW METHODS AND PROCESSES.

I. A new method of preparing Layer Plates.

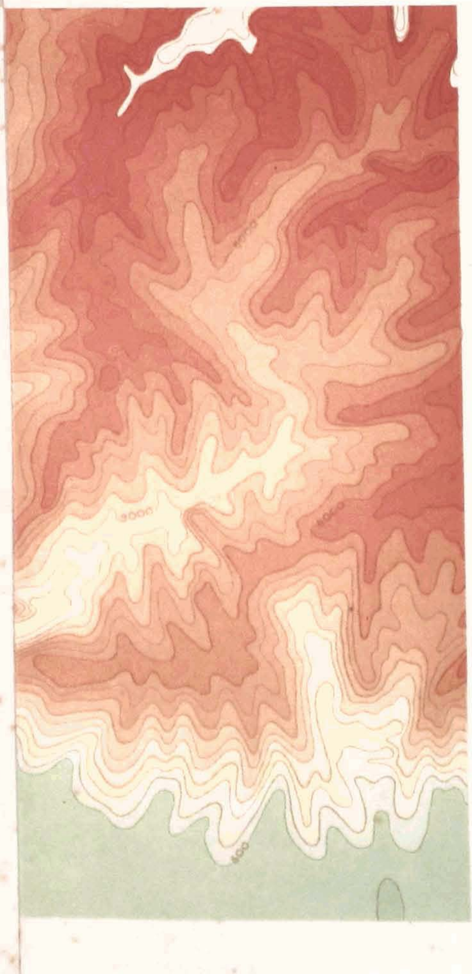
Old method.

1. The principle in use in the printing of layers for Survey of India maps is with the exception of the yellow plate, to prepare each layer plate to print three different tints of the same colour, namely a light tint, a medium tint and a solid tint. The yellow plate, however, is only made up to print two tints, a light tint and a medium tint. A reference to the diagram will make the matter clear.

2. The method which has been in use up to date, of preparing these various layer plates, is both laborious and not particularly satisfactory. To get an idea of the amount of labour expended on the preparation of a full set of layer plates, it will be sufficient to consider the labour involved in the preparation of one plate, and imagine that multiplied by the number of layer plates. A fair example will be to consider the labour and time formerly expended on a plate such as the "first brown" plate in the diagram. It may be noted that the light brown extends from 2,000 to 2,500 feet, the medium from 2,500 to 3,000 feet and the whole area above 3,000 feet will be printed solid brown, *vide* column 8 which will in its turn receive further graduated tints of brown and red.

3. First of all an off-set (or image in black powder) of the detail and contours combined, had to be laid down on a clean grained zinc plate. The whole of the plate below that part which was to receive the light tint now had to be carefully gummed out by hand with a brush. In addition, all areas above the lower limit of the light tint, which were not to receive a layer tint such as lakes and double lined streams, were also gummed out. The upper limits of both the light and medium tints then had to be marked on the plate by means of a line scratched into the plate with a sharp point. A tint transfer from a copper plate consisting of fine engraved lines was then laid down on the plate, passed several times through a hand press, and finally washed, leaving the tint on the ungummed portion of the plate. The whole of the area of the plate which had to print either a light, a medium or a solid tint was by this method covered with fine parallel lines which formed the light tint.

4. The whole of the plate now had to be painted out with gum again, only leaving exposed those portions which were to print the medium and the solid tint, the lower of the two lines already scratched on to the plate forming the guide for the draughtsman. The portion of the plate which is required to print the light tint was thus protected by gum from receiving any further transfers. Another tint transfer was now laid down with the lines of the tint crossing at right angles the lines of the tint which was first laid down. After washing off the second transfer, the light and the medium tints were complete. The portion of the plate which was to print the solid tint was however still covered with the cross lines forming the medium tint; this portion, therefore had then to be painted in solid with litho. ink by hand down to the higher of the two lines previously scratched into the plate.



HELIOZINCOGRAPHED AT THE SURVEY OF INDIA OFFICES, CALCUTTA.

5. It will be seen from the above that even if all went well it was a laborious process. It was, however, the exception rather than the rule for everything to work satisfactorily; for instance, it often happened that a transfer did not go down satisfactorily; in which case the whole of the work already done on the plate was wasted and had to be done over again. Even if a plate appeared to be satisfactorily prepared it was very often spoilt in printing, as plates with these fine tints *transferred* on to them are very delicate and will not stand as much rough usage as when the tint has been put on to the plate ***photographically***.

When it is realised that the above labour was necessary for the preparation of one plate, some idea can be gathered of the amount of time and labour involved in the preparation of a full set of such plates.

New method.

6. The first stage of the new method is the preparation of what is termed the "Layer Original". For this purpose a blue print of the detail and contours combined is made on a piece of any good quality smooth surfaced paper which has been previously mounted on zinc. The portions of this blue print corresponding to the black portions of the layer original in column (1) of the diagram are then painted in solid with opaque Indian Ink using the layer guide which has been prepared by the Circle or Drawing office as an assistance to the draughtsman. Certain of the contours also have to be inked up with a fine black line. Again referring to column (1) of the diagram it will be seen that the 1,000, 3,500, 6,000 and 12,500 feet contours have to be inked up to show the limits between contiguous portions which are left white on the layer original. In the case of maps in which every contour bounds a layer as is the case with our $\frac{1}{1,000,000}$ sheets (*i.e.* on which there are no intermediate contours) the inking in of the contours by hand can be saved by printing the contours in black instead of in blue on the print on which the layer original is prepared. Any areas such as lakes, double-lined streams and perpetual snow areas which should not receive a layer tint, are, if they fall within the blackened areas, left white; if they fall in the areas left white they are outlined by a fine black line.

7. The layer original having been completed, it is sent to the Photo. Branch where as many negatives as there are to be layer plates are made of it, the negatives, however being made through a half-tone screen using a special "X" shaped stop in the Lens. The exposure for these negatives is so regulated that the black portions of the layer original come out on the negatives as clear glass covered with small opaque dots, while the white portions come out as an opaque ground covered with small transparent dots. The inked-up contours and areas which are to receive no layers such as lakes, double-lined streams and snow areas of course appear clearly on the negatives. An idea of what each negative looks like can be got by reference to column (2) of the diagram.

8. One negative is now selected for each layer plate and the negatives are sent to the Retouching Section for duffing. Considering the first brown plate [*vide* column (7) of diagram]:—This negative is duffed from the 2,000 feet contour downwards; above this no duffing is necessary except to duff out lakes, double-lined streams and perpetual snow areas. The second brown negative is similarly treated except that it is duffed from 3,500 feet downwards, and likewise with the first and second red negatives which are duffed from 6,000 feet and 12,500 feet downwards respectively. The yellow negative, however, (*vide* column (5) of the diagram) is duffed from 2,000 feet upwards and from 1,000 feet downwards, while all sea areas and areas above 1,000 feet are duffed out from the green negative [diagram column (3)]. Register marks are cut in at the corners of all the negatives, and helio plates are made from all the negatives. These helios now appear as in columns (3), (5), (7), (9), (11) and (13) of the diagram.

