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OF THE

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Volume XIII

(Supplementary to General Report 1917-18).

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PARTIES AND OFFICES

1917-18.

PREPARED UNDER THE DIRECTION OF

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Offg. Surveyor General of India.

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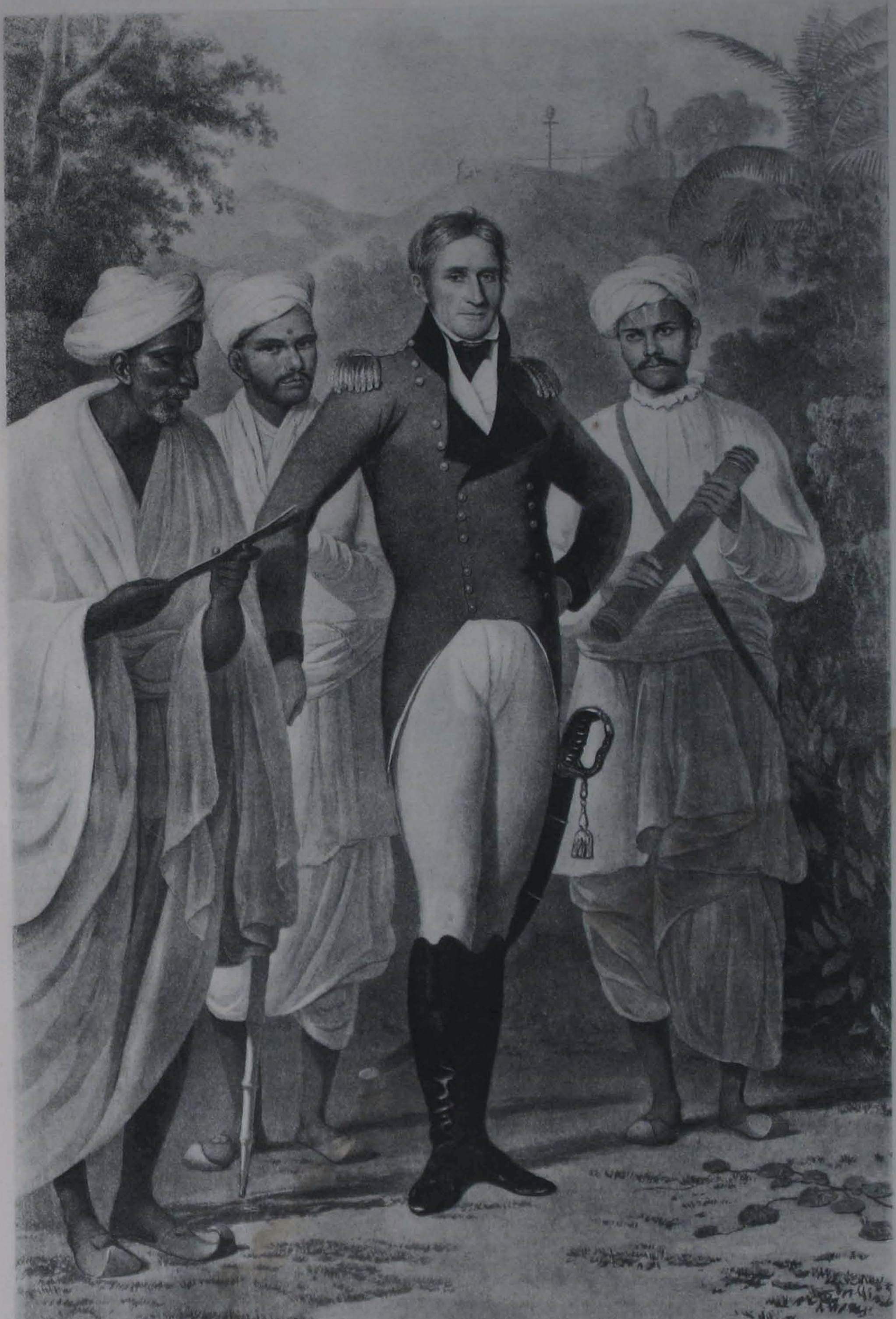
MAJOR GENERAL JOHN GARSTIN.

Surveyor General of India, 1808-1814.



Photogravure.

Survey of India Offices, Calcutta, 1918.

COLONEL COLIN MACKENZIE.

Surveyor General of India, 1816-21.

THE PORTRAIT PUBLISHED AS THAT OF COLONEL COLIN MACKENZIE IN RECORDS VOL. Nº IX WAS NOT AUTHENTIC.

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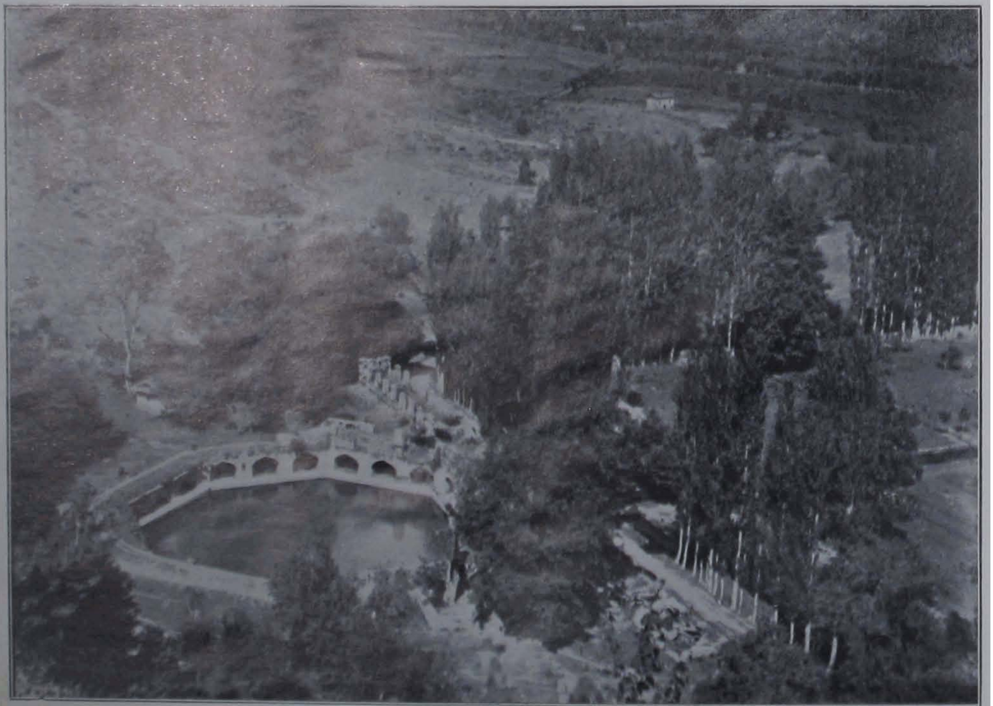
Type of 20 feet guyed signal used in observations by Sind Sāgar Party.

From a photograph by Mr. J. C. C. Lears.



Vernāg Spring with enclosure and garden, built by the Mogul Emperor Jahangir: Anantnāg Tahsil, Kashmir. This spring is the main source of the Jhelum River.

PART I.—TOPOGRAPHICAL SURVEY.

NORTHERN CIRCLE.

(*Vide* Index Maps 1 and 4.)

Summary.—The topographical work of the Circle was greatly retarded owing to depletion of strength due to the war, and to the following causes:—

(*a*) No. 4 Party was kept in abeyance as a topographical unit on the formation of the Sind-Sāgar Rectangulation Party as reported last year.

(*b*) The three topographical parties remaining had to carry out urgent survey on the three-inch scale of seven Artillery Practice Camps, which were in some cases very distant from current work.

(*c*) Nos. 2 and 3 Parties had to carry out a good deal of special Himālayan Forest Survey.

The detail survey consisted of:—

1286	square	miles	of	half-inch original survey.
7	,,	,,	,,	one-inch original survey.
1,207	,,	,,	,,	one-inch supplementary survey.
452	,,	,,	,,	one-inch revision survey.
459	,,	,,	,,	two-inch original survey.
524	,,	,,	,,	three-inch original survey.
122	,,	,,	,,	four-inch original survey.
144	,,	,,	,,	four-inch supplementary survey.

Besides this the Sind-Sāgar Party completed the triangulation of the Sind-Sāgar area preliminary to the demarcation of rectangles, and the Riverain Detachment continued its usual work for the Punjab Government.

During the recess season, 14 civilian pupils and 9 soldier surveyors joined the department and were given preliminary training by No. 1 Party.

The Circle was under the administrative control of Lieut.-Colonel C. L. Robertson, C.M.G., R.E., up to 15th March 1918, of Colonel C.H.D. Ryder, C.I.E., D.S.O., R.E., from 16th to 30th March 1918, of Colonel G.P. Lenox-Conyngham, R.E., F.R.S., from 31st March to 9th April 1918 and of Lieut.-Colonel H.L. Crosthwait, R.E., after that date.

No. 1 PARTY (PUNJAB AND NORTH-WEST FRONTIER PROVINCE).

BY CAPTAIN W.E. PERRY, M.C., R.E.

1. The field head-quarters of the party opened at Hoshiārpur on the 5th November 1917, and reopened on 15th May 1918 at its recess quarters in Mussoorie.

PERSONNEL.

Imperial Officer.

Major E.A. Tandy, R.E., in charge from 16th May 1918.

Provincial Officers.

Mr. B.R. Hughes, in charge from 1st October 1917 to 9th April 1918.
,, G.J.S. Rae.
,, H.P.D. Morton to 4th July 1918 and in charge from 10th April to 15th May 1918.
,, P.A.T. Kenny.
,, R.C. Hanson.
,, G.A. Norman.

Upper Subordinate Service.

Mr. Sher Jang, K.B. (on leave).
,, Jagdeesh Prasad Vastav.
,, Afraz Gul Khan (Probationer).

Lower Subordinate Service.

35 Surveyors, etc.

The country surveyed during the winter consisted of low intricate siwāliks as well as higher wooded hills, and low cultivated valleys and plains intersected by numerous watercourses.

The health of the party was good.

2. *Plane-tabling.*—The 1561 square miles of country surveyed on the scale of one inch to a mile, comprised 7 square miles of original survey in Chamba State, 347 square miles of revision survey in Hoshiārpur and Jullundur districts, and 1,207 square miles of supplementary survey in Hoshiārpur and Kāngra districts and the Simla Hill States, and lay in the following sheets:—

$43 \frac{P}{15(\text{part})}$ and $53 \frac{A}{1, 2, 3, 4, 6, 7}$.

The part of sheet $43 \frac{P}{15}$ was isolated from the main programme, and comprised an area of 7 square miles of original survey in Chamba State, and 29 square miles of supplementary survey in Kāngra district. The survey was particularly required in order to complete this sheet to margin and enable it to be drawn as a full sheet, the rest of it having been surveyed in 1916-17. This survey necessitated special arrangements being made, and as the area was very small, the cost-rates are considerably higher than usual; this work has been shown separately in the tables etc., accompanying this report. Sheets 53 $\frac{A}{6 \text{ and } 7}$ were shown as surveyed in modern style in previous Indexes, but actually they had only been drawn in new style from previous surveys, and have now been revised.

In addition to survey work on the scale of one inch to a mile, an area of 306·5 square miles was surveyed on the scale of three inches to one mile for Artillery Practice Camps. Four of these Artillery Practice Camps were surveyed. (1) An area of 102·7 square miles at Akora in the Peshāwar district of the North-West Frontier Province; (2) an area of 61·4 square miles in the Hoshiārpur district of the Punjab; (3) and (4) an area of 142·4 square miles in the Quetta-Pishīn district of Baluchistān for the contiguous Artillery Practice Camps of Yāru and Bostān.

In the Akora area the country consisted of open cultivated plains and low hills of an intricate nature intersected by numerous streams. The Hoshiārpur country has been described in para one. The Yāru-Bostān area comprised intricate broken hills and plains intersected by numerous dry watercourses, and very sparsely cultivated; the ground varied from 4,900 to over 11,000 feet in height. The water in this area was bad, and there was much fever and dysentery, and one death, amongst the section under Mr. P. A. T. Kenny who did the survey, which moreover was carried out in very hot weather between June and September.

The distribution of the party for carrying out the above programme was as follows. A section of 12 surveyors under Mr. H. P. D. Morton was employed from October to November on the Akora three-inch Artillery Practice Camp work. This section then proceeded to Hoshiārpur. In the meantime, a section of 12 surveyors under Mr. R. C. Hanson had started on sheets 53 $\frac{A}{1, 2, 3, 4}$. Mr. B. R. Hughes, (then officer in charge), started the three-inch Hoshiārpur Artillery Practice Camp work with Mr. G. A. Norman and 3 surveyors. On the arrival of Mr. Morton's section, 18 surveyors were divided into :—

No. 1 Camp.—Mr. Morton sheets 53 $\frac{A}{1, 2, 6}$.

No. 2 Camp.—Mr. Hanson sheets 53 $\frac{A}{3, 4, 7}$.

When Mr. Hughes was transferred, Mr. Morton took over the Hoshiārpur Artillery Practice Camp work. Mr. Vastav surveyed the outlying portion of sheet 43 $\frac{P}{15}$.

Mr. Kenny in June 1918 with a section consisting of Mr. Norman, Mr. Afraz Gul Khan, and 13 surveyors (including 7 pupil soldier-surveyors), undertook the Quetta-Pishīn work already mentioned.

The cost-rates of the different classes of survey were :—

One-inch original	Rs.	88·7
Do. supplementary (Kāngra)	„	14·5
Do. supplementary (ordinary)	„	20·9
Do. revision	„	9·5
Three-inch Akora Artillery Practice Camp	„	87·0
Do. Hoshiārpur do.	„	93·8
Do. Yāru and Bostān do.	„	123·8

The higher rate of the last named is due to the fact that seven soldier surveyor pupils, who joined the party in July 1918 for their first period of extra training, were put on to this work, and being beginners their out-turn was small; also considerable sums had to be paid for local escorts. The high cost-rate of the one-inch original survey has already been explained.

3. *Triangulation.*—No triangulation in advance has been done during the year under report for the ordinary programme of the party.

4. *Traversing.*— No traversing in advance was done during the year under report for the ordinary programme of the party, but a supplementary traverse of 23·6 miles was run by Mr. Morton for the Artillery Practice Camp survey at Hoshiārpur, to furnish intersected points and heights to trijunction pillars. The cost-rate was Rs. 19·8 per linear mile.

5. *Recess Duties.*— During the field season Messrs. Rae (on leave from November to January) and Kenny were employed at recess headquarters with a section of 16 draftsmen and surveyors on fair-mapping.

Distribution at first:—

Mr. Kenny and 16 men,

Four-inch Peshāwar military survey.

Three-inch Akora Artillery Practice Camp.

One-and-half-inch mapping, sheets 43 $\frac{P}{3,4,6,7,8,11,12}$.

Then from March:—

(*a*) Mr. Rae and 7 men,

One-and-half-inch fair-mapping, sheets 43 $\frac{P}{3,4,5,6,7,8,9,10,11,12,13,14}$.

(*b*) Mr. Kenny and 9 men,

Four-inch Peshāwar military survey.

Three-inch Akora Artillery Practice Camp.

Three-inch Hoshiārpur Artillery Practice Camp.

During recess the duties were allotted as follows:—

(*a*) Mr. Rae with a section of 13 men,

One-and-half-inch mapping, sheets 43 $\frac{P}{3,5,6,7,11,12,15}$.

Three-inch Hoshiārpur Artillery Practice Camp.

(*b*) Mr. Hanson with a section of 13 men,

One-and-half-inch mapping, sheets 43 $\frac{O}{8,12,16}$, $\frac{P}{9,10,13,14}$.

Mr. Morton was in charge of a Training section of 14 civilian pupil surveyors and 2 pupil soldier-surveyors who joined in June and July.

Mr. Vastav took over the training of the above pupil surveyors in July 1918, and also of 7 other pupil soldier-surveyors on their return from Quetta in the middle of September 1918.

The total out-turn of fair-mapping during the year was:—

(*a*) One-inch mapping	... ...	2359·8 square miles.
(*b*) Three-inch mapping,—		
(i) Akora Artillery Practice Camp	...	102·7 square miles.
(ii) Hoshiārpur Artillery Practice Camp	...	61·4 square miles.
(*c*) Four-inch mapping,—		
Peshāwar military survey left over from 1916-17		171·5 square miles.

Cost-rates were as follows:—

One-inch mapping	Rs. 10·8.
Three-inch mapping Akora Artillery Practice Camp ...	Rs. 23·3.
Three-inch mapping Hoshiārpur Artillery Practice Camp ...	Rs. 33·1.
Four-inch mapping Peshāwar military survey ...	Rs. 17·9.

The following sheets were submitted for publication during the year:—

One-inch sheet 43 $\frac{P}{3,4,8,12}$.

Three-inch ... Akora and Hoshiārpur Artillery Practice Camps.

Four-inch ... Peshāwar military survey.

The following still remain to be submitted:—

One-inch sheets 43 $\frac{O}{8,12,16}$ (in hand),

43 $\frac{P}{5,6,7,9,10,11,13,14,15}$ (in hand),

53 $\frac{A}{1,2,3,4,6,7}$.

The Yāru and Bostān surveys were only completed at the end of September 1918, and plane-tables have not been received from the field.

6. *Inspections.*—The Surveyor General inspected the party in recess in September 1918.

No. 2 PARTY (RĀJPUTANA, UNITED PROVINCES AND DELHI PROVINCE).

BY LT.-COLONEL E. A. TANDY, R. E. (Information supplied by Mr. H. P. D. Morton).

PERSONNEL.

Provincial Officers.

Mr. T. W. Babonau in charge to 4th July 1918.
" H. P. D. Morton in charge from 5th July 1918.
" R. E. Saubolle.
" J. H. Johnson.
" J. A. Calvert.
" Duni Chand Puri.

Upper Subordinate Service.

Mr. Ghulam Hasan.
" Daulat Ram Vohra.

Lower Subordinate Service

21 Surveyors etc., in the field.
11 Draftsmen employed on fair-mapping during the field season.
21 Surveyors etc., on an average, in Recess, excluding absentees

The *field programme* was as follows :—

(*a*) Continuation of the topographical programme on the half-inch scale in the Rājputāna States of Jaipur and Alwar.

(*b*) Survey on the three-inch scale of two Artillery Practice Camps, one at Roorkee, and one at Tughlakābād about 14 miles south of Delhi.

(*c*) Supplementary Survey on the 4-inch scale of the leased Forests of Tehrī-Garhwāl.

(*d*) Triangulation and boundary traverses in the Jaunsār-Bāwar Forests of the Chakrātā Forest Division.

(*e*) Traverse of 20 linear miles of the Chakrātā Cantonment boundary.

Distribution.—Mr. Calvert was in charge of items (*a*) and (*b*) above, having a camp averaging 5 surveyors on the half-inch topography, and another of similar size for the two Artillery Practice Camps; besides which he himself had to carry out the supplementary triangulation and traverse required for Roorkee.

Mr. Johnson was in charge of the three remaining items, having 2 surveyors on the forest survey in Tehrī-Garhwāl, and an average of 5 traversers on the Jaunsār-Bāwar forest boundaries; while Mr. Ghulam Hasan carried out the Jaunsār-Bāwar triangulation and the Chakrātā boundary traverse under his direction.

Besides the above a drawing section was maintained throughout the year at Mussoorie, in charge of Messrs. Saubolle and Duni Chand Puri, to deal with the arrears of mapping, which included 5 sheets taken over from No. 4 Party.

Field Season.—Field headquarters opened at Delhi on the 30th October 1917, and closed at the end of April 1918; but the forest surveys in the hills were carried on till the end of June. The health of the party was satisfactory.

Half-inch Topography.—The detail survey was based on the triangulation and traverses executed during the previous season, and consisted in the completion of sheets $54 \frac{A}{2,5,6}$ and the whole of sheets $54 \frac{A}{3,4,8}$. The country was intricate, consisting of narrow cultivated plains separated by small rocky ranges rising abruptly about 1,000 feet above the plains and mostly covered with dense brush-wood and stunted trees. Though good fixings were obtainable, they were difficult of access, and the out-turn was not large, amounting to 1,286 square miles, at a cost-rate of Rs. 9·8 per square mile.

The Artillery Practice Camps consisted mostly of flat or undulating cultivation, that at Roorkee being intersected by streams from the Siwāliks, and that at Tughlakābād by low outcrops of bare rock. The areas were 133 and 54 square miles respectively.

The Roorkee survey was based on old district traverses of 1877-78, supplemented by 40 square miles of triangulation and 54 linear miles of traverse, the cost-rates of which were Rs. 53·5 per square mile and Rs. 13·7 per linear mile respectively.

The triangulation and traverse heights were based on a G. T. Bench-Mark; the triangulation was based on a measured base-line and closed by traverse on to old triangulation.

The Tughlakābād survey was based on triangulation executed by No. 3 Party in 1910-11.

The average cost-rate for these two surveys on the 3-inch scale was Rs. 50·5 per square mile, excluding the cost of the supplementary triangulation and traverse work at Roorkee mentioned above.

Leased Forests of Tehrī-Garhwāl.—The following old four-inch sheets of these forests were brought up-to-date in respect of roads, chaks, etc., and in some cases re-contoured, for the Forest Department :—

Sheets 222 $\frac{\text{S.E.}}{2,3,4}$ and $\frac{\text{N.E.}}{4}$; 223 $\frac{\text{N.E.}}{2}$; 226 $\frac{\text{N.W.}}{3,4}$, $\frac{\text{S.W.}}{1,2,3,4}$ and $\frac{\text{S.E.}}{1}$; 227 $\frac{\text{N.W.}}{1,2,3}$.

The country consisted of forest-covered Himalayan foot-hills reaching to altitudes of from 5,000 to 10,000 feet. The area was 144 square miles and the cost-rate Rs. 28·3 per square mile.

Triangulation and Traverse of Jaunsār-Bāwar Forests.—The existing triangulation covering the old Jaunsār-Bāwar two-inch sheets 1 and 2 was supplemented to give further points for the proposed 4-inch survey, and closing points for the boundary traverses. This supplementary triangulation covered 156 square miles, and the cost-rate, including that of computation, was Rs. 49·8 per square mile.

The traversing was carried along 175 miles of the boundaries of the Deogarh, Bāwar, and Deoban Ranges of the Chakrātā Forest Division, and was in every way unfortunate. In the first place the work was much hampered by difficulties of transport and supplies, and by the attempt to carry it through in the same season as the triangulation on which it had to be closed, and without having the boundary lines first cleared by the Forest Department.

Apart from these natural difficulties, traversing in such steep and thickly-wooded hills requires expert traversers and chainmen; and owing to the depleted state of the Department neither of these were obtainable. The chainmen were untrained coolies, and the traversers inferior workmen with no previous hill experience.

As a result much revision was necessary, sometimes more than once, and traversers went sick out of fear of the hills, and others procured in their place were little better. So that with an average of 5 traversers only 175 linear miles of traverse was done, at an average cost, including computation, of Rs. 98·1 per linear mile.

As we have no prospect of getting better traversers in the near future, and as bearings and distances of boundaries are not very useful in this sort of country, we have advised the Forest Department to dispense with further traverse work on these boundaries. The remainder will therefore be determined by plane-table, in conjunction with the 4-inch survey now to be commenced by No. 3 Party, to whom this work is being transferred.

The Chakrātā Cantonment Boundary traverse was carried out at the request of the Cantonment Magistrate, Chakrātā, with a view to amending the boundary Notification and laying down intermediate pillars. The 20 linear miles included 296 theodolite stations, and the cost-rate was Rs. 49·6 per linear mile.

Recess Duties.—(*a*) The arrears of fair-mapping, which were dealt with by the drawing section left in Mussoorie during the field season, and in conjunction with current work during the recess, were as follows:—

Four four-inch sheets of Delhi and vicinity.
Five one-inch sheets in 53 D and 54 A.
Two half-inch sheets in 54 A.
Five one-inch sheets in 63 M and N (from No. 4 Party).

The following sheets were completed and submitted for publication during the year:

(i) Four four-inch sheets of Delhi and vicinity.
(ii) Five three-inch sheets of Roorkee and Tughlakābād.
(iii) Six one-inch sheets, 54 $\frac{A}{1}$ and 63 $\frac{M}{4}$, $\frac{N}{1,2,5,6}$.
(iv) Four half-inch sheets.
(v) Four one-inch sheets were also completed and nearly ready for submission by the end of September, thus bringing the fair-mapping of the party nearly up-to-date.

(*b*) Other recess duties included the computation of the supplementary triangulation and boundary traverses of the Jaunsār-Bāwar forests.

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

No. 3 PARTY (UNITED PROVINCES).

BY H. H. B. HANBY.

The party in reduced strength arrived in Bareilly, which was again the field head-quarters, on 1st November 1917 and returned to Mussoorie towards the end of May 1918. One small section was left in Mussoorie during the winter to carry on the arrears of mapping.

PERSONNEL.

Provincial Officers.

Mr. H. H. B. Hanby in charge.
" E. J. Biggie to 5th May.
" A. M. Talati.
" G. E. R. Cooper.
" Moqimuddin.

Upper Subordinate Service.

Mr. Muhammad Husain.
" A. A. S. Matlub Ahmad.

Lower Subordinate Service.

44 Surveyors, &c.

The major portion of the party's programme lay in the hill-tracts of Kumaun, but parts of the Mirzāpur district and Nepāl State also came under operations.

The nature of the country was generally hilly and densely wooded.

Topography.—The programme of work comprised :—

(i) Revision survey on the 1-inch scale in sheet $53\frac{O}{2\ (part)}$.

(ii) Survey on scale 4-inches = 1 mile in sheets $53\frac{O}{11\ (part),\ 12\ (part),\ 15\ (part),\ 16\ (part)}$.

(iii) Survey on the scale 2-inches = 1 mile in sheets $53\frac{O}{1,2\ (part),\ 5,6\ (part),\ 9,10\ (part)}$.

(iv) Survey on the scale 3-inches = 1 mile in sheets $63\frac{K}{12\ (part)}$, $63\frac{L}{9\ (part)}$ of the Kutwa Artillery Practice Camp.

It was first decided that a contour interval of 50 feet would satisfy military requirements in the area that was to be surveyed on the scale of 3-inches to a mile, but on completion of the work fresh orders were issued and a vertical interval of 25 feet was decided upon. This change involved the loss of a month. Then the health of the party was not very good, and owing to sickness among the surveyors, no work in sheets $53\frac{O}{5,\ 9,\ 10}$ could be taken up.

The work was distributed among four camps under Messrs. E. J. Biggie, A. M. Talati, Moqimuddin and surveyor Jit Singh.

In the month of May 1918, Mr. E. J. Biggie was transferred to the Eastern Circle, and Mr. Moqimuddin took charge of his camp in addition to his own.

The party's out-turn on all scales was 717 square miles.

(a)	Revision survey on 1-inch scale	105	" "
(b)	Survey on 2-inch scale ...	459	" "
(c)	Survey on 3-inch scale ...	31	" "
(d)	Survey on 4-inch scale ...	122	" "

The cost-rate of (a) was Rs. 22·1 per square mile.
" " " (b) " Rs. 65·4 " " "
" " " (c) " Rs. 58·6 " " "
" " " (d) " Rs. 58·5 " " "

Triangulation.—The total area triangulated during the year under report amounted to 1,122 square miles. Of this, 30 square miles were executed for the 3-inch survey in district Mirzāpur, in sheets $63\frac{K}{12\ (part)}$ and $63\frac{L}{9\ (part)}$, the remainder, 1,092 square miles in sheets $53\frac{O}{12\ (part),\ 15\ (part),\ 16\ (part)}$, $62\frac{C}{2,\ 3,\ 4\ (part),\ 6\ (part),\ 7\ (part),\ 8\ (part)}$ was of a supplementary nature for 2-inch and 1-inch surveys in future years.

The whole area of 1,122 square miles was triangulated by computer Bal Krishna.

The cost-rate of triangulation for 3-inch survey was Rs. 5·2 per square mile.

The computation of triangulation for 2-inch and 1-inch work has not been completed.

Traversing—Under this head 315 linear miles were executed in all, 25 linear miles being for 4-inch special forest survey, and 290 linear miles for future surveys on scale 1-inch = 1 mile.

The cost-rates of traversing
for 1-inch survey was Rs. 18·7 per linear mile.
" 4-inch " " Rs. 59·1 " " "

Recess Duties.—(*a*) The fair-mapping was divided into two sections under Messrs. G. E. R. Cooper and Moqimuddin.

Mr. Cooper, assisted by Mr. Muhammad Husain, Sub-Assistant Superintendent, supervised the mapping of last and previous year's arrears, which included four half-inch sheets, 8 two-inch sheets, $53\frac{K}{5}$ N & S, $53\frac{K}{9}$ N & S, $53\frac{K}{13}$ N & S, and $53\frac{K}{14}$ N & S, and five one-inch sheets $53\frac{K}{10}$, $53\frac{O}{3,4,7,8}$. Mr. Moqimuddin supervised the fair-mapping of sheets $53\frac{O}{1}$ N & S, $53\frac{O}{2}$ N & S, and the 3-inch map of the "Kutwa" Artillery Practice Camp. Of the two-inch sheets, $53\frac{K}{6}$ N & S have now to be completed to margin, $53\frac{K}{14}$ N has to be redrawn to admit of reduction to half scale, and $53\frac{K}{14}$ S, which was originally drawn as an outrigger to $53\frac{K}{14}$ N, has to be prepared as a separate sheet and completed to margin. $53\frac{K}{14}$ N was formerly mapped for reproduction only. The object with which the aforementioned sheets are being completed to margin is to meet the requirements of the Forest Department.

The fair-mapping of sheet $53\frac{K}{5}$ on the 1½-inch scale was abandoned. When sheets $53\frac{K}{6}$ N & S have been completed, a one-inch edition can be prepared from reductions of these two sheets.

None of the sheets surveyed during the year under report have as yet been completed for publication. The following sheets however will be submitted for publication during the next two months:—

$53\frac{O}{3,4,7,8}$, and the "Kutwa" Artillery Practice Camp map.

For want of men no progress could again be made on sheets $53\frac{K}{N.W}$ and $\frac{K}{N.E}$.

(*b*) The computations of the following areas were completed:—

(i) 1,043 square miles of triangulation for 2-inch survey, intersected points (arrears).
(ii) 290 linear miles of traversing for 1-inch survey.
(iii) 25 ,, ,, ,, ,, ,, 4-inch survey.

No triangulation charts have been drawn, and the computation of 1,092 square miles triangulated during the year under report has still to be undertaken.

Miscellaneous.—Two draftsmen received training in hill surveying.

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

SIND-SĀGAR PARTY (PUNJAB).

By Dhani Ram Verma.

PERSONNEL.

Imperial Officer.

Lieut.-Colonel H. L. Crosthwait, R. E., in charge to 21st April 1918.

Provincial Officers.

Mr. Dhani Ram Verma, attached from 21st October 1917 and in charge from 22nd April 1918.
,, J. C. C. Lears.
,, F. J. Grice.

Upper Subordinate Service.

Mr. Chuni Lal Kapur.
,, Muhammad Husain Khan.
,, Nabidad Khan.

Lower Subordinate Service.

26 Surveyors, etc.

The programme of the party consisted in the execution of network triangulation as a preliminary to the rectangular survey for the purposes of canal alignment, colonization, and the preparation of a record of rights, in the area situated between the Indus and Jhelum, and Chenāb rivers, commonly known as the Sind-Sāgar Doāb, lying within the limits of Miānwāli, Shāhpur, Jhang and Muzaffargarh districts in the Punjab.

The triangulation was undertaken at the request of the Punjab Government in connection with the Sind-Sāgar Doāb canal and colonization project, for laying out on the ground temporary marks to be eventually used in the location of the true corners of 4,000-acre rectangles, of dimensions 15,840 feet north and south by 1,1000 feet east and west, to be finally subdemarcated into 100-acre rectangles of dimensions 1,980 feet north and south by 2,200 feet east and west.

The general nature of the country is that of a vast rolling desert of sand dotted over with sand hillocks. A large portion is treeless but parts are wooded, trees generally confining themselves to the strips of land between the hillocks.

The recess office of the party closed at Mussoorie on the 12th October 1917, and the field head-quarters opened at Miānwāli on the 29th October 1917. The office at Miānwāli was closed on the 8th April 1918, and the recess office was opened in Mussoorie on the 18th

April 1918. The section under Mr. F. J. Grice continued field operations till 20th April, and returned to Mussoorie at the end of the month.

The health of the party during the field season was satisfactory.

Triangulation.—The area for triangulation embraced the following sheets:— 38 $\frac{\text{P}}{\text{4, 7, 8 \& 11 (parts), 13, 15 (part), and 16}}$; 39 $\frac{\text{I}}{\text{15 \& 16 (parts)}}$; 39 $\frac{\text{J}}{\text{13 \& 14 (parts)}}$; 39 $\frac{\text{M}}{\text{1, 2 \& 3 (parts), 4, 5 to 15 and 16 (part)}}$; 39 $\frac{\text{N}}{\text{1, 2, 3 \& 4 (parts) 5, 6 \& 7, 8, 10 \& 11 (parts)}}$; 43 $\frac{\text{D}}{\text{3, 4, 7 \& 8 (parts)}}$ and 44 $\frac{\text{A}}{\text{1 to 4 (parts)}}$.

The party was divided into three triangulation camps under Messrs. Dhani Ram Verma, J. C. C. Lears and F. J. Grice.