9. Each helio plate has now had two tints (the light tint and the medium tint) produced on it photographically, out of the three tints which it has to print. It now only remains to paint in on the helios with litho. ink those portions of each plate which are to print solid, still leaving blank those portions such as lakes, double-lined streams and snow areas which have no layers on them. This completes the preparation of the layer plates. The plates having had the solid portions painted in and having been inked up in their appropriate colours will now give prints as in columns (4), (6), (8), (10), (12) and (14) of the diagram while the combined result of printing all the plates is shown in column (15).

10. The advantages of the new method are as follows:—

(*a*) A saving of time and labour is effected.

(*b*) The results are as good as, and even superior to, those achieved by the old method.

(*c*) If by any mischance a plate is spoiled in the printing a new helio can be obtained in half an hour which only has to have the solid portion painted on. In other words a new plate could, on an average map, be prepared in a day. This would have taken about a week by the old method.

(*d*) There is less liability for a plate to be spoiled in the printing, as an image produced photographically on a plate is more durable than one produced by the transfer method.

(*e*) In a very difficult or complicated sheet it is almost impossible for the draughtsman to follow the contour lines on an off-set. By the new method this trouble is overcome during the preparation of the layer original where the draughtsman works on a clear blue print which is much easier to follow than an off-set.

(*f*) Owing to the fact that no transferring has to be done, the time of the hand presses is not taken up on this work; hand presses are thus free to do their legitimate work which is proving.

(*g*) The relative depths of the light, medium, and dark shades are absolutely under control and can be varied at will as required by giving suitable exposures in the camera when the layer original is photographed.

(*h*) Two-thirds of what was hand work by the old method is produced photographically on the plate by the new method.

11. This method has been used in the preparation of the layer plates of numerous sheets. The results prove conclusively that there is a great saving of time by the new method and that the cost incurred is no more than by the old. The saving of time is noteworthy as the duffing is of an entirely new description to the men employed on it and considerable time had to be spent in explaining to the duffers the work that had to be done. As the duffers get better accustomed to this work the saving of time should be even more marked.

II. Description of some Developments and Improvements in Methods of preparing Tint Plates.

1. The methods in use in the Photo.-Litho. Office for the reproduction of line work such as is used for maps are as up to date and as satisfactory as the modern methods of Photo.-Lithography will allow: the reproduction of the necessary tints on our maps has however in the past entailed a very great deal of labour, though in the main the results have been fairly satisfactory. It is on account of the vast amount of manual labour expended on producing these tints that a great deal of time and thought have been devoted of late in the Photo.-Litho. Office towards the simplification of this work.

2. In the past if a tint had to be laid down on a zinc plate the portion which was not to receive the tint had to be protected with a film of gum: a print in transfer ink had then to be obtained from the necessary engraved copper tint plate in the Engraving Office and this transfer had to be laid down on the portions of the zinc left unprotected by gum. This "gumming out" of the zinc plate was a laborious enough task when it only had to be done once, but it often happened that the tint did not transfer properly from the transfer paper to the zinc, in which case the zinc plate was spoilt and all the work of "gumming out" had to be done again on a fresh zinc plate.

3. The causes of failure in transferring tints to zinc from transfers from engraved copper plates are numerous and it will be sufficient if a few of the causes are enumerated. Firstly the copper plates themselves are apt to get damaged when in constant use and any scratches are apt to cause flaws in the transfers. Again if the transfers are kept any length of time they become useless. A third cause of trouble is that on a print from a copper plate the ink on the lines or dots forming the tint is actually projecting above the surface of the transfer paper in the form of ridges or small mounds: this projecting ink is apt to get squeezed out flat during the act of transferring the tint to the zinc thus causing a thickening of the lines or dots and spoiling the tint and entailing rejection of the zinc plate. In general it may be said that the laying down on zinc of transfers from engraved copper tint plates is an uncertain business involving great risk of spoiling a plate, a matter which becomes serious if the zinc plate has had much labour expended on its preparation prior to receiving the tint. The above, however, is not the end of the trouble for a tint transferred as described requires very delicate handling both during preparation for the machine and in the machine itself and is very liable to be spoiled at both those stages.

4. Mr. Vandyke directed his attention to trying to overcome one of the great difficulties mentioned in para. 3 which is caused by the ink on a transfer from a copper plate being raised above the surface of the paper and consequently liable to spread when subjected to pressure during transferring. This difficulty was finally overcome by preparing large size zinc tint plates from transfers from the engraved copper tint plates by means of transfers. Many transfers are of course wasted and spoiled in order to produce one good transfer on zinc. The zinc plate is then etched in relief by biting with nitric acid when it can be rolled up and prints on to transfer paper be made from it. The ink on transfers thus made does not stand up above the surface of the paper, and when these transfers are laid down on to other zinc plates prepared to receive them there is no tendency for the ink to spread.

5. Mr. Vandyke while working on the above discovered that the use of transfer paper of any kind was not necessary. Having prepared a zinc plate with the tint all over it and having etched it in relief he found that by inking it up and placing it face to face with a clean zinc plate the tint could be transferred from one plate to the other by passing the two plates together through a press. It is doubtful if there is any advantage in this direct "plate to plate" transferring as it would seem that there is bound to be a tendency to wear down the relief of the zinc tint plate by continual use in this way owing to the contact under pressure of the hard surfaces of the two zinc plates. Furthermore the transfers prepared as described in para. 4 appear to be so satisfactory and avoid wearing out the zinc tint plates, that they are perhaps to be preferred to transferring from plate to plate, though some workers prefer the latter method.

6. Concurrently with what has already been described a great deal of improvement has been effected towards the same end by a different method. It was noticed that the half-tone plates made by Mr. Taylor's "high light" method such as are used in the Photo-Litho. Office for hill shade and which are in effect plates with dotted tints (stipples) on them would stand rougher usage during preparation for the machine and in the machine than plates which had stipples transferred to them. These half-tone plates are prepared by the ordinary helio process. This led to the fact being realised that if tints could also be got on to the zinc plate by the helio process they would be much easier to work with than tints laid down by means of transfers. Mr. Vandyke from this evolved the plan of making an artificial negative by hand on which the portions to be covered with tint were clear glass and the remainder opaque. If this artificial negative be placed face to face with a sensitised helio plate but with a thin film or piece of tracing paper, on which a suitable "tint" or stipple is printed in some opaque medium, between the negative and the helio plate, and an exposure to light made, the tint or stipple will appear on the helio plate on development only on those portions falling directly underneath the clear glass of the artificial negative. It will be seen that this method depends on the interposed film being sufficiently thin to prevent the action of light spreading to these portions of the helio plate underneath the opaque parts of the negative. This method gives very perfect results and is suitable for such tints as the blue of sea areas, etc., cultivation and Forest areas. It is not suitable for such tints as the red stipple on roads and villages as these tints have to be put on to plates on which there is existing work in the form of the lines forming the roads and the out-lines of sites which cannot be protected from harm during the inking up of the stipple prior to development. There is also the difficulty of getting the artificial negative to register accurately with the existing work on the zinc when placing it in the printing frame.