No. 1 Camp.—Under Mr. Dhani Ram Verma, assisted by Mr. Chuni Lal Kapur, with 8 surveyors, triangulated an area of 2,552 square miles in sheets Nos. 38 $\frac{\text{P}}{\text{15 (part), \& 16}}$; 39 $\frac{\text{M}}{\text{13 to 15, \& 16 (part)}}$; 39 $\frac{\text{N}}{\text{9 \& 13 (parts)}}$; 43 $\frac{\text{D}}{\text{3, 4, 7 \& 8 (parts)}}$; and 44 $\frac{\text{A}}{\text{1 to 4 (parts)}}$.

No. 2 Camp.—Under Mr. J. C. C. Lears, assisted by Mr. Muhammad Husain Khan, with 8 surveyors, triangulated an area of 1,650 square miles in sheets Nos. 38 $\frac{\text{P}}{\text{4,7,8 \& 11(parts), \& 12}}$; 39 $\frac{\text{M}}{\text{1 \& 2 (parts), 5 \& 9}}$.

No. 3 Camp.—Under Mr. F. J. Grice, assisted by Mr. Nabidad Khan, with 7 surveyors, triangulated an area of 3,228 square miles in sheets Nos. 39 $\frac{\text{I}}{\text{15 (part)}}$; 39 $\frac{\text{M}}{\text{3 \& 4 (parts), 6 to 8, and 10 to 12}}$; & 39 $\frac{\text{N}}{\text{1 to 4 (parts), 5, 6, 7, 8, 10 \& 11 (parts)}}$.

In the earlier part of the field season, Mr. Muhammad Husain Khan was employed in distributing stakes to centres throughout the area, and rejoined No. 2 Camp in the middle of December 1917 on the termination of this duty. Surveyor Hazara Singh was lent to No. 15 Party (Triangulation) to assist in building stations and rejoined No. 1 Camp at the beginning of January 1918. Surveyor Abuzar Khan was employed in recruiting khalasis for the party and rejoined No. 3 Camp at the end of November 1917.

The country triangulated is locally known as "Thal" (sandy desert). The entire tract is sandy, studded with hillocks ("tibbas") assuming generally a north-east and south-west direction, and alternating with narrow strips of land called "Luks" or "pattis". The eastern portion of the "Thal" which is designated as "high Thal" or "grazing Thal" is distinguishable from the western portion called the "agricultural Thal", by the unculturable and more or less bare sand hills which are higher and more numerous. The country is sparsely inhabited, the population is mostly rural and pastoral. The northern part of the "Thal" is extensively cultivated and the southern part has scattered cultivation on wells in the "pattis".

On the formation of the party, surveyors were given a preliminary training in reconnaissance and observation in recess, but it was found necessary to supplement this instruction by a practical training in the field when the party reached its field headquarters. This supplementary training was given over the open ground east of Kundiān railway station for about 20 days. In some cases backward men were placed with others for extra further training when actual field work was in progress.

The object of the triangulation carried out during the season was to fix stations and intersected points as near as possible to the actual corners of 4,000-acre rectangles. To locate such stations and points on the ground the one-inch maps which were available for almost the whole ground were utilised as field charts. The values of the graticule corners of the sheets were computed as rectangular coordinates from the origin which had been chosen for the survey *i.e.* the intersection of the meridian of 71° 30′ with the parallel of 31° 30′ (this point falls near the centre of the figure of the area comprised in the scheme), and were plotted on the one-inch maps and the rectangles ruled up in red. The stations of every fourth series of rectangles running east and west were made stations of observation, the stations of the intermediate series being intersected from three stations of observation. The east and west series were joined at intervals of about 20 miles by a north and south chain, the whole being tied to a continuous series skirting the outer limits of the area. All the series arranged consisted of quadrilateral figures. With the rectangles marked on his one-inch maps the surveyor carried out his reconnaissance, which consisted in locating on the ground by interpolation, with the aid of such detail as was available, a position for his station or intersected point as near as possible to the actual corner of the rectangle plotted on his one-inch sheet. Having reconnoitred and fixed at least 8 stations in this way, he proceeded to observe the network thus formed, using the signals and stakes described below. The inexperience of the staff in work of this kind, and the hazy atmosphere in November necessitated the reduction of the size of the series to 2000-acre rectangles. As the men became familiar with the work, and as the atmosphere and the nature of the country permitted, large series were resumed. But the ground in the north-western portion of the tract was not favourable for large series at all on account of the jungle on the hills.

Stations and intersected points were marked by creosoted stakes, 30 inches long and 3 inches square in section and pointed at one end, which were driven into the ground, 9 inches being exposed. With a view to the recovery of the stakes in the case of their being obscured by drift of sand, and as a precaution against damage to or removal of stakes, clods of earth were piled around them and tripods made of stout branches of trees were erected over them and firmly fixed into the ground. All stakes were placed in the custody of the lambardars of villages, receipts being taken for the number made over to them.

The signals used were 20 and 30 feet high, made up of "chir" wood poles 10 feet long with single or double socket joints according to the height of signal, surmounted by a strong white cloth top and plumbed by means of 4 guy ropes fixed to the lower ring of the hoop. From experience it was found that the ropes soon became loose and the pole knocked out of the vertical. This was due to the fact that the pegs of the guy ropes could not hold in the sand to ensure stability. The 30 feet or double jointed signal was useful to overcome obstacles on the ray such as trees or hamlets. The double joint had a tendency to weaken the pole, which could not always sustain the strain imposed on it; when erecting the signal broke easily. The great disadvantage of this signal was that it never kept vertical, it oscillated in the air, and consequently steady intersection of the signal could not be made in the telescope.

Reconnaissance was carried out without much line-clearing except in the very densely wooded portions of the country such as that around Khushāb. It was invariably possible to locate stations on the tops of sand dunes as the hill tops were generally bare. Work progressed under exceptional weather conditions, more rain fell during the winter than has hitherto been recorded for that period of the year, but notwithstanding this in the afternoon the atmosphere was hazy enough to prevent opaque signals being used at a greater distance than 3½ miles. On account of the hot vapours arising from the desert, the signals became so magnified that reliable intersection could not be obtained. All these atmospheric conditions necessitated the observations for base connections with secondary series having rays about 7 miles long to be taken early in the morning or late in the evening.

The triangulation was connected with secondary series executed by No. 15 Party (Triangulation) at frequent intervals, to obtain values for sides and bearings and for checking and distributing errors, altogether 67 bases were connected and 87 stations for coordinate values. The connections were made by officers with 6-inch transit theodolites (3-vernier) reading to 10 seconds.

The surveyors used 5-inch and 6-inch vernier theodolites, reading to 30 seconds and 20 seconds respectively, for observing horizontal angles; no vertical angles were observed as the party was not concerned with the determination of altitudes.

The thickly wooded area of about 378 square miles in sheets $39\ \frac{I}{16\ \text{(part)}}$, $39\ \frac{J}{13\ \&\ 14\ \text{(parts)}}$, $39\ \frac{M}{4}$ and $39\ \frac{N}{1\ \text{to}\ 3}$, in which triangulation was impracticable was left over for traversing next field season. With this exception the programme laid down for the field season was completed. The total out-turn of triangulation was 7,430 square miles, the average monthly out-turn per man was 80·2 square miles. The total number of points trigonometrically fixed was 1888.

The average cost-rate of triangulation including computation was Rs. 15/- per square mile, or 4·5 pies per acre.

Recess Duties.—The computation of the triangulation completed was distributed as follows:—

No. 1 Section.—Under Mr. J. C. C. Lears, sheets $38\ \frac{P}{4,\ 7,\ 8\ \&\ 11\ \text{(parts)}\ \&\ 12}$; and $39\ \frac{M}{1\ \&\ 2\ \text{(parts)},\ 5\ \&\ 9}$.

No. 2 Section.—Under Mr. F. J. Grice, sheets $39\ \frac{I}{15\ \text{(part)}}$; $39\ \frac{M}{3\ \&\ 4\ \text{(parts)},\ 6\ \text{to}\ 8\ \&\ 10\ \text{to}\ 12}$; and $39\ \frac{N}{1\ \text{to}\ 4\ \text{(parts)},\ 5,\ 6,\ 7,\ 8,\ 10\ \&\ 11\ \text{(parts)}}$.

No. 3 Section.—Under Mr. Chuni Lal Kapur, sheets $38\ \frac{P}{15\ \text{(part)}\ \&\ 16}$; $39\ \frac{M}{13\ \text{to}\ 15\ \&\ 16\ \text{(part)}}$; $39\ \frac{N}{9\ \&\ 13\ \text{(parts)}}$; $43\ \frac{D}{3,\ 4,\ 7\ \&\ 8\ \text{(parts)}}$; and $44\ \frac{A}{1\ \text{to}\ 4\ \text{(parts)}}$.

All the computations of the triangulation done during the field season were completed by three sections. The chief point in computation worth mentioning is that the rectangular co-ordinates of the stations and intersected points were worked out by Gale's traverse system, using the lengths of sides and the angles from the computation of triangles; 15 intersected points have not proved, they will be retriangulated next field season.

The average errors of connection work and net-work are shown in the annexed table:—

Nature of work.	Mean Triangular error in seconds.	Average Linear error per mile in feet.	Average closing error in distance on meridian in 1,000.	Average closing error in distance on perpendicular in 1,000
Connection work ...	6·7	0·12	...	...
Net-work stations ...	17·1	0·22	0·11	0·12
,, points ...	...	0·63	...	...

Manuscript triangulation charts for Degree sheets 38P, 39I, 39M, 39N, 43D and 44A have been prepared, the fair charts will be prepared next year; the preparations for the field season have taken up a good deal of time during the recess owing to the very large number of 4,000-acre plots having to be prepared.

Triangulated points were plotted on 4,000-acre rectangle prints on the scale 6 inches to 1 mile. They were examined and inked up and other necessary data were entered on them for the guidance of the surveyors and the patwāris in demarcation. One set of 1,257 plots was completed. The duplicate set is expected to be ready before the party takes the field.

Miscellaneous.—(*a*) Almost all the transport of the Sind-Sāgar Doāb is done by camels, which can be obtained in the villages but not without difficulty. With the exception of the Jhang-Bhakkar road which runs across the desert, the country has no other road. There are numerous camel paths but these are obliterated in a storm and are unrecognisable after a shower of rain. There are wells at the villages and scattered about the desert, but their water is generally brackish and bitter. Supplies are difficult to obtain, there are some large villages in the interior, but they are far between and are only centres of indigenous trade. Previous arrangements through the district authorities are necessary. There are Government Rakhs in the "Thal", but they are patches of waste land leased for grazing and are almost treeless.

(*b*) Mr. Muhammad Husain Khan and surveyor Muhammad Yakub Khan who had been selected for the Eastern Persia Survey Party were trained by Mr. Chuni Lal Kapur in astronomical observations for latitude, azimuth, and time, and in their computation for about a fortnight in September.

Inspections.—The Superintendent, Northern Circle, inspected the party frequently in recess. The Surveyor General inspected the party in September 1918.

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.
,, Ram Narayan Hastir from the 4th September 1918
,, Lakshmi Dutt Joshi.
,, Vidya Dhor Chopra.

1 Nāib Tahsildār (Settlement staff)

Lower Subordinate Service.

76 Surveyors, Traversers, etc.
1 *Kānungo* (Settlement establishment) from the 29th May 1918.

The field operations were started on the 1st October 1917, and were closed early in July 1918. The head-quarters of the detachment remained at Campbellpore till the 12th April 1918, after which it was shifted to Jhelum where the office opened on the 22nd April 1918.

2. The detachment was divided into four camps and four sections. The former consisted of 12 to 14 traversers each, and the latter varied in strength according to requirements.

The assistants supervised the work as follows:—

Mr. Paras Ram. *No. 1 Camp* (Indus) for the first $3\frac{1}{2}$ months. The Indus boundary compilation for the remaining part of the year.

Mr. Lakshmi Dutt Joshi. The plotting and the boundary compilation of the Rāvi, and the final examination of the Kāngra computation records.

Mr. Vidya Dhor Chopra.	*No. 2 Camp* (Indus). The plotting of the Indus. The training of new hands, and miscellaneous duties.
Munshi Ganda Singh, *Nāib Tahsildār*.	*No. 3 Camp* (Indus), during the field. Correspondence, and accounts during recess.
Babu Ishwar Singh, Surveyor.	*No. 4 Camp* (Rāvi & Sutlej), and the examination of instruments.
Computer Badlu Ram,	Computing Section.

3. The detachment continued the work of traversing and laying down base lines. 440 linear, and 706 square miles of main circuits; and 3, 904 linear, and 762 square miles of minor traverses were run; and 780 theodolite stations of the former and 16, 282 of the latter, were fixed in the area under water action of 251 villages of the rivers Indus, Rāvi, and Sutlej in districts Dera Ghāzi Khān, Muzaffargarh, Multān, and Bahāwalpur State. 519 corners of 173 squares were demarcated in 1, 181 square miles with permanent mark-stones on both banks of the Indus and the Rāvi, to serve as bases for the future survey and demarcation of boundaries and fields in the beds of the rivers. Some of the base lines on the Indus could not be fixed and were postponed to next season on account of the sites having been covered with water due to floods.

2, 935 plotted, and 816 boundary *masāvis* (Settlement mapping sheets) on the scale of $\frac{1}{2640}$, and 40 four-inch sheets were traced, and supplied to the Settlement Officers. Besides these, 377 miscellaneous traces were prepared, and all the traverse stations marked during the year were plotted on 58 four-inch sheets. The computation volumes yet remain to be completed due to the period of the recess being very short.

Some of the Kāngra computation volumes have been completed, and work in some still remains to be done. Two candidates of the Gwalior State were trained in traversing and computations from the 23rd March to the 30th September 1918.

4. 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 $\frac{1}{2640}$.	120	252	122	210	606	3,304	13,650	187	495	165	1,173	
Rāvi River. District Multān (Kabirwala *Tahsil*). Scale $\frac{1}{2640}$.	40	...	...	...	156	600	2,632	64	24	8	8	
Sutlej River. District Multān, (Mailsi *Tahsil*), and Bahāwalpur State. Scale $\frac{1}{2640}$.	55	454	318	570	...	...	...	...	...	...	...	
Total ...	215	706	440	780	762	3,904	16,282	251	510	173	1,181	

(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.
Indus ...	Dera Ghāzi Khān	$\frac{1}{2,640}$	2,342	674	31	47
Rāvi ...	Multān ...	„	593	142	9	11
	Total ...	...	2,935	816	40	58

Besides these, 377 miscellaneous traces were prepared.

5. Much trouble was experienced early in the season due to fever prevailing along the Indus, and for want of khalasis, as sufficient men could not be had locally, and definite orders regarding recruitment from other districts, and the enhanced rates of their pay were not received till the 8th October 1918. Besides these, there were various other difficulties which hampered the progress of work, such as the constant changes in the Settlement Officers' demands; crossing and recrossing the Indus at various places for throwing points on islands and isolated spots in the bed of the river; the clearing of extraordinary heavy jungle along the Indus; and the scarcity of transport, supplies, and labour, on account of the military expedition against the Marris in the Dera Ghāzi Khān district.

6. The riverain area under water action was usually broken, full of swamps, shrubs, high grass, and sand; and was in parts densely wooded. Large isolated plots in the bed of the Indus, and portions of villages above the high banks were open, flat, and well cultivated.

7. Those members of the detachment who were employed along the Indus during October, November, and December 1917 suffered badly from fever due to heavy floods in September 1917. The health of the other members was fairly satisfactory. One surveyor, one draftsman, and one khalasi died.

8. The Indus main circuits were connected with Kambar Shāh T. S. XC; and those of the Sutlej with Josar T. S. XXVIII, Tāmiwālī Platform Station XX, Shekhwahān T. S. XXII, Ghallū T. S. XXIV, Jīwan T. S. XXVI, and Mandresa T. S. XXX.

9. The average errors were as follows :—

(*a*) Base-lines 0·84 foot 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	2·57	0·14
Sutlej	3·27	0·33
(*c*) Minor traverse		
Indus	9·27	0·57
Rāvi	7·87	0·55

10. The total expenditure of the detachment from the 1st October 1917 to the 30th September 1918 was Rs. 1,09,132/-.

SOUTHERN CIRCLE.

(*Vide* Index Map 2).

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, 8 and 20 Parties, No. 4 Drawing Office, the Training Section and the Salonika Survey Detachment.

During the year Nos. 5, 6, 7 and 8 Parties completed 12,589 square miles of detail survey, 11,878 square miles of triangulation and 836 linear miles of theodolite traversing.

The detail survey consisted of :—

6,675	square miles of	$\frac{1}{2}$-inch original survey.
3,942	" " "	1-inch original survey.
682	" " "	1-inch revision survey.
478	" " "	1-inch supplementary survey.
138	" " "	$1\frac{1}{2}$-inch original survey.
271	" " "	$1\frac{1}{2}$-inch resurvey.
163	" " "	2-inch original survey.
58	" " "	3-inch original survey.
137	" " "	3-inch resurvey.
45	" " "	4-inch original survey.

No. 20 Party surveyed an area of 26,841 acres in cantonments and military stations.

Owing to the great shortage of supervising officers on account of the war, topographical survey operations were 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 $\frac{1}{2}$-inch sheets compiled from published sheets of the 1-inch map.

The Training Section carried out detail survey on the $1\frac{1}{2}$-inch scale in sheets 57 $\frac{G}{10, 14}$. 17 pupil surveyors received instruction in detail surveying.

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

Reproductions	...	...	120
Enlargements	...	...	107
Reductions	...	...	167
Sheets vandyked	...	...	135
Copies printed	...	...	4,249

NO. 5 PARTY (BERAR, BOMBAY AND CENTRAL PROVINCES).

By P. R. Anderson.

PERSONNEL.

Provincial Officers

Mr. P. R. Anderson, in charge.
" Haji Abdul Rahim, K. B.

Upper Subordinate Service.

Mr. Damodar Khadilkar.

Lower Subordinate Service.

27 Surveyors, etc.

This party took the field in reduced strength and completed the detail survey on the 1-inch scale of sheets 55 $\frac{C}{11, 12, 15, 16}$ and on the 3-inch scale of the Royal Artillery Practice Camps of Aundh in sheets 47 $\frac{F}{10, 14}$ and of Barelā in sheet 64 $\frac{A}{4}$. The party also completed the triangulation of sheets 55 $\frac{N}{2, 3, 6, 7, 10, 14}$ and 64 $\frac{B}{1, 2, 5, 6}$.

The general nature of the country surveyed on the 1-inch scale is well cultivated fertile fields and intricate jungle-clad hills.

The field season opened on the 1st November 1917 and closed on the 20th April 1918. The field head-quarters of the party remained at Bangalore throughout the year.

Considering the malarious tracts in which the party worked and the high price of food throughout the season, the health of the party was good. There were no deaths.

Plane-tabling.— The nature of the country surveyed is varied. The 1-inch detail survey covered those portions of the rich and fertile valleys of the Pūrna and Tāpti rivers, and the intricate and jungle-clad Gāwilgarh range separating them, which fall in sheets 55 $\frac{C}{11, 12, 15, 16}$;

the original survey being confined to the plains and the revision survey to the hills. The 3-inch detail survey comprised the Royal Artillery Practice Camps of Aundh and Barelā. The camp of Aundh lies about 6 miles north-west of Poona and covers the undulating plains, steep-sided flat-topped hills and confined valleys of the basins of the Pauna and Muta rivers in sheets $47\frac{F}{10,14}$. The camp of Barelā, falling in sheet $64\frac{A}{4}$, covers a tract of embanked fields, wooded and undulating plains and rocky jungle-clad hills round about Barelā which is a large village 10 miles south-east of Jubbulpore on the Mandlā road.

The field work was divided between two camps:—

No. 1 Camp.— Under Mr. Anderson, consisted of 3 surveyors and completed the detail survey on the 3-inch scale of the camps of Aundh and Barelā.

No. 2 Camp.— Under Mr. Haji Abdul Rahim, K.B. assisted by a senior surveyor, consisted of 9 surveyors and completed the detail survey on the 1-inch scale of sheets $55\frac{C}{11,12,15,16}$.

There was also a surveyor under Mr. Anderson detailed to survey, on to the original plane-table sections, new railway lines in sheets 55 H and 55 L.

The 1-inch original survey presented no great difficulties. The portion falling in $55\frac{C}{12,16}$ was surveyed by beginners under a senior surveyor and proved a good training ground. The 1-inch revision survey was carried out on vandyked reductions of previous 4-inch surveys, which proved to be very reliable. The 3-inch detail survey (original survey of Aundh and resurvey of Barelā) was undertaken purely for military purposes. As there were a sufficient number of previously triangulated points to ensure an accurate and reliable graphic triangulation, this method was adopted, and a great number of points were fixed by the plane-table and their heights determined by the theodolite. Great attention was paid to the representation of tree growth and, as far as the scale would allow, this was depicted true to nature, care being taken to show the shapes of solitary and conspicuous trees. Where necessary certain contours were surveyed by means of the clinometer used as a level. The supplementing of new railway lines proved very easy as the original plane-tabling, done by Provincial Officers under training, was exceptionally accurate.

A total area of 1,214 square miles was completed. The total out-turn of 1-inch original survey, of 1-inch revision survey and of 3-inch survey was 570 , 527 and 117 square miles respectively, the average monthly out-turn per man was 29·1, 48·1 and 9·3 square miles respectively, and the cost-rate per square mile was Rs. 20·9, Rs. 12·6 and Rs. 59·0 respectively. 112 miles of railway line were supplemented at a total cost of Rs. 326.

Triangulation.—The country triangulated lies entirely on what is known as the plateau of the Sātpurās. It consists of the mango-studded plains around Mandlā and the ragged jungle-covered jumble of hills which enclose the tortuous rock-bound course of the Narbadā river in sheets $64\frac{B}{1,2,5,6}$; of the Laknadon plateau, which is a well-wooded and rolling country of alternate ridges and hollows, in sheets $55\frac{N}{10,14}$, and of the highlands of northern Chhindwāra, which consist of series of jungle-fringed plateaus separated by valleys and ravines in sheets $55\frac{N}{2,3,6,7}$. Communications, throughout this tract of country, are bad and the population sparse.

The triangulation was divided between Mr. Damodar Khadilkar and surveyor Nur Muhammad. Mr. Damodar Khadilkar completed an area of 1,373 square miles in sheets $55\frac{N}{14}$ and $64\frac{B}{1,2,5,6}$, and the surveyor completed an area of 1,374 square miles in sheets $55\frac{N}{2,3,6,7,10}$. The country had been previously triangulated, and whenever found the old stations were utilized. The total out-turn was 2,747 square miles and the cost-rate per square mile was Rs. 5·3.

Recess Duties.—(*a*) The fair-mapping was divided among 3 sections :—

No. 1 Section.—Under Mr. Anderson was employed throughout the year on the ½-inch sheets (compiled from 1-inch published sheets) $47\frac{M}{S.W.}$, $55\frac{D}{N.W., S.W., N.E., S.E.}$, $55\frac{G}{N.E., S.E.}$, $55\frac{H}{N.W., S.W., N.E., S.E.}$, $55\frac{K}{N.W., S.W., N.E.}$ and $55\frac{L}{N.W., S.W., N.E.}$, and assisted No. 6 Party in the fair-mapping of 2-inch state forest maps of the Hyderābād State.

No. 2 Section.—Under Mr. Haji Abdul Rahim, K. B. worked during the recess season only on 1-inch sheets $55\frac{C}{11,12,15,16}$.

No. 3 Section.—Under Mr. Anderson worked during the recess season only on the 3-inch maps of the camps of Aundh, Barelā, Kāpra (for No. 6 Party) and Rājankunti (for No. 8 Party).

Sheets 55 $\frac{D}{N.W., S.W., N.E., S.E.}$ and 55 $\frac{G}{S.E.}$ have been completed and submitted for publication, sheets 55 $\frac{G}{N.E.}$ and 55 $\frac{K}{N.W., S.W., N.E.}$ have nearly been completed, and sheets 47 $\frac{M}{S.W.}$, 55 $\frac{H}{N.W., S.W., N.E., S.E.}$ and 55 $\frac{L}{N.W., S.W., S.E.}$ are in hand. The fair-mapping of 1-inch sheets 55 $\frac{C}{11, 12, 15, 16}$ is well advanced and should be completed by the end of the recess season. Of the 3-inch maps, Aundh and Barelā have been submitted for publication, Kāpra is nearly completed and Rājankunti is in hand.

A total area of 8,579 square miles was fair-mapped. The out-turn for the ½-inch, 1-inch and 3-inch scales was 7,323, 1,109 and 147 square miles respectively, and the cost-rate per square mile was Rs. 1·9, Rs. 0·9 and Rs. 3·4 respectively.

(*b*) A computing section under Mr. Anderson was employed throughout the year. During the field season it computed sheet 56 H and part of sheet 56 L for No. 6 Party and completed the arrears in sheets 55 C and 55 F. During the recess season it computed sheets 55 $\frac{N}{2, 3, 6, 10, 14}$ and 64 $\frac{B}{1, 2, 5, 6}$, and during September it helped in the computations of No. 6 Party's triangulation.

Owing to the dearth of officers, due to the war, the preparation of the material for triangulation pamphlets has progressed very slowly. Sheets 46 O, 46 P, 54 L, 55 G and 55 I are still in hand.

Miscellaneous.—Considering the rugged and mountainous nature of the country covered by the 1-inch plane-tabling this year, the communications throughout were very good. A well-planned system of cart-tracks, which took every advantage of the configuration of the land, has been laid out and maintained by the Forest Department, and well-laden carts can travel anywhere. The question of clearing triangulation stations becomes acuter and more expensive year by year in the Central Provinces. As the conservation of forests becomes more thorough, the Forest Department is insisting on a scientific felling of trees. This means that either the triangulator has to lose time in personally superintending all hill clearing, or he has to entrust the clearing to his tindals and consequently has to cut back badly felled trees on his return visits to stations. Each method is expensive, and arrangements are being made in the ensuing field season to get the Forest Department to lend guards to superintend hill-clearing in all forest lands; it is hoped by these means to keep down expense.

No. 6 PARTY (HYDERĀBĀD AND MADRAS).

By J. O'B. Donaghey.

This party completed the detail survey on the ½-inch scale of sheets 56 $\frac{C}{9\ to\ 16}$ and 56 $\frac{G}{1\ to\ 16}$, on the 1½-inch scale of scattered areas of state forests in sheets 56 $\frac{A}{10, 14}$, 56 $\frac{E}{2, 7, 11, 12, 15}$, 56 $\frac{G}{6, 7, 10, 11, 12, 15, 16}$ and 56 $\frac{I}{3, 4}$ and on the 3-inch scale of the Royal Artillery Practice Camp of Kāpra in sheets 56 $\frac{K}{10, 11}$. The state forests surveyed in sheets 56 $\frac{A}{10, 14}$ and 56 $\frac{E}{2, 7, 11, 12, 15}$ and the area of the Kāpra camp had been previously surveyed on the ½-inch scale.

PERSONNEL.

Provincial Officers.

Mr. J. O'B. Donaghey, in charge.
" E. A. Meyer.
" Munshi Lal, B.A.
" F. W. Smith.
" M. S. Ganesa Aiyar.

Upper Subordinate Service.

Mr. Eknath Battu.
" Ram Narayan Bastir, to 22nd April 1918.
" K. Mandanna.
" Masud Khan.

Lower Subordinate Service.

34 Surveyors, etc.

The party also undertook the triangulation for detail survey on the ½-inch and 1½-inch scales in sheets 56 $\frac{L}{9\ to\ 16}$, 56 $\frac{O}{3, 4, 7, 8, 11, 12, 15, 16}$ and 56 $\frac{P}{1\ to\ 6, 9, 10, 13, 14}$, for the 1-inch scale in sheets 56 $\frac{O}{12, 16}$ and 56 $\frac{P}{13}$ and for the 3-inch scale in sheets 56 $\frac{K}{10, 11}$. 95 linear miles of traversing was completed in sheets 56 $\frac{G}{6, 7, 10, 11}$.

The general nature of the country is hilly, interspersed with undulating cultivated areas.

The field season opened on the 15th November 1917 and closed on the 15th May 1918. The field head-quarters was at Secunderābād.

The health of the party was on the whole good, the head-quarters camp suffered somewhat from malaria which was prevalent in an epidemic form at Secunderābād. There were four deaths among the menials, two being from cholera while the men were on their way to join the party, one from old age and one from the effects of an accident.

Plane-tabling.—The nature of most of the country surveyed is hilly and undulating, the undulating areas being cultivated; the south-western portion is almost flat and is highly cultivated. The state forest areas consist of wooded hills.

The work was divided among four camps as follows :—

No 1 Camp.— Under Mr. Meyer, with Messrs. Smith and Ram Narayan Hastir and 12 Surveyors completed the original survey on the ½-inch scale of sheets 56 $\frac{C}{9 \text{ to } 16}$ and 56 $\frac{G}{2,3,4,8}$.

No. 2 Camp.— Under Mr. Ganesa Aiyar, with Messrs. Mandanna and Masud Khan and 10 surveyors completed the original survey on the ½-inch scale of sheets 56 $\frac{G}{1,5,6,7,9 \text{ to } 16}$, excluding state forest areas surveyed by No. 3 Camp.

No. 3 Camp.— Under Mr. Munshi Lal, with 6 surveyors was employed on the original survey and resurvey on the 1½-inch scale of scattered areas of state forests in sheets 56 $\frac{A}{10,14}$, 56 $\frac{E}{2,7\ 11,12,15}$, 56 $\frac{G}{6,7,10,11,12,15,16}$ and 56 $\frac{I}{3,4}$.

No. 4 Camp.— Under Mr. Donaghey, with 2 surveyors carried out the resurvey on the 3-inch scale of the Kāpra camp in sheets 56 $\frac{K}{10,11}$.

A total area, amounting to 7,114 square miles, was completed. The out-turn of the ½-inch original survey, 1½-inch original survey, 1½-inch resurvey and 3-inch resurvey was 6,675, 138, 271 and 30 square miles respectively, the average monthly out-turn per man was 53·8, 8·9, 10·9 and 5·6 square miles respectively and the cost-rate per square mile was Rs. 6·7, Rs. 51·7, Rs. 42·2 and Rs. 66·9 respectively. The whole of the area surveyed on the ½-inch and 1½-inch scales, amounting to 7,084 square miles, is in Hyderābād.

Triangulation.—The nature of the country was hilly, interspersed with open undulating areas, the portion along the Kistna river in sheets 56 $\frac{L}{12,16}$ being difficult as it is heavily wooded and sparsely inhabited. The area triangulated in sheets 56 $\frac{K}{10,11}$ for the 3-inch scale was open with rocky hills.

Mr. Eknath Battu completed an area of 1,779 square miles (including 70 square miles for the 3-inch scale) in sheets 56 $\frac{K}{10,11}$ and 56 $\frac{L}{9,10,11,13,14,15}$, surveyor Jagan Nath completed an area of 2,769 square miles in sheets 56 $\frac{L}{12,16}$, 56 $\frac{O}{3,4,7,8}$ and 56 $\frac{P}{1 \text{ to } 6}$ and surveyor Dharmaji Narsu completed an area of 1,860 square miles in sheets 56 $\frac{O}{11,12,15,16}$ and 56 $\frac{P}{9,10,13,14}$.

The total out-turn was 6,338 square miles for detail survey on the ½-inch, 1-inch and 1½-inch scales and 70 square miles for the 3-inch scale and the cost-rate per square mile was Rs. 2·8 and Rs. 12·1 respectively. Areas of 4,891 square miles for the ½-inch scale and 1,288 square miles for the 1½-inch scale were in Hyderābād.

Traversing.—The nature of the country was hilly and heavily wooded.

The work was carried out by Mr. Ram Narayan Hastir and a computer. The total out-turn was 126 square miles, or 95 linear miles, and the cost-rate per square and linear mile was Rs. 25·9 and Rs. 34·3 respectively. 84 and 42 square miles were traversed for the ½-inch and 1½-inch detail survey respectively. The whole area is in Hyderābād.

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

No. 1 Section.—Under Mr. Meyer, ½-inch sheets 56 $\frac{C}{N.E., S.E.}$ and 56 $\frac{G}{S.W.}$ and also completing 56 $\frac{K}{N.W., N.E., S.W., S.E.}$ remaining from 1916-17.

No. 2 Section.—Under Mr. Ganesa Aiyar, ½-inch sheets 56 $\frac{G}{N.W., N.E., S.E.}$.

No. 3 Section.—Under Mr. Munshi Lal, the fair-mapping on the 2-inch scale of 14 sheets of state forests and also completing 19 such sheets remaining from 1916-17.

The fair-mapping of the 3-inch map of Kāpra camp was carried out by No. 5 Party.

Sheets 56 $\frac{K}{N.W., S.W.}$ have been submitted for publication, sheets 56 $\frac{K}{N.E., S.E.}$ have been completed and the 19 two-inch sheets remaining from 1916-17 have been practically completed. The other sheets are in hand and will probably be completed by No. 5 Party during the coming field season.

A total area of 7,214 square miles was fair-mapped. The out-turn for the $\frac{1}{4}$-inch and 2-inch scales was 6,805 and 409 square miles respectively and the cost-rate per square mile was Rs. 2·0 and Rs. 8·8 respectively. The whole of the area fair-mapped is in Hyderābād.

Owing to the transfer of most of the party's best draftsmen on field service, it has been found very difficult to keep the fair-mapping out-turn up to date.

(*b*) The computations of the triangulation have not been completed.

No triangulation pamphlets have been undertaken by the party.

No. 7 PARTY (MADRAS).

By W. M. Gorman.

This party completed the detail survey of sheets $57\frac{N}{1 \text{ to } 10, 13, 14}$ and $66\frac{B}{1, 2}$ on the 1-inch scale, of certain reserved forests falling in sheets $57\frac{N}{1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 14, 15}$ on the 2-inch scale and of the balance of the special survey, remaining from last season, of reserved forests Udayagiri Velikonda Block A with Extensions and Gundlakonda, falling in sheets $57\frac{N}{1, 2, 5}$ on the 4-inch scale.