7. The next development was made when it was realised that the work of preparing the artificial negative described in para. 6 was practically doing over again work which had already been done once by the Circle or Drawing office which prepared the yellow and green colour guides. The question then arose as to whether the work already done on these colour guides could not be utilised to produce without any further hand work a negative to take the place of the artificial negative. Experiments were tried and it was found that if a blue print instead of a black was used on which to prepare the colour guides and if a sufficiently strong gamboge and Hooker's green No. 2 were employed in their preparation, the colour guides themselves could be photographed to produce negatives to replace the artificial negatives. This procedure has consequently been adopted and is now in general use throughout the department.

8. A large amount of thought and many experiments have been devoted towards producing the thin transparent screens with stipples or tints on them, referred to in para. 6, for use between the negative and the helio plate, and it is by improving the methods of production of these that better results will be obtained.

An ideal screen for this purpose would be one of celluloid with the tint composed of cross lines cut into it and the lines filled up with some opaque medium. Endeavours have been made to rule such a screen but the irregular structure of the celluloid seems to be against it and results in some parts of the lines cutting quite clean while other parts cut with jagged edges.

Another method which has given a fair amount of success is to coat a glass with an opaque "ground" or varnish and rule through this "ground" by means of a ruling machine. This ruled glass is then used as a negative and a helio is made from it and the helio used for making prints on tracing paper or other transparent medium, these prints being used as screens for interposing between negative and helio. The difficulty in this method has been to prepare a suitable "ground" with which to coat the glass and which will not chip while in the ruling machine.

9. The most successful results so far obtained in making these screens have been photographic reproductions in one form or another of the ruled screens used in half-tone work. A positive of the half-tone screen is made in a camera by the wet plate or collodion process, the glass being French chalked before sensitising in order to facilitate the subsequent stripping of the collodion film from the glass. When this positive is dry it is accurately levelled and coated with gelatine. If a thick coating of gelatine is put on, the collodion film with the gelatine adhering to it, can, when dry, be stripped from the glass and forms a good though rather destructible screen for interposing as described in para. 6.

A more durable screen though a less transparent one can however be made by only laying a thin coating of gelatine on the collodion film: on to this a sheet of tracing paper, which has been coated thinly with gelatine and chrome alum, is squeegeed down: when dry the whole is cut round the edges and pulled off the glass. This method right through is a very delicate one, the making of the positive reproduction of the half-tone screen being a most difficult matter as any dust spots, irregularities of the collodion coating or bath marks make the result useless. The final stripping from the glass also is fraught with difficulty.

10. Some very fairly successful screens have been made on tracing paper as follows:—

A negative is made from a half-tone screen in the camera and from this a helio is made on a polished zinc plate. This helio is etched with nitric acid until the cross lines stand slightly up in relief after which the cross lines are inked up with an ink mixed with very stiff varnish. The tacky ink is then black-leaded and a print made on to varnished tracing paper the image on which is formed by the black lead adhering to the varnish on the tracing paper.

By means of varying the shape of the stop in the camera lens when the negative is being made it is possible not only to reproduce the half-tone screen in its "cross lined" form but it is also possible to produce a negative consisting of parallel diagonal lines or of dots: thus, given a large half-tone screen of the ordinary type, it is possible to produce thin screens of all varieties of tints for interposing between negative and helio. Many other methods have been tried but the screens we use to most advantage are prepared by one of the above methods.

REPORT ON THE LEVELLING CARRIED OUT TO WATCH THE BEHAVIOUR OF BENCH-MARKS FIXED TO TREES IN THE COMPOUND OF THE TRIGONOMETRICAL SURVEY OFFICE, DEHRA DUN, DURING THE PERIOD APRIL 1914 TO APRIL 1917.

By Colonel G. P. Lenox Conyngham, R. E.

The line of levels formed a small circuit starting from and closing upon the G. T. S. Standard Bench-mark in the above compound. The levelling was done twice yearly, once in April and once in October, before and after the monsoons, *i. e.* just before and after the period of greatest vegetative activity.

Ten trees of different kinds and ages were selected on which bench-marks consisting of zinc plates bearing the inscription $\frac{\text{G. T. S.}}{\text{B. M.}}$ (⊖) were nailed, the horizontal line through the circle being the point of reference.

The Bench-marks were numbered serially from 1 to 24 and the numbers were stamped on the zinc plates. 18 of these zinc-plate-bench-marks were fixed vertically on the trunks of the trees at heights varying from 9 inches to 6 feet above ground, some on the bark and some on the sapwood after removing the bark. Three were fixed horizontally to the heartwood in large nicks cut in buttresses near the base of the trunk; two were fixed horizontally on the root of a rubber tree, and one on that of a teak tree.

The ten trees to which bench-marks have been fixed are :—

(*a*)	Large Tun tree	Bench-marks	10, 11 and 23
(*b*)	Small Tun tree	do.	19 and 20
(*c*)	Large Shisham tree	do.	17 and 18
(*d*)	Small Shisham tree	do.	3
(*e*)	Large Chir tree	do.	5, 6 and 21
(*f*)	Small Chir tree	do.	4
(*g*)	Large Gambar tree (*Gmelina Arborea*)	do.	7, 8 and 9
(*h*)	Large Teak tree	do.	12, 13, 14 and 24
(*i*)	Large Rubber tree (*Ficus Elastica*)	do.	1 and 2
(*j*)	Small Silver Oak (*Grevillea Robusta*)	do.	15 and 16

These levelling operations have been carried out at the request of the Forest Department in order to decide whether the stems of trees rise bodily during the process of growth.

From the results given in the table attached it will be seen that during this period there has been no appreciable change in the constancy of the elevation of the bench-marks in question. From the effects on and the conditions of the bench-marks nailed to the bark or to the sapwood of the trees there is evidence of the growth in the girth of the trees, for several of the zinc plates were actually forced over the heads of the nails and were found lying on the ground and most of the remainder have become distorted, owing to strain caused by this growth.

Those bench-marks which are fixed vertically cannot be connected by direct levelling, that is to say the levelling staff cannot be placed directly on the bench-mark. In such cases a peg was driven into the ground as near the bench-mark as possible and the staff was placed on that, then the vertical distance from the top of the peg to the horizontal line on the zinc plate was measured with a tape.

The small discrepancies shown in the table may be in part due to errors in the tape measurements which were in some instances rather difficult to make. The results of the levelling to the horizontal bench-marks, on which the staff could be erected, show scarcely any changes at all during the three years that the work has been going on.