The party also completed the triangulation of sheets $56\frac{L}{16}$ (up to the Kistna river), $57\frac{I}{13}$ and $57\frac{J}{1, 2, 5, 6, 9, 10, 13, 14}$.

The country surveyed embraces a portion, mostly reserved forests, of the Eastern Ghāts and an undulating expanse of cultivated and wooded land, studded with low isolated hills, between the foot of these Ghāts and the sea-coast.

PERSONNEL.

Provincial Officers.

Mr. W. M. Gorman, in charge.
,, F. H. Grant.
,, B. T. Wyatt.
,, N. S. Harihara Iyer.

Upper Subordinate Service.

Mr. Abdul Hakk, K. S.
,, P. S. Vengusvami.
,, Shib Lal.
,, Shaikh Muhammad Salik.
,, E. N. Natesan, B. A.
,, Pulin Behari Roy.
,, Jitendra Mohan Mukerji, to 31st July 1918.

Lower Subordinate Service.

30 Surveyors, etc.

The field season opened at Kāvali field head-quarters on the 1st November 1917 and closed on the 9th May 1918, with the exception of a few surveyors and the triangulators who arrived on the 30th May and 26th June respectively.

The health of the party was on the whole good. Two menials died from natural causes during the field season.

Plane-tabling.—The country surveyed may with advantage be divided into two tracts, possessing totally different features, *viz.* the Eastern Ghāts on the west and the undulating expanse starting from the foot of the same to the sea-coast on the east. In the former, the Velikonda range, precipitous on its eastern side but with a more gradual slope on the west, presents a natural and well-defined line separating Cuddapah from Nellore district and marks the boundary between the two, this continuous mountain wall running north and south is pierced by the Penner river at Somasila; inland, this range breaks into a less elevated and more irregular group of hills, of fragmentary spurs and ridges, separated by a fertile plain from the more defined and denser mass of hills, known as the Pālkondas or Seshāchalam, further west. From the Velikonda range eastwards, the country undulates in broad tracts of scrub jungle and cultivated expanses studded with isolated hills to the sea-coast. Nearly all the drainage of the country is into the Penner river, flowing from west to east through the Cuddapah and Nellore districts, in its upper reaches it drains rather than waters the country through which it flows, lower down it is dammed at Sangam and Nellore and its accumulated waters are led off to supply many irrigation channels. Much is also done for irrigation in the shape of numerous tanks which husband the local rainfall. The north-west and north-east lines of the Madras and Southern Mahratta railway (broad gauge) traverse the extreme west and east respectively of the area surveyed. The intervening country between the railways is well served with main and other roads radiating in every direction, supplemented by numerous cart-tracks. Besides the one main road connecting Cuddapah with Nellore and crossing the Ghāts at the Dornal pass, several foot-paths cross the main range throughout its entire length. Double and single bullock carts ply on all roads and motor buses on a few, but they are very uncertain owing to break-downs and want of proper management. There are no archæological remains of any interest except the hill fort at Udayagiri.

The work was divided among three camps as follows:—

No. 1 Camp, under Mr. Abdul Hakk, K. S. with 7 surveyors, completed an area of 60 square miles of 2-inch original survey of reserved forests, 711 square miles of 1-inch original survey and 316 square miles of 1-inch supplementary survey in sheets 57 $\frac{N}{3, 4, 7, 8}$ and 57 $\frac{N}{11, 15}$.

No. 2 Camp, under Mr. Grant assisted by surveyor Shadi Lal Dube as instructor, with Mr. Wyatt and 12 surveyors, completed 45 square miles of 4-inch special original survey of reserved forests, 87 square miles of 2-inch original survey of reserved forests, 1,384 square miles of 1-inch original survey and 162 square miles of 1-inch supplementary survey in sheets 57 $\frac{N}{1, 2, 5, 6, 9, 10}$.

No. 3 Camp, under Mr. Shib Lal with 8 junior surveyors and the help of a surveyor from No. 1 Camp, completed 16 square miles of 2-inch original survey of reserved forests, and 845 square miles of 1-inch original survey in sheets 57 $\frac{N}{13, 14}$ and 66 $\frac{B}{1, 2}$.

Bold rugged hills, with bare crests, steep eastern slopes, and undulating ground at their base, covered with a dense growth of trees and much detail, comprised the ground, surveyed on the 4-inch scale, of the special reserved forests remaining over from the last season. All main streams in the low ground were traversed with the plane-table and chain, otherwise features and detail lent themselves to sketching and interpolation. With the exception of the western boundary, between the Gundlakonda reserve and the Udayagiri Velikonda reserve, found undemarcated at time of survey but cleared later on representation, all boundaries were found cleared and marked with pillars (un-numbered). Stations of the theodolite traverse run in 1916-17 were found and utilised.

The number of reserved forests with extensions, surveyed on the 2-inch scale, are 29 and lay scattered throughout the work. They embraced high rocky hills, several low isolated hills, a long range of low hills known as the Yerrakondas and the plains of Nellore, and were composed mostly of scrub jungle. Interpolation and plane-table traversing, where necessary, were employed. Forest plans, as far as received from the forest authorities, were utilised in checking the run of the forest boundaries and for local names contained therein.

Direct blue prints on Bristol boards of 1-inch prints supplied by the Madras Revenue Survey were very sparingly used, owing to the junior nature of the surveyors. The remaining 1-inch prints were transferred in blue by surveyors as the work progressed. Very little help was obtained from the work of the Madras Revenue Survey in the Cuddapah district owing to its scanty and detached nature, elsewhere it was found helpful in parts. Zamīndāri areas on the above prints were of no great use to the survey.

The 1-inch supplementary survey consisted of reserved forests previously surveyed on the 4-inch scale by the Survey of India in the Cuddapah district. They were reduced to the 1½-inch scale in blue, inked up in regard to detail and hill features, and pasted on 1½-inch plotted and projected sheets on drawing paper by means of common trigonometrical points; the whole being reduced to the 1-inch scale by direct blue prints on Bristol boards, and brought up to date during survey in detail and contouring.

A total area of 3,626 square miles was surveyed. The total out-turn of the 4-inch original survey, 2-inch original survey, 1-inch original survey and 1-inch supplementary survey was 45, 163, 2,940 and 478 square miles respectively, the average monthly out-turn per man was 4·3, 6·7, 28·3 and 32·8 square miles respectively and the cost-rate per square mile was Rs. 95·5, Rs. 41·3, Rs. 11·5 and Rs. 5·5 respectively.

Triangulation.— The country triangulated is a continuation southward of the previous season's work and is similar to the ground topographically surveyed in the Cuddapah district. It embraces the high and thickly forest-clad Lankamalla hills, mostly reserved forests, and the Nallamalais where they project into the plains of Cuddapah on the east, the undulating country between the above hills and the detached group of the Mallyala and Gandikota hills on the west, and the plains of Anantapur. The chief river is the Penner, flowing eastwards into Nellore, which contains a great volume of water in the rains, but during the hot months dwindles down to an inconsiderable stream. Its tributaries are the Cheyyeru and Pāpaghni from the south, the Kunderu from the north and the waters from the Kurnool-Cuddapah canal. The area is well served with a net-work of main and other roads and, in addition, the north-west line of the Madras and Southern Mahratta Railway (broad gauge) practically traverses the centre of it.

The total area triangulated, based on the Great Arc Meridional Series, is 2, 723 square miles, of which Mr. Shaikh Muhammad Salik completed an area of 1, 286 square miles in sheets 56 $\frac{L}{16}$, 57 $\frac{I}{13}$ and 57 $\frac{J}{10, 13, 14}$ and Mr. Vengusvami completed an area of 1, 437 square miles in sheets 57 $\frac{J}{1, 2, 5, 6, 9}$. The cost-rate per square mile was Rs. 6·5.

The ¼-inch traverse chart of 57 J by the Madras Revenue Survey, after all forest and party data contained therein had been plotted and rays inked up, was sent to the Photo.-Zinco. Office and direct blue prints obtained which were made over to the triangulators. These greatly simplified their work, besides enabling them to fix trijunctions and traverse stations of the local survey to check the accuracy of that work. The nine trijunctions fixed were computed and compared with the Madras Revenue Survey spherical values reduced from rectangular co-ordinates. The error is 1·27 seconds in latitude and 0·41 seconds in longitude.

Recess Duties.— (*a*) The fair-mapping of the survey completed was divided as follows:—

No. 1 Section, under Mr. Grant, sheets 57 $\frac{N}{1, 2, 5, 6, 9, 10}$.

No. 2 Section, under Mr. Wyatt, sheets 57 $\frac{N}{3, 4, 7, 8}$.

No. 3 Section, under Mr. Shib Lal, sheets 57 $\frac{N}{13, 14}$ and 66 $\frac{B}{1, 2}$.

It is expected that the above 14 sheets will be fully fair-drawn and some be ready for publication before the end of the recess season, the others will be held over until the typing, which is backward, is completed. The total area of the fair-mapping is 3, 737 square miles and its cost-rate is Rs. 6·6 per square mile.

The fair-mapping of the 4-inch special reserved forests, surveyed during 1916-17 and this season, will be undertaken by the Forest Map Office, Dehra Dūn, as soon as possible after the submission of the current season's fair-mapping in which the 4-inch field sections are incorporated.

(*b*) Arrears of computations in 56 P and 57 M were completed in the field season. There still remain arrears of computations from last season in 56 L and 57 I and, owing to the shortage of hands due to the war, it is expected that a portion of the current season's work will also be in arrears. These arrears will be undertaken during the coming field season by the party computers. No progress has been made with the triangulation pamphlets owing to the party being undermanned. Chart 57 H was started but has been held over.

No. 8 PARTY (MADRAS).

By C. E. C. French.

PERSONNEL.

Provincial Officers.

Mr. W. F. E. Adams, in charge to 17th January 1918.
,, C.E.C. French, in charge from 17th June 1918.
,, V. M. Morton from 18th January and in charge to 16th June 1918.
,, M. Mahadeva Mudaliar, M.A.

Upper Subordinate Service.

Mr. K. Narayanasvami Chetti.
,, H. Narasimhamurti Rao.

Lower Subordinate Service.

29 Surveyors, etc.

This party took the field in reduced strength and completed the detail survey on the 1-inch scale of sheets 58 $\frac{H}{5, 6}$ and on the 3-inch scale of the Royal Artillery Practice Camp of Rājankunti in sheets 57 $\frac{G}{11, 12}$. The party also carried out theodolite traversing in sheets 58 $\frac{H}{6}$ and 58 $\frac{K}{5, 6, 9, 10, 11, 15}$.

The area surveyed on the 1-inch scale comprises densely wooded hills, terminating abruptly in flat country, while the traversed area consists of featureless plains.

The field season opened on the 19th November 1917 and closed on the 18th May 1918. The head-quarters of the party, with the majority of its members, remained in Bangalore throughout the year.

The health of the party, generally, was good; men in the field however suffered a good deal from fever in the forest tracts. Mr. Adams died in Bangalore on the 26th January 1918. 1 surveyor died during the recess season and 3 khalasis died of cholera during the field season.

Plane-tabling.—The highlands of the area surveyed on the 1-inch scale comprise a region of wild mountainous forms, clothed with impenetrable forest, their precipitous and craggy declivities merging suddenly into broad fertile plains. Sheets 58 $\frac{\text{H}}{5,6}$, of which the detail survey was completed by Mr. Mahadeva Mudaliar with 9 surveyors, comprises mostly an area of remote hill tracts, covered with dense forest and devoid of communication, thereby rendering the problem of survey no easy one. The want of labour for jungle clearing necessitated the building of platforms on tall trees, some 60 to 70 feet above the ground, from which a view of the country was obtained and survey made possible.

The resurvey on the 3-inch scale of 48 square miles of open, undulating country, situated some 14 miles north of Bangalore and known as the Royal Artillery Practice Camp of Rājankunti, was also completed by 1 surveyor.

A total area of 635 square miles was surveyed. The total out-turn of the 1-inch original survey, 1-inch revision survey and 3-inch resurvey was 432, 155 and 48 square miles respectively; the average monthly out-turn per man was 15·5, 16·1 and 6·9 square miles respectively and the cost-rate per square mile was Rs. 39·8, Rs. 39·8 and Rs. 32·5 respectively.

Traversing.—The fixing of points by theodolite traverse for detail survey on the 1-inch scale was carried on over a country of fertile plains, well served with communications and intersected by a section of the South Indian Railway. Mr. Narasimhamurti Rao with 1 surveyor traversed 727 linear miles at a cost-rate per linear mile of Rs. 9·9.

Section VI of the Tinnevelly-Travancore boundary was identified and fixed by 14 linear miles of theodolite traverse, following the alignment as described in orders issued by the Madras Government. Difficulties were experienced on this portion of the work. Owing to the extreme inaccessibility of the densely wooded range of hills along which the boundary runs, labour was hard to obtain, weather and inadequate assistance to the surveyor also hampered progress considerably.

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

No. 1 Section.—Under Mr. Narayanasvami Chetti working throughout the year, ½-inch sheets (compiled from 1-inch published sheets) 48 $\frac{\text{K}}{\text{N.E., S.E.}}$, 57 $\frac{\text{O}}{\text{N.W., S.W., S.E.}}$ 57 $\frac{\text{P}}{\text{N.W., S.W., N.E., S.E.}}$, 58 $\frac{\text{B}}{\text{S.W.}}$, 58 $\frac{\text{C}}{\text{N.E., S.E.}}$, 58 $\frac{\text{D}}{\text{N.E.}}$, 66 $\frac{\text{C}}{\text{S.W.}}$ and 66 $\frac{\text{D}}{\text{N.W., S.W.}}$.

No. 2 Section.—Under Mr. Mahadeva Mudaliar, and while he was on leave under Mr. Morton, working during the recess season only, 1-inch sheets 58 $\frac{\text{H}}{5,6}$.

The fair-mapping of the 3-inch map of Rājankunti camp is being undertaken by No. 5 Party.

Sheets 58 $\frac{\text{B}}{\text{S.W.}}$, 58 $\frac{\text{C}}{\text{S.E.}}$ and 66 $\frac{\text{D}}{\text{N.W., S.W.}}$ have been completed and submitted for publication, sheets 48 $\frac{\text{K}}{\text{N.E., S.E.}}$, 57 $\frac{\text{P}}{\text{N.W.}}$, 58 $\frac{\text{C}}{\text{N.E.}}$ and 58 $\frac{\text{D}}{\text{N.E.}}$ have nearly been completed and sheets 57 $\frac{\text{O}}{\text{N.W., S.W., S.E.}}$, 57 $\frac{\text{P}}{\text{S.W., N.E., S.E.}}$ and 66 $\frac{\text{C}}{\text{S.W.}}$ are in hand. The fair-mapping of sheets 58 $\frac{\text{H}}{5,6}$ is nearly completed.

A total area of 5,204 square miles was fair-mapped. The out-turn for the ½-inch and 1-inch scales was 4,744 and 460 square miles respectively and the cost-rate per square mile was Rs. 4·1 and Rs. 4·1 respectively.

(*b*) The preparation of triangulation pamphlets and the computations of the party have been under Mr. Mahadeva Mudaliar's supervision. The material for triangulation pamphlet 58 C has been submitted, for 58 A will be ready shortly and for 58 B and 58 M is under preparation. Computations sufficient for next field season have been finished and some arrears of previous seasons will be completed during the next few months.

No. 20 PARTY (CANTONMENT).

By B. R. Hughes.

PERSONNEL.

Provincial Officers.

Mr. A. Ewing, in charge to 29th April 1918.
„ B. R. Hughes, in charge from 30th April 1918.
„ E. O. Pilcher, from 8th May to 1st August 1918.
„ O. D. Jackson.

Upper Subordinate Service.

Mr. Dharmu.
„ Jitendra Mohan Mukerji, from 1st August 1918.

Lower Subordinate Service.

25 Surveyors, etc.

During the year the party completed the survey of cantonments and military stations and of *bāzārs* in the Northern Circle and continued survey operations in the Southern Circle.

The field season continued throughout the year. The head-quarters of the party was at Poona until the end of April 1918 and at Secunderābād for the remainder of the year.

The health of the party was indifferent. Several of the draftsmen and khalasis suffered from malaria at Poona and Secunderābād.

Plane-tabling.—The survey on the 16-inch scale of the cantonments and military stations of Dalhousie (Thatt Hill), Chaman, Manora, Erinpura, Agar, Jhānsi, Aurangābād and New Delhi was completed and of Ahmadnagar and Hosūr Remount Depôt was commenced, and the survey on the 64-inch scale of the *bāzārs* of Manora, Erinpura, Agar, Jhānsi, Aurangābād and New Delhi was completed and of Ahmadnagar and Hosūr Remount Depôt was commenced.

Mr. Ewing inspected the survey of Chaman, Manora, Erinpura, Agar, Jhānsi, Aurangābād, Ahmadnagar and New Delhi; Mr. Hughes inspected the survey of Manora, Aurangābād, Ahmadnagar and Hosūr Remount Depôt; Mr. Jackson was in charge of the survey of Jhānsi and New Delhi and Mr. Dharmu was in charge of the survey of Dalhousie (Thatt Hill), Erinpura, Agar and Hosūr Remount Depôt. The accuracy of the survey was tested by Messrs. Ewing, Hughes, Pilcher, Jackson and Dharmu by 5, 1, 3, 35 and 35 linear miles of test lines respectively.

The total areas plane-tabled on the 16-inch and 64-inch scales were 26,527 and 314 acres respectively; the average monthly out-turn per man was 279·2 and 21·4 acres respectively and the cost-rate per acre was Rs. 1·3 and Rs. 11·7 respectively.

Triangulation.—Sufficient numbers of stations and intersected points were fixed from the nearest Great Trigonometrical Series in Dalhousie (Thatt Hill), Manora, Erinpura, Agar and Aurangābād for the connection of the theodolite traversing. Mr. Dharmu and one surveyor were employed on the triangulation.

The total area triangulated was 272 square miles and the cost-rate per square mile was Rs. 3·7.

Traversing.—The traversing of Dalhousie (Thatt Hill), Manora, Erinpura, Agar, Aurangābād, Sātāra, New Delhi, Bellary and Hosūr Remount Depôt was completed and of Secunderābād and Bolārum was commenced by Mr. Dharmu and 2 surveyors.

A total of 356 linear miles was traversed at a cost-rate per linear mile of Rs. 26·9.

Levelling.—Levelling was undertaken by Messrs. Jackson and Dharmu and one surveyor in Erinpura, Agar, Aurangābād and New Delhi, and from 5 to 10 bench-marks were fixed in each at a total cost of Rs. 1,646.

Recess Duties.—42 fair sheets of Rāwalpindi, Topa, Jhelum, Siālkot, Neemuch and Deoli were submitted to Dehra Dūn for publication, and 60 sheets of Drosh, Chitrāl, Ghairat, Dalhousie (Thatt Hill), Chaman, Manora, Erinpura, Agar, Nasīrābād, Jhānsi, Aurangābād, New Delhi, Drazinda, Jatta, Zām and Jandola were being, or were ready to be, fair-mapped at the end of the year. The fair-mapping is fairly well up-to-date.

The total areas fair-mapped on the 16-inch and 64-inch scales were 22,113 and 416 acres respectively and the cost-rate per acre was Rs. 0·3 and Rs. 3·8 respectively.

Miscellaneous.—The survey of Colaba and Military and Dockyard areas in Bombay was not undertaken as the Bombay City Survey will be sufficient. The survey of Deolāli has been indefinitely postponed. After the traversing of Sātāra had been completed, information was received that the survey was being undertaken by the Land Records Department, Bombay and this will be sufficient.

EASTERN CIRCLE.

(*Vide* Index Maps 3 and 6).

Summary.—The four topographical parties of this Circle completed, during the year, the detail survey of :—

2,501	square miles of country	on the	$\frac{1}{2}$-inch scale.
5,353	do.	do.	1-inch scale.
34	do.	do.	1-inch scale (revision).
473	do.	do.	2-inch scale.
35	do.	do.	4-inch scale.

The triangulation of 5,934 square miles of country was completed, and 1,616 linear miles of theodolite traversing was run during the year.

Lieutenant-Colonel R. T. Crichton, C. I. E., I. A. proceeded on leave on 30th March 1918 and was succeeded in the control of the Circle by Lieut.-Colonel C. L. Robertson, C. M. G., R. E. The latter proceeded on 6 weeks privilege leave on 8th May, and during his absence Lieut.-Colonel A. Mears, I. A. acted for him.

On return from leave Lieut.-Colonel Robertson resumed the superintendentship of the Circle till the end of the year.

No. 9 PARTY (BENGAL).

By E. J. Biggie.

The programme of work of the party, as in the preceding year, lay in Bengal.

PERSONNEL.

Provincial Officers

Mr. J. Smith, in charge to 13th September 1918.
,, E. J. Biggie,* from 20th May 1918, and in charge from 14th September 1918.
,, A. B. Hunter.
,, B. C. Newland.
,, Amar Krishna Mitra.

Upper Subordinate Service.

Mr. Amulya Charan Ghosh.
,, Gopal Lal Mitra.

Lower Subordinate Service.

23 Surveyors, etc.

The country surveyed is intersected by numerous swamps and rivers. It is flat, widely cultivated and well populated. The rivers of importance are the Bhāgīrathi, the Jalangī with the Bhairab and the Mātābhānga with the Churni, known as the Nadiā river. They are deltaic branches of the Ganges and form the headwaters of the Hooghly river. The country is well provided with railways and roads. Tanks are numerous and in, and around, the villages they provide drinking water. Wells are to be found only in towns and large villages.

The field head-quarters of the party opened at Krishnagar on the 10th November 1917 and closed on the 10th April 1918. The party took the field in reduced strength, a section remaining in Shillong for half-inch mapping.

The general health of the party throughout the field season was good. Among the lower subordinates there was only one prolonged case of sickness, due to fever. One khalasi died of cholera.

Plane-tabling.—The country lay in the flat, open plains of Bengal. The work was of an easy nature as most of it was done by interpolation, except in the interior of villages, where traversing had to be resorted to.

For the greater part of the season the topographical surveyors working on the one-inch scale were divided into two camps.

No. 1 Camp, consisting of 10 surveyors, under Mr. B. C. Newland, and later, under Mr. A. B. Hunter, surveyed on the one-inch scale 1,363 square miles in sheets 79 $\frac{A}{7, 10, 11, 13, 14}$ and revised 34 square miles of previous survey on the same scale in sheet 79 $\frac{A}{0}$.

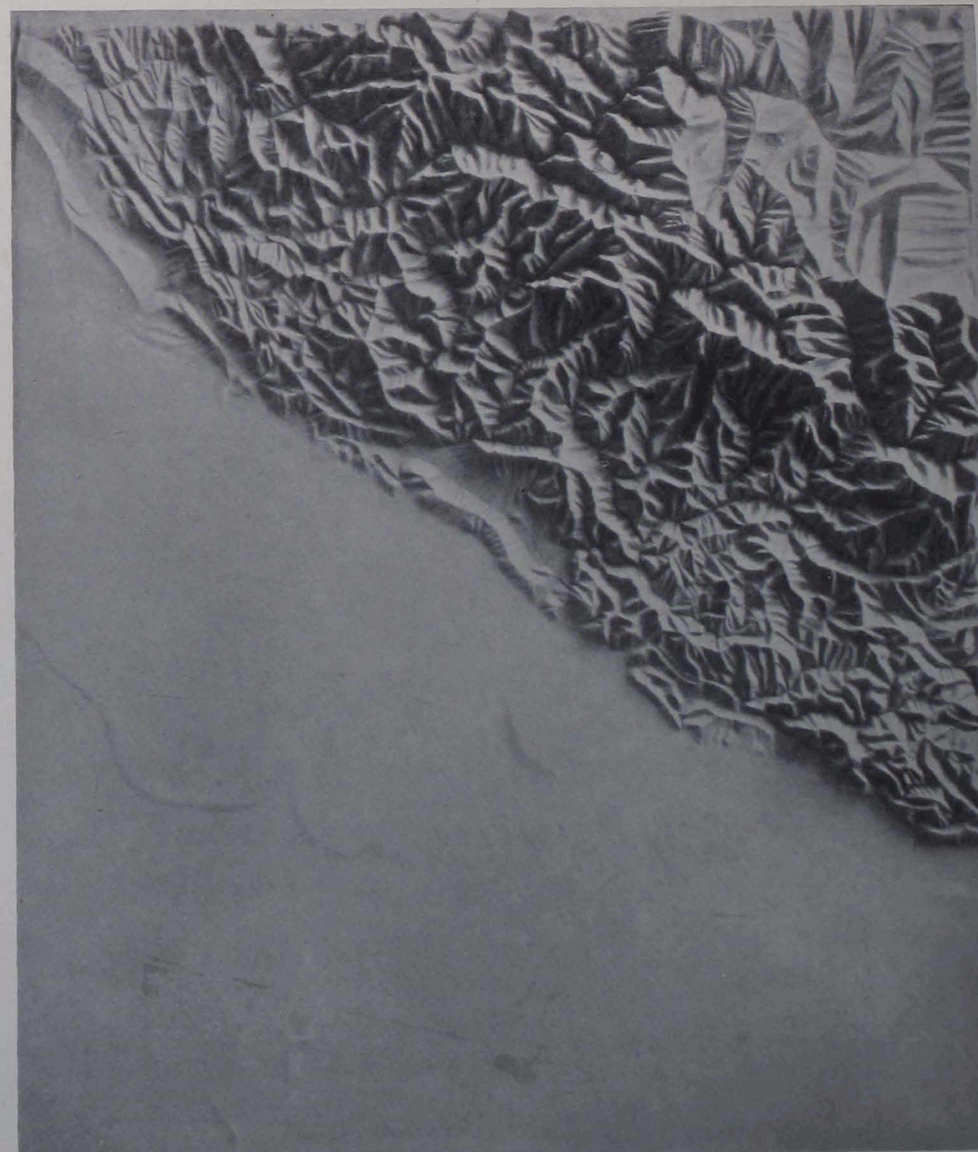
No. 2 Camp, of 3 surveyors under Mr. A. K. Mitra, surveyed 821 square miles on the 1-inch scale in sheets 79 $\frac{A}{3, 4, 8}$.

Mr. Newland returned to Shillong after making over charge of No. 1 Camp to Mr. Hunter about the end of December, and took up the supervision there of the half-inch mapping.

The cost-rate for original detail survey works out to Rs. 8·0 per square mile and that for revision survey to Rs. 3·4 per square mile.

PHOTOGRAPHS OF A MODEL OF $\frac{1}{M}$ SHEET No. 53, CONSTRUCTED BY MAJOR M. O'C. TANDY, R.E.

(a) LIGHTED FROM THE N.-W.



(b) LIGHTED FROM THE N.-E.

It is thought that the publication of these photographs may be of interest to officers concerned with the preparation of hill shade originals: the superiority of the N.-E. over the N.-W. light for this particular sheet is due to the fact that the ranges trend from S.-E. to N.-W.

Photo-engraved & printed at the Offices of the Survey of India, Calcutta, 1919.

Triangulation.— No triangulation was carried out by the party during the season under report.

Traversing.— The country traversed was much of the same nature as that surveyed, except that in the south-east portion there are extensive areas of marshy lands where boats were the means of transport.

The traverse camp consisted of two Upper Subordinates and two traversers under Mr. Mitra and executed advance traversing in sheets 79 $\frac{B}{1, 2, 5, 6, 9, 10, 13, 14}$ for detail one-inch survey in subsequent seasons at a cost of Rs. 11, 344. The cost-rate of this per linear mile worked out to Rs. 13·7. The traversing was purely for topographical purposes, main and sub-circuits being run along roads and railways, and a few sub-circuits across country, where it was open. From the traverse stations conspicuous objects, such as temples, mosques, isolated trees, large buildings and bridges were fixed as intersected points. Connections were made with 15 G. T. stations, and 1, 785 intersected points fixed by observations from traverse stations. There were 34 stations permanently marked by circles and dots cut on the masonry of bridges, culverts and mile-stones, the remaining traverse stations were marked by wooden pegs.

Recess Duties.— (*a*) The fair-mapping of the field season's out-turn, comprising 8 one-inch sheets, was carried out by 2 sections.

No. 1 Section, consisted of one Upper Subordinate and 6 draftsmen. It was under Mr. Hunter up to 20th May 1918, and was then taken over by Mr. Biggie. It fair-mapped sheets 79 $\frac{A}{3, 4, 7, 8, 11}$ for publication on the one-inch scale.

No. 2 Section, consisted of 6 draftsmen under Mr. Newland, and carried out the fair-mapping, for publication on the one-inch scale, of sheets 79 $\frac{A}{10, 13, 14}$; in addition to sheets 93 $\frac{E}{N. W., N. E.}$, 94 $\frac{B}{N.E., S.E.}$, 94 $\frac{C}{N. E.}$ and 95 $\frac{K}{N. W.}$ for publication on the half-inch scale. Sheet 83 $\frac{J}{N.W.}$ has just been put in hand. This section was taken over by Mr. Mitra on 4th September 1918 when Mr. Newland was transferred to Mesopotamia.

The fair-mapping of all the 1-inch sheets was carried out by the direct-mapping process on blue print enlargements from the plane-table sections, that of the ½-inch sheets on blue print enlargements from the component 1-inch published sheets.

The out-turn of 1-inch fair-mapping is 1, 777 square miles and that of ½-inch is 4, 870 square miles.

The cost-rate for 1-inch mapping is Rs. 7·4 per square mile and that for ½-inch mapping is Rs. 1·9 per square mile.

The fair-mapping of the 1-inch sheets will be completed before the party takes the field except as regards the entry of district and sub-division boundaries, traces of which have been sent to the Collectors for verification. Of the ½-inch mapping, sheets 93 $\frac{E}{N. W.}$, 94 $\frac{B}{S. E.}$ and 94 $\frac{C}{N. E.}$ are complete except for the final examination.

(*b*) Other recess duties comprised the computation of the season's traversing, of which that required for 6 sheets will be ready at the close of the recess; and the preparation of triangulation charts and manuscript lists of data of all triangulation done by the party since its transfer to the Eastern Circle. Mr. Hunter, assisted by an Upper Subordinate and a small staff of computers, had charge of these duties.

Charts of degree sheets 73 B and 73 F have been submitted to the Superintendent of the Trigonometrical Survey. The preparation of degree charts 64 N and 64 O was in hand during the year, but they were not completed.

Miscellaneous.— The river Hooghly and its tributaries the Bhāgīrathi and Jalangī were surveyed in seasons 1853-56 by the Bengal Revenue Survey, and in season 1917-18 by this party. The new survey has disclosed the fact that the Bhāgīrathi, which lower down after its confluence with the Jalangī is called the Hooghly, has completely changed its course. The new river has forced a passage for itself right across its former course, now to the east of it, now to the west, and formerly where a large loop in the river was towards the east it is now towards the west. After a lapse of over 60 years such changes are bound to take place in the course of every stream, whether large or small, flowing through the plains of Bengal, which to a great extent are alluvial in character, as it is well known that in country of this description streams are constantly altering their courses, eating away on one bank and depositing on the other, until the channel in which they formerly flowed becomes silted up, and the water is compelled to seek another course.

No. 10 PARTY (UPPER BURMA).

By M. C. Petters.

Personnel.

Provincial Officers.

Mr. M. C. Petters, in charge to 20th June and again from 6th September 1918 to end of year.
" W. G. Jarbo, in charge from 21st June to 5th September 1918.
" H. H. Creed.
" A. V. Dickson.
" Dhirendra Nath Banerji, 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.

The previous season's operations were continued northwards and embraced sheets $92\frac{C}{6, 10, 14}$ and sheets $92\frac{E}{N.W., N.E., S.W.}$. The triangulation was extended in sheets $92\frac{E}{N.W., N.E.}$.

The country surveyed in sheets $92\frac{E}{N.W., N.E., S.W.}$ consisted of the high mountainous tract at the headwaters of the Irrawaddy river, and varied in altitude from 600 feet in the low ground to 15,000 feet above sea-level in the high range forming the water-parting of the Brahmaputra and Irrawaddy rivers. The whole of this area was densely wooded and heavy jungle clearing, for from 2 to 4 days at each site, was necessary at selected places before plane-table fixings by resection were possible. The rate of work was very much impeded by rain and heavy mist, which made plane-table fixings by interpolation impossible for days together. Nung and Shan coolies were employed as porters for the carriage of equipment and rations over large areas in which no roads and villages existed. About 56 miles of mule road had to be made to enable rations to be stocked at depots within reasonable distances of surveyors' camps. All rations other than rice had to be transported from Myitkyinā over, in some instances, a distance of 30 marches. The area surveyed in sheets $92\frac{C}{6, 10, 14}$ varies in altitude from 600 to 5,000 feet, and is cut up by numerous low-lying valleys covered with dense forest growth.

The field season opened on 1st November 1917 for Nos. 1, 2 and 3 Camps and the triangulators, and on 1st December 1917 for No. 4 Camp and the Training Section. The field season closed on different dates between 4th and 20th June 1918.

The health of the party was good during the field season, but a large number of men suffered from ulcers due to leech bites and the stings of a variety of poisonous flies.

Plane-tabling.—The programme of survey on the one-inch scale was completed, but, owing to transfers from the party at the commencement of the field season and to heavy rain in March, April and May, the half-inch area was not finished, and portions of sheets $92\frac{E}{N.W., N.E., S.W.}$ remain to be surveyed. The work was divided into three camps under Messrs. W. G. Jarbo, H. H. Creed and D. N. Banerji, and, towards the end of the season, Mr. A. V. Dickson was in charge of a small camp. Mr. Maung Kyaw Nyein was in charge of the instruction of pupils.