TABLE OF RESULTS.

No. of Bench-mark	Description of Bench-mark	How Fixed	Height above ground (feet)	Height in feet above (+) or below (−) the Standard Bench-mark near the Office of the Superintendent of the Trigonometrical Survey — Date: April 1914	October 1914	April 1915	October 1915	May 1916	October 1916	April 1917	Remarks (May 1917)
10	Large Tun tree	Vertically on bark,	4¾ ...	+4·189	+4·199	+4·180	...	...	...	...	Forced over the heads of the nails.
11		Vertically on sapwood,	4 ...	+3·589	+3·567	+3·606	...	...	...	...	Do. do. do.
23		Horizontally to heartwood,	¾ ...	+0·585	+0·581	+0·581	+0·583	+0·581	+0·584	+0·582	In good condition. Connected by direct levelling.
7	Large Gambar tree (*Gmelina Arborea*)	Vertically on bark,	4¾ ...	+6·959	+6·932	+6·964	+6·947	+6·959	+6·958	+6·957	Bent and being forced out. Connected by tape measurements.
9		Vertically on sapwood,	3½ ...	+5·739	+5·702	+5·730	+5·708	+5·720	+5·716	+5·714	Growth of bark on right edge of plate, otherwise in good condition. Connected by tape measurements.
8		Horizontally to heartwood,	2½ ...	+4·750	+4·754	+4·752	+4·752	+4·758	+4·761	+4·759	In good condition. Connected by direct levelling.
5	Large Chir tree	Vertically on bark,	4 ...	+7·421	+7·412	+7·479	+7·403	+7·399	+7·407	+7·399	In good condition. Connected by tape measurements.
6		Vertically on sapwood,	3 ...	+6·246	+6·223	+6·237	+6·229	+6·228	+6·247	+6·253	Growth of bark on right edge of plate, otherwise in good condition. Connected by tape measurements.
21		Horizontally to heartwood,	1¾ ...	+4·658	+4·667	+4·663	+4·662	+4·668	+4·672	+4·667	In good condition. Connected by direct levelling.
4	Small Chir tree	Vertically on sapwood,	4 ...	+7·344	+7·317	+7·325	+7·321	7·333	...	...	This tree was removed in 1916.
3	Small Shisham tree	Vertically on bark,	3¾ ...	+6·771	+6·757	+6·763	+6·745	+6·765	+6·763	+6·755	Growth of bark on both edges of plate, which is bent. Connected by tape measurements.
1	Large Rubber tree (*Ficus Elastica*)	Horizontally on sapwood of root,	1½ ...	+6·105	+6·128	+6·120	+6·120	+6·126	+6·144	+6·118	Growth of bark on all sides of the plate, which is bent and not horizontal. Connected by direct levelling.
2		Horizontally on bark of root,	¾ ...	+5·192	+5·219	+5·212	+5·206	+5·201	+5·212	+5·204	Do. do. do. do.
19	Small Tun tree	Vertically on bark,	5 ...	+6·481	+6·477	+6·508	+6·492	+6·503	+6·510	+6·523	The plate, which is bent, is sticking only ¼ inch out of the tree at its right edge and the nail on this side has been forced out. Connected by tape measurements.
20		Vertically on sapwood,	4½ ...	+5·977	+5·971	+5·979	...	...	...	...	Forced over the heads of the nails.
22	Large Shisham tree	Horizontally to heartwood,	2½ ...	+4·448	+4·457	+4·459	+4·455	+4·459	+4·466	+4·460	In good condition. Connected by direct levelling.
17		Vertically on bark,	6 ...	+7·647	+7·659	+7·613	+7·640	+7·648	+7·647	+7·657	Do. do. Connected by tape measurements.
18		Vertically on sapwood,	4½ ..	+6·276	+6·268	+6·287	+6·279	+6·288	+6·276	+6·271	Bent and being forced out particularly at the left edge which is not quite against the tree. Connected by tape measurements.
15	Small Silver Oak (*Grevillea Robusta*)	Vertically on bark,	3¾ ...	+1·981	+1·986	+1·995	+1·985	+1·988	+1·994	+1·981	Growth of bark on both edges of plate, which is bent. Connected by tape measurements.
16		Vertically on sapwood,	3½ ...	+1·433	+1·432	+1·442	+1·438	+1·436	+1·448	+1·435	Do. do. do. do.
14	Large Teak tree	Horizontally on bark of root,	¾ ...	−3·481	−3·464	−3·463	...	...	...	...	Forced out.
24		Horizontally to heartwood,	1¼ ...	−3·092	−3·086	−3·084	−3·096	−3·097	−3·091	−3·096	In good condition. Connected by direct levelling.
12		Vertically on bark,	5¼ ...	+1·285	+1·284	+1·229	+1·259	+1·264	+1·252	+1·260	Bent a little. Connected by tape measurements.
13		Vertically on sapwood,	5 ...	+0·975	+0·988	−0·974	+0·954	+0·949	+0·948	+0·955	Do. do. do. do.

APPENDIX I.

NOTE ON BASEVI'S PENDULUM OBSERVATIONS AT MORÉ.

By Colonel G. P. Lenox Conyngham, R.E., F.R.S.

In the geographical journal for September, 1916 there is a paper "On the accuracy of Basevi's determinations of the value of gravity in India" by R. D. Oldham, F.R.S.

The object of the paper is to arrive at a value of g for Moré, Captain Basevi's last station, and to estimate the probable error of the value adopted.

This question was dealt with in the Report of the International Geodetic Conference of 1909 by Prof. Borrass of the Prussian Geodetic Institute.

Taking all the pendulum stations visited by Basevi and Heaviside in the years 1865-1873, at which observations with modern apparatus have since been made, and using Kew as the base station, Prof. Borrass computes the value of g at each station from the " vibration numbers" given in Vol. V of the "*Account of the Operations of the G. T. Survey*". Then taking the values of g obtained from the modern observations, he finds the corrections which the earlier results require. The errors of the old observations are unquestionably principally due to the absence of means for measuring flexure in the old apparatus.

Prof. Borrass finds that at the majority of the stations the correction is tolerably uniform, but that Dehra Dun and Mian Mir are in a class by themselves. He points out that a special light stand was used at Mian Mir and says that "in all probability the same was used at Dehra Dun". In this he was mistaken. The light stand was made for the expedition to Moré and was used only at Mian Mir which place Captain Basevi visited just before starting on the expedition. At Dehra the ordinary stand was used but it was erected on four masonry pillars, so as to raise it above the flues used for heating the room during the determination of the temperature correction.