No. 1 Camp, under Mr. W. G. Jarbo with 7 surveyors, completed an area of 1,356 square miles on the half-inch scale in sheets $92\frac{E}{N.W., S.W.}$. Towards the end of the season two of these surveyors were transferred to a small camp under Mr. A. V. Dickson.

No. 2 Camp, under Mr. H. H. Creed with 5 surveyors, completed an area of 18 square miles on the one-inch in sheets $92\frac{E}{9, 13}$, and 960 square miles on the half-inch in sheet $92\frac{E}{N.E.}$.

No. 3 Camp, under Mr. A. V. Dickson with 2 surveyors transferred from No. 1 Camp, continued, on the half-inch scale, the survey of sheet $92\frac{E}{S.W.}$, and completed an area of 108 square miles.

No. 4 Camp, under Mr. D. N. Banerji with 9 surveyors, completed an area of 459 square miles on the one-inch scale in sheets $92\frac{C}{6, 10}$. Mr. Banerji personally surveyed 9 square miles of this total.

Mr. Maung Kyaw Nyein was in charge of a Training Section composed of 7 pupils, 4 of whom were attached to No. 10 from No. 11 Party for training. The work of the pupils had to be rigorously tested before being accepted. This was done by tests carried out on the original plane-tables, and, after the small areas had been transferred on to a large block, by a further test and correction by the Camp Officer. Mr. Maung Kyaw Nyein personally surveyed an area of 67 square miles, and the pupils 185 square miles on the one-inch scale in sheet 92 $\frac{C}{14}$.

Out-turns and cost-rates are as follows:—
½-inch survey, 2,424 square miles @ Rs. 24·7 per square mile.
1-inch „ , 477 „ „ @ Rs. 48·7 „ „ „

The cost-rate of the area surveyed on the 1-inch scale by the Training Section is not included in the above.

The cost-rates are higher than those of the previous year, owing to the greater distances, as compared with last year, of the centre of gravity of the *locale* of operations from the rail-head at Myitkyinā.

Triangulation.—Mr. Hayat Muhammad, K. S., triangulated an area of 1,684 square miles for detail survey on the one-inch and half-inch scales, in sheets 92 $\frac{E}{N.W., N.E.}$, while Mr. Ram Prasad, R. S. carried out the triangulation of a further 1,400 square miles for purposes of detail survey on the ½-inch scale.

An endeavour was made to extend the net-work of triangulation in sheet 92 E, westwards to the high watershed forming the boundary between Burma and Assam, to admit of a convenient connection at some future date with the Assam triangulation. Mr. A. V. Dickson was deputed for this work, but, owing to the refusal of local coolies to cross the snow-line, after two attempts the extension had to be postponed.

The cost-rate of triangulation executed for purposes of detail survey on the 1-inch scale worked out to Rs. 12·7 per square mile, and that for those of detail survey on the ½-inch scale to Rs. 7·4 per square mile.

Recess Duties.—(*a*) The fair-mapping of the season's out-turn, comprising 3 complete one-inch sheets and portions of 3 half-inch sheets, was carried out by two sections under the supervision of Messrs. H. H. Creed (3 sheets) and D. N. Banerji (3 sheets). Except for a small area, of which the survey was completed late in the season, the direct-mapping system was again adopted this year, and appreciably expedited the progress of the work. Sheets 92 $\frac{C}{6, 10, 14}$ will be submitted for publication before the party takes the field. Sheets 92 $\frac{E}{N.W., N.E., S.W.}$ are not completely surveyed and any portions of the surveyed areas remaining unmapped at the end of the recess will be completed in the Maymyo drawing office.

In addition, sheets 92 $\frac{C}{7, 11, 15}$, $\frac{G}{1, 5}$ and sheets 92 $\frac{F}{N.W., N.E., S.E.}$ of the previous season have been submitted for publication during the year under report. The fair originals of sheets 92 $\frac{C}{12}$ and 92 $\frac{G}{6}$ were also corrected and brought up to date. Sheet 92 $\frac{F}{S.W.}$ was surveyed and fair-mapped last year but the delay in its submission for publication is due to the district boundary between Myitkyinā and Putao, which has been under investigation by the district authorities, not being finally settled.

The out-turn of one-inch and half-inch mapping is 805 and 1,130 square miles respectively, and the cost-rates Rs. 12·2 and Rs. 5·7 per square mile respectively. These cost-rates are somewhat higher than last year. This is due to the drawing power of the party being much reduced by the recent transfers of its more skilled draftsmen—2 officers of the Upper Subordinate Service and 3 of the Lower Subordinate Service being sent on service overseas, and one first class surveyor being transferred from the party. One officer of the Upper Subordinate Service retired on pension during the year.

(*b*) The computations of the season's triangulation were completed during the recess by Mr. A. V. Dickson assisted by Mr. D. N. Saha and two computers.

No. 11 PARTY (LOWER BURMA).

By J. O. Greiff.

The party was employed in Lower Burma, in the districts of Mergui, Tavoy and Amherst. The drawing office remained at Maymyo.

Personnel.

Provincial Officers.

Mr. J. O. Greiff in charge.
,, C. E. C. French, to 3rd June 1918.
,, O. J. H. Hart.
,, E. M. Kenny, from 1st June 1918.
,, C. O. Picard.

Upper Subordinate Service.

Mr. Lachman Daji Jadu, R. B., to 18th August 1918.
,, Dalbir Rai
,, Pratul Chandra Sen Gupta, B. Sc.

Lower Subordinate Service.

34 Surveyors, etc.

The area surveyed on all scales was 1,475 square miles, distributed as follows :—

1,158 square miles of plane-tabling on the 1-inch scale, in sheets 95 $\frac{K}{15\ (part),\ 16\ (part)}$, 95 $\frac{O}{3\ (part),\ 4\ (part)}$ and 95 $\frac{P}{1\ (part),\ 6\ (part),\ 8\ (part),\ 12}$, in the Mergui district.

Original survey on the 2-inch scale of 282 square miles of reserved forest, in sheets 95 $\frac{J}{1,\ 5}$, in the Tavoy district.

Original special survey on the 4-inch scale of 35 square miles, in sheets 95 $\frac{I}{2,\ 6,\ 7}$, in the Amherst district.

The field season extended from the 14th November 1917 to varying dates between the 15th May and 2nd July 1918. The season was prolonged owing to abnormal rain in May. From the 7th to 28th of May it rained incessantly, the rainfall being more than double the normal fall.

The surveyors and camp officers left Mergui on the 21st November, and got to Kyaukpya, on the Tenasserim river, on the 15th December. Work generally was started in the Mergui district about the 15th January 1918. At the start small boats were not available, although requisitioned at Tatmu a fortnight in advance of the arrival of the camp. The average number of working days is about 100 per surveyor for the season, this includes days spent in cutting and clearing hills. This figure is significant of the delay there was in transporting a large camp over country with little habitation and precarious means of communications. Work in Tavoy began about the 20th December 1917.

The health of the party was not good. There was quite an epidemic of malaria, dysentery, and diarrhœa, from which the surveyors and menials suffered badly. The average daily attendance at the camp hospital was twelve. Seven khalasis died as a result of these complaints and pneumonia.

The country surveyed in the Mergui district lay in the upper valley of the Tenasserim river and extended to the confines of Burma on the east, and, on the west, to the main watershed dividing the Tenasserim valley and the sea-board area. In the Tavoy district a reserved forest area was surveyed on the upper waters of the Tavoy river. This basin separates Tavoy from Siam on the east, and from the district of Amherst to the north. The mean range of elevation, in both these areas, is from about 200 feet in the valleys to over 5,000 feet on the watersheds. The hills are very densely wooded, with dark, impenetrable evergreen forests, within which gloom and silence reign. The undergrowth is a tangled mass of creepers, intermixed with cane and bamboo. In the Tavoy area there was a fair amount of undulating ground, densely wooded, and consequently difficult to survey. *Machans* had to be built on tree-tops to enable the surveyor to fix his position and obtain some check on the accuracy of his plane-table traversing.

The upper valley of the Tenasserim river is interesting and possesses much beauty. Along the banks of the river are to be found evidences of this tract having once, probably a hundred years ago, been inhabited. The banks are rich in wild flowers, and the trees festooned with orchids of the *Dendrobium* variety.

The river in this part of its course is more of the nature of a torrent. The gradient is not uniform, and the river has the appearance of descending in a series of steps. Rapids are numerous, the majority being difficult to negotiate. The channel is navigable only by canoes or dug-outs. When ascending the river, portage is necessary across these rapids. Each boat has to be unloaded, the loads carried across by coolies, and the empty boats pulled over. The Karen is extremely skilful in steering his little boat over the rapids when descending, but notwithstanding, there were frequent mishaps, resulting in losses; and, in one instance, very nearly in the death of a menial. The country in Mergui, except for about half a dozen small Karen villages along the banks of the Tenasserim river is uninhabited and without communications of any kind. Every road and path had to be cut and cleared. Along both banks of the river, from Sanpe village, in sheet $95\frac{L}{14}$, to the north limit of the season's work, roads had to be cut, to make mule transport practicable.

The provisioning and rationing of the camps employed in Mergui presented great difficulties, and was a source of heavy expenditure. The head-quarters of the camp officer was 14 stages by boat from Mergui. In the country itself no provisions of any kind, except a few fowls, were procurable. Rice in sufficient quantity for the use of local coolies on duty with the various camps was not obtainable. These coolies had to be provisioned by the party. As far as Tatmu on the banks of the Tenasserim river and eight stages from Mergui, the river is practicable for moderate-sized boats. From this point up, only dug-outs can be used.

Kyaukpya, situated on the Tenasserim river, and 4 stages higher up than Tatmu, was selected as the head-quarters of one of the camps into which the party was divided. From it the mule transport was used for the distribution of supplies to the surveyors working in the field.

Plane-tabling.— The party was divided into four field camps as follows:—

No. 1 Camp, under Mr. Lachman Daji Jadu, R.B. with Mr. Hart and seven surveyors completed the survey, on the one-inch scale, of 842 square miles in sheets $95\frac{K}{15(part), 16(part)}$, $95\frac{O}{3(part), 4(part)}$, $95\frac{P}{1(part, 6(part)}$, in the Mergui district.

No. 2 Camp, under Mr. P. C. Sen Gupta with seven surveyors completed the survey, on the two-inch scale, of 282 square miles of the Heinze and Kaleinaung reserved forests in sheets $95\frac{J}{1,5}$, in the Tavoy district. It also ran 65 linear miles of simple and boundary traversing.

No. 3 Camp, under Mr. Dalbir Rai with three surveyors completed the survey, on the one-inch scale, of 316 square miles in sheets $95\frac{P}{8(part), 12}$ in the Mergui district.

No. 4 Camp consisted of four surveyors and completed the special survey, on the four-inch scale, of 35 square miles in the Kyunchaung, Bawchaung, Mezali, Megwa and Thinganny-inaung reserved forests in sheets $95\frac{I}{2,6,7}$, Amherst district, and of 70 square miles of supplementary triangulation and 68 linear miles of boundary traversing. The direction and control of the work of this camp was under the officer in charge of the party, while the actual checking of the plane-tabling in the field was done by surveyor Muhammad Yusuf Khan, in addition to the triangulation and traversing above mentioned. The officer in charge of the party had not time to visit the surveyors a second time.

The cost-rates for the different classes of survey are as follows :—

Original one-inch	Rs. 74·4	per square mile.
Original two-inch	Rs. 122·8	" " "
Original four-inch	Rs. 173·7	" " "

These cost-rates appear to be high, but this is due to the long distances that had to be covered, across practically uninhabited and roadless country, before work could be started; to the heavy expenditure on account of transport for conveyance of supplies; and to the stoppage of work for nearly a month owing to incessant rain. The cost of boat hire alone, for the carriage of supplies to No. 1 Camp, in the Tenasserim valley, was over Rs. 1,000/- monthly. Approximately 300 miles of road was cut and cleared in the Tenasserim valley for mule transport. During the past three seasons the party has been moving up the valleys, and consequently getting further away from its base of supplies. For the one-inch work, the average out-turn per man for 24 working days is higher this season than in the previous year, being 27 square miles against 20 square miles.

The high cost-rate for the four-inch detail survey is due to the scattered nature of the work. The small area surveyed was spread over seven reserves. Supplies were not procurable locally, and had to be imported from Moulmein, over a distance of about 120 miles.

The same remarks apply to the cost-rates for two-inch work. In the area of 2-inch survey there was much prospecting for wolfram being done and the daily rate for labour was

Rs. 1/4/- to Rs. 1/8/-. With the exception of one road leading into Siam, all others to the main watershed had to be cut and cleared.

Triangulation.—New triangulation was carried out over an area of 2,780 square miles by Mr. Picard in sheets 94 $\frac{\text{H}}{\text{16 (part)}}$, 94 $\frac{\text{L}}{\text{4, 8, 12 (parts)}}$, 95 $\frac{\text{E}}{\text{9, 10, 13, 14}}$, 95 $\frac{\text{I}}{\text{1, 2, 5, 6, 7, 9, 10, 11}}$, in the Amherst district. The cost-rate per square mile is Rs. 7·6.

The country triangulated consisted of a series of ranges, extending from the Burma-Siam boundary to the sea-coast, drained by the waters of the Ye, Ataran, Zami, and Haungtharaw rivers, and having a mean elevation of between 3,000 and 4,000 feet. Some of the peaks in the extreme east rise to over 6,000 feet. The country is fairly well inhabited and supplied with cart roads and bridle-paths. The Irrawaddy Flotilla Company has a daily steam-launch service between Moulmein and Kya-in Seikkyi, about sixty miles south, the head-quarters of the township of the same name. A large part of the area triangulated is reserved forest. The hills are heavily wooded, those inland being steep and precipitous. A peculiar, and interesting, feature in the country are the out-crops of lime-stone rock in the plains and valleys. These take the form of a series of steeply carved hills rising sheer from the base to elevations ranging from a 100 feet to 2,000 feet. Hot springs are found at the bases of several.

Recess Duties.—(*a*) In recess the party was divided into three sections.

The drawing office was under the supervision of Mr. French during the field season, and was taken over by Mr. Hart in June 1918, on Mr. French's transfer to the Southern Circle. During the year under report 15 one-inch sheets were submitted for publication. The fair-mapping done comprised 1,511 square miles on the one-inch scale in sheets 93 $\frac{\text{C}}{\text{5, 9}}$, 93 $\frac{\text{B}}{\text{8, 12}}$, 95 $\frac{\text{J}}{\text{6}}$, 95 $\frac{\text{K}}{\text{15, 16}}$, 95 $\frac{\text{L}}{\text{6, 7, 11, 12, 13, 15, 16}}$ and 95 $\frac{\text{P}}{\text{2, 4, 6, 7}}$; 2,501 square miles, on the half-inch scale, in sheets 93 $\frac{\text{A}}{\text{N. E., S. E.}}$, 93 $\frac{\text{E}}{\text{S. W.}}$, 93 $\frac{\text{I}}{\text{N. W.}}$; also 1,375 square miles, on the quarter-inch scale, in sheets 93 E. and 93 J.

Blue prints and traces of particular areas in the Tavoy and Mergui districts were prepared and supplied to the district officials in the interests of mining and forest operations.

Mr. Kenny supervised the fair-mapping of a further 631 square miles on the one-inch scale in sheets 95 $\frac{\text{O}}{\text{3,4}}$, 95 $\frac{\text{P}}{\text{8,12}}$. Also the forest boundary plots, on the four-inch scale, of the areas surveyed in the Amherst district.

The whole of the area surveyed on the one-inch scale will be fair-mapped before the party takes the field again.

The areas of mapping executed and the cost-rates for each scale are as follows:—

2,142	square miles	on the one-inch scale at Rs. 9·0	per square mile.
2,501	do.	half-inch scale at Rs. 2·1	,,
1,375	do.	quarter-inch scale at Rs. 1·2	,,

The higher rates for mapping are due to a great deal of sickness this recess amongst the surveyors and draftsmen. During the influenza epidemic, more than half the party was laid up for nearly a month.

(*b*) A section, under Mr. Picard, was employed on completing the computations left unfinished from the previous season's work, the computations of the current field season's triangulation, and the preparation of degree triangulation charts 95 L, 95 O, 95 P. It has not been possible to make much progress with the computations for the current season's triangulation, owing to lack of fully trained computers in the party. It is hoped during the coming field season to be able to complete the computations. The degree triangulation charts are well advanced, and should be disposed of next recess.

Miscellaneous.— Last field season, on account of the limitations imposed on the number of menials that could be recruited from Hazāribāgh, the deficit was made up by the employment of ticket-of-leave men, supplied by the Burma Government. The employment of prison labour in mines and public works departments had been tried by the Local Government in the previous year, with certain amount of success, and its introduction into the Survey of India was regarded as a promising experiment. The innovation was a failure, from the points of view both of economy and efficiency. The prisoners were conditionally released for the period they had contracted to serve. The rate of pay fixed by the Local Government was Rs. 18/- per mensem. They were collected, from the various jails in Burma, at Rangoon whence conveyed under police escort to Mergui and there handed over to the party on each signing a contract bond. With the exception of a few, these men were taken over by the party practically destitute. They had to be provided with clothes, bedding, shoes, cooking pots and pans etc. and had to be fed by the party till they took the field. The restrictions which had to be imposed while they were in service with the party, their rationing, disbursement of pay in small amounts, roll-calls, police reports etc., made the undertaking quite an onerous and troublesome one. The upkeep of the supply of rations was most troublesome. The demands for supplies made by these men were extravagant in the extreme, and the compliance with these only to the extent of the necessaries of life, was the cause of much discontent.

Physically also the men were a total failure. Large numbers at a time were invalided with malarial fever, from the effects of which they never seemed to recover. They were not amenable to discipline imposed by Indian surveyors, though willing to submit to it under a European.

The season's operations along the Burma-Siam boundary disclosed errors in the position of the watershed as shown on the existing maps to the scale of 8 miles = 1 inch. As the position of the boundary depends on that of this watershed, it seems probable that the geographical position of the former needs revision on the old maps. The matter was reported to the Deputy Commissioner of Mergui.

4 surveyors and 1 draftsman were transferred from the party for work overseas, in Mesopotamia and East Africa, during the recess season.

No. 12 PARTY (ASSAM).

By H. W. Biggie.

PERSONNEL.

Provincial Officers.

Mr. H. W. Biggie, in charge.
,, E. G. Hardinge.
,, Pramadaranjan Ray, R. S.
,, Prafulla Chandra Mitra, B. A.
,, K. S. Gopaluchari, B. A.

Upper Subordinate Service.

Mr. Girija Sonker Bagchi.

Lower Subordinate Service.

29 Surveyors, etc.

This party continued topographical operations in the Assam valley in the Lakhimpur and Sibsāgar districts and the Central and Eastern Sections of the North-East Frontier Tract. The country worked over lies mostly in the alluvial plains of the Brahmaputra river and includes, on its southern limits, the northern slopes of the hills bordering the Nāgā tribal area, which rise here to 3,000 feet above sea-level. A small area of 37 square miles was surveyed in Sikkim and Bhutān in connection with the settlement of a portion of the inter-state boundary.

The field season extended over a period of about five and a half months, from November to the middle of April, during which time the head-quarters of the party remained at Dibrugarh.

The health of the party was not entirely satisfactory during the field season, at the commencement of which the officer in charge was laid up for two weeks in Shillong and the arrangements at Dibrugarh for starting field work were delegated, as a temporary measure, to Mr. Hardinge. These arrangements were much delayed by the menial strength of the party from Hazāribāgh having to go into quarantine on their arrival, due to an outbreak of cholera en-route, which resulted in four deaths out of seven cases. Subsequently malarial fever and scabies were the chief forms of sickness among menials. Mr. Bagchi was laid up with fever for about ten days. Among the lower subordinates there were four cases of illness more or less prolonged. One of these men had to be sent home on medical leave soon after taking the field. Another surveyor who suffered during the field season from malarial fever in a mild form, became worse after reaching his home, and died there while on departmental leave.

Plane-tabling.—The greater portion of the country that came under survey is covered with dense forest, consisting of trees and bamboos with undergrowth of scrub, cane and thorny creepers. Low hills rising to an altitude of about 650 feet above sea-level were met with in the Upper Dihing forest reserve and in the oil-producing area round Digboi, in sheet $83\frac{M}{11}$. In the Jaipur forest reserve, in sheet $83\frac{M}{8}$, the hills attain an altitude of about 1,600 feet above sea-level. Elsewhere the country plane-tabled was generally flat. The forests of the Assam valley contain numerous swamps generally known as *bil* or *daloni*, which, in places, occur in almost continuous stretches and are never, at any time of the year, entirely free from damp.

They favour a luxuriant growth of knotted masses of evergreen vegetation, in which the thorny cane was the surveyor's worst enemy. Elephant grass occurs here and there. Leeches were also a great source of trouble, and the usual precaution of providing leech-bite socks was adopted, and found to be a sufficient protection. Besides the Brahmaputra river, which flows in a south-westerly direction, the Dibāng, Dihāng, Luhit, Lāli, Burhi Dihing, Dibru and Disāng are the only other streams of importance. The open parts of the area that came under survey contain numerous tea gardens and rice cultivation. There are a few good winter roads maintained by Government agency—private enterprise on the part of garden managers has led to the construction of good motorable roads in tea areas, but permission for carts to use these roads is not generally given. A few foot-paths are the only means of communication in the forest-clad portions of the area dealt with.

The detail work in the field was divided into two camps.

That under Mr. Hardinge, with seven surveyors and two pupils, surveyed 608 square miles on the one-inch scale and 62 square miles on the two-inch scale in sheets 83 $\frac{M}{9, 12, 14, 15, 16 \text{ (parts)}}$ and 83 $\frac{M}{10, 11}$.

That under Mr. Pramadaranjan Ray, R. S., with Mr. Gopalachari, one Sub-Assistant Superintendent, ten surveyors and three pupils surveyed 539 square miles on the one-inch scale and 129 square miles on the two-inch scale in sheets 83 $\frac{M}{5, 8 \text{ (parts)}}$ and 83 $\frac{M}{6, 7}$.

For the most part the method of surveying was based on traversing with the chain and compass, the plane-table being set up at alternate stations. To help visibility through foliage in jungle, the clearing of which would have entailed an inordinate expenditure of time and labour, small mirrors were used as signals by both back and forward flag men. Rays to objects lying on either side of the chain and compass traverse were taken to sound with sufficient precision up to short distances. The method of checking work in jungle-clad country was the same as that adopted in surveying it. The party's elephants were found to be invaluable as a means of transport in forest areas, and enabled the work of surveyors in those areas to be efficiently checked.

In addition to the areas of 1-inch plane-tabling mentioned above, the survey on that scale of 3 square miles of country along the proposed alignment of the Sibsāgar-Nāgā Hills district boundary, in sheet 83 $\frac{J}{13}$, was carried out in connection with the settlement of that boundary. These portions of this boundary had remained unsurveyed when the survey of the remainder had been carried out in the previous season. The cost-rates per square mile for one-inch and two-inch surveys are respectively Rs. 33·9 and Rs. 104·4.

The area of 37 square miles surveyed on the one-inch scale in Sikkim and Bhutān lies in the Himālayas, and ranges in altitude from 6,000 to 12,000 feet above sea-level. It is densely clad in forest growth, and was surveyed by surveyor Amrit Ram. The cost-rate for this survey was Rs. 18·0 per square mile.

The portion of the district boundary between Sibsāgar and Darrang, where it crosses the Brahmaputra river along a straight alignment, in sheets 83 $\frac{F}{9, 10}$, has been shown on the map to accord with the alignment of the topographical survey of 1914-15, the point marking the northern end of the alignment of this boundary having been washed away with the river bank on which it stood. This point was refixed on the north bank on an extension of the alignment of 1914-15. Cairns were built over the points marking the position of the alignment on each bank of the river where, as relayed in 1917-18, it crosses it. Each point has two reference pillars or cairns erected near it, but on safe ground, and either point, and its two reference marks lie in a straight line. The distances in chains from each point to the nearer of its two reference marks, and thence to the second mark, were recorded on the original field section, and, with the help of this information the direction of the alignment can be relaid in the future, if necessary. The work was done on the one-inch scale by Mr. Mitra and cost Rs. 514.

Triangulation.—A little supplementary triangulation, which was to have been done in sheet 83 $\frac{M}{8}$ to help the survey of the hills in the Jaipur reserve, had to be abandoned. Owing to the extreme density of the jungle covering flat-topped knolls, it was found impossible to obtain intervisibility between selected points of observation and stations of previous triangulation. Even the attempt to provide intersected points from G. T. stations had to be given up, as nobody could be found who could climb the very tall, massive trees which were selected for flags or signals. Some of these rose to a height of 180 feet. It was decided to base the work on existing traverse stations, and, with care in the method of traversing with the chain and compass, these were found sufficient for purposes of survey.

Traversing.—The greater portion of the area traversed is low-lying and densely wooded. Village-sites are wide apart over the area, but are more numerous along the main roads and rivers. In the more open parts there are tea gardens and rice cultivation. The work was under Mr. Mitra with seven traversers, and lay chiefly in sheets 83 $\frac{I}{2, 3, 4, 6, 7, 8, 10, 11, 14}$. Of the total of 629 linear miles traversed, 51 linear miles consisted of traversing of artificial boundaries of reserved forests, 211 of the stations of observation were permanently marked, and 281 were marked with zinc cylinders.

The cost-rate per linear mile for 578 miles of traversing for topographical survey and 51 linear miles of traversing of artificial forest boundaries is Rs. 37·9 and Rs. 21·7 respectively.

The cost-rate per square mile for the area of 1,519 square miles traversed is Rs. 15·1.

Recess Duties.—(*a*) The fair-mapping was divided into two sections.

No. 1 Section, under Mr. Hardinge with eight surveyors, did the fair-mapping of sheets 83 $\frac{M}{9, 12, 15, 16 \text{ (parts)}}$, 83 $\frac{M}{10, 11}$ and a small area in sheet 83 $\frac{M}{14}$ which was fair-mapped as an outrigger to sheet 83 $\frac{M}{10}$.

No. 2 Section, under Mr. Pramadaranjan Ray, R. S. with one Sub-Assistant Superintendent and seven surveyors, did the fair-mapping of sheets 83 $\frac{M}{5, 8 \text{ (parts)}}$ and 83 $\frac{M}{6, 7}$.

Mr. Gopalachari worked with each section for equal periods.

Most of the fair-mapping was done on blue prints for direct-mapping. The process of transferring from traces either enlarged or reduced was adopted for 129 square miles of one-inch work and for the whole of the two-inch work surveyed during the year under report. An area of 53 square miles in the Upper Dihing reserve, West Block, surveyed in seasons 1913-1915 on the four-inch scale, was first re-drawn on blue prints to scale of the four-inch published sheets. Reductions from these drawings were then prepared for use by the transfer process. For the remaining portion, 45 square miles, of this reserve, which was surveyed on the two-inch scale in 1912-14, reductions from the two-inch published sheets were prepared for use by the transfer process.

The total area fair-mapped for publication on the one-inch scale is 1,387 square miles, and was carried out at a cost of Rs. 16·8 per square mile.

(*b*) Mr. P. C. Mitra, with four traversers and computers, completed the computations of traverses run in field season 1917-18 for detail survey in the following year, and the preparation of four-inch plots of traverses of artificial boundaries of reserved forests for the Forest Department.

Miscellaneous.—Owing to war conditions there was difficulty in procuring the full complement of Hazāribāgh khalasis. To make up the deficiency the Superintendent, Eastern Circle imported 22 men from Gondā and the officer in charge No. 9 Party arranged for 30 Kols from Singhbhūm. The men from Gondā arrived early in December. They were of a poor type, physically, and unsuited for work in the jungles of Assam. They clamoured frequently for their release, and after they had refunded their advances and paid the half-cost of warm-clothing issued to them they were allowed to go back to their homes with the least delay.

Owing to elephant-catching operations in the Dibru reserve, the work of two surveyors employed there was temporarily stopped. They were employed elsewhere until the end of March, and returned with three other surveyors to complete the area in the reserve in April.

The unsettled condition of the boundaries dealt with was again a source of delay, and necessitated numerous references. The Deputy Commissioner, Lakhimpur was requested to have the alignment of the new boundary of the Lakhimpur Frontier Tract demarcated for purposes of survey, and he very kindly deputed Maulvi S. S. M. Chisti, Sub-Deputy Collector, Tinsukia Circle for this duty. The alignment as demarcated has been surveyed and shown on the fair-sheet and the question of its acceptance is now before the Deputy Commissioner for approval.

Owing to supplies not being obtainable locally, rice and *dal* had to be sent periodically to three surveyors and their squads working in the Dibru reserve and in the North-East Frontier Tract in the area adjoining the reserve.

TABLE I.

OUT-TURNS OF PLANE-TABLING 1917-18.

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 ...	1,286	73·6	5·9	
		S	No. 6	Hyderābād ...	6,675	53·8	6·2	
		E	No. 10	Upper Burma ...	2,501	76·3	0·7	0·9
1-inch	Original Survey	N	No. 1	Chamba State ...	7	28·0	6	
		S	No. 5	Berār and Central Provinces ...	570	29·1	7·9	
		S	No. 7	Madras ...	2,940	28·3	7·9	2·7
		S	No. 8	Madras ..	432	15·5	8·6	8·1
		E	No. 9	Bengal ...	2,184	39·1	6·2	6·0
		E	No. 10	Upper Burma ...	824	25·6	2·0	17·4
		E	No. 11	Lower Burma ...	1,158	27·4	1·6	1·8
		E	No. 12	Assam, Sikkim and Bhutān ...	1,187	19·9	0·4	20·9
1-inch	Revision Survey	N	No. 1	Punjab ...	347	26·8	14	
		N	No. 3	United Provinces ...	105	30	7·6	
		S	No. 5	Berār ...	527	48·1	4·3	
		S	No. 8	Madras ...	155	16·1	4·8	4·7
		E	No. 9	Bengal ...	34	50·4	5·5	4·6
1-inch	Supplementary Survey	N	No. 1	Punjab and Simla Hill States ...	1,207	24·7	10	
		S	No. 7	Madras ...	478	32·8	5·2	0·2
1½-inch	Original Survey	S	No. 6	Hyderābād ...	138	8·9	18·9	33·6
1½-inch	Resurvey	S	No. 6	Hyderābād ...	271	10·9	15·8	13·1
2-inch	Original Survey	N	No. 3	United Provinces ...	459	9·2	22·5	
		S	No. 7	Madras ...	163	6·7	25·2	17·2
		E	No. 11	Lower Burma ...	282	8·0	2·7	39·2
		E	No. 12	Assam ...	191	5·9	...	62·7
3-inch	Original Survey (Military)	N	No. 1	Punjab, North-West Frontier Province and Baluchistān ...	306·5	7·4	6	
		N	No. 2	United Provinces and Delhi Province ...	187	9·1	49·9	

TABLE I.—*Concluded.*

OUT-TURNS OF PLANE-TABLING 1917-18.—*Concluded.*

Scale.	Class of Survey.	Circle.	Party.	Locality.	Out-turn, square miles.		Average number of fixings per square mile.	
					Total.	Average per man per month of 24 working days.	*In situ* (by resection).	Plane-table traverse.
3-inch .	Original Survey (Military)	N	No. 3	United Provinces ...	31	4·4	55·4	
		S	No. 5	Bombay ...	58	9·3	33·7	
3-inch .	Resurvey (Military) .	S	No. 5	Central Provinces	59	9·3	33·7	
		S	No. 6	Hyderābād ...	30	5·6	58·7	
		S	No. 8	Mysore ...	48	6·9	48·6	22·1
4-inch .	Original Survey .	N	No. 3	United Provinces ...	122	3	82·5	
		S	No. 7	Madras ...	45	4·3	29·9	43·7
		E	No. 11	Lower Burma ...	35	2·6	6·2	151·3
4-inch .	Supplementary Survey .	N	No. 2	United Provinces ...	144	17·6	23·2	
16-inch .	Original Survey and Resurvey .	S	No. 20	Dalhousie (Thatt Hill), Chaman, Manora, Erinpura, Agar, Jhānsi, Ahmadnagar, Aurangābād, New Delhi and Hosūr Remount Depôt.	acres 26,527	acres 279·2		
64-inch .	Original Survey and Resurvey .	S	No. 20	Manora, Erinpura, Agar, Jhānsi, Ahmadnagar, Aurangābād, New Delhi and Hosūr Remount Depôt.	314	21·4		

TABLE II.

DETAILS OF TRIANGULATION AND TRAVERSING 1917-18.

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. Number of Stations fixed.	Stations. Triangular error in seconds.	Stations. Linear error per mile in feet.	Intersected Points. Number of intersected points fixed.	Intersected Points. 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.
3-inch .	Military Survey .	N	No. 1	Punjab .	6	...	...	...	...	...	...	...	...	...	23·6	22	1·1	0·4
3-inch .	Military Survey .	N	No. 2	United Provinces .	5	40	1·1	1·2	6	21·7	...	29	0·81	...	54·7	116	1·0	0·5
4-inch .	Special Forest Re-survey and Revision Survey.	N	No. 2	Ditto .	5 & 6	156	1·0(*a*)	1·0(*a*)	52	10·9	0·40	102	3·00	...	175·1	2,425	5·8	2·5
4-inch .	Traversing .	N	No. 2	Ditto .	6	...	...	...	...	...	...	...	...	...	20·0	296	5·9	0·7
1-inch .	Traversing .	N	No. 3	Ditto .	5	...	...	...	...	...	...	...	...	...	290	1,715	4·2	1·4
1-inch .	Triangulation .	N	No. 3	Ditto .	6	334	(*b*)	(*b*)	13	(*b*)	(*b*)	290	(*b*)	...	...	...	...	...
2-inch .	Ditto .	N	No. 3	Ditto .	6	758	(*b*)	(*b*)	41	(*b*)	(*b*)	1,015	(*b*)	...	...	...	...	...
3-inch .	Ditto .	N	No. 3	Ditto .	6	30	1·0	1·0	2	3	1·4	27	0·6	...	...	...	...	...
4-inch .	Traversing .	N	No. 3	Ditto .	5	...	...	...	...	...	...	...	...	...	25	398	2·9	11·1
1-inch .	Original and Revision Survey	S	No. 5	Central Provinces .	6	2,747	5·8(*a*)	5·8(*a*)	75	10·5	0·36	395	0·65	...	...	...	...	...
½-inch, 1-inch and 1½-inch.	Original Survey .	S	No. 6	Hyderābād and Madras .	6	6,408	(*b*)	(*b*)	(*b*)	(*b*)	(*b*)	(*b*)	(*b*)	126	95	853	3·5	0·7

(*a*) Additional points, previously fixed, will also be used in this area.

(*b*) Computations not yet completed.

TABLE II.—*Concluded.*

DETAILS OF TRIANGULATION AND TRAVERSING 1917-18.—*Concluded.*

Scale.	Class of Survey.	Circle.	Party.	Locality.	Triangulation.				Stations.			Intersected Points.		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.	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.
1-inch and 2-inch.	Original and Supplementary Survey	S	No. 7	Madras	6	2,723	6·8(*a*)	(*b*)	43	9·0	0·16	356	0·44	...	...	...	...	...
1-inch	Original and Supplementary Survey	S	No. 8	Madras	...	...	...	...	...	...	...	...	...	2,344	741	2,384	1·6	0·5
16-inch and 64-inch.	Original Survey and Re-survey	S	No. 20	Dalhousie, (Thatt Hill), Manora, Erinpura, Agar, Aurangābād, Sātāra, New Delhi, Secunderābād, and Bolārum, Bellary and Hosūr Remount Depôt.	5 & 6	272	24·7	30·2	8	17·1	1·0	3	1·0	43	356	3,223	3·5	1·0
1-inch	Original and Revision Survey	E	No. 9	Bengal	...	...	...	...	..	...	...	...	...	2,020	831	2,546	6·8	1·1
½-inch	Original Survey	E	No. 10	Upper Burma	6	2,804	11·0	11·6	33	11·8	0·88	223	2·12	...	...	...	...	...
1-inch	Original Survey	E	No. 10	Do.	6	280	12·2	12·2	2	10·0	0·32	21	3·38	...	...	...	...	...
1-inch	Original Survey	E	No. 11	Lower Burma	6	2,780	7·1	7·1	32	9·0	0·16	360	0·40	...	...	...	...	...
2-inch	Original Survey	E	No. 11	Do.	6	...	...	...	...	...	...	...	...	...	65	1,180	0·2	3·9
4-inch	Original Survey	E	No. 11	Do.	6	70	1·4	1·4	8	25·0	0·40	41	0·83	...	68	1,205	0·1	1·4
1-inch and 2-inch.	Original Survey	E	No. 12	Assam	...	...	...	...	...	...	...	...	...	1,519	629	5,145	2·7	2·0

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

TABLE III.

COST-RATES OF SURVEY 1917-18.

Circle.	Party.	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.
			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 survey.	8-inch original survey.	4-inch original survey.	4-inch supplementary survey.	16-inch original survey and resurvey.	64-inch original survey and resurvey.	Triangulation per square mile.	Traversing per linear mile. Topographical.	Traversing per linear mile. Forest boundary.	Fair-mapping, per square mile.		Rs.	
N	No. 1	Punjab ...	...	88·7	...	9 5	17·7	...	...	...	93 8	...	...	...	...	...	...	19·8	...	20·5 }	1,868	(a) 92,404	(a) Excludes Rs. 3,080 incurred for fair-mapping of 4 inches = 1 mile Military Survey at Peshāwar of which survey and portion of fair-mapping were carried out in previous season 1916-17.
N	No. 1	Baluchistān ...	...	...	...	...	...	...	..	...	123 8	...	...	...	...	...	...	...	...	... }			
N	No. 1	N.W. Frontier Province	...	...	...	...	...	...	...	...	87 0	...	...	...	...	...	...	...	...	23 3 }			
N	No. 2	Rājputāna, United Provinces, and Delhi Province.	9·8	...	...	...	...	...	...	...	50 5	...	...	28·3	...	...	(b)49·8 (c)53 5	(c)13 7	98·1 & 49·6	15 1	1,617	(d) 46,231	(b) For 4-inch Special Forest Survey. (c) For 3-inch Original Survey. (d) Excludes Rs. 30,000 debitable to the Forest Department.
N	No 3	United Provinces ...	...	...	...	22·1	...	...	...	65·4	58·6	...	58 5	...	...	...	* 6·9	18·7	59·1	64·1	717	(e) 87,182	(e) Excludes Rs. 8,614 debitable to the Forest Department.
S	No. 5	Berār, Bombay, and Central Provinces.	...	20·9	..	12·6	...	...	...	...	59·0	59·0	...	...	...	...	* 5·3	...	...	(f)1·9 (g)0·9 (h)3·4	1,214	55,848	(f) For ½-inch. (g) For 1-inch. (h) For 3-inch.
S	No. 6	Hyderābād and Madras	6·7	...	...	...	...	51·7	42·2	...	...	66·9	...	...	...	...	2·8	34·3	...	(i) 2·0 (j) 8·8	7,114	1,04,549	(i) For ½ inch. (j) For 2-inch.
S	No. 7	Madras ...	...	11·5	...	...	5 5	...	...	41·3	...	...	95·5	...	...	...	* 6 5	...	...	6·6	3,626	89,931	

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

TABLE III.—*Concluded.*

COST-RATES OF SURVEY 1917-18.—*Concluded.*

Circle.	Party.	Locality.	COST-RATES, RUPEES, PLANE-TABLING, PER SQUARE 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 survey.	3-inch resurvey.	4-inch original survey.	4-inch supplementary survey.	16-inch original survey and resurvey.	64-inch original survey and resurvey.	COST-RATES, RUPEES. Triangulation per square mile.	Traversing per linear mile. Topographical.	Traversing per linear mile. Forest boundary.	Fair-mapping, per square mile.	Total plane-tabling out-turns on all scales, square miles.	Total cost of party. Rs.	Remarks.
S	No. 8	Madras and Mysore ...	...	39·8	...	39·8	...	...	...	...	...	32·5	...	...	...	...	...	9·9	...	4·1	635	55,440	
S	No. 20	Drosh, Chitrāl, Ghairat, Rāwalpindi, Topa, Jhelum, Siālkot, Dalhousie (Thutt Hill), Chaman, Manora, Neemuch, Deoli, Erinpura, Agar, Nasīrābād, Jhānsi, Ahmadnagar, Aurangābād, Sātāra, New Delhi, Secunderābād and Bolārum, Bellary, Hosūr Remount Depôt, Drazinda, Jatta, Zām and Jandola.	...	...	...	...	...	...	...	...	...	...	...	...	(k) 1·3	(k) 11·7	3·7	26·9	...	(l) 0·3 (m) 3·8	(k) 26,841	57,502	(k) These entries refer to acres. (l) Per acre for 16-inch. (m) Per acre for 64-inch.
E	No. 9	Bengal ...	...	8·0	...	3·4	...	...	...	...	...	...	...	..	...	...	...	13·7	...	(n) 3·4	2,218	78,804	(n) Based on mapping on the 1-inch and ½-inch scales.
E	No. 10	Upper Burma ...	24·7	48·7	...	...	...	...	...	...	..	...	...	...	...	...	7·9	...	...	(n) 8·4	3,325	1,44,640	
E	No. 11	Lower Burma ...	...	74·4	...	...	...	...	...	122·8	...	...	173·7	...	...	...	7·6	57·8	49·6	(o) 4·4	1,475	1,90,840	(o) Based on mapping on the 1-inch, ½-inch and ¼-inch scales.
E	No. 12	Assam ...	...	33·9	...	...	...	...	...	104·4	...	...	...	...	...	...	...	37·9	21·7	16·8 }	1,378	1,06,116	
E	No. 12	Sikkim and Bhutān ...	...	18·0	...	...	...	...	...	...	...	...	...	...	...	..	...	...	...	... }			

PART II.—GEODETIC AND SCIENTIFIC OPERATIONS.

TRIGONOMETRICAL SURVEY.

ASTRONOMICAL LATITUDES AND PENDULUM OPERATIONS.

Nos. 13 AND 14 PARTIES.

BY MAJOR H. McC. COWIE, R. E.

PERSONNEL.

Imperial Officer.

Major H. McC. Cowie, R. E. in charge.

Lower Subordinate Service.

No. 13 Party 1 Computer.
No. 14 Party 1 Computer.

War conditions still continuing during the year under report, no latitude or Pendulum operations were carried out and the personnel of these parties was employed at the Head Quarter Offices and in continuing the calculation of the Hayford reduction for Pendulum stations in India.

NO. 15 PARTY (TRIANGULATION).

By H. G. Shaw.

PERSONNEL.

Imperial Officer.

Major E. A. Tandy, R. E., in charge from 12th October 1917 to 15th May 1918.

Provincial Officers.

Mr. H. G. Shaw, in charge up to 11th October 1917 and from 16th May 1918.
" L. Williams up to 31st August 1918.
" R. B. Mathur, B. A., up to 8th September 1918.
" Abdul Karim, B. A., from 15th October 1917.
" N. N. Chuckerbutty, L. C. E., from 18th October 1917 to 14th August 1918.

Upper Subordinate Service.

Mr. Jugal Behari Lal.

Lower Subordinate Service.

13 Computers, etc.

The programme of field work during the past field season consisted of:—

(1) The continuation of the reconnaissance and building of the Sind-Sāgar Doāb triangulation which was commenced last year and the completion of observations at all the stations.

(2) The survey of the Mayo Salt Mine at Khewra, Punjab.

The table below gives details regarding the triangulation.

Particulars of triangulation during 1917-18.

Number of stations observed at	107
Number of stations newly-selected and built	56
Length of triangulation completed in miles	375
Length of triangulation remaining to be done	Nil
Area of triangulation in square miles	1950
Number of triangles observed	114
Maximum triangular error	9"·14
Average triangular error	2"·39
Value of m	1"·875
Value of M	3"·24
Theodolites used	T. & S. 6-inch micrometer Nos. 1097, 1100, 1403 and 1404.

Sind-Sāgar Doāb Triangulation.—Four detachments were employed on the work mentioned in (1) above, which was carried out as follows:—

No. 1 Detachment under Mr. L. Williams carried out observations from Abbāswāla T. S. and Māhīwāla T. S. of the Great Indus Series, near Sanāwān in Muzaffargarh district, up to the vicinity of Khushāb in Shāhpur district.

No. 2 Detachment under Mr. Raj Bahadur Mathur carried out observations from Shāhpur T. S. and Mohammad Shāh T. S. of the Great Indus Series, near Leiah in Muzaffargarh district, up to the vicinity of Miānwāli and also laid out and built a small cross series making connection with the series of No. 1 Detachment.

No. 3 Detachment under Mr. Abdul Karim laid out and built the series from Nūrpur southward, half way to Sanāwān, and observed the small series connecting No. 2 Detachment's work with Ahmad Sindi T. S. and Miāni T. S. of the Great Indus Series, and assisted Nos. 1 and 2 Detachments in making the final connection of their series with the G. T. Stations in the hills north of the Sind-Sāgar Doāb.

No. 4 Detachment under Mr. Jugal Behari Lal laid out and built the series from Sanāwān northward, half way to Nūrpur, and observed the small series built by Mr. R. B. Mathur. Towards the end of March 1918 this detachment was sent to Khewra and amalgamated with the Khewra Detachment.

The observations of the triangulation, which was in character midway between Minor and Geodetic, were carried out with 6-inch micrometer theodolites. At each station measures were made on four zeros, namely :—

$$\frac{\text{R } 0^\circ\text{—}1'}{\text{L } 180^\circ\text{—}1'},\ \frac{\text{L } 45^\circ\text{—}2'}{\text{R } 225^\circ\text{—}2'},\ \frac{\text{R } 90^\circ\text{—}4'}{\text{L } 270^\circ\text{—}4'},\ \frac{\text{L } 135^\circ\text{—}6'}{\text{R } 315^\circ\text{—}6'}.$$

The measures on each zero included four swings, two clockwise and two counter-clockwise, thus the total number of measures of each angle was 16.

The signals observed to were :—

(a) Helios when practicable.

(b) Opaque signals.

(c) Ordinary hurricane lanterns raised to a few feet above the station marks.

Owing to the nature of the country, which consisted of scattered sand mounds of almost uniform height, helios could only be used at a few of the stations, and it was necessary to resort to opaque signals. These were of a type not previously used for triangulation and it will be useful to put a description of them on record for future work in similar country. The signal-poles were made of galvanized iron and were similar in appearance to ordinary telegraph posts. For convenience of transport a pole was made up of three or four sections constructed so as to fit together and form a hollow upright post 20 to 30 feet high. These were placed over the station pillars and guyed down by ropes fastened to tent pegs driven in the sand. A bamboo basket covered with cloth, shaped in the form of a sphere, by means of hoops, was placed on the topmost section and was used for intersection. To facilitate correct centering and to test the verticality of the signal, a plummet was suspended from the basket through the hollow upright. An aperture was cut in the bottom section at the base of the signal so that it could be seen whether the plummet was accurately over the station mark. These signals proved of very great assistance throughout the work.

Owing to abnormal refraction at night, it was found that ordinary hurricane lanterns, raised about four feet above the ground, were clearly visible where high signals were necessary during the day. The use of lanterns at night accelerated the work a good deal and night observations were attended with marked success.

All four detachments left Dehra Dūn early in November 1917 and after completing the programme, Nos. 1, 2 and 3 Detachments returned to recess in Mussoorie in the beginning of April 1918.

No difficulties or impediments were encountered in the execution of the work except for ray clearing between Abbāswāla T. S. and Māhīwāla T. S in the beginning of the season, and abnormally wet and cloudy weather in the latter half of March 1918. The health of the detachments on the whole was good throughout the season.

Computations.—Major Tandy has supplied the following note in regard to the grinding and distribution of the closing errors of this triangulation :—" The results were urgently required by the Sind-Sāgar Party, and I therefore arbitrarily disposed of the closing errors as follows :— A complete chart was made showing the discrepancies in latitudes, longitudes, azimuths, and log. sides, for each side where series emanating from G. T. bases met one another. By a careful inspection of these discrepancies definite values for each of these closing sides were adopted, and the resulting corrections entered against them on the Chart and gradually distributed backwards through the sides of each series.

These corrections were then read off from the Chart and applied to the computed values of all sides before converting them into the rectangular values required by the Sind-Sāgar Party. After it was too late to make any change, it was found that the triangle Nikru Shahid, Nawa Sighu, Sidha, near the northern junction of all the series, had been wrongly computed, the log. cosec. being too large by 0·00001. Fortunately the grinding was found to have cleared off this error from the bases immediately affected, but the necessity for distributing it must have rather spoilt the satisfactory grinding of all neighbouring parts of the work".

Survey of the Mayo Salt Mine, Khewra, Jhelum District, Punjab.—A special detachment carried out this work under Mr. N. N. Chuckerbutty. The nature of the work is described in Part II of the General Report for 1917-1918, and full particulars are to be found in a special pamphlet entitled " Survey of the Mayo Salt Mine", which has been printed at the Trigonometrical Survey Office for the use of the Salt Department.

No. 16 PARTY (TIDAL OPERATIONS).

BY O. C. OLLENBACH.

Tidal registrations by means of self-registering tide-gauges were continued during the year under report at the following ports:—

PERSONNEL.

Provincial Officers.

Mr. O.C. Ollenbach, in charge from 29th October 1917.

,, Syed Zille Hasnain, K.S., in charge till 28th October 1917.

Lower Subordinate Service.

20 Computers, &c.

Aden, Karāchi, Appollo Bandar (Bombay), Prince's Dock (Bombay), Madras, Kidderpore, Rangoon, Moulmein and Port Blair. The work is carried out under the direction of this department, but the immediate control of all the tidal observatories is entrusted to the local officers of the ports concerned.

In addition to the automatic tidal registrations at the above ports, readings of high and low water were taken during day-light on tide-poles at Bhaunagar, Akyab and Chittagong throughout the year for the purpose of checking the corresponding predictions which were based on observations taken some years ago.

TIDAL OBSERVATIONS AT BASRAH.

Hourly readings of a tide-gauge at Basrah were supplied to this department throughout the year by the Director Inland Water Transport, Mesopotamia. The readings for the year commencing 1st January 1917 were reduced by the method of harmonic analysis and the constants thus deduced were used in the computation of data for the tide-tables for Basrah for 1919. These data were forwarded on 10th April 1918 to the National Physical Laboratory Teddington, England, where tidal predictions were made from them with the aid of the tide-predicting machine. A set of the predictions was received from the Laboratory on 29th August 1918. The tide-tables for Basrah for 1919 are being printed at the Trigonometrical Survey Office at Dehra Dūn and will be despatched to the Director Inland Water Transport Mesopotamia in October 1918.

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.

List of Tidal Stations.

Serial No.	Stations.	Automatic or Personal observations	Date of commencement of observtions	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	39	
4	Maskat	"	1893	1898	5	
5	Bushire	"	1892	1901	8	
6	*Karāchi*	"	1868 1881	1880 Still Working	*13 38 } 51	* 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	40	
14	*Bombay (Prince's Dock)*	"	1888	"	30	
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 } 33 23	
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	37	
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	38	
39	Amherst	"	1880	1886	6	
40	*Moulmein*	"	1880 Restarted 1909	1886 Still Working	6 } 15 9	
41	Mergui	"	1889	1894	5	
42	*Port Blair* ...	"	1880	Still Working	38	
43	Basrah	Personal	1916	"	2	observations taken on a tide-pole.

Working of the Observatories.

The inspection of all the tidal observatories was carried out during the year, Mr. O. C. Ollenbach taking up the inspection of Aden, Karāchi, Bombay (Apollo Bandar), Bombay (Prince's Dock) and Madras, and Mr. Syed Zille Hasnain inspecting the remaining observatories. During the inspection of each observatory the tide-gauge and other instruments were thoroughly overhauled, cleaned and put in working order; the observatory well was cleaned and the inlet holes were examined; the level of the bed-plate of the tide-gauge was carefully tested by spirit-levelling between it and the bench-mark of reference, in order to ascertain whether any change had taken place in its position since the last inspection; the zero of each tide-gauge and graduated staff was also tested and adjusted; the observatory cabin was examined and arrangements were made for any repairs, if necessary.

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

Aden.—This observatory continued to give trouble until it was inspected in December 1917. It was found that the tide-gauge had been badly neglected and the clerk in charge appeared to take little or no interest in his work. The inspecting officer brought the matter to the notice of the Chief Engineer of the port with the result that a better clerk was found and the observatory properly looked after. Since the last inspection the working of the observatory has considerably improved. There have been a few minor interruptions in the registrations of the tide-gauge due to the stoppage of the driving clock.

Karāchi.—The tide-gauge at this observatory has worked satisfactorily during the past year. The inlet hole in the well was temporarily blocked seven times, but was reopened each time as soon as the defect was noticed. The size of the inlet hole was increased from ½ to ¾ inch in diameter last year and this greatly reduced the number of interruptions in the registrations of the tide-gauge due to the blocking of the inlet hole, which were very frequent last year.

Bombay (Apollo Bandar).—There was a break of about 2½ days in the registrations of the tide-gauge at this observatory in June 1918. It appears that the pin which holds the pencil wheel in its position dropped out and in consequence the wheel became loose on its axle and failed to work the recording pencil. This was put right by a mechanic of the Deputy Chief Engineer of the port and the gauge has worked well since.

Bombay (Prince's Dock).—Tidal registrations at this observatory were carried out satisfactorily up to the middle of September 1917. Owing to some friction the diagram paper, in passing over the central drum on which the recording pencil works, was constantly torn by the projecting pins fixed at the hour intervals near the top and bottom of the drum and this continued up to the 30th November 1917. When the diagrams were finally examined at Dehra Dūn before being read off, it was found that the times indicated by the clock, as entered on the diagrams by the observatory clerk twice a day, disagreed with the times marked on the diagrams by the projecting pins at the hour intervals. This defect started on 14th September 1917 and disappeared on 30th November 1917. The total discrepancy in time at the end of November was nearly two hours. The observations between the above dates were therefore rejected and the gap was filled by substituting observations taken at Apollo Bandar after applying the necessary corrections due to the difference of zeros at the two observatories.

Madras.—There have been no interruptions in the work of this observatory since the last inspection.

Kidderpore.—The tide-gauge at this observatory has worked without a break during the past year. The observatory was found in a neat and tidy condition, having beeen built in April 1917.

Rangoon.—This observatory has continued to work well during the year under report. At the time of the inspection in March 1918 it was found that the floor of the cabin needed repairs and the canvas stretched below the roof of the cabin was old and torn in places. The Deputy Conservator of the port was requested to have the cabin thoroughly repaired and to have a wooden ceiling fixed to the roof.

Moulmein.—The working of this observatory has improved since the last inspection. No interruptions have taken place in the tidal registrations. The inspecting officer, however, found the cabin in an untidy condition and in need of a thorough overhauling. The matter was brought to the notice of the Port Officer who was requested to do the needful. The old graduated staff was washed away on 15th December 1917 and was replaced by a new staff when the inspecting officer visited the port in February 1918.

Port Blair.—The tide-gauge at this observatory has, as usual, worked in a very satisfactory manner during the past year.

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 1917 have been reduced by harmonic analysis. In addition, the observations taken at Basrah on a tide-gauge erected by the military authorities and supplied to this department by the Director Inland Water Transport for the year 1917 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 (ζ) at the various stations; they also give the values of H and K which are connected with R and ζ, 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.

1917

Tide symbol	ADEN				KARÂCHI				BOMBAY (Apollo Bandar)			
	$A_0 = 5\cdot795$ feet				$A_0 = 7\cdot368$ feet				$A_0 = 10\cdot324$ feet			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period		°		°		°		°		°		°
S_1	0·042	201·80	0·042	201·80	0·101	180·34	0·101	180·34	0·072	189·62	0·072	189·62
S_2	0·665	256·93	0·665	256·93	0·987	323·21	0·987	323·21	1·569	3·50	1·569	3·50
S_4	0·002	312·88	0·002	312·88	0·008	38·12	0·008	38·12	0·025	217·56	0·025	217·56
S_6	0·002	254·06	0·002	254·06	0·007	274·76	0·007	274·76	0·008	130·19	0·008	130·19
S_8	0·001	225·00	0·001	225·00	0·002	43·15	0·002	43·15	0·004	342·90	0·004	342·90
M_1	0·103	192·26	0·052	357·97	0·104	201·94	0·052	8·38	0·104	204·46	0·052	11·11
M_2	1·482	63·10	1·492	237·66	2·579	118·03	2·597	294·08	3·936	154·64	3·962	331·08
M_3	0·011	131·54	0·011	213·39	0·030	254·92	0·030	338·99	0·064	297·30	0·065	21·97
M_4	0·007	340·71	0·007	329·83	0·021	359·71	0·021	351·81	0·097	322·07	0·098	314·96
M_6	0·009	236·92	0·009	40·60	0·046	38·27	0·046	206·42	0·012	251·57	0·012	60·91
M_8	0·003	275·44	0·003	253·69	0·009	293·63	0·009	277·83	0·010	352·96	0·010	338·75
O_1	0·681	71·50	0·644	43·54	0·691	73·83	0·654	47·41	0·681	74·65	0·645	48·64
K_1	1·347	201·98	1·302	40·83	1·373	207·12	1·326	45·91	1·441	206·71	1·392	45·48
K_2	0·175	22·13	0·164	240·22	0·256	100·53	0·239	318·50	0·404	139·15	0·377	357·09
P_1	0·392	231·06	0·392	40·62	0·393	232·72	0·393	42·34	0·394	231·86	0·394	41·49
J_1	0·081	169·02	0·077	79·63	0·074	170·02	0·069	79·77	0·089	171·82	0·084	81·35
Q_1	0·145	137·63	0·138	41·59	0·140	139·56	0·132	45·86	0·140	142·96	0·132	49·89
L_2	0·050	164·01	0·066	241·18	0·076	227·05	0·100	304·91	0·103	220·99	0·136	299·03
N_2	0·411	126·85	0·414	233·33	0·609	168·11	0·613	276·88	0·934	206·61	0·940	315·99
ν_2	0·139	207·48	0·140	262·58	0·180	251·95	0·181	309·23	0·249	291·24	0·251	349·09
μ_2	0·067	218·54	0·068	207·66	0·045	291·47	0·045	283·57	0·196	320·71	0·199	313·61
T_2	0·036	28·99	0·036	30·07	0·046	36·34	0·046	37·47	0·097	70·70	0·097	71·85
$(MS)_4$	0·013	353·71	0·013	168·28	0·027	135·62	0·028	311·67	0·076	211·86	0·077	28·30
$(2SM)_2$	0·014	309·86	0·014	135·30	0·014	252·72	0·014	76·67	0·029	276·61	0·029	100·16
$2N_2$	0·070	162·66	0·071	201·07	0·076	205·91	0·076	247·40	0·135	235·19	0·136	277·50
$(M_2N)_4$	0·012	335·47	0·012	256·52	0·028	66·24	0·028	351·05	0·011	326·00	0·011	251·83
$(M_2K_1)_3$	0·018	78·88	0·018	92·29	0·042	67·53	0·041	82·37	0·073	154·55	0·071	169·77
$(2M_2K_1)_3$	0·019	178·46	0·019	328·73	0·026	231·41	0·026	24·72	0·072	275·51	0·070	69·63
Long Period		°		°		°		°		°		°
Mm	0·036	306·40	0·037	14·48	0·074	303·52	0·076	10·80	0·101	280·79	0·104	347·86
Mf	0·069	341·95	0·061	32·44	0·061	326·30	0·054	15·18	0·059	317·94	0·053	6·39
MSf	0·013	196·08	0·013	21·52	0·024	126·13	0·024	310·08	0·031	36·59	0·031	220·14
Sa	0·383	70·95	0·383	351·39	0·074	100·57	0·074	20·95	0·139	7·09	0·139	287·45
Ssa	0·098	315·95	0·098	156·83	0·113	319·90	0·113	160·67	0·090	33·76	0·090	234·49

1917

Tide symbol	BOMBAY (Prince's Dock)				MADRAS				KIDDERPORE			
	$A_0 = 8·374$ feet				$A_0 = 2·368$ feet				$A_0 = 10·807$ feet			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period		°		°		°		°		°		°
S_1	0·089	185·56	0·089	185·56	0·028	76·06	0·028	76·06	0·096	190·67	0·096	190·67
S_3	1·639	4·19	1·639	4·19	0·459	271·12	0·459	271·12	1·523	97·17	1·523	97·17
S_4	0·023	205·89	0·023	205·89	0·003	161·57	0·003	161·57	0·083	108·48	0·083	108·48
S_6	0·005	164·85	0·005	164·85	0·001	126·87	0·001	126·87	0·002	46·98	0·002	46·98
S_8	0·001	339·44	0·001	339·44	0·000	225·00	0·000	225·00	0·007	313·78	0·007	313·78
M_1	0·109	200·67	0·055	7·32	0·007	110·06	0·003	276·95	0·019	47·77	0·010	214·94
M_2	3·994	152·54	4·022	328·99	1·067	65·27	1·075	242·23	3·703	237·50	3·728	55·00
M_3	0·066	296·81	0·066	21·48	0·005	305·10	0·005	30·52	0·028	231·96	0·028	318·20
M_4	0·095	341·35	0·097	334·25	0 010	190·70	0·010	184·60	0·731	36·06	0·741	31·05
M_6	0·013	353·66	0·013	163·01	0·005	303·34	0·005	114·20	0·146	138·18	0·149	310·67
M_8	0·002	347·47	0·002	333·27	0·001	92·55	0·001	80·35	0·084	273·56	0·086	263·55
O_1	0·675	72·33	0·639	46·33	0·100	349·62	0·095	324·14	0·224	47·03	0·212	22·12
K_1	1·461	206·69	1·411	45·46	0·303	138·83	0·292	337·58	0·418	218·22	0·404	56·95
K_2	0·370	138·97	0·345	356·91	0·127	45·45	0·118	263·35	0·478	229·75	0·447	87·61
P_1	0·389	232·00	0·389	41·63	0·090	170·48	0·090	340·13	0·144	235·60	0·144	45·28
J_1	0·089	171·01	0·084	80·53	0·013	44·68	0·012	313·91	0·013	79·70	0·013	348·61
Q_1	0·138	141·79	0·131	48·72	0·007	324·16	0·006	231·89	0·030	78·35	0·028	346·93
L_2	0·107	237·54	0·142	315·58	0·037	211·44	0·049	289·72	0·192	15·92	0·252	94·45
N_2	0·965	203·66	0·971	313·04	0·244	128·69	0·246	238·84	0·649	289·09	0·653	40·08
ν_2	0·214	283·64	0·215	341·50	0·068	206·87	0·068	265·47	0·246	340·68	0·247	40·08
μ_2	0·178	324·95	0·181	317·85	0·021	187·60	0·022	181·50	0·315	182·73	0·319	177·72
T_2	0·101	58·33	0·101	59·48	0·016	10·44	0·016	11·61	0·162	171·90	0·162	173·09
$(MS)_4$	0·106	221·92	0·107	38·37	0·008	23·41	0·008	200·36	0·668	253·48	0·672	70·97
$(2SM)_2$	0·052	284·06	0·052	107·61	0·015	24·44	0·015	207·49	0·078	163·85	0·078	346·35
$2N_2$	0·164	234·51	0·165	276·82	0.022	164·79	0·022	208·15	0·077	43·23	0·077	87·72
$(M_2N)_4$	0·007	101·98	0·007	27·81	0·002	249·78	0·002	176·88	0·268	87·45	0·272	15·94
$(M_2K_1)_3$	0·085	148·67	0·082	163·89	0·014	59·18	0·013	74·89	0·102	359·25	0·099	15·48
$(2M_2K_1)_3$	0·072	280·71	0·071	74·83	0·003	158·63	0·003	313·78	0·036	191·80	0·035	348·06
Long Period		°		°		°		°		°		°
Mm	0·091	279·41	0·093	346·47	0·063	193·61	0·065	260·41	0·239	322·28	0·245	28·78
Mf	0·052	340·16	0·046	28·61	0·045	310·33	0·040	358·24	0·314	355·40	0·279	42·73
MSf	0·031	43·29	0·031	226·84	0·020	104·55	0·020	287·59	0·899	217·19	0·905	39·70
Sa	0·177	24·14	0·177	304·50	0·444	308·25	0·444	228·59	2·863	244·72	2·863	165·04
Ssa	0·122	35·29	0·122	236·02	0·258	266·72	0·258	107·41	0·948	152·41	0·948	353·05

1917

Tide symbol	RANGOON				MOULMEIN				PORT BLAIR			
	$A_0 = 10 \cdot 303$ feet				$A_0 = 8 \cdot 426$ feet				$A_0 = 4 \cdot 836$ feet			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period		°		°		°		°		°		°
S_1	0·124	127·23	0·124	127·23	0·113	137·30	0·113	137·30	0·034	69·44	0·034	69·44
S_2	2·185	167·99	2·185	167·99	1·555	144·32	1·555	144·32	0·963	312·96	0·963	312·96
S_4	0·081	261·22	0·081	261·22	0·082	218·20	0·082	218·20	0·006	289·09	0·006	289·09
S_6	0·010	40·03	0·010	40·03	0·010	193·31	0·010	193·31	0·004	266·91	0·004	266·91
S_8	0·002	291·25	0·002	291·25	0·005	181·22	0·005	181·22	0·005	45·88	0·005	45·88
M_1	0·035	99·92	0·018	267·35	0·008	99·83	0·004	267·31	0·017	68·20	0·009	235·52
M_2	5·812	312·28	5·851	130·30	4·201	291·41	4·224	109·53	1·978	101·05	1·992	278·84
M_3	0·016	49·64	0·016	136·67	0·023	55·40	0·024	142·59	0·006	292·69	0·006	19·39
M_4	0·471	170·94	0·477	166·99	0·951	164·01	0·964	160·26	0·011	123·39	0·011	118·98
M_6	0·260	276·15	0·265	90·23	0·065	348·07	0·066	162·44	0·003	241·19	0·003	54·57
M_8	0·083	119·49	0·085	111·59	0·057	104·24	0·058	96·74	0·001	116·57	0·001	107·74
O_1	0·323	46·85	0·305	22·49	0·269	65·62	0·255	41·36	0·169	326·01	0·160	301·41
K_1	0·713	196·31	0·688	35·02	0·474	199·27	0·457	37·98	0·405	126·85	0·391	325·57
K_2	0·611	310·81	0·570	168·62	0·398	286·53	0·371	144·33	0·260	90·13	0·243	307·96
P_1	0·169	248·72	0·169	58·42	0·135	247·35	0·135	57·05	0·133	153·78	0·133	323·47
J_1	0·037	160·98	0·035	69·59	0·020	176·78	0·018	85·31	0·017	49·33	0·016	318·07
Q_1	0·032	107·46	0·030	16·88	0·038	136·18	0·036	45·75	0·024	328·35	0·023	237·40
L_2	0·398	98·23	0·525	177·00	0·300	84·05	0·396	162·87	0·069	222·02	0·091	300·69
N_2	1·039	2·11	1·046	113·92	0·712	341·23	0·717	93·19	0·388	160·81	0·390	272·26
ν_2	0·399	75·43	0·401	135·60	0·262	70·84	0·263	131·15	0·109	238·84	0·110	298·67
μ_2	0·566	291·12	0·573	287·17	0·428	273·17	0·434	269·42	0·078	319·25	0·079	314·84
T_2	0·086	210·45	0·086	211·66	0·082	176·89	0·082	178·11	0·044	1·05	0·044	2·26
$(MS)_4$	0·416	29·72	0·419	207·74	0·770	22·35	0·776	200·47	0·021	43·56	0·021	221·36
$(2SM)_2$	0·159	225·72	0·160	47·70	0·143	220·65	0·144	42·53	0·019	332·21	0·019	154·42
$2N_2$	0·176	150·03	0·177	195·61	0·114	110·04	0·115	155·83	0·067	221·18	0·067	266·28
$(M_2N)_4$	0·160	221·24	0·162	151·07	0·321	213·73	0·325	143·81	0·004	89·36	0·004	18·61
$(M_3K_1)_3$	0·137	33·36	0·134	50·10	0·153	52·45	0·149	69·28	0·017	100·43	0·017	116·94
$(2M_2K_1)_3$	0·111	250·48	0·109	47·82	0·114	256·46	0·112	54·01	0·007	36·21	0·007	193·08
Long Period		°		°		°		°		°		°
Mm	0·132	328·96	0·135	35·18	0·338	318·15	0·347	24·32	0·042	320·29	0·043	26·64
Mf	0·204	350·20	0·182	36·95	0·373	356·28	0·332	42·92	0·045	310·33	0·040	357·33
MSf	0·522	220·65	0·526	42·63	1·230	222·23	1·239	44·11	0·013	9·92	0·013	192·13
Sa	1·206	241·02	1·206	161·32	2·359	234·86	2·359	155·15	0·218	260·14	0·218	180·46
Ssa	0·185	163·30	0·185	3·90	0·671	109·46	0·671	310·06	0·149	276·73	0·149	117·35

1917.