To reduce to the Potsdam system, in which g at Kew is 981·201, Prof. Borrass finds that for the Indian stations at which the ordinary stand was used Basevi's values of g, computed from the differences from Kew, require a correction of $+0·036 \pm 0·003$. For Dehra Dun he finds the correction $+ 0·103$ and for Mian Mir $+ 0·112$. Taking the mean of Dehra Dun and Mian Mir, he adopts $+ 0·107 \pm 0·004$ for Moré. As explained above, Prof. Borrass was mistaken in thinking that the conditions at Dehra Dun were similar to those at Moré. The value 0·107 therefore is based on a misconception and must be reconsidered.

The fact is that with regard to Moré, we have no evidence at all except the Mian Mir result, and if we wish to make use of the Moré observations the only possible course is to assume that the flexure of the stand was the same at Moré as it was at Mian Mir, but we have no evidence as to whether the light stand used at Mian Mir and at Moré was equally rigid wherever it was erected.

This point will be returned to, but before proceeding further it is important to state to what the correction $+ 0·112$ is to be applied. This correction is necessary in order to remove the error caused by the difference between the flexure at Moré and that at the *base station*. At Kew the way in which the pendulums were erected was quite different from the plan adopted in India, and the corrections given by Prof. Borrass are only applicable when *Kew is made the base station.* Prof. Borrass alludes to this, but Mr. Oldham does not and the omission might possibly lead readers who are not familiar with the methods of pendulum observations into error.

Since the arrangements at Kew were not at all similar to those made in India, and since we now have trustworthy values of g at a good many Indian stations it will somewhat simplify the discussion of Capt. Basevi's observations if Kew is altogether omitted and if one of the Indian stations is made the base.

Dehra Dun would have been the most natural station to choose, since it is the base of the modern work, but, as has already been said, Basevi's pendulum stand was erected at this station in a special way so that Dehra has the same disadvantage as Kew.

Kaliana will be the best station to choose as the base. It was visited three times by Capt. Basevi and the conditions of work seem to have been normal and satisfactory. The modern Indian operations give the following results based on g at Kew $=981 \cdot 200$.

g at Dehra Dun $=979 \cdot 063$*
g at Kaliana $=979 \cdot 154$*

Making Kaliana the base and using the value $979 \cdot 154$, the results of Basevi's observations at stations which have since been visited with the modern apparatus, and at Moré, are shown in the table, and alongside of these are given the results of the modern determinations.

	Basevi's values	Modern values	M – B
Bangalore ...	978·044	978·025	–0·019
Madras ...	978·284	978·279	–0·005
Colaba ...	978·652	978·631	–0·021
Kalianpur ...	978·770	978·777	+0·007
Nojli ...	979·163	979·143	–0·020
Dehra Dun ...	979·009	979·063	+0·054
Mussoorie ...	978·798	978·793	–0·005
Mian Mir ...	979·321	979·383	+0·062
Moré ...	978·184	...	...

We see that Bangalore, Colaba and Nojli resemble each other very closely, that Madras, Kalianpur and Mussoorie agree fairly well with one another, and that Dehra and Mian Mir while agreeing with each other differ widely from the rest. The mean correction for the six normal stations is $-0 \cdot 010$.

The effect of flexure is to increase the time of vibration; if the time of vibration is too large the resulting value of g is too small. If therefore a result uncorrected for flexure is too large it means that the flexure at the station concerned was less than at the base station. It appears therefore that the flexure at Kaliana was greater than that at any of the other normal stations (*i. e.* omitting Dehra and Mian Mir) except Kalianpur.

Also that the correction necessary to reduce to a flexure equal to that at Kaliana varies from $+0 \cdot 007$ to $-0 \cdot 021$. We do not know what the flexure correction at Kaliana, or at any other station, was and we therefore cannot say whether this variation is a large proportion of the whole or not; it would be quite incorrect to say, for instance, that the flexure at Nojli was four times as great as that at Mussoorie. Our position is similar to that of a person who is told that the thermometer reads 50° at one place and 30° at another and is not told what kind of thermometer was used, whether C., F. or R. He knows that one place was hotter than the other but not how much hotter.

Mr. Oldham finds that the mean correction to the normal stations is $+0 \cdot 039$ with an uncertainty of $0 \cdot 01$, and that at Mian Mir the correction is $+0 \cdot 109$. He proceeds, " From this it seems that the use of the light stand introduces a correction of about twice as much as in the case of the heavier and probably an uncertainty in the same proportion."

The corresponding figures when Kaliana is used as the base are :—

Mean correction to normal station $-0 \cdot 010 \pm 0 \cdot 01$.
Correction to Mian Mir $+0 \cdot 062$.

It is not possible to make any deduction with regard to the uncertainty of the Moré correction. We know that the heavy stand, which was taken to pieces at the conclusion of the observations at each station and re-erected at the next was sometimes more rigid than at Kaliana and sometimes less; we know nothing at all about the behaviour of the light stand, but it is natural to suppose that it would be liable to greater variations.

* Prof. Borrass prefers 979·065 and 979·156 but as all the recent Indian results have been based on 979·063 at Dehra it is preferable to adhere to this value until it is confirmed or modified by a fresh expedition with the pendulums to Kew and back again.

As has been said above, the only way of deriving a value of g at Moré from Capt. Basevi's observations is to assume that the correction found at Mian Mir, namely $+0\cdot062$, applies equally to Moré. As to the uncertainty the present writer can merely say that he would be surprised if the correction was to prove less than $+0\cdot030$ or greater than $+0\cdot120$; in his opinion therefore g at Moré will probably be found to lie between $978\cdot214$ and $978\cdot304$ or in round numbers between $978\cdot2$ and $978\cdot3$.

The latitude of Moré is 33° 15′ 39″ and the height 15427 feet.

Hence $\gamma_0 = 979\cdot584$*

Correction for height $= -1\cdot446$†

$\gamma_A = 978\cdot138$

Bouguer correction $= +0\cdot519$‡

$\gamma_B = 978\cdot657$

The Hayford, or compensation, correction has recently been computed by Major Cowie. The topography of the surroundings is not accurately known and therefore the result is liable to some uncertainty. The value obtained was $+0\cdot081$ and the probable error may be estimated at about $\pm 0\cdot003$.

$$\text{Hence} \quad \gamma_C = \gamma_A + \text{Hayford correction.}$$
$$= 978\cdot219.$$

Retaining two places of decimals only, and even the second is very uncertain, we have:—

$$g - \gamma_B = 978\cdot25 - 978\cdot66 = -0\cdot41.$$
$$g - \gamma_C = 978\cdot25 - 978\cdot22 = +0\cdot03.$$

So far attention has only been drawn to the uncertainty at Moré due to the light stand. There were, however, other special sources of error. In India the pendulum stand was always erected on a masonry floor; if none existed a floor was constructed for the occasion. At Moré there was no such floor.

At all the Indian stations the apparatus was set up in a room which gave tolerable protection from changes of temperature. At Moré a tent had to be used. A specially thick tent was employed and Capt. Basevi was well pleased with the amount of protection it afforded, but its use must have introduced some additional uncertainty. For these reasons the view has been held in the Survey of India that the Moré observations are too uncertain for any argument to be based on them.