Tide symbol	BASRAH											
	A_0 = 6·110 feet				A_0=				A_0=			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period		°		°								
S_1	0·182	203·30	0·182	203·30								
S_2												
S_4												
S_6												
S_8												
M_1												
M_2	1·327	291·61	1·336	106·37								
M_3												
M_4												
M_6												
M_8												
O_1	0·480	20·65	0·454	352·89								
K_1	0·823	191·70	0·795	30·54								
K_2												
P_1	0·192	200·95	0·192	10·52								
J_1	0·017	236·60	0·016	147·09								
Q_1	0·080	81·23	0·075	345·48								
L_2												
N_2												
ν_2												
μ_2												
T_2												
$(MS)_4$												
$(2SM)_2$												
$2N_2$												
$(M_2N)_4$												
$(M_2K_1)_3$	0·232	25·94	0·226	39·54								
$(2M_2K_1)_3$	0·215	215·13	0·211	5·79								
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 1921, ready for use for the tide-predicting machine.

(*b*) Values of the tidal constants for the tide-tables for Basrah for the year 1919.

(*c*) Actual values of high and low water during 1916 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*) Comparisons of the above with predicted values for 1916, the errors being tabulated in such form as to be of use in improving the predictions, if possible.

ERRORS IN PREDICTIONS.

The predicted times and heights for high and low water for the year 1917, 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 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 1917.

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.	645	20	25	9	16	30
Karāchi ...	,,	699	40	43	7	7	3
Bhaunagar ...	T. P.	365	66	34	0	0	0
Bombay (Apollo Bandar)	Auto.	704	38	44	8	7	3
Bombay (Prince's Dock)	,,	651	43	39	8	7	3
Madras ...	,,	704	40	40	6	8	6
Kidderpore ...	,,	705	26	43	13	12	6
Chittagong ...	T. P.	365	33	39	8	10	10
Akyab ...	,,	365	100	0	0	0	0
Rangoon ...	Auto.	705	49	38	7	4	2
Moulmein ...	,,	705	36	43	10	9	2
Port Blair ...	,,	706	33	47	10	8	2

NO. 2.

Percentages and amounts of the errors in the predicted times of low water at the various tidal stations for the year 1917.

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.	652	20	22	11	18	29
Karāchi ...	,,	704	32	39	12	12	5
Bhaunagar ...	T.P.	365	67	33	0	0	0
Bombay (Apollo Bandar)	Auto.	705	40	45	5	7	3
Bombay (Prince's Dock)	,,	551	36	44	8	8	4
Madras ...	,,	705	41	40	7	7	5
Kidderpore ...	,,	705	30	42	12	12	4
Chittagong ...	T.P.	365	24	42	13	12	9
Akyab ...	,,	365	99	1	0	0	0
Rangoon ...	Auto.	705	31	37	14	15	3
Moulmein ...	,,	699	23	34	13	16	14
Port Blair ...	,,	703	23	49	16	10	2

No. 3.

Percentages and amounts of the errors in the predicted heights of high water at the various tidal stations for the year 1917.

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.	645	6·7	92	7	1	0
Karāchi ...	,,	699	9·3	60	32	7	1
Bhaunagar ...	T.P.	365	31·4	59	36	5	0
Bombay (Apollo Bandar)	Auto.	704	13·9	75	22	2	1
Bombay (Prince's Dock)	,,	551	13·9	63	29	8	0
Madras ...	,,	704	3·5	79	19	2	0
Kidderpore ...	,,	705	11·7	40	22	18	20
Chittagong ...	T.P.	365	13·3	35	26	18	21
Akyab ...	,,	365	8·3	74	21	5	0
Rangoon ...	Auto.	705	16·4	53	30	12	5
Moulmein ...	,,	705	12·7	34	28	20	18
Port Blair ...	,,	706	6·6	89	11	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 1917.

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.	652	6·7	97	3	0	0
Karāchi ...	"	704	9·3	81	17	2	0
Bhaunagar ...	T.P.	365	31·4	61	34	5	0
Bombay (Apollo Bandar)	Auto.	705	13·9	71	24	4	1
Bombay (Prince's Dock)	"	551	13·9	64	30	5	1
Madras ...	"	705	3·5	82	17	1	0
Kidderpore ...	"	705	11·7	43	24	17	16
Chittagong ...	T.P.	365	13·3	37	22	13	28
Akyab ...	"	365	8·3	68	24	7	1
Rangoon ...	Auto.	705	16·4	38	31	16	15
Moulmein ...	"	699	12·7	32	25	17	26
Port Blair ...	"	703	6·6	92	8	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 1917.

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	23	22	·025	·025	2	2
Karāchi	"	9·3	10	12	·036	·027	4	3
Bhaunagar	T.P.	31·4	5	5	·011	·011	4	4
Bombay (Apollo Bandar)	Auto.	13·9	10	9	·018	·018	3	3
Bombay (Prince's Dock)	"	13·9	9	10	·024	·024	4	4
Madras	"	3·5	01	10	·071	·071	3	3
Akyab	T.P.	8·3	0	0	·030	·040	3	4
Port Blair	Auto.	6·6	10	12	·025	·025	2	2
General Mean	...	...	10	10	·030	·030	3	3
Riverain.								
Kidderpore	Auto.	11·7	13	12	·057	·057	8	8
Chittagong	T.P.	13·3	13	14	·050	·056	8	9
Rangoon	Auto.	16·4	8	12	·025	·036	5	7
Moulmein	"	12·7	10	16	·052	·066	8	10
General Mean	...	...	11	14	·046	·054	7	9

Summary for 1917.

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	75	72	96	98	96	97
2 „	Tide-pole	100	100	95	94	100	99
3 Riverain	S.R. Tide-gauge	78	65	69	64	92	86
1 „	Tide-pole	72	66	61	59	88	84

COMPARISONS OF THE PREDICTIONS FOR THE YEAR 1917 WITH THOSE FOR THE PREVIOUS YEAR.

The predictions of times and heights of high and low water for the year 1917 at the nine working stations were compared against the predictions for the previous year and were found to be practically of the same degree of accuracy, except at Aden and Port Blair where the predictions of times were slightly less accurate than those for the year 1916.

The greatest difference between the actual and predicted heights of low water for 1917 at the riverain ports was as follows :—

Kidderpore ... 4 feet 4 inches on 9th October 1917, actuals being higher.
Rangoon ... 2 feet 3 inches on 6th July 1917, actuals being lower.
Moulmein ... 3 feet 6 inches on 7th July 1917, actuals being lower.

TIDE-TABLES.

The tide-tables for the year 1919 have not yet been received from England.

The tide-tables for Basrah for the year 1919 are being printed at the office of the Trigonometrical Survey at Dehra Dūn and will be despatched to the Director Inland Water Transport Basrah in October 1917.

The amount realized on the sale of tide-tables during the year ending September 1917 is Rs. 1747/7/6.

PROGRAMME FOR SEASON 1918-19.

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

No. 17 PARTY (LEVELLING).

BY H. G. SHAW.

PERSONNEL.

Provincial Officers.

Mr. H. G. Shaw, in charge. Retired: in temporary employ from 21st February 1918.
" D. H. Luxa, up to 15th September 1918.
" J. Mc Craken, from 15th August 1918 to 15th September 1918.
" N. N. Chuckerbutty, L. C. E., up to 17th October 1917 and again from 15th August 1918 to 15th September 1918.

Upper Subordinate Service.

Mr. Satish Chandra Mukerjee, up to 15th September 1918.

Lower Subordinate Service

3 Computers.
5 Recorders.
2 Clerks.

Two detachments were employed in levelling operations during the past field season. The out-turn, including branch lines, amounted to 152 miles of " fore and back double levelling of precision " and 285 miles of single revisionary levelling of precision, in the United Provinces, Bengal, and Bihār and Orissa, in the course of which the heights of 1 principal station of triangulation, 15 primary and 586 secondary bench-marks were determined, including 11 primary and 411 secondary old bench-marks which were reconnected during the revisionary and check levelling. Full details of the out-turn of work are given in table I. appended.

The health of the detachments was on the whole good. Only a few men occasionally suffered from malaria.

Levelling operations.—The programme of work consisted of—

(*a*) Levelling from Cawnpore to Jhānsi along the main road *via* Kālpī.
(*b*) Revising lines of levels
 (i) from Karamnāsā to Aurangābād.
 (ii) from Barākar to Burdwān.
 (iii) from Rānchī to Barākar.

Two detachments, called Nos. 1 and 2 Detachments, carried out the programme described below; each detachment consisted of one levelling officer, 2 recorders and 19 menials.

Mr. S. C. Mukerjee was in charge of No. 1 and Mr. D. H. Luxa of No. 2 Detachment.

No. 1 Detachment revised the line from Rānchī to Barākar, and a part of the Barākar-Burdwān line between Barākar and Rājbāndh.

No. 2 Detachment revised the line from Karamnāsā to Aurangābād, and a part of the Barākar-Burdwān line between Burdwān and Rājbāndh.

Then both the detachments, working in opposite directions, levelled the Cawnpore-Jhānsi line, *via* Kālpī along the main road, crossing the Jumna by the G.I.P. Railway bridge *en route*. This is a new line and is useful for both geodetic and irrigation purposes.

One of the objects of running this new line of levels was to test the height of the standard bench-mark at Jhānsi which was based on that of Colonel Sanders' monument, $\frac{\text{BM. 6}}{\text{54 F}}$, when the connection was made in 1905-07.

When the line Agra-Gwalior was revised in 1915-16 the height of this B.M. was found to differ by $-1\cdot700$ feet from that determined by the old levelling of 1861-62. It was assumed then that the difference was due to the point of reference in 1905-06 and 1915-16 not being the same as that used in 1861-62. The line Cawnpore-Jhānsi now definitely proves that this assumption was correct. This line breaks up the large circuit Allahābād-Cawnpore-Agra-Gwalior-Sironj-Katni-Allahābād, into two smaller ones, *viz*.- (1) Cawnpore-Agra-Gwalior-Jhānsi-Cawnpore, and (2) Cawnpore-Jhānsi-Gwalior-Sironj-Katni-Allahābād-Cawnpore, which close with errors of $-0\cdot724$ and $+0\cdot731$ of a foot respectively, as shown below:—

Circuit (1).

Lines. From	Lines. To	Distance in miles.	Unadjusted dynamic difference of height in feet.	Year.
Block-stone B.M. at Cawnpore.	Block-stone B.M. at Agra.	189·9	+ 143·321	{ 1864-65 1861-62
Block-stone B.M. at Agra.	Pedestal of Lt.-Col. Sanders' monument.	52·3	+ 28·472	1915-16
Pedestal of Lt.-Col. Sanders' monument.	Standard B.M. at Jhānsi.	83·7	+ 269·237	1905-06-07
Standard B.M. at Jhānsi.	Block-stone B.M. at Cawnpore.	141·3	− 441·754	1917-18
	Total ...	467·2	− 0·724	

Circuit (2).

Lines. From	Lines. To	Distance in miles.	Unadjusted dynamic difference of height in feet.	Year.
Block-stone B.M. at Cawnpore.	Standard B.M. at Jhānsi.	141·3	+ 441·754	1917-18
Standard B.M. at Jhānsi.	Pedestal of Lt.-Col. Sanders' monument.	83·7	− 269·237	1905-06-07
Pedestal of Lt.-Col. Sanders' monument.	Lower mark-stone Sironj Base-line N.E. end.	202·3	+ 899·796	1861-62
Lower mark-stone Sironj Bose-line N.E. end.	G.T.S. ○ B.M. Katni Ry. Station.	193·0	− 224·596	1898-99
G.T.S. ○ B.M. Katni Ry. Station.	G.T.S. ● B.M. at Allahābād Fort.	161·5	− 956·019	1898-99
G.T.S. ● B.M. at Allahābād Fort.	Block-stone B.M. at Cawnpore.	129·0	+ 109·033	1864-65
	Total ...	910·8	+ 0·731	

The line Cawnpore-Jhānsi was levelled on the new system of "fore and back double levelling". The practice adopted in previous years was that the two levellers working from opposite directions of a line of levels, took only one set of observations at each station and exchanged data on meeting each other. Then, as the work advanced over the line already levelled in the reverse direction, if either found that the results of his levelling between a pair of bench-marks did not agree, within the prescribed limits, with those obtained by the other leveller, he relevelled that section of the line both in the forward and backward direction.

This procedure is open to the following objections:—

(a) Each leveller was inclined to increase his daily rate of progress in order, if possible, to finish more than half the line before meeting the other leveller, so that his liability to irksome repetitions might be reduced. This tended to a sacrifice of accuracy to speed.

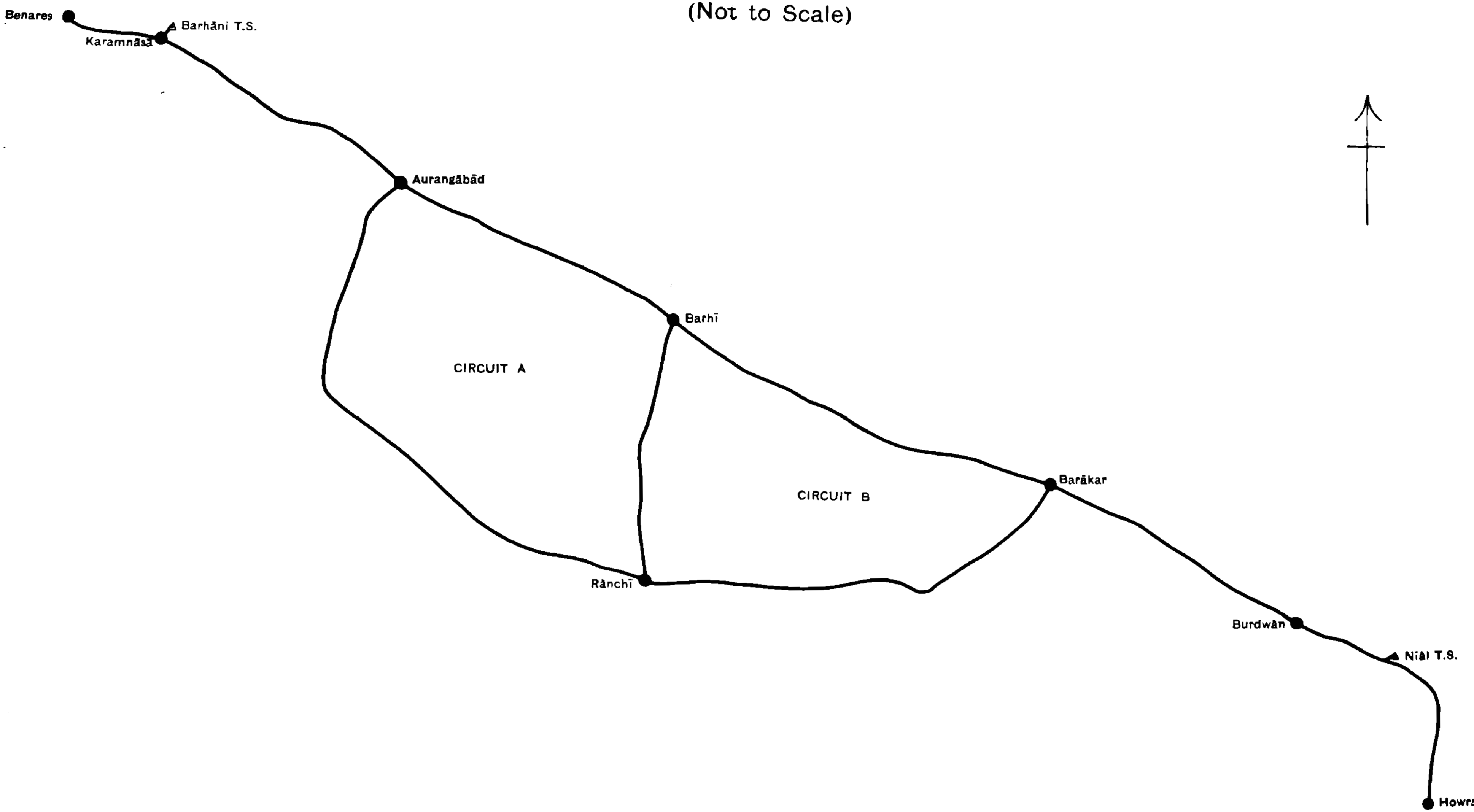
(b) It resulted in a high percentage of relevelments and occasionally it was found that the results obtained by the first leveller had to be rejected on relevelment by the second leveller. In levelling of high precision this should very seldom occur.

To remedy the above, the following procedure was adopted on the Cawnpore-Jhānsi line:—

(i) The system of the levellers exchanging data on meeting each other was discontinued; they were made to send, from time to time as the work progressed, all the data to the head-quarters office of the party, and each gave the other only the descriptions of bench-marks

ROUGH DIAGRAM OF LEVELLING

(Not to Scale)



for identification. The head-quarters office after comparing the results of the two levellers issued to them instructions as to relevelments required.

(ii) *Two sets of observations were taken every time the instrument was set up.* After the first set of readings the instrument was dislevelled and raised or lowered by moving the legs of the stand so that on relevelment different graduations on the staves were intersected. A second set of readings was then taken in the reverse order to the readings of the first set. In the event of the means of the two sets of readings differing from each other by more than 0·004 of a foot, a third set was taken, and when the third set did not differ by more than 0·001 of a foot from the mean of the first and second sets, the mean of all the three results was retained, otherwise the discordant set was rejected. This will be made clear by the following examples :—

ft.		
0·280	result of 1st set	The mean of all the three was kept.
0·285	result of 2nd set	
0·282	result of 3rd set	
ft.		
0·051	result of 1st set	1st set rejected and the mean of 2nd and 3rd kept.
0·057	result of 2nd set	
0·057	result of 3rd set	
ft.		
5·208	result of 1st set	2nd set rejected and the mean of 1st and 3rd kept.
5·215	result of 2nd set	
5·209	result of 3rd set	

The probable systematic errors of the line are given below from which it will be seen that the probable accidental error is slightly in excess while the probable systematic error is well within the prescribed limits.

Lines	Length in miles	Probable accidental error	Probable systematic error	Year
		Ft. per mile ±0·00416*	Ft. per mile ±0·00106*	
Cawnpore to Jhānsi	143·0	±0·00485	±0·00031	1917-18

The revisionary levelling was undertaken to clear up the large discrepancy of −1·899 feet between the old and new values of the height of the standard bench-mark at Benares based on that of the inscribed bench-mark $\left(\frac{\text{BM } 264}{79\text{ B}}\right)$ at Howrah, Botanical Gardens, which was disclosed by last year's levelling operations ; and to investigate the large closing error of −0·989 of a foot, in the circuit Rānchī-Barākar-Barhī-Rānchī which was completed last year (*vide* diagram attached).

The values obtained by single revisionary levelling of the lines Karamnāsā-Aurangābād and Barākar-Burdwān show that the previous results got by double levelling are perfectly reliable, the unadjusted orthometric discrepancies of −0·134 and −0·216 of a foot respectively being mostly due to the accumulation of levelling error generated during the single revisionary levelling operations.

The question therefore still remains as before why there is a large discrepancy of −1·899 feet between the old and new values of the difference in height between the Benares standard bench-mark and the inscribed bench-mark at Howrah, Botanical Gardens, $\left(\frac{\text{BM } 264}{79\text{ B}}\right)$. An inspection of the table given below shows that a very large portion of this error, *i.e.*, −1·619 feet is in the portion between Barhāni T.S. and Niāl T.S. All the component parts of this part of the Benares-Howrah line are practically above suspicion for the following reasons :—

The portions Karamnāsā-Aurangābād and Barākar-Burdwān have been revised and found correct as stated above. The portion Aurangābād-Barhī enters into circuit A (*vide* diagram attached) which closes very well, *i.e.*, with an error of −0·089 of a foot. The portion Burdwān-Niāl T.S. is practically errorless, the difference between the old and new

* Limits which must not be exceeded in "Levelling of High Precision".

levelling being only −0·026 of a foot. The only portion left is from Barhī to Barākar. It enters into circuit B which on being revised closes with an error of −0·561 of a foot. Had this circuit error been on the portion Barhī-Barākar, it would have increased by its amount the error under discussion of −1·621 feet and made it −2·182 feet.

The only conclusion, therefore, to be drawn is that the discrepancy in question is almost certainly unreal, the closing error being probably due to errors in the old work, which includes the two terminal bench-marks. For present purposes therefore and until the new net of modern levelling can be treated as a whole the amount of error to be assigned to each line in order to remove the circuit error mentioned above and the discrepancy between the old and new results, has be n determined by the method of minimum squares; and along each line the assigned portion of error has been dispersed by applying to the height of each bench-mark a correction proportional to its distance from the starting point.

TABLE.

Lines.	Distance in miles.	Difference of published orthometric heights in feet. (Old levelling *via* Dildārnagar and Pīrpanti).	Year	Unadjusted orthometric difference of heights in feet. (New levelling *via* Barākar and Burdwān).	Year	Discrepancy in feet.
Benares S. B. M. to Barhāni T.S.	35	+17·631	1863-65 1869-70	+ 17·533	1914-15	−0·101
Barhāni T.S. to Niāl T.S. ...	362	−236·080	1869-70 1862-63	−237·702	1909-10 1914-15 1916-17	−1·619
Niāl T.S. to Howrah, Botanical Gardens, (B.M.264 / 79 B)	56	−22·197	1862-63 1 81-83	− 22·376	1909-10 1913-14 1916-17	−0 179
					Total ...	−1 899

As regards the large closing error of − 0·989 of a foot in circuit B, out of the three lines forming this circuit (*vide* diagram attached) the line Barhī-Rānchī enters in circuit A and is above suspicion as circuit A closes very well. The line Barhī-Barākar is also beyond doubt for the reasons given above. The line Rānchī-Barākar however is in hilly undulating country and the results of the revisionary levelling on this line do not accord with those obtained last year, the differences being most probably due to the accumulation of personal observational errors on account of refraction and radiation. By using the mean of the three values, two obtained last year, and one during the year under report, the circuit error is reduced from − 0·989 to − 0·561 of a foot.

General Notes.

The usual weekly comparison of the staves against 10-foot standard steel tapes Nos. 2 and 5 were made with the object of determining the changes in the lengths of the staves A table showing the results of the staff comparisons is appended, *see* table V. The lengths of the steel tapes were carefully determined on the new comparator at Dehra Dūn by comparisons against the 10-foot Standard Bar A before and after the field season and were found as shown below:—

Results of comparisons against 10-foot Standard Bar A.

Date of comparison.	Length at 62° F.			
	Tape No. 2.		Tape No. 5.	
	Edge A.	Edge B.	Edge A.	Edge B
October 1917 ...	9·9996590	9·9996937	9·9999134	9·9998159
May 1918 ...	9·9996302	9·9996851	9·9998224	9·9998498
Mean lengths ...	9·9996446	9·9996894	9·9998679	9·9998495

TABLE I.—*Tabular statement of out-turn of work, season 1917-18.*

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. Protected. Old.	New.	Standard. Old.	New.	Principal stations of triangulation. Old.	New.	Secondary. Embedded. Old.	New.	Rock-cut. Old.	New.	Inscribed. Old.	New.	P. W. D. Old.	New.	Railway. Old.	New.
			Mls.Chs.Lks.	Mls.Chs.Lks.	Mls.Chs.Lks.	Mls.Chs.Lks.																			
2	Karamnāsā to Aurangābād	November 1917	54 09 88	4 25 56	59 15 44	1 33 40	305·178	182 569	578	..	...	...	...	...	...	9	...	...	...	53	...	2	.	...	...
		December 1917	19 52 12	1 07 70	20 59 82	...	137·280	136 627	204																
		Totals	74 42 00	5 33 26	79 75 26	1 33 40	442·458	319 196	782	...	..	...	..	...	...	9	.	...	...	53	...	2	...	...	..
1	Rāneni to Barākar	November 1917	28 39 88	...	28 39 88	...	578 440	1538·501	412																
		December 1917	69 48 10	...	69 48 10	.	1374 074	1900 868	822	7	...	1	...	...	...	10		94	...	100	...	2	...	..	...
		January 1918	27 57 06	...	27 57 06	...	621·488	943 206	318																
		Totals	125 65 04	..	125 65 04	.	2574·002	4382·575	1552	7	...	1	...	.	..	10	...	94	...	100	...	2	...	...	...
1 and 2	Part of Line Burdwān to Barākar (Revision)	December 1917	8 25 02	...	8 25 02	...	174 680	249·466	114	...	.	1	...	...	...	7	...	0	...	105	...	4	...	...	...
		January 1918	68 28 26	2 79 58	71 27 84	1 73 96	1165·438	821·725	770																
		Totals	76 53 28	2 79 58	79 52 86	1 73 96	1340·118	1071·191	884	...	...	1	.	...	...	7	...	10	...	105	.	4	.	...	...
1 and 2	Cawnpore to Jhānsi	January 1918	13 67 43	...	13 67 43	...	219 868	200·936	308																
		February 1918	48 76 59	3 43 85	52 40 44	0 60 00	543 486	362 036	549																
		March 1918	59 60 02	4 42 20	64 22 22	...	595 392	353·190	648	..	4	2	...	1	...	1	14	...	16	17	132	...	12	...	1
		April 1918	20 39 68	1 03 46	21 43 14	...	177·457	189·664	222																
		Totals	143 03 72	9 09 71	152 13 23	0 60 00	1536 203	1105 826	1727	...	4	2	...	1	...	1	14	..	16	17	132	..	12	...	1
		Grand Totals	420 04 01	17 42 55	437 46 39	4 07 36	5892 781	6878·788	4945	7	4	4	...	1	...	27	14	104	16	275	132	8	12	...	1

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.			Distance from starting bench-mark.	OBSERVED HEIGHT ABOVE (+) OR BELOW (−) STARTING BENCH-MARK AS DETERMINED BY			Difference (check-original). The sign + denotes that the height was greater, and the sign − less in 1917-18 than when originally levelled.	REMARKS.
Number.	Degree Sheet.	Description.		Original levelling.	Date.	Check-levelling 1917-18.		
			Miles	Feet		Feet	Feet	
				Check-Levelling between Karamnāsā and Saiyadraja.				
34	63 O	Embedded, Khajura	0·0	0·000	1914-15	0·000	0·000	Good condition.
33	,,	Bridge over Karamnāsā R. ...	0·2	+13·055	,,	+13·061	+0·006	Ditto.
32	,,	Culvert ...	1·0	+ 6·245	,,	+ 6·267	+0·022	Inscription worn; letters re-cut.
30	,,	Well ...	3·8	+11·160	,,	+11·119	−0·041	Stone slab appeared to have subsided.
29	,,	Embedded, Saiyadraja	4·4	+ 7·863	,,	+ 7·861	−0·002	Good condition.
				Check-Levelling at Aurangābād.				
106	72 D	Embedded, Aurangābād	0·0	0·000	1914-15	0·000	0·000	Good condition.
107	,,	Bridge ..	0·8	+16·409	,,	+16·374	−0·035	Surface worn.
108	,,	Mile-stone ...	1·1	+14·087	,,	+14·137	+0·050	Good condition.
				Check-Levelling at Barākar.				
270	73 I	Embedded, Barākar	0·0	0·000	1914-15	0·000	0·000	Good condition.
269	,,	Bridge over Barākar R.	0·2	+ 3·033	,,	+ 3·042	+0·009	Fair ,,
268	,,	,, ,, ,, ,,	0·6	+ 7·547	,,	+ 7·559	+0·012	,, ,,
267	,,	Rock *in situ* ...	1·8	+30·378	,,	+30·399	+0·021	,, ,,
				Check-Levelling at Burdwān.				
96	73 M	Standard bench-mark, Burdwān ...	0·0	0·000	1916-17	0·000	0·000	Good condition.
95	,,	Embedded, Burdwān	0·0	− 5·118	,,	− 5·111	+0·007	,, ,,
94	,,	Masonry pillar ...	0·4	+ 2·543	,,	+ 2·548	+0·005	,, ,,
93	,,	Culvert ...	0·8	− 1·114	,,	− 1·103	+0·011	,, ,,
92	,,	,, ...	1·1	− 2·945	,,	− 2·935	+0·010	,, ,,
91	,,	,, ...	1·6	− 3·242	,,	− 3·236	+0·006	,, ,,
90	,,	,, ...	2·2	− 3·684	,,	− 3·659	+0·025	,, ,,
89	,,	,, ...	3·0	− 3·953	,,	− 3·911	+0·042	,, ,
				Check-Levelling at Cawnpore.				
59	63 B	Standard bench-mark, Cawnpore ...	0·0	0·000	1915-16	0·000	0·000	Good condition.
58	,,	Verandah flooring (office) ...	0·0	− 0·658	,,	− 0·656	+0·002	,, ,,
57	,,	Verandah flooring G.P.O. ...	0·3	− 0·897	,,	− 0·895	+0·002	,, ,,
56	,,	Church step ...	0·6	− 1·413	,,	− 1·413	0·000	,, ,,
55	,,	Verandah flooring (office) ...	0·8	− 1·121	,,	− 1·124	−0·003	,, ,,
54	,,	Statue ...	1·2	+ 7·677	,,	+ 7·683	+0·006	,, ,,
53	,,	Stone plinth of verandah ...	1·4	+ 7·130	,,	+ 7·133	+0·003	,, ,,
52	,,	Block-stone embedded, Cawnpore ...	1·7	+ 0·021	,,	+ 0·028	+0·007	,, ,,
1/52	,,	Verandah flooring ...	1·8	+ 5·290	,,	+ 5·291	+0·001	,, ,,
A/52	,,	Railway bridge ...	3·5	+ 8·178	,,	+ 8·191	+0·013	,, ,,
B/52	,,	,, culvert ...	7·6	+10·141	,,	+10·146	+0·005	,, ,,
C/52	,,	,, bridge ...	8·3	+14·106	,,	+14·112	+0·006	,, ,,
				Check-Levelling at Jhānsi.				
51	54 K	Standard bench-mark, Jhānsi ...	0·0	0·000	1906-07	0·000	0·000	Good condition.
50	,,	Step, church ...	0·0	− 0·797	,,	− 0·796	+0·001	
49	,,	,, ,, ...	0·1	− 0·746	,,	− 0·747	−0·001	
48	,,	Verandah flooring, Railway institute ...	0·5	+ 8·549	,,	+ 8·562	+0·013	
46	,,	Verandah flooring, Railway office ...	0·9	+15·061	,	+15·072	+0·011	
44	,,	Platform coping, Railway station ...	1·3	+ 2·373	,,	+ 2·372	−0·001	Fair condition.
43	,,	Platform coping, Railway station ...	1·4	+ 2·409	,,	+ 2·452	+0·043	Fair condition, but has probably been disturbed.
47	,,	Verandah flooring, Railway rest-house	2·0	+23·356	,,	+23·360	+0·004	Good condition.

TABLE IV.

List of G. T. S. Triangulation stations connected by spirit-levelling, season 1917-18.

Name of station	Height above mean-sea-level.			Difference (Triangulation − Spirit-Levelling).	Remarks.
	New spirit-levelling.	Old spirit-levelling.	Triangulation.		
	Feet	Feet	Feet	Feet	
Gora T. S. of the Rangīr Meridional Series.	466·980	...	477·000	+10·020	⊙ on ground floor mark-stone connected.

TABLE V.—No. 1 Levelling Detachment.

Results of comparison of staves with standard steel Tape No. 5, Season 1917-18.

Place and date of comparison.		Staff − Tape		Remarks.
		Staff 23 B.	Staff 22 B.	
		Foot	Foot	
Chutia (Rānchī)	18-11-17	+0·00149	+0·00158	Clear and cool breeze.
Jonha	27-11-17	+0·00216	+0·00208	Do.
Sili	5-12-17	+0·00231	+0·00203	Do.
Jaipur	13-12-17	+0·00188	+0·00189	Clear and strong cool breeze.
Jhaprā	23-12-17	−0·00013	+0·00068	Strong cool breeze.
Barākar	29-12-17	+0·00084	+0·00071	Scattered clouds and cool breeze.
Siarsol	6- 1-18	+0·00076	+0·00077	Clear and cool breeze.
Rājbāndh	12- 1-18	+0·00064	+0·00030	Clear overhead and hazy on horizon.
Raghunāthpur	19- 1-18	+0·00106	+0·00051	Cloudy.
Barākar	26- 1-18	+0·00068	+0·00015	Clouds on horizon, strong cool breeze.
Jhānsi	8- 2-18	+0·00062	−0·00004	Clear and cool breeze.
Jhānsi	16- 2-18	−0·00081	−0·00105	Do.
Chirgaon	24- 2-18	−0·00030	−0·00021	Cloudy.
Pūnchh	5- 3-18	−0·00103	−0·00079	Clear and cool breeze.
Orai	14- 3-18	−0·00118	−0·00197	Light clouds and cool breeze.
Ata	23- 3-18	−0·00132	−0·00233	Cloudy & strong cool breeze.
Pukhrāyān	31- 3-18	−0·00127	−0·00215	Clear.
Nagin Jasi	9- 4-18	−0·00147	−0·00237	Light clouds and cool breeze.
Cawnpore	18- 4-18	−0·00271	−0·00368	Clear.
Cawnpore	22- 4-18	−0·00229	−0·00337	Do.

TABLE V.—No. 2 LEVELLING DETACHMENT.

Results of comparison of staves with standard steel Tape No. 2, Season 1917-18.

Place and date of comparison		Staff – Tape		REMARKS.
		Staff 25 A	Staff 25 B	
		Foot	Foot	
Karamnāsā	11-11-17	+0·00337	+0·00128	Clear and dry cool breeze.
Mohania	19-11-17	+0·00177	−0·00059	Do.
Sasarām	26-11-17	+0·00158	−0·00022	Light scattered clouds, cool breeze, dry.
Dehrī	3-12-17	+0·00141	−0·00078	Clear and cool breeze, dry.
Jasaiya (Aurangābād)	9-12-17	+0·00125	−0·00084	Clear and cool breeze.
Burdwān	30-12-17	+0·00149	−0·00029	Light scattered clouds, cool breeze, dry.
Galsi	5-1-18	+0·00093	−0·00172	Clear overhead, cool breeze.
Rājbāndh	12-1-18	+0·00067	−0·00176	Clear and cool breeze, mornings foggy.
		Staff 24 A	Staff 24 B	
Nārainpur (Cawnpore)	21-1-18	−0·00420	−0·00279	Clear and cool breeze.
Sachendi	28-1-18	−0·00446	−0·00294	Clear overhead, sudden gusts of strong cool breeze.
Hānsi Man	4-2-18	−0·00416	−0·00315	Clear and cool breeze.
Kālpi	11-2-18	−0·00512	−0·00362	Do.
Ata	19-2-18	−0·00581	−0·00441	Scattered clouds and cool breeze, few drops of rain during comparison.
Ait	26-2-18	−0·00558	−0·00423	Light scattered clouds and cool breeze.
Pūnchh	5-3-18	−0·00620	−0·00466	Clear and cool breeze.
Moth	12-3-18	−0·00662	−0·00459	Scattered clouds, sudden gusts of cool breeze.
Baragaon	19-3-18	−0·00654	−0·00522	Light scattered clouds and cool breeze.
Tālpura (Jhānsi)	26-3-18	−0·00778	−0·00656	Clear and cool breeze.
Tālpura (Jhānsi)	2-4-18	−0·00811	−0·00662	Clear.

No. 18 PARTY (MAGNETIC SURVEY).

By E. C. J. Bond.

PERSONNEL.

Provincial Officers.

Mr. E. C. J. Bond, in charge.
" R. P. Ray, B. A. up to 30th June 1918.
" N. R. Mazumdar.

Upper Subordinate Service.

Mr. K. K. Das, B. A., up to 31st May 1918.
" B. B. Shome.

Lower Subordinate Service.

2 Magnetic Observers.
12 Computers, etc.

The present report on the work of the Magnetic party in 1917-18 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 the observatories in 1917.

An index map showing the stations of the magnetic survey is appended.

I.—Work during the field and recess seasons.

1.—*Work during the field season.*—The magnetic observatories at Dehra Dūn and Toungoo were inspected by the officer in charge and a complete set of observations of Declination, Dip and Horizontal Force was taken at each for the comparison of instruments. The Alibāg and Kodaikānal observatories, under the Meteorological Department, were also visited for comparative observations.

Galle, a seaport in the south of Ceylon, was visited for the purpose of establishing a permanently marked repeat station. Such a station is required for determining the annual changes in the magnetic elements in the south of India and in the island of Ceylon, where no observations have been repeated since the magnetic survey of the island in 1910. The original site of the field station at Galle was not suitable for a repeat station, a new site was therefore selected near the north-eastern bastion of Galle Fort and observations of the magnetic elements were taken at a permanent traverse mark of the Ceylon Survey Department: observations will be repeated at this spot in 1919-20 and thereafter at intervals of 5 years when each of the other 74 repeat stations of the magnetic survey is revisited. The Surveyor General of Ceylon and the Superintendent of Surveys at Galle very kindly rendered every assistance to the officer in charge in the selection of a suitable site.

The staff of the party was employed in completing the reduction of the observations of the general survey to epoch and in tabulating the results for publication.

2. *Work during the recess.*—The computation of the comparative observations taken at the observatories and the computation and tabulation of the provisional values of Declination, Dip, Horizontal Force and Vertical Force for the three observatories (Dehra Dūn, Toungoo and Kodaikānal) for 1917 have been completed. The mean values of these elements for the year, derived from the measurements 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 observations of the detailed survey to the epoch 1909·0 is now in hand: the observations consist of Declination, Dip and Horizontal Force taken at 407 stations distributed over eleven magnetically disturbed areas. The investigation of the results of these observations, which may perhaps disclose the existence of some special magnetic features, will be published next year.

Publication of the results of the Magnetic Survey.

The observations taken between 1901 and 1915, at the 74 repeat stations and 1351 field stations of the general survey, have been reduced to the epoch 1909·0. The results will be published shortly in a separate volume of the Records of the Survey of India. The publication will contain a brief history of the magnetic survey; particulars of the work at the observatories and field stations with a reference to the instruments used and the methods employed in the reduction of the observations; tables of the Declination, Dip, Horizontal Force, Total Force and rectangular components and the values of annual change for the first three elements at each station of observation. The volume will also contain maps showing the true course of the iso-magnetic lines as obtained from the actual observed values corrected for diurnal variation, short lived disturbances, and reduced to epoch. No attempt has been made to smooth out any irregularities in the iso-magnetic curves due to the magnetically disturbed nature of certain areas.

Programme for 1918-19.—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.

II.—The Observatories in 1917-18.

Dehra Dun Observatory.

1. The magnetographs have continued to work satisfactorily; the V.F. magnetograph, however, which has never worked as well as the other two self-registering instruments, had to be opened several times for cleaning the agates to give the magnet a free motion.

The rainy season has always been a period of anxiety at this observatory but no trouble was experienced this year as no subsoil water entered the passage of the underground room, the rainfall being much below the average.

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. The values of m are also given, as determined by the revised distribution factor and moment of inertia used for the computations for 1915. Vibration observations with the chronograph were used in deriving the values of m in the table.

Mean values of the constants of magnet No. 17 in 1917.

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 ...	− 7 2	6·11	6·84	7·30	−382	807·09	806·80 throughout
February ...	− 7 8	6·18	6·83				
March ...	− 7 6	6·05	6·68			806·93	
April ...	− 7 11	5·86	6·93			806·96	
May ...	− 7 11	5·84	6·79			806·99	
June ...	− 7 12	5·83	6·83			806·97	
July ...	− 7 16	6·00	6·46			806·94	
August ...	− 7 14	6·01	6·51			806·98	
September ...	− 7 13	6·08	6·87			807·07	
October ...	− 7 16	6·09	6·68			807·24	
November ...	− 7 16	6·02	6·52			807·26	
December ...	− 7 20	5·91	6·74			807·16	

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 1917. 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 1917.

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 28·1	1 28·1		·32754	·32754	
February ...	1 28·2	1 28·2		·32750	·32750	
March ...	1 28·5	1 28·5		·32749	·32749	
April ...	1 28·6	1 28·6		·32754	·32754	
May ...	1 28·6	1 28·6		·32749	·32749	to 10h. on 30th May.
June ...	1 31·2	1 31·2	to 12th June.	·32727	·32727	From 31st May to 12th June.
July ...	1 31·9	1 31·9	From 11h. on 28th June	·32718	·32719	From 28th June to end of July.
August ...	1 32·3	1 32·3		·32715	·32715	
September ...	1 32·3	1 32·3		·32708	{ ·32710 { ·32706	up to 18th. From 19th.
October ...	1 32·8	1 32·8		·32703	·32703	
November ...	1 32·2	1 32·2		·32700	·32700	
December ...	1 31·8	1 31·8		·32702	·32702	

4. *Mean scale values and temperature range.*—The mean scale values for 1917 for an ordinate of $\frac{1}{25}$ inch are:—

Horizontal Force	4·42 gammas.
Declination	1·03 minutes.
Vertical Force	4·97 to 6·13 gammas.

The mean temperature for the year was 26°·8 C., with maximum and minimum monthly values of 27°·0 C. and 26°·4 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 1916 and 1917 and the annual changes for that period; these annual changes are deduced from the values of H corrected for the moment of inertia and the revised distribution factor used in the computations for 1915.

Annual changes at Dehra Dūn in 1916-17.

Months.	Horizontal Force ·32000 C. G. S. +			Declination E. 2° +			Dip N. 44° +			Vertical Force. ·32000 C. G. S. +		
	1916	1917	Annual change.	1916	1917	Annual change.	1916	1917	Annual change.	1916	1917	Annual change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January ...	1063	1011	−52	13·2	8·3	−4·9	34·9	42·5	+7·6	583	677	+94
February ...	1072	1021	−51	12·8	7·7	−5·1	34·7	42·1	+7·4	589	679	+90
March ...	1052	1025	−27	12·7	8·0	−4·7	36·3	42·1	+5·8	599	681	+82
April ...	1061	1024	−37	12·2	7·5	−4·7	36·2	42·3	+6·1	606	685	+79
May ...	1057	1022	−35	11·8	6·9	−4·9	36·9	42·8	+5·9	616	692	+76
June ...	1064	1024	−40	10·9	6·5	−4·4	37·0	43·0	+6·0	625	699	+74
July ...	1053	1020	−33	10·9	6·4	−4·5	38·0	44·0	+6·0	632	713	+81
August ...	1018	987	−61	10·6	6·7	−3·9	38·5	46·2	+7·7	637	724	+87
September ...	1038	999	−39	10·0	5·7	−4·3	39·4	45·6	+6·2	644	723	+79
October ...	1034	993	−41	9·7	5·8	−3·9	40·3	45·8	+5·5	658	722	+64
November ...	1028	995	−33	9·0	4·7	−4·3	41·1	45·8	+4·7	666	722	+56
December ...	1025	991	−31	8·6	4·1	−4·5	41·3	46·4	+5·1	667	733	+66
Means	1050	1010	−40	11·0	6·5	−4·5	37·9	44·1	+6·2	627	704	+77

Toungoo Observatory.

1. The magnetographs worked satisfactorily throughout the year. During the inspection of the observatory in March 1917 the Declination, Horizontal Force and Vertical Force instruments were each adjusted on account of the gradual shift of the trace due to the annual changes in the magnetic elements.

The Earth Inductor, No. 44, was reported by the observer to be working very unsatisfactorily and a spare Earth Inductor, No. 46, was sent from Dehra Dūn for use at Toungoo. The observatory instrument always gave good results and it is hoped that it may be possible to put it into working order again when the officer in charge visits the observatory early next year.

2. *Mean values of the 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 for 1915.

Mean values of the constants of magnet No. 19A in 1917.

Months.	Declination Constants.	H. F. Constants.						Remarks.
		Distribution Factors.				Mean values of m.		
	Mean magnetic collimation.	$P_{1\cdot2}$	$P_{2\cdot3}$	Accepted values.		Monthly means.	Accepted m.	
				p	q			
	′ ″							
January ...	− 11 33	8·29	8·95			874·29	874·29	
February ...	− 11 33	8·29	8·98			874·22	874·22	
March ...	− 11 34	8·10	9·44			874·21	874·21	
April ...	− 11 30	8·23	9·77			{ 873·96 { 873·67	873·96 873·67	to 18th. From 19th to end of April.
May ...	− 11 17	8·06	9·29	10·19	−·546			
June ...	− 11 24	8·10	9·37					
July ...	− 10 49	8·16	9·47			} 873·22	873·22	
August ...	− 10 58	8·19	9·28					
September ...	− 11 7	8·24	9·24			873·09	873·09	
October ...	− 10 59	8·14	9·26			873·02	873·02	
November ...	− 11 17	8·18	9·34			872·94	872·94	
December ...	− 11 9	8·20	9·26			872·92	872·92	

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 1917. 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 1917.

Months.	Declination.		Horizontal Force.	
	Mean value of Base line.	Base line accepted.	Mean value of Base line.	Base line accepted.
	° ′	° ′	C. G. S.	C. G. S.
January	0 52·0	0 52·0	·38594	·38594
February	0 51·9		·38590	·38590
March	0 51·9		·38592	·38592
April	0 51·9	} 0 51·9	·38581	·38581
May	0 51·2		·38577	·38577
June	0 51·9		·38572	·38572
July	0 52·4	0 52·4	·38564	·38564
August	0 52·2	0 52·2	·38566	·38566
September	0 52·4	0 52·4	·38562	·38562
October	0 52·4	0 52·4	·38561	·38561
November	0 52·3	0 52·3	·38560	·38560
December	0 52·3	0 52·3	·38562	·38562

4. *Mean scale values and temperature range.*—The mean scale values for 1917 for an ordinate of 1/25 inch are:—

Horizontal Force 5·41 gammas.
Declination 1·04 minutes.
Vertical Force { 5·62 gammas up to May.
{ 5·81 gammas from June to the end of the year.

The mean temperature for the year was 89°·2 F., with maximum and minimum monthly values of 89°·6 and 88°·9 F. The temperature of reduction is 89°·0 F.

5. *Mean monthly values and annual changes.*—The table below gives the mean monthly values of the magnetic elements for 1916 and 1917 and the annual changes for that period: the values of annual change 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 1916-17.

Months.	Horizontal Force ·39000 C. G. S. +			Declination W. 0° +			Dip N. 23° +			Vertical Force ·16000 C. G. S. +		
	1916.	1917.	Annual change.	1916.	1917.	Annual change.	1916.	1917.	Annual change.	1916.	1917.	Annual change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January ...	13	26	+13	6·3	11·1	+4·8	7·3	9·0	+1·7	658	687	+29
February ...	22	38	+16	6·6	11·3	+4·7	7·7	8·6	+0·9	667	686	+19
March ...	04	48	+44	6·9	11·6	+4·7	8·6	8·3	−0·3	671	686	+15
April ...	21	38	+17	7·5	12·1	+4·6	8·3	8·4	+0·1	675	683	+ 8
May ...	15	39	+24	8·0	12·6	+4·6	8·6	9·2	+0·6	676	695	+19
June ...	26	44	+18	8·2	12·7	+4·5	8·5	8·1	−0·4	679	682	+ 3
July ...	21	38	+17	8·8	13·0	+4·2	9·0	8·0	−1·0	684	678	− 6
August ...	20	18	− 2	9·0	13·0	+4·0	9·0	8·9	−0·1	684	681	− 3
September ...	14	37	+23	9·5	13·5	+4·0	9·2	8·2	−1·0	684	681	− 3
October ...	17	36	+19	9·7	13·7	+4·0	8·6	8·3	−0·3	677	681	+ 4
November ...	25	43	+18	10·3	13·9	+3·6	8·7	8·2	−0·5	681	683	+ 2
December ...	19	44	+25	10·5	14·4	+3·9	8·8	8·4	−0·4	681	686	+ 5
Means ...	18	37	+19	8·4	12·7	+4·3	8·5	8·5	0·0	676	684	+ 8

Kodaikanal Observatory.

1. The observatory is under the control of the Meteorological Department but the records of the observations continue to be forwarded by the Director of the Kodaikānal observatory to be computed and kept for record in the party.

Every assistance has very kindly been rendered by the Director in all matters connected with the magnetic work.

The results of the self-recording instruments have been satisfactory.

The observer's absolute observations of horizontal force, after his return from a month's leave in August 1917, showed a rise of about half a unit in the moment of the observatory magnet (No. 16) up to February 1918, and though there was a slight diminution in his values of "m" in the following month yet they have remained higher than the normal value; whereas the results obtained by the Recorder, who carried on the observations during the absence of the Observer in August and subsequently for short periods, show practically the same values as those obtained by the Observer previous to his leave. The officer in charge, during his visit to the observatory in March 1918 took careful eye-and-ear observations with the observatory instrument and obtained similar values of "m" to those of the Recorder. A scrutiny of the base-line values of the magnetograph and the Observer's observations does not reveal any real change in "m": the apparent rise in the Observer's values since his return from leave seems to be due to a personal error developed by him with the chronograph in taking the vibration observations.

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. Vibration observations with the chronograph were used in deriving the values of "m" in the table.

Mean values of the constants of magnet No. 16 in 1917.

Months.	Declination constants.	H. F. constants.					
		Distribution Factors.				Mean values of m.	
	Mean magnetic collimation.	$P_{1\cdot2}$	$P_{2\cdot3}$	Accepted values		Monthly means	Accepted m.
				p	q		
	′ ″						
January ...	−3 31	6·22	8·39			883·30	
February ...	−3 30	6·21	8·39			883·26	
March ...	−3 31	6·14	8·42			883·16	
April ...	−3 31	6·22	8·32			882·94	
May ...	−3 28	6·20	8·27			882·92	
June ...	−3 29	6·22	8·41	11·39	−1621	882·86	
July ...	−3 28	6·23	8·46			883·38	882·77 throughout
August ..	−3 33	6·21	8·23				
September ...	−3 33	6·19	8·54			883·58	
October ...	−3 30	6·14	8·49			883·55	
November ...	−3 31	6·22	8·62			883·56	
December ...	−3 31	6·29	8·41			883·61	

3. *Mean base line values.*—The following table gives the mean monthly observed and accepted values of the Declination and H.F. base lines; the accepted values have been used to compute the values of these elements for 1917. 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 1917.

Months.	Declination.		Horizontal Force.	
	Mean value of Base line.	Base line accepted.	Mean value of Base line.	Base line accepted.
	° ′	° ′	C.G.S.	C.G.S.
January	2 34·1	2 34·1	·37341	·37341
February	2 33·9	2 33·9	·37344	·37344
March	2 33·8	2 33·8	·37344	·37344
April	2 33·6	2 33·6	·37343	·37343
May	2 33·5	2 33·5	·37345	·37345
June	2 33·4	2 33·4	·37341	·37341
July	2 33·3	2 33·3	·37337	·37337
August	2 33·7	2 33·7	·37341	·37341
September	2 33·5	2 33·5	·37337	·37337
October	2 33·4	2 33·4	·37338	·37338
November	2 33·5	2 33·5	·37337	·37337
December	2 32·9	2 32·9	·37335	·37335

4. *Mean scale values and temperature range.*— The mean scale values for 1917 for an ordinate of $\frac{1}{25}$ inch are :—

Horizontal Force	5·91 gammas.
Declination	1·03 minutes.
Vertical Force	6·26 gammas.

The mean temperature for the year was 17°·4 C. with maximum and minimum monthly values of 18°·1 C. and 16°·6 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 1916 and 1917 and the annual changes for that period; these annual 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 1916-17.

Months.	Horizontal Force ·37000 C. G. S. +			Declination W. 1° +			Dip N. 4° +			Vertical Force ·02000 C. G. S. +		
	1916.	1917.	Annual change.	1916.	1917.	Annual change.	1916.	1917.	Annual change.	1916.	1917.	Annual change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January ...	623	630	+ 7	25·5	31·4	+ 5·9	19·0	25·2	+ 6·2	839	906	+ 67
February ...	630	648	+ 18	25·6	31·8	+ 6·2	20·4	25·4	+ 5·0	855	913	+ 58
March ...	622	658	+ 36	...	32·2	...	20·6	25·7	+ 5·1	858	916	+ 58
April ...	637	657	+ 20	26·4	32·6	+ 6·2	21·0	26·3	+ 5·3	862	922	+ 60
May ...	634	662	+ 28	26·9	33·0	+ 6·1	21·7	26·9	+ 5·2	871	930	+ 59
June ...	638	665	+ 27	27·2	33·4	+ 6·2	22·4	27·6	+ 5·2	879	938	+ 59
July ...	635	665	+ 30	27·5	33·8	+ 6·3	22·9	27·2	+ 4·3	884	933	+ 49
August ...	635	653	+ 18	28·4	34·6	+ 6·2	23·5	27·6	+ 4·1	890	937	+ 47
September ...	630	673	+ 43	28·9	35·1	+ 6·2	23·3	28·0	+ 4·7	888	943	+ 55
October ...	636	671	+ 35	29·5	35·4	+ 5·9	23·8	28·0	+ 4·2	894	942	+ 48
November ...	637	673	+ 36	29·9	36·0	+ 6·1	24·6	28·4	+ 3·8	903	947	+ 44
December ...	636	671	+ 35	30·6	36·0	+ 5·4	25·1	28·6	+ 3·5	908	950	+ 42
Means ...	633	661	+ 28	...	33·8	...	22·4	27·1	+ 4·7	878	931	+ 53

III.—Tables of Results.

Mean values of the magnetic elements at observatories in 1917.

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 44·1	E. 2 6·5	·33010	·32704
Toungoo	18 55 45 N 96 27 3 E	N. 23 8·5	W. 0 12·7	·39037	·16684
Kodaikānal	10 13 50 N 77 27 46 E	N. 4 27·1	W. 1 33·8	·37661	·02931

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 1917.

1917	January.			February.			March.		
Dates.	D	T	K	D	T	K	D	T	K
1 ...	S	S	S	C	C	C	S	S	S
2 ...	C	C	C	C	C	C	C	C	C
3 ...	C	C	C	C	C	C	C	C	C
4 ...	G	G	G	C	C	C	S	S	S
5 ...	G	G	S	S	S	S	S	S	M
6 ...	S	S	S	S	S	S	S	S	S
7 ...	S	S	S	S	S	S	S	S	S
8 ...	S	C	S	S	S	S	S	S	S
9 ...	S	C	C	C	C	C	S	S	S
10 ...	S	S	S	C	C	C	C	C	S
11 ...	S	S	C	C	C	C	C	C	C
12 ..	S	S	S	C	C	C	C	C	C
13 ...	S	S	S	C	C	C	S	S	S
14 ...	C	C	C	C	C	C	C	C	C
15 ...	C	C	C	G	G	G	S	S	S
16 ...	C	C	C	G	S	G	S	S	S
17 ...	C	C	C	S	S	S	C	C	C
18 ...	C	C	C	S	S	S	C	C	C
19 ...	S	S	S	S	S	S	C	C	C
20 ...	S	S	S	G	G	G	S	S	S
21 ...	S	S	S	S	S	S	S	S	S
22 ...	M	S	S	S	S	S	S	S	C
23 ...	S	S	S	S	S	S	S	S	S
24 ...	S	S	S	S	S	S	S	S	C
25 ...	S	S	S	S	S	S	S	S	S
26 ...	S	S	S	S	S	S	S	S	S
27 ...	S	S	S	S	C	S	S	S	S
28 ...	C	C	C	S	S	S	C	C	C
29 ...	C	C	C	...	...	...	C	C	C
30 ...	S	C	C	...	...	...	C	C	C
31 ...	S	S	S	...	...	...	C	C	C
C ...	9	12	12	10	11	10	13	13	14
S ...	19	17	18	15	15	15	18	18	16
M ...	1	...	...	...	...	...	...	...	1
G ...	2	2	1	3	2	3	...	...	...
V.G. ...	...	...	...	...	...	...	...	...	...
Trace lost ...	...	...	...	...	...	...	...	...	...

1917	April.			May.			June.		
Dates.	D	T	K	D	T	K	D	T	K
1 ...	S	S	S	M	S	S	C	C	C
2 ...	S	S	S	S	S	S	C	C	–
3 ...	S	S	S	S	S	S	S	C	–
4 ...	S	S	S	S	S	S	S	S	–
5 ...	S	S	S	S	C	S	C	C	C
6 ...	M	S	S	C	C	C	S	S	S
7 ...	S	C	C	S	S	S	G	M	M
8 ...	S	S	C	C	C	C	M	M	M
9 ...	M	M	M	S	C	S	S	S	S
10 ...	S	S	C	S	S	S	S	S	S
11 ...	C	C	C	S	S	S	C	C	C
12 ..	C	C	C	C	C	C	C	C	C
13 ...	C	C	C	C	C	S	S	S	S
14 ...	C	C	C	S	C	S	S	S	S
15 ...	S	S	S	S	S	S	C	C	C
16 ...	S	S	S	M	M	M	S	S	S
17 ...	S	S	C	S	S	S	S	C	S
18 ...	S	S	S	S	S	S	C	C	C
19 ...	C	C	C	S	S	S	C	C	C
20 ...	C	C	C	C	C	C	C	C	C
21 ...	C	C	C	S	S	S	C	C	C
22 ...	S	S	S	S	S	S	S	S	S
23 ...	S	S	S	S	S	S	M	M	M
24 ...	S	S	C	S	S	S	G	G	M
25 ...	S	S	S	S	S	S	S	S	S
26 ...	M	M	M	S	S	S	S	S	S
27 ...	C	S	C	S	S	S	C	C	C
28 ...	C	C	C	S	S	S	C	C	C
29 ...	S	S	S	S	S	S	C	C	C
30 ...	S	S	C	S	S	S	C	C	C
31 ...	...	...	...	C	C	S	...	...	...
C ...	9	9	15	6	9	4	14	16	13
S ...	18	19	13	23	21	26	12	10	10
M ...	3	2	2	2	1	1	2	3	4
G ...	...	...	...	...	...	...	2	1	...
V.G. ...	...	...	...	...	...	...	...	...	...
Trace lost ...	...	...	...	...	...	...	...	...	3

1917	July.			August.			September.		
Dates.	D	T	K	D	T	K	D	T	K
1 ...	C	C	C	M	M	M	C	C	C
2 ...	M	S	M	C	C	C	S	S	S
3 ...	M	M	M	C	C	C	S	–	S
4 ...	S	S	S	–	C	C	S	–	S
5 ...	C	C	C	–	C	C	G	G	G
6 ...	C	C	C	C	C	C	M	M	S
7 ...	S	S	S	S	S	C	C	C	C
8 ...	S	S	S	S	S	S	C	C	C
9 ...	C	C	C	V.G.	V.G.	V.G.	S	S	S
10 ...	S	S	S	V.G.	V.G.	V.G.	C	C	C
11 ...	S	S	S	S	S	S	C	C	C
12 ..	S	S	S	C	C	C	C	C	C
13 ...	S	S	S	G	G	G	S	S	S
14 ...	S	S	S	G	G	G	S	S	S
15 ...	C	C	C	G	G	M	S	S	S
16 ...	C	C	C	S	S	S	S	S	S
17 ...	C	C	C	C	C	S	S	S	S
18 ...	C	C	C	C	C	S	S	S	C
19 ...	C	C	C	C	C	C	S	S	S
20 ...	C	C	C	G	G	M	S	S	–
21 ...	S	C	C	G	G	M	S	S	–
22 ...	S	S	S	M	M	M	S	S	S
23 ...	C	C	C	M	S	S	C	C	C
24 ...	S	C	C	S	M	S	S	S	S
25 ...	C	C	C	S	S	S	S	S	S
26 ...	C	C	C	G	G	G	C	C	C
27 ...	S	S	S	S	S	S	C	C	C
28 ...	M	M	M	C	C	C	M	M	M
29 ...	S	S	S	C	C	C	S	S	S
30 ...	S	S	S	S	S	S	S	S	S
31 ...	G	G	G	S	S	C	...	...	...
C ...	13	15	15	9	11	11	9	9	10
S ...	14	13	12	9	9	10	18	16	16
M ...	3	2	3	3	3	5	2	2	1
G ...	1	1	1	6	6	3	1	1	1
V.G. ...	...	...	...	2	2	2	...	...	...
Trace lost ...	...	...	...	2	...	...	...	2	2

1917	October.			November.			December.		
Dates.	D	T	K	D	T	K	D	T	K
1 ...	S	S	S	S	S	S	C	C	C
2 ...	S	S	S	C	C	C	S	S	S
3 ...	S	S	S	C	C	C	S	S	S
4 ...	S	S	S	C	C	C	M	S	S
5 ...	S	S	S	C	C	C	S	S	S
6 ...	S	S	S	C	C	C	S	S.	S
7 ...	C	C	C	S	S	S	S	S	S
8 ...	S	S	S	C	C	S	S	S	S
9 ...	S	S	S	C	C	C	S	S	S
10 ...	S	S	S	C	C	C	C	C	C
11 ...	S	S	S	S	S	S	S	S	S
12 ..	S	C	C	G	G	M	S	S	S
13 ...	S	S	S	M	M	S	C	S	C
14 ...	G	G	G	G	G	G	S	S	C
15 ...	S	S	S	C	C	C	S	[illegible]	C
16 ...	C	C	C	C	C	C	V.G.	V.G.	V.G.
17 ...	C	C	C	C	C	C	V.G.	V.G.	V.G.
18 ...	C	C	C	C	C	C	V.G.	V.G.	V.G
19 ...	C	C	C	S	S	S	M	S	S
20 ...	C	C	C	S	S	S	M	M	S
21 ...	C	C	C	C	C	C	S	S	S
22 ...	C	C	C	S	S	S	C	C	C
23 ...	S	S	C	C	C	C	C	C	C
24 ...	S	S	S	C	C	C	C	C	C
25 ...	S	S	S	S	S	S	C	C	C
26 ...	C	C	C	S	S	S	S	S	S
27 ...	C	C	C	M	S	S	S	S	C
28 ...	G	G	G	S	S	S	C	C	C
29 ...	G	G	G	C	C	C	S	S	S
30 ...	M	M	M	C	C	C	S	S	S
31 ...	S	S	S	...	...	...	. C	C	C
C ...	10	11	12	17	17	16	9	9	12
S ...	17	16	15	9	10	12	16	18	16
M ...	1	1	1	2	1	1	3	1	...
G ...	3	3	3	2	2	1	...	...	...
V.G. ...	...	...	...	...	...	...	3	3	3
Trace lost ...	...	...	...	...	...	...	...	...	...