But for the war we should long ere this have had the results of the pendulum observations made by the members of the de Filippi expedition of 1913-14. Commander Alessio of the Royal Italian Navy made a great effort to take a set of observations at Moré, but unfortunately he was only able to spare time for this expedition in the early part of 1914 and snowy weather frustrated his plans. Observations were however made at Leh and at several other places in those regions and, when the results are published, much light will be thrown on the state of isostatic compensation underlying them.

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* Computed by Helmert's formula $\gamma_0 = 978\cdot030\ (1 + 0\cdot005302 \sin^2\phi - 0\cdot000007 \sin^2 2\phi)$.

† Correction for height $= -\dfrac{2gh}{R} = -\dfrac{2 \times 979\cdot584 \times 15427}{20{,}900{,}000} = -1\cdot446$

‡ Bouguer correction for mass $= +\dfrac{3}{4} \times \dfrac{\delta}{\Delta} \times \dfrac{2gh}{R}$

$$= +\frac{3}{4} \times \frac{2\cdot67}{5\cdot576} \times 1\cdot446 = +0\cdot519$$

In Prof. Borrass's Report the corrections for height and mass are given the values $1\cdot449$ and $0\cdot542$ respectively. The difference of $0\cdot003$ in the correction for height seems to be due to a difference in the adopted value of R, the mean radius of the earth. The difference in the Bouguer correction is due to difference in the adopted values of the surface and mean density, $2\cdot8$ and $5\cdot52$ having been employed instead of $2\cdot67$ and $5\cdot576$.

APPENDIX II.

List of Survey of India Publications

(Corrected up to 30th September 1917)

PUBLICATIONS

OF THE

SURVEY OF INDIA

SYNOPSIS

A—HISTORY AND GENERAL REPORTS.

(Obtainable from the Superintendent, Map Publication, 13, Wood Street, Calcutta).

MEMOIRS.

1. A Memoir on the Indian Surveys. *By C. R. Markham*. India Office, London, 1871. *Price Rs. 5 or 6s-8d.*
2. Ditto (second edition). *By C. R. Markham, C.B., F.R.S.*, India Office, London, 1878. *Price Rs. 5-8 or 7s-4d.*
3. Abstract of the Reports of the Surveys and of other Geographical Operations in India, 1869-78. *By C. R. Markham and C. E. D. Black*, India Office, London. Published annually between 1871 and 1879. (Out of print).
4. A Memoir on the Indian Surveys, 1875-1890. *By C.E.D. Black*, India Office, London 1891. *Price Rs. 5-8 or 7s-4d.*

ANNUAL REPORTS.

Reports of the **Revenue Branch** . 1851-1877.—(1851-67 and 1869-70, out of print). *Price Rs. 3 or 4s.*

Ditto **Topographical Branch** . 1860-1877.—(Out of print).

Ditto **Trigonometrical Branch** . 1861-1878.—(1861-71, out of print). *Price Rs. 2 or 2s-8d.*

In 1878 the three branches were amalgamated, and from that date onwards annual reports in single volumes for the whole department, are available as follows:—

General Reports { from 1877-1900 (1877-79, 1887-88, 1895-96 and 1897-98, out of print). *at Rs. 3 or 4s per volume.* from 1900-1917 (1902-04 and 1906-08, out of print) *at Rs. 2 or 2s-8d per volume.*

From 1900 onwards the Report has been issued annually in the form of a condensed statement known as the **"General Report"** supplemented by fuller reports, which were called **"Extracts from Narrative Reports"** up to 1909, and since then have been styled **"Records of the Survey of India."** These fuller reports are available as follows:—

(*a*) **"Extracts" Volumes** *at Rs. 1-8 or 2s per volume.*

1900-01—Recent Improvements in Photo-Zincography. G. T. Triangulation in Upper Burma. Latitude Operations. Experimental Base Measurement with Jäderin Apparatus. Magnetic Survey. Tidal and Levelling. Topography in Upper Burma. Calcutta, 1903. (Out of print).

1901-02—G. T. Triangulation in Upper Burma. Latitude Operations. Magnetic Survey. Tidal and Levelling. Topography in Upper Burma. Topography in Sind. Topography in the Punjab. Calcutta, 1904 (Out of print.)

1902-03—Principal Triangulation in Upper Burma. Topography in Upper Burma. Topography in Shan States. Survey of Sāmbhar Lake. Latitude Operations. Tidal and Levelling. Magnetic Survey. Introduction of the Contract System of Payment in Traverse Surveys. Traversing with the Subtense Bar. Compilation and Reproduction of Thāna Maps. Calcutta, 1905.

1903-04—Magnetic Survey. Pendulum. Tidal and Levelling. Astronomical Azimuths. Utilization of old Traverse Data for Modern Surveys in the United Provinces. Identification of Snow Peaks in Nepāl. Topographical Surveys in Sind. Notes on town and Municipal Surveys. Notes on Riverain Surveys in the Punjab. Calcutta, 1906.

1904-05—Magnetic Survey. Pendulum Operations. Tidal and Levelling. Triangulation in Baluchistān. Survey Operations with the Somaliland Field Force. Calcutta, 1907.

1905-06—Magnetic Survey. Pendulum Operations. Tidal and Levelling. Topography in Shan States. Calcutta, 1908.

1906-07—Magnetic Survey. Pendulum Operations. Tidal and Levelling. Triangulation in Baluchistān. Astronomical Latitudes. Topography in Shan States. Calcutta, 1909.

1907-08—Magnetic Survey. Tidal and Levelling. Astronomical Latitudes. Pendulum Operations. Topography in Shan States. Calcutta, 1910.

1908-09—Magnetic Survey. Tidal and Levelling. Pendulum Operations. Triangulation. Calcutta, 1911.

ANNUAL REPORTS—(*Continued*).

(*b*) **"Records of the Survey of India"** *at Rs. 4 or 5s.-4d per volume, except where otherwise stated.*

Vol. I—**1909-10**—Annual reports of parties and offices ... ... Calcutta, 1912.
II—**1910-11**—Annual reports of parties and offices ... ... Calcutta, 1912.
III—**1911-12**—Annual reports of parties and offices ... ... Calcutta, 1913.
IV—**1911-13**—*Explorations on the North-East Frontier* ... ... Calcutta, 1914.
V—**1912-13**—Annual reports of parties and offices ... ... Calcutta, 1914.
VI—**1912-13**—*Link connecting the Triangulations of India and Russia* Dehra Dūn, 1914.
VII—**1913-14**—Annual reports of parties and offices ... ... Calcutta, 1915.
VIII—{ **1865-79—Part I** / **1879-92—Part II** } *Explorations in Tibet and neighbouring regions* { Dehra Dūn, 1915. *Price of each Part Rs. 4 or 5s.-4d.*
IX—**1914-15**—Annual reports of parties and offices ... ... Calcutta, 1916.
X—**1915-16**—Annual reports of parties and offices ... Dehra Dūn, 1917.
XI—**1916-17**—Annual reports of parties and offices ... Dehra Dūn, 1918.

SPECIAL REPORTS.

1. *Report on the Mussoorie and Landour, Kumaun and Garhwāl, Ranikhet and Kosi Valley Surveys extended to Peshāwar and Khāgān Triangulation during 1869-70 *By Major T. G. Montgomerie, R.E.* (Out of print).

2. *Account of the Survey Operations in connection with the Mission to Yārkand and Kashghar in 1873-74. *By Captain Henry Trotter, R.E.* Calcutta, 1875.

3. Report on the Trans-Himālayan Explorations during 1869. (Out of print).

4. Report on the Trans-Himālayan Explorations during 1870. Dehra Dūn, 1871. (Out of print).

5. Report on the Trans-Himālayan Explorations during 1878. Calcutta, 1880. (Out of print).

"Notes of the Survey of India" are issued monthly. (Stocked in the Surveyor General's Office, Calcutta). *Price as. 2 or 2d.*

B—GEODETIC WORKS OF REFERENCE.

(Obtainable from the Superintendent of the Trigonometrical Survey, Dehra Dūn, U.P.)

EVEREST'S GREAT ARC BOOK.

1. An account of the Measurement of an Arc of the Meridian between the parallels of 18° 3′ and 24° 7′. *By Capt. George Everest.* East India Company, London, 1830. (Out of print.)

2. An account of the Measurement of two Sections of the Meridional Arc of India, bounded by the parallels of 18° 3′ 15″, 24° 7′ 11″, and 29° 30′ 48″. *By Lt.-Col. G. Everest, F. R. S.* East India Company, London, 1847. (Out of print.)

3. Engravings to illustrate the above. London, 1847. (Out of print.)

G.T.S. VOLUMES—describing the Operations of the Great Trigonometrical Survey.

Price Rs. 10-8 or 14s per volume, except where otherwise stated.

Vol. I—**Standards of Measure and Base-Lines,** also an Introductory Account of the early Operations of the Survey, during the period of 1800-1830.
Dehra Dūn, 1870. (Out of print.)

Appendix No. 1. Description of the method of comparing, and the apparatus employed.
Appendix No. 2. Comparisons of the Lengths of 10-feet Standards **A** and **B**, and determinations of the Difference of their Expansions.
Appendix No. 3. Comparisons between the 10-feet Standards **I**$_B$ **I**$_S$ and **A**.
Appendix No. 4. Comparisons of the 6-inch Brass Scales of the Compensated Microscopes.
Appendix No. 5. Determination of the Length of the Inch [7.8] on Cary's 3-foot Brass Scale.
Appendix No. 6. Comparisons between the 10-feet Standard Bars **I**$_S$ and **A** for determining the Expansion of bar **A**.
Appendix No. 7. Final determination of the Differences in Length between the 10-feet Standards **I**$_B$ **I**$_S$ and **A**.
Appendix No. 8. On the Thermometers employed with the Standards of Length.
Appendix No. 9. Determination of the Lengths of the Sub-divisions of the Inch [*a.b*].
Appendix No. 10. Report on the Practical Errors of the Measurement of the Cape Comorin Base.

II—**A History and General Description of the Reduction** of the Principal Triangulation. ... Dehra Dūn, 1879. (Out of print.)

Appendix No. 1. Investigations applying to the Indian Geodesy.
Appendix No. 2. The Micrometer Microscope Theodolites.
Appendix No. 3. On Observations of Terrestrial Refraction at certain stations situated on the plains of the Punjab.
Appendix No. 4. On the Periodic Errors of Graduated Circles, &c.
Appendix No. 5. On certain Modifications of Colonel Everest's System of Observing introduced to meet the specialities of particular instruments.
Appendix No. 6. On Tidal Observations at Kurrachee in 1855.
Appendix No. 7. An alternative Method of obtaining the Formulæ in Chapters VIII and XV employed in the Reduction of Triangulation.—Additional Formulæ and Demonstrations.

* For Departmental use only.

G.T.S. VOLUMES—(*Continued*).

Appendix No. 8. On the Dispersion of Circuit Errors of Triangulation after the Angles have been corrected for Figural conditions.

Appendix No. 9. Corrections to azimuthal Observations for imperfect Instrumental Adjustments.

Appendix No. 10. Reduction of the N.W. Quadrilateral—the Non-Circuit Triangles and their Final Figural Adjustments.

Appendix No. 11. The Theoretical Errors of the Triangulation of the North-West Quadrilateral.

Appendix No. 12. Simultaneous Reduction of the N.W. Quadrilateral—the Computations.

Vol. III—**North-West Quadrilateral.**—The Principal Triangulation, the Base-Line Figures, the Karāchi Longitudinal, N. W. Himālaya, and the Great Indus Series. ... ... Dehra Dūn, 1873. (Out of print.)

IV—**North-West Quadrilateral**—The Principal Triangulation, the Great Arc—Section 24°-30°, Rahūn, Gurhāgarh and Jogi-Tīla Meridional Series and the Sutlej Series. ... ... Dehra Dūn, 1876.

IVA—**North-West Quadrilateral**—The Principal Triangulation, the Jodhpore and the Eastern Sind Meridional Series with the details of their Reduction and the Final Results. ... ... Dehra Dūn, 1886.

V—**Pendulum Operations** of Captains J. P. Basevi and W. J. Heaviside, and their Reduction. Dehra Dūn and Calcutta, 1879.

Appendix No. 1. Account of the Remeasurement of the Length of Kater's Pendulum at the Ordnance Survey Office, Southampton.

Appendix No. 2. On the Relation between the Indian Pendulum Operations, and those which have been conducted elsewhere.

Appendix No. 3. On the Theory, Use and History of the Convertible Pendulum.

Appendix No. 4. On the Length of the Seconds Pendulum determinable from Materials now existing.

Appendix No. 5. A Bibliographical List of Works relating to Pendulum Operations in connection with the Problem of the Figure of the Earth.

VI—**South-East Quadrilateral**—The Principal Triangulation and Simultaneous Reduction of the following Series:—Great Arc—Section 18° to 24°, the East Coast, the Calcutta and the Bider Longitudinal, the Jabalpur and the Bilāspur Meridionals. ... ... Dehra Dūn, 1880. (Out of print.)

VII—**North-East Quadrilateral**—General Description and Simultaneous Reduction. Also details of the following five series:—North-East Longitudinal, the Budhon Meridional, the Rangir Meridional, the Amua Meridional, and the Karāra Meridional. ... ... Dehra Dūn, 1882.

Appendix No. 1. The Details of the Separate Reduction of the Budhon Meridional Series or Series J of the North-East Quadrilateral.

Appendix No. 2. Reduction of the North-East Quadrilateral. The Non-circuit Triangles and their Final Figural Adjustments.

Appendix No. 3. On the Theoretical Errors Generated Respectively in Side, Azimuth, Latitude and Longitude in a Chain of Triangles.

Appendix No. 4. On the Dispersion of the Residual Errors of a Simultaneous Reduction of Several Chains of Triangles.

VIII—**North-East Quadrilateral**—Details of the following eleven series:—Gurwāni Meridional, Gora Meridional, Hurilāong Meridional, Chendwār Meridional, North Pārasnāth Meridional, North Malūncha Meridional, Calcutta Meridional, East Calcutta Longitudinal, Brahmaputra Meridional, Eastern Frontier—Section 23°-26°, and Assam Longitudinal. ... Dehra Dūn, 1882.

IX—**Telegraphic Longitudes**—during the years 1875-77 and 1880-81. Dehra Dūn, 1883.

Appendix to Part I.
1. Determination of the Geodetic Elements of Longitude Stations.
2. Descriptions of Points used for Longitude Stations.
3. Comparison of Geodetic with Electro-Telegraphic Arcs of Longitude.
4. Circuit Errors of Observed Arcs of Longitude.
5. Results of Idiometer Observations made during Season 1880-81.

Appendix to Part II.
1. Situations of the Longitude Stations at Bombay, Aden and Suez.
2. Survey Operations at Aden.
3. Results of the Triangulation
4. Right Ascensions of Clock Stars.

X—**Telegraphic Longitudes**—during the years 1881-82, 1882-83, and 1883-84. Dehra Dūn, 1887.

Appendix to Part I.
1. Determination of the Geodetic Elements of the Longitude Stations.
2. Descriptions of Stations of the Connecting Triangulation and of those at which the Longitude Observations were taken.
3. On the Errors in ΔL caused by Armature-time and the Retardation of the Electric Current.
4. On the Rejection of some doubtful Arcs of Season 1881-82.
5. On the probable Causes of the Errors of Arc-measurements, and on the Nature of the Defects in the Transit Instruments which might produce them.

G.T.S. VOLUMES—(*Continued*).

Vol. XI—**Astronomical Latitudes**—during the period 1805-1885. Dehra Dūn, 1890.

XII—**Southern Trigon**—General Description and Simultaneous Reduction. Also details of the following two series:—Great Arc—Section 8°-18°, and Bombay Longitudinal. ... ... Dehra Dūn, 1890.

XIII—**Southern Trigon**—Details of the following five series:—South Konkan Coast, Mangalore Meridional, Madras Meridional and Coast, South-East Coast, and Madras Longitudinal. ... ... Dehra Dūn, 1890.

XIV—**South-West Quadrilateral**—Details of Principal Tringulation and Simultaneous Reduction of its component series. ... Dehra Dūn, 1890.

XV—**Telegraphic Longitudes**—from 1885 to 1892 and the Revised Results of Volumes IX and X: also the Simultaneous Reduction and Final Results of the whole Operations. ... ... Dehra Dūn, 1893.

Appendix No. 1. Determination of the Geodetic Elements of the Longitude Stations.

Appendix No. 2. On Retardation (a numerical mistake was made in this appendix in the conversion of a formula from kilometres to miles: the conclusions drawn cannot therefore be upheld).

XVI—**Tidal observations**—from 1873 to 1892, and the Methods of Reduction. Dehra Dūn, 1901.

XVII—**Telegraphic Longitudes**—during the years 1894-95-96. The Indo-European Arcs from Karāchi to Greenwich. .. ... Dehra Dūn, 1901

Appendix No. 1. Descriptions of Points used for Longitude Stations.

Appendix No. 2. The Longitude of Madras.

XVIII—**Astronomical Latitudes** from 1885 to 1905 and the Deduced Values of Plumb-line Deflections. ... ... Dehra Dūn, 1906.

Appendix No. 1. On Deflections of the Plumb-line in India.

Appendix No. 2. Determination of the Geodetic Elements of the Latitude Stations of Bajamara, Bahak, Lambatach and Kidarkanta.

Appendix No. 3. On the (N—S) Difference exhibited by Zenith Sector No. 1.

Appendix No. 4. On the Value of the Micrometer of the Zenith Telescope.

Appendix No. 5. On the Azimuth Observations of the Great Trigonometrical Survey of India.

Appendix No. 6. A Catalogue of the Publications of the Great Trigonometrical Survey of India.

Appendix No. 7. On the combination weights employed.

XIX—**Levelling of Precision in India** from 1858 to 1909. Dehra Dūn, 1910.

Appendix No. 1. Experiment to test the changes, due to Moisture and Temperature, in the Length of a Levelling Staff.

Appendix No. 2. On the erection of Standard Bench-Marks in India during the years 1904-1910.

Appendix No. 3. Memorandum on the steps taken in 1905-1910 to enable movements of the Earth's crust to be detected.

Appendix No. 4. Dynamic and Orthometric corrections to the Himālayan levelling lines and circuit; and a consideration of the order of magnitude of possible refraction errors.

Appendix No. 5. The passage of rivers by the Levelling Operations.

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„	38	32° – 36°	68° – 72°	„ 1912.	„	46	20° – 24°	72° – 76°	„ 1912.
„	39	28° – 32°	68° – 72°	„ 1913.		47	16° – 20°	72° – 76°	„ 1912.
„	„	Addendum		1916.	„	„*	Addendum		„ 1915.
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Eastern Ports—

Galle (Ceylon)—Trincomalee (Ceylon)—Colombo (Ceylon)—Negapatam—Madras—Cocanāda—Vizagapatam—False-Point—Dublat (Saugor Island)—Diamond Harbour—Kidderpore (Calcutta)—Chittagong—Akyab—Diamond Island (Burma)—Bassein—Elephant Point (Burma)—Rangoon—Amherst—Moulmein—Mergui—Port Blair.

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1.—Government of India Orders.—	690
2.—Circular Orders (Administrative).—	378
3.—Circular Orders (Professional).—	194
4.—Departmental Orders. (appointments, promotions, transfers, etc.)	

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   Ditto ditto 1904-1908.—Calcutta, 1909. (Out of print).
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3. * Regulations on the subject of Language Examinations for Officers of the Survey of India. Calcutta, 1914.

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5. Specimens of papers set at Examinations for the Provincial Service.—Dehra Dūn, 1903.—(Out of print).

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6. Catalogue of Scientific Books and Subjects in the Library of the Trigonometrical Survey Office. Dehra Dūn, 1908. *Price Re. 1 or 1s-4d.*
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(2) Levelling across the Ganges at Dāmukdia.
(3) Experiment to test the increase in the length of a Levelling Staff due to moisture and temperature.
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(5) Nickel-steel alloys and their application to Geodesy. (*Translated from the French.*)
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