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

Hourly Means of the Declination at Dehra Dun in 1917, 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.	8·5	8·5	8·6	8·4	8·3	7·9	7·9	8·0	8·7	9·3	8·8	7·5	6·9	7·1	7·7	8·2	8·5	8·4	8·3	8·5	8·5	8·5	8·5	8·6	8·4	8·3
	Feb.	8·1	8·0	8·0	7·9	7·5	7·4	7·4	7·6	8·9	9·8	9·8	8·5	7·0	6·0	6·1	6·6	7·2	7·5	7·4	7·6	7·7	7·8	7·9	8·1	8·1	7·7
	Mar.	8·2	8·2	8·1	8·1	8·0	7·8	8·0	9·3	10·6	11·0	10·0	7·9	6·4	5·6	5·7	6·6	7·5	7·8	7·5	7·6	7·7	7·9	7·9	8·0	8·2	8·0
	Oct.	6·3	6·1	6·0	6·0	5·8	5·7	5·9	7·2	8·3	8·1	7·0	5·3	3·9	3·8	3·9	4·0	5·6	5·5	5·1	5·4	5·6	5·7	5·9	6·1	6·3	5·8
	Nov.	5·2	5·0	5·0	4·8	4·6	4·3	4·4	4·6	5·6	6·0	5·5	4·4	3·6	3·7	4·0	4·2	4·3	4·5	4·4	4·7	4·6	4·8	4·9	5·1	5·1	4·7
	Dec.	4·4	4·5	4·3	4·2	3·9	3·5	3·4	3·1	3·6	4·6	5·4	5·0	4·4	4·2	4·1	3·9	3·8	3·9	4·1	4·1	4·2	4·1	4·3	4·5	4·4	4·1
	Means	6·8	6·7	6·7	6·6	6·4	6·1	6·2	6·6	7·6	8·1	7·8	6·4	5·4	5·0	5·3	5·7	6·2	6·3	6·1	6·3	6·4	6·5	6·6	6·7	6·8	6·4
Summer.	April	7·7	7·8	7·7	7·7	7·7	7·7	8·6	9·9	10·9	10·8	9·3	7·1	5·4	4·5	4·8	5·7	6·5	7·2	7·2	6·9	7·0	7·2	7·4	7·5	7·7	7·5
	May	7·3	7·5	7·6	7·6	7·6	7·9	9·2	10·2	10·2	9·2	7·4	5·4	4·2	3·7	4·0	4·7	5·6	6·5	7·0	6·7	6·5	6·7	6·9	7·0	7·2	6·9
	June	7·1	7·0	7·2	7·1	7·2	7·4	8·7	9·8	10·1	9·6	8·3	6·2	4·5	3·4	3·0	3·4	4·1	5·1	5·9	5·9	5·7	6·0	6·3	6·5	6·8	6·5
	July	6·4	6·6	6·9	6·9	7·0	7·4	8·9	10·0	10·1	9·2	7·6	5·5	4·2	3·3	3·3	3·9	4·9	5·8	6·6	6·4	5·8	5·9	5·9	6·1	6·4	6·4
	Aug.	6·6	6·8	7·0	6·9	7·0	7·5	9·4	10·9	11·2	10·0	7·9	5·4	3·8	2·9	2·8	3·9	5·0	6·2	6·8	6·6	6·5	6·3	6·5	6·5	6·5	6·7
	Sep.	5·9	6·0	6·1	6·1	6·2	6·4	7·5	9·2	9·5	8·4	6·2	4·0	2·6	1·9	2·6	3·9	5·1	5·5	5·4	5·3	5·3	5·5	5·5	5·7	5·9	5·7
	Means	6·8	7·0	7·1	7·1	7·1	7·4	8·7	10·0	10·3	9·5	7·8	5·6	4·1	3·3	3·4	4·3	5·2	6·1	6·5	6·3	6·1	6·3	6·4	6·6	6·8	6·6

Diurnal Inequality of the Declination at Dehra Dun in 1917, 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.	+0·2	+0·2	+0·3	+0·1	0·0	−0·4	−0·4	−0·3	+0·4	+1·0	+0·5	−0·8	−1·4	−1·2	−0·6	−0·1	+0·2	+0·1	0·0	+0·2	+0·2	+0·2	+0·2	−0·3	+0·1	
	Feb.	+0·4	+0·3	+0·3	+0·2	−0·2	−0·3	−0·3	−0·1	+1·2	+2·1	+2·1	+0·8	−0·7	−1·7	−1·6	−1·1	−0·5	−0·2	−0·3	−0·1	0·0	+0·1	+0·2	+0·4	+0·4	
	Mar.	+0·2	+0·2	+0·1	+0·1	0·0	−0·2	0·0	+1·3	+2·6	+3·0	+2·0	−0·1	−1·6	−2·4	−2·3	−1·4	−0·5	−0·2	−0·5	−0·4	−0·3	−0·1	−0·1	0·0	+0·2	
	Oct.	+0·5	+0·3	+0·2	+0·2	0·0	−0·1	+0·1	+1·4	+2·5	+2·3	+1·2	−0·5	−1·9	−2·5	−1·9	−0·9	−0·2	−0·3	−0·7	−0·4	−0·2	−0·1	+0·1	+0·3	+0·5	
	Nov.	+0·5	+0·3	+0·3	+0·1	−0·1	−0·4	−0·3	−0·1	+0·9	+1·3	+0·8	−0·3	−1·1	−1·0	−0·7	−0·5	−0·4	−0·2	−0·3	0·0	−0·1	+0·1	+0·2	+0·4	+0·4	
	Dec.	+0·3	+0·4	+0·2	+0·1	−0·2	−0·6	−0·7	−1·0	−0·6	+0·5	+1·3	+0·9	+0·3	+0·1	0·0	−0·2	−0·3	−0·2	0·0	0·0	+0·1	0·0	+0·2	+0·4	+0·3	
	Means	+0·4	+0·3	+0·3	+0·2	0·0	−0·3	−0·2	+0·2	+1·2	+1·7	+1·4	0·0	−1·0	−1·4	−1·1	−0·7	−0·2	−0·1	−0·3	−0·1	0·0	+0·1	+0·2	+0·3	+0·4	
Summer.	April	+0·2	+0·3	+0·2	+0·2	+0·2	+0·2	+1·1	+2·4	+3·4	+3·3	+1·8	−0·4	−2·1	−3·0	−2·7	−1·8	−1·0	−0·3	−0·3	−0·6	−0·5	−0·3	−0·1	0·0	+0·2	
	May	+0·4	+0·6	+0·7	+0·7	+0·6	+1·0	+2·3	+3·3	+3·3	+2·3	+0·5	−1·5	−2·7	−3·2	−2·9	−2·2	−1·3	−0·4	+0·1	−0·2	−0·4	−0·2	0·0	+0·1	+0·3	
	June	+0·6	+0·5	+0·7	+0·6	+0·7	+0·9	+2·2	+3·3	+3·6	+3·1	+1·8	−0·3	−2·0	−3·1	−3·5	−3·1	−2·4	−1·4	−0·6	−0·6	−0·8	−0·5	−0·2	0·0	+0·3	
	July	0·0	+0·2	+0·5	+0·5	+0·6	+1·0	+2·5	+3·6	+3·7	+2·8	+1·2	−0·9	−2·2	−3·1	−3·1	−2·5	−1·5	−0·6	+0·2	0·0	−0·6	−0·5	−0·5	−0·3	0·0	
	Aug.	−0·1	+0·1	+0·3	+0·2	+0·3	+0·8	+2·7	+4·2	+4·5	+3·3	+1·2	−1·3	−2·9	−3·8	−3·9	−2·8	−1·7	−0·5	+0·1	−0·1	−0·2	−0·4	−0·2	−0·2	−0·2	
	Sep.	+0·2	+0·3	+0·4	+0·4	+0·5	+0·7	+1·8	+3·5	+3·8	+2·7	+0·5	−1·7	−3·1	−3·8	−3·1	−1·8	−0·6	−0·2	−0·3	−0·4	−0·4	−0·2	−0·2	0·0	+0·2	
	Means	+0·2	+0·4	+0·5	+0·5	+0·5	+0·8	+2·1	+3·4	+3·7	+2·9	+1·2	−1·0	−2·5	−3·3	−3·2	−2·3	−1·4	−0·5	−0·1	−0·3	−0·5	−0·3	−0·2	0·0	+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 1917, from all available days. *Horizontal Force = ·32000 C.G.S. + tabular quantity.*

Season	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.	1010	1009	1008	1011	1010	1014	1013	1015	1014	1006	1004	1011	1019	1020	1018	1014	1012	1010	1008	1008	1006	1008	1010	1011	1013	1011
	Feb.	1015	1018	1020	1019	1021	1021	1022	1025	1026	1028	1026	1026	1025	1028	1027	1022	1020	1019	1018	1019	1016	1016	1019	1017	1016	1021
	Mar.	1018	1022	1022	1019	1021	1021	1022	1022	1021	1024	1031	1038	1041	1041	1039	1032	1023	1021	1020	1018	1017	1018	1018	1019	1019	1025
	Oct.	989	991	991	993	994	995	996	995	992	991	997	1004	1011	1011	1005	996	988	984	981	983	984	985	985	990	990	993
	Nov.	987	990	990	990	991	994	996	1000	1004	1008	1010	1012	1012	1006	997	992	989	987	988	985	983	983	987	990	989	995
	Dec.	987	986	990	989	990	993	996	1002	1008	1013	1014	1013	1009	1000	997	992	989	988	986	986	983	984	984	986	989	994
	Means	1001	1003	1004	1004	1005	1006	1008	1010	1011	1012	1014	1017	1020	1018	1014	1008	1004	1002	1000	1000	998	999	1001	1002	1003	1007
Summer	April	1021	1021	1020	1022	1022	1022	1023	1020	1019	1023	1032	1040	1016	1047	1041	1033	1025	1015	1012	1012	1014	1015	1018	1019	1020	1024
	May	1018	1015	1017	1016	1018	1019	1020	1017	1016	1017	1025	1037	1043	1047	1043	1034	1027	1018	1012	1011	1013	1016	1015	1016	1018	1022
	June	1017	1017	1016	1016	1014	1017	1022	1020	1015	1021	1028	1036	1041	1047	1044	1035	1028	1022	1019	1017	1017	1018	1018	1020	1019	1024
	July	1017	1013	1013	1013	1015	1017	1019	1017	1016	1019	1022	1034	1042	1044	1039	1031	1021	1016	1010	1008	1011	1013	1014	1015	1017	1020
	Aug.	981	982	980	982	985	982	986	979	974	976	981	989	999	1007	1011	1004	997	990	984	982	982	985	987	989	991	987
	Sep.	997	997	1000	999	999	998	998	992	985	985	990	997	1009	1020	1021	1014	1005	998	995	993	994	994	996	997	997	999
	Means	1009	1008	1008	1008	1009	1009	1011	1008	1004	1007	1013	1022	1030	1035	1033	1025	1017	1010	1005	1004	1005	1007	1008	1009	1010	1013

Diurnal Inequality of the Horizontal Force at Dehra Dun in 1917, deduced from the above Table.

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

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 1917, 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.	678	678	678	678	678	678	678	679	680	676	672	668	670	673	675	676	677	678	678	678	678	679	679	678	679	677
	Feb.	681	682	682	681	682	681	682	683	685	682	676	670	665	667	670	674	677	679	680	681	681	682	683	683	683	679
	Mar.	686	687	686	686	686	686	687	690	689	683	673	664	662	666	672	677	681	682	681	683	685	686	687	687	687	681
	Oct.	725	725	726	726	726	726	726	729	728	722	716	707	704	707	713	718	720	721	722	725	726	728	728	729	729	722
	Nov.	725	726	725	725	726	726	726	727	727	723	718	711	709	713	715	717	720	722	723	723	725	726	727	727	726	722
	Dec.	736	736	736	735	735	735	735	734	736	736	734	730	728	727	727	728	730	733	734	734	734	736	736	736	736	733
Means		705	706	706	705	706	705	706	707	708	704	698	692	690	692	695	698	701	703	703	704	705	706	707	707	707	702
Summer.	April	690	690	690	690	690	690	693	694	691	683	674	665	665	670	676	681	684	685	686	687	688	690	691	691	691	685
	May	698	697	698	698	698	699	702	700	694	686	680	675	677	681	684	688	692	694	694	694	696	697	697	698	699	692
	June	704	705	704	705	705	706	712	710	702	695	689	680	679	682	686	690	695	701	704	703	704	705	706	706	707	699
	July	718	718	718	718	718	720	724	722	716	709	700	695	697	700	703	708	713	717	717	716	717	718	719	720	720	713
	Aug.	731	731	730	731	731	731	738	736	729	719	710	702	703	706	713	719	723	726	726	725	727	728	729	723	728	724
	Sep.	728	728	729	729	729	729	732	734	730	722	714	704	705	708	714	719	722	723	723	725	727	728	729	730	730	723
Means		712	712	712	712	712	713	717	716	710	702	695	687	688	691	696	701	705	708	708	708	710	711	712	712	713	706

Diurnal Inequality of the Vertical Force at Dehra Dun in 1917, 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.	+ 1	+ 1	+ 1	+ 1	+ 1	+ 1	+ 1	+ 2	+ 3	− 1	− 5	− 9	− 7	− 4	− 2	− 1	0	+ 1	+ 1	+ 1	+ 1	+ 2	+ 2	+ 1	+ 2	
	Feb.	+ 2	+ 3	+ 3	+ 2	+ 3	+ 2	+ 3	+ 4	+ 6	+ 3	− 3	− 9	−14	−12	− 9	− 5	− 2	0	+ 1	+ 2	+ 2	+ 3	+ 4	+ 4	+ 4	
	Mar.	+ 5	+ 6	+ 5	+ 5	+ 5	+ 5	+ 6	+ 9	+ 8	+ 2	− 8	−17	−19	−15	− 9	− 4	0	+ 1	0	+ 2	+ 4	+ 5	+ 6	+ 6	+ 6	
	Oct.	+ 3	+ 3	+ 4	+ 4	+ 4	+ 4	+ 4	+ 7	+ 6	0	− 6	−15	−18	−15	− 9	− 4	− 2	− 1	0	+ 3	+ 4	+ 6	+ 6	+ 7	+ 7	
	Nov.	+ 3	+ 4	+ 3	+ 3	+ 4	+ 4	+ 4	+ 5	+ 5	+ 1	− 4	−11	−13	− 9	− 7	− 5	− 2	0	+ 1	+ 1	+ 3	+ 4	+ 5	+ 5	+ 4	
	Dec.	+ 3	+ 3	+ 3	+ 2	+ 2	+ 2	+ 2	+ 1	+ 3	+ 3	+ 1	− 3	− 5	− 6	− 6	− 5	− 3	0	+ 1	+ 1	+ 1	+ 3	+ 3	+ 3	+ 3	
Means		+ 3	+ 4	+ 4	+ 3	+ 4	+ 3	+ 4	+ 5	+ 6	+ 2	− 4	−10	−12	−10	− 7	− 4	− 1	+ 1	+ 1	+ 2	+ 3	+ 4	+ 5	+ 5	+ 5	
Summer.	April	+ 5	+ 5	+ 5	+ 5	+ 5	+ 5	+ 8	+ 9	+ 6	− 2	−11	−20	−20	−15	− 9	− 4	− 1	0	+ 1	+ 2	+ 3	+ 5	+ 6	+ 6	+ 6	
	May	+ 6	+ 5	+ 6	+ 6	+ 6	+ 7	+10	+ 8	+ 2	− 6	−12	−17	−15	−11	− 8	− 4	0	+ 2	+ 2	+ 2	+ 4	+ 5	+ 5	+ 6	+ 7	
	June	+ 5	+ 6	+ 5	+ 6	+ 6	+ 7	+13	+11	+ 3	− 4	−10	−19	−20	−17	−13	− 9	− 4	+ 2	+ 5	+ 4	+ 5	+ 6	+ 7	+ 7	+ 8	
	July	+ 5	+ 5	+ 5	+ 5	+ 5	+ 7	+11	+ 9	+ 3	− 4	−13	−18	−16	−13	−10	− 5	0	+ 4	+ 4	+ 3	+ 4	+ 5	+ 6	+ 7	+ 7	
	Aug.	+ 7	+ 7	+ 6	+ 7	+ 7	+ 7	+14	+12	+ 5	− 5	−14	−22	−21	−18	−11	− 6	− 1	+ 2	+ 2	+ 1	+ 3	+ 4	+ 5	+ 4	+ 4	
	Sep.	+ 5	+ 5	+ 6	+ 6	+ 6	+ 6	+ 9	+11	+ 7	− 1	− 9	−19	−18	−15	− 9	− 4	− 1	0	0	+ 2	+ 4	+ 5	+ 6	+ 7	+ 7	
Means		+ 6	+ 6	+ 6	+ 6	+ 6	+ 7	+11	+10	+ 4	− 4	−11	−19	−18	−15	−10	− 5	− 1	+ 2	+ 2	+ 2	+ 4	+ 5	+ 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 Dehra Dun in 1917, determined from all available days. *Dip = N. 44° + 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.	42·6	42·7	42·8	42·6	42·6	42·4	42·5	42·4	42·5	42·8	42·6	42·0	41·8	41·8	42·1	42·3	42·5	42·6	42·8	42·8	42·9	42·8	42·7	42·6	42·5	42·5
	Feb.	42·6	42·4	42·3	42·4	42·3	42·2	42·2	42·1	42·2	41·9	41·7	41·4	41·2	41·1	41·3	41·8	42·0	42·2	42·3	42·4	42·5	42·6	42·4	42·5	42·6	42·1
	Mar.	42·6	42·5	42·4	42·6	42·5	42·5	42·5	42·6	42·6	42·2	41·3	40·5	40·2	40·4	40·8	41·4	42·1	42·3	42·3	42·5	42·6	42·6	42·7	42·7	42·7	42·1
	Oct.	46·2	46·1	46·1	46·0	46·0	45·9	45·9	46·1	46·2	45·9	45·3	44·5	43·9	44·1	44·7	45·5	46·0	46·3	46·5	46·5	46·5	46·6	46·6	46·4	46·4	45·8
	Nov.	46·3	46·2	46·2	46·2	46·1	46·0	45·9	45·8	45·5	45·1	44·7	44·3	44·2	44·7	45·3	45·6	45·9	46·2	46·1	46·3	46·5	46·6	46·4	46·3	46·2	45·8
	Dec.	46·9	46·9	46·7	46·7	46·7	46·5	46·4	46·0	45·8	45·5	45·4	45·2	45·3	45·8	45·9	46·2	46·5	46·7	46·8	46·8	47·0	47·1	47·1	46·9	46·8	46·4
Means		44·5	44·5	44·4	44·4	44·4	44·3	44·2	44·2	44·1	43·9	43·5	43·0	42·8	43·0	43·4	43·8	44·2	44·4	44·5	44·6	44·7	44·7	44·7	44·6	44·5	44·1
Summer	April	42·7	42·7	42·7	42·6	42·6	42·6	42·7	43·0	42·9	42·2	41·3	40·4	40·1	40·3	40·9	41·6	42·2	42·8	43·0	43·0	43·0	43·0	42·9	42·9	42·8	42·3
	May	43·3	43·4	43·3	43·4	43·3	43·3	43·3	43·4	43·2	42·7	42·0	41·1	40·9	40·9	41·2	41·9	42·5	43·1	43·4	43·4	43·4	43·3	43·4	43·4	43·3	42·8
	June	43·6	43·7	43·7	43·7	43·8	43·7	43·8	43·8	43·6	43·0	42·3	41·4	41·1	40·9	41·3	42·0	42·6	43·2	43·5	43·6	43·6	43·6	43·7	43·6	43·7	43·0
	July	44·4	44·6	44·6	44·6	44·5	44·5	44·6	44·6	44·3	43·8	43·2	42·3	42·0	42·0	42·4	43·1	43·9	44·4	44·7	44·7	44·6	44·6	44·6	44·6	44·5	44·0
	Aug.	46·9	46·9	46·9	46·9	46·7	46·9	47·0	47·3	47·2	46·6	45·8	45·0	44·5	44·3	44·4	45·1	45·7	46·2	46·5	46·6	46·7	46·6	46·5	46·4	46·2	46·2
	Sep.	46·0	46·0	45·8	45·9	45·9	45·9	46·1	46·5	46·7	46·2	45·6	44·7	44·1	43·7	43·9	44·6	45·2	45·6	45·8	46·0	46·0	46·1	46·0	46·1	46·1	45·6
Means		44·5	44·6	44·5	44·5	44·5	44·5	44·6	44·8	44·7	44·1	43·4	42·5	42·1	42·0	42·4	43·1	43·7	44·2	44·5	44·6	44·6	44·5	44·5	44·5	44·4	44·0

Diurnal Inequality of the Dip at Dehra Dun in 1917, 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	+0·2	+0·3	+0·1	+0·1	−0·1	0·0	−0·1	0·0	+0·3	+0·1	−0·5	−0·7	−0·7	−0·4	−0·2	0·0	+0·1	+0·3	+0·3	+0·4	+0·3	+0·2	+0·1	0·0	
	Feb.	+0·5	+0·3	+0·2	+0·3	+0·2	+0·1	+0·1	0·0	+0·1	−0·2	−0·4	−0·7	−0·9	−1·0	−0·8	−0·3	−0·1	+0·1	+0·2	+0·3	+0·4	+0·5	+0·3	+0·4	+0·5	
	Mar.	+0·5	+0·4	+0·3	+0·5	+0·4	+0·4	+0·4	+0·5	+0·5	+0·1	−0·8	−1·6	−1·9	−1·7	−1·3	−0·7	0·0	+0·2	+0·2	+0·4	+0·5	+0·5	+0·6	+0·6	+0·6	
	Oct.	+0·4	+0·3	+0·3	+0·2	+0·2	+0·1	+0·1	+0·3	+0·4	+0·1	−0·5	−1·3	−1·9	−1·7	−1·1	−0·3	+0·2	+0·5	+0·7	+0·7	+0·7	+0·8	+0·8	+0·6	+0·6	
	Nov.	+0·5	+0·4	+0·4	+0·4	+0·3	+0·2	+0·1	0·0	−0·3	−0·7	−1·1	−1·5	−1·6	−1·1	−0·5	−0·2	+0·1	+0·4	+0·3	+0·5	+0·7	+0·8	+0·6	+0·5	+0·4	
	Dec.	+0·5	+0·5	+0·3	+0·3	+0·3	+0·1	0·0	−0·4	−0·6	−0·9	−1·0	−1·2	−1·1	−0·6	−0·5	−0·2	+0·1	+0·3	+0·4	+0·4	+0·6	+0·7	+0·7	+0·5	+0·4	
Means		+0·4	+0·4	+0·3	+0·3	+0·3	+0·2	+0·1	+0·1	0·0	−0·2	−0·6	−1·1	−1·3	−1·1	−0·7	−0·3	+0·1	+0·3	+0·4	+0·5	+0·6	+0·6	+0·6	+0·5	+0·4	
Summer	April	+0·4	+0·4	+0·4	+0·3	+0·3	+0·3	+0·4	+0·7	+0·6	−0·1	−1·0	−1·9	−2·2	−2·0	−1·4	−0·7	−0·1	+0·5	+0·7	+0·7	+0·7	+0·7	+0·6	+0·6	+0·5	
	May	+0·5	+0·6	+0·5	+0·6	+0·5	+0·5	+0·5	+0·6	+0·4	−0·1	−0·8	−1·7	−1·9	−1·9	−1·6	−0·9	−0·3	+0·3	+0·6	+0·6	+0·6	+0·5	+0·6	+0·6	+0·5	
	June	+0·6	+0·7	+0·7	+0·7	+0·8	+0·7	+0·8	+0·8	+0·6	0·0	−0·7	−1·6	−1·9	−2·1	−1·7	−1·0	−0·4	+0·2	+0·5	+0·6	+0·6	+0·6	+0·7	+0·6	+0·7	
	July	+0·4	+0·6	+0·6	+0·6	+0·5	+0·5	+0·6	+0·6	+0·3	−0·2	−0·8	−1·7	−2·0	−2·0	−1·6	−0·9	−0·1	+0·4	+0·7	+0·7	+0·6	+0·6	+0·6	+0·6	+0·5	
	Aug.	+0·7	+0·7	+0·7	+0·7	+0·5	+0·7	+0·8	+1·1	+1·0	+0·4	−0·4	−1·2	−1·7	−1·9	−1·8	−1·1	−0·5	0·0	+0·3	+0·4	+0·5	+0·4	+0·3	+0·2	0·0	
	Sep.	+0·4	+0·4	+0·2	+0·3	+0·3	+0·3	+0·5	+0·9	+1·1	+0·6	0·0	−0·9	−1·5	−1·9	−1·7	−1·0	−0·4	0·0	+0·2	+0·4	+0·4	+0·5	+0·4	+0·5	+0·5	
Means		+0·5	+0·6	+0·5	+0·5	+0·5	+0·5	+0·6	+0·8	+0·7	+0·1	−0·6	−1·5	−1·9	−2·0	−1·6	−0·9	−0·3	+0·2	+0·5	+0·6	+0·6	+0·5	+0·5	+0·5	+0·4	

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 1917, 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.	11·0	11·1	11·0	10·9	11·2	11·2	11·5	11·4	10·9	10·4	10·9	12·0	12·4	11·9	11·3	10·9	10·5	10·7	11·0	10·7	10·9	11·0	11·1	11·2	11·1	11·1
	Feb.	11·2	11·2	11·2	11·4	11·5	11·8	11·9	11·7	10·9	10·1	10·0	10·5	11·6	12·1	12·2	12·0	11·5	11·2	11·4	11·3	11·2	11·2	11·3	11·3	11·2	11·3
	Mar.	11·6	11·6	11·4	11·6	11·7	11·9	11·7	10·6	9·9	9·9	10·5	11·5	12·7	13·2	13·0	12·3	11·7	11·5	12·0	11·8	11·6	11·7	11·9	11·8	11·6	11·6
	Oct.	13·6	13·6	13·6	13·8	13·8	13·9	13·7	12·6	12·0	12·1	13·0	14·0	14·9	15·1	14·6	14·0	13·6	13·6	14·1	13·8	13·8	13·9	13·9	13·8	13·7	13·7
	Nov.	14·0	13·9	14·0	14·0	14·3	14·5	14·7	14·5	13·6	12·9	12·9	13·3	13·6	13·8	13·9	14·2	14·0	13·9	14·1	13·9	13·8	14·0	14·1	14·0	14·0	13·9
	Dec.	14·3	14·4	14·4	14·7	14·7	15·0	15·2	15·6	15·3	14·2	13·3	13·0	13·3	13·9	14·4	14·7	14·4	14·1	14·5	14·3	14·3	14·5	14·5	14·4	14·4	14·4
Means		12·6	12·6	12·6	12·7	12·9	13·1	13·1	12·7	12·1	11·6	11·8	12·4	13·1	13·3	13·2	13·0	12·6	12·5	12·9	12·6	12·6	12·7	12·8	12·8	12·7	12·7
Summer.	April	12·1	11·9	11·9	12·0	12·1	12·2	11·4	10·2	10·0	10·2	10·9	12·2	13·7	14·1	13·9	13·2	12·3	11·9	12·0	12·2	12·4	12·5	12·3	12·2	12·1	12·1
	May	12·6	12·4	12·3	12·2	12·2	12·1	11·2	10·3	10·5	11·5	12·8	13·8	14·5	14·6	14·2	13·7	12·9	12·4	12·4	12·7	13·1	13·0	13·0	12·8	12·6	12·6
	June	12·8	12·6	12·4	12·4	12·4	12·4	11·3	10·0	9·8	10·4	11·5	12·9	14·1	14·6	14·8	14·5	13·9	13·2	12·6	13·0	13·3	13·3	13·2	13·0	12·8	12·7
	July	13·3	13·1	12·9	12·8	12·8	12·6	11·3	10·4	10·4	11·0	12·2	13·4	14·2	14·5	14·6	14·3	13·8	13·3	13·0	13·1	13·4	13·5	13·5	13·5	13·3	13·0
	Aug.	13·2	13·0	12·8	12·9	12·7	12·5	11·0	9·8	10·0	11·0	12·6	14·1	15·1	15·5	15·4	14·7	13·6	12·8	12·6	13·0	13·2	13·3	13·3	13·3	13·3	13·0
	Sep.	13·6	13·3	13·2	13·2	13·2	13·2	11·9	10·6	10·7	12·0	13·5	15·1	16·3	16·4	15·7	14·4	13·2	13·0	13·6	13·6	13·6	13·7	13·8	13·7	13·5	13·5
Means		12·9	12·7	12·6	12·6	12·6	12·5	11·4	10·2	10·2	11·0	12·3	13·6	14·7	15·0	14·8	14·1	13·3	12·8	12·7	12·9	13·2	13·2	13·2	13·1	12·9	12·8

Diurnal Inequality of the Declination at Toungoo in 1917, 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.	+0·1	0·0	+0·1	+0·2	−0·1	−0·1	−0·4	−0·3	+0·2	+0·7	+0·2	−0·9	−1·3	−0·8	−0·2	+0·2	+0·6	+0·4	+0·1	+0·4	+0·2	+0·1	0·0	−0·1	0·0	
	Feb.	+0·1	+0·1	+0·1	−0·1	−0·2	−0·5	−0·6	−0·4	+0·4	+1·2	+1·3	+0·8	−0·3	−0·8	−0·9	−0·7	−0·2	+0·1	−0·1	0·0	+0·1	+0·1	0·0	0·0	+0·1	
	Mar.	0·0	0·0	+0·2	0·0	−0·1	−0·3	−0·1	+1·0	+1·7	+1·7	+1·1	+0·1	−1·1	−1·6	−1·4	−0·7	−0·1	+0·1	−0·4	−0·2	0·0	−0·1	−0·3	−0·2	0·0	
	Oct.	+0·1	+0·1	+0·1	−0·1	−0·1	−0·2	0·0	+1·1	+1·7	+1·6	+0·7	−0·3	−1·2	−1·4	−0·9	−0·3	+0·1	+0·1	−0·4	−0·1	−0·1	−0·2	−0·2	−0·1	0·0	
	Nov.	−0·1	0·0	−0·1	−0·1	−0·4	−0·6	−0·8	−0·6	+0·3	+1·0	+1·0	+0·6	+0·3	+0·1	0·0	−0·3	−0·1	0·0	−0·2	0·0	+0·1	−0·1	−0·2	−0·1	−0·1	
	Dec.	+0·1	0·0	0·0	−0·3	−0·3	−0·6	−0·8	−1·2	−0·9	+0·2	+1·1	+1·4	+1·1	+0·5	0·0	−0·3	0·0	+0·3	−0·1	+0·1	+0·1	−0·1	−0·1	0·0	0·0	
Means		+0·1	+0·1	+0·1	0·0	−0·2	−0·4	−0·4	0·0	+0·6	+1·1	+0·9	+0·3	−0·4	−0·6	−0·5	−0·3	+0·1	+0·2	−0·2	+0·1	+0·1	0·0	−0·1	−0·1	0·0	
Summer.	April	0·0	+0·2	+0·2	+0·1	0·0	−0·1	+0·7	+1·9	+2·1	+1·9	+1·2	−0·1	−1·6	−2·0	−1·8	−1·1	−0·2	+0·2	+0·1	−0·1	−0·3	−0·4	−0·2	−0·1	0·0	
	May	0·0	+0·2	+0·3	+0·4	+0·4	+0·5	+1·4	+2·3	+2·2	+1·1	−0·2	−1·2	−1·9	−2·0	−1·6	−1·1	−0·3	+0·2	+0·2	−0·1	−0·5	−0·4	−0·4	−0·2	0·0	
	June	−0·1	+0·1	+0·3	+0·3	+0·3	+0·3	+1·4	+2·7	+2·9	+2·3	+1·2	−0·2	−1·4	−1·9	−2·1	−1·8	−1·2	−0·5	+0·1	−0·3	−0·6	−0·6	−0·5	−0·3	−0·1	
	July	−0·3	−0·1	+0·1	+0·2	+0·2	+0·4	+1·7	+2·6	+2·6	+2·0	+0·8	−0·4	−1·2	−1·5	−1·6	−1·3	−0·8	0·3	0·0	−0·1	−0·4	−0·5	−0·5	−0·5	−0·3	
	Aug.	−0·2	0·0	+0·2	+0·1	+0·3	+0·5	+2·0	+3·2	+3·0	+2·0	+0·4	−1·1	−2·1	−2·5	−2·4	−1·7	−0·6	+0·2	+0·4	0·0	−0·2	−0·3	−0·3	−0·3	−0·3	
	Sep.	−0·1	+0·2	+0·3	+0·3	+0·3	+0·3	+1·6	+2·9	+2·8	+1·5	0·0	−1·6	−2·8	−2·9	−2·2	−0·9	+0·3	+0·5	−0·1	−0·1	−0·1	−0·2	−0·3	−0·2	0·0	
Means		−0·1	+0·1	+0·2	+0·2	+0·2	+0·3	+1·4	+2·6	+2·6	+1·8	+0·5	−0·8	−1·9	−2·2	−2·0	−1·3	−0·5	0·0	+0·1	−0·1	−0·4	−0·4	−0·4	−0·3	−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 1917, from all available days. Horizontal Force='38000 C.G.S.+tabular quantity.

Season	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.	1014	1018	1020	1018	1020	1021	1024	1025	1028	1033	1039	1047	1050	1047	1040	1033	1024	1018	1018	1016	1015	1014	1015	1020	1018	1026
	Feb.	1025	1025	1026	1029	1029	1030	1032	1034	1041	1051	1060	1064	1066	1061	1053	1046	1038	1032	1030	1029	1028	1024	1023	1027	1026	1038
	Mar	1029	1031	1032	1035	1033	1034	1037	1039	1050	1067	1085	1095	1096	1088	1071	1055	1044	1038	1037	1037	1032	1030	1028	1029	1023	1048
	Oct	1021	1022	1023	1025	1027	1029	1030	1029	1036	1052	1068	1079	1081	1072	1056	1043	1033	1027	1024	1020	1018	1017	1020	1021	1022	1036
	Nov	1026	1027	1029	1030	1031	1032	1036	1042	1052	1066	1079	1086	1091	1070	1057	1047	1042	1036	1034	1032	1026	1022	1022	1024	1029	1043
	Dec.	1026	1029	1031	1034	1034	1037	1041	1048	1058	1066	1074	1079	1076	1067	1057	1049	1040	1037	1036	1033	1031	1027	1027	1028	1028	1041
	Means	1024	1025	1027	1029	1029	1031	1033	1036	1044	1056	1068	1075	1075	1068	1056	1046	1037	1031	1030	1028	1025	1022	1023	1025	1024	1039
Summer	April	1021	1022	1026	1026	1028	1030	1029	1031	1042	1062	1079	1089	1085	1076	1060	1044	1030	1023	1018	1016	1014	1015	1016	1020	1020	1038
	May	1023	1025	1024	1025	1026	1026	1028	1034	1045	1061	1070	1080	1079	1074	1065	1051	1035	1026	1023	1024	1023	1022	1023	1022	1023	1039
	June	1026	1028	1028	1028	1028	1028	1030	1037	1047	1062	1076	1085	1087	1081	1070	1057	1043	1032	1029	1030	1030	1029	1028	1027	1029	1044
	July	1023	1025	1023	1023	1023	1025	1028	1033	1041	1054	1067	1077	1080	1075	1064	1051	1037	1026	1023	1024	1022	1023	1022	1023	1022	1038
	Aug.	995	998	999	1002	1001	1003	1004	1007	1015	1030	1045	1055	1059	1054	1046	1037	1024	1014	1011	1009	1006	1003	1006	1005	1005	1018
	Sep.	1024	1023	1021	1024	1024	1026	1023	1020	1026	1044	1062	1075	1082	1079	1068	1054	1039	1031	1029	1027	1022	1020	1021	1022	1023	1037
	Means	1019	1020	1020	1021	1022	1023	1024	1027	1036	1052	1067	1077	1079	1073	1062	1049	1035	1025	1022	1022	1020	1019	1019	1020	1020	1036

Diurnal Inequality of the Horizontal Force at Toungoo in 1917, deduced from the above Table.

Season	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.	−12	−8	−6	−8	−6	−5	−2	−1	+2	+7	+13	+21	+24	+21	+14	+7	−2	−8	−8	−11	−11	−12	−11	−6	−8
	Feb.	−13	−13	−12	−9	−9	−8	−6	−4	+3	+13	+22	+26	+28	+23	+15	+8	0	−6	−8	−9	−10	−14	−15	−11	−12
	Mar.	−19	−17	−16	−13	−15	−14	−11	−9	+2	+19	+37	+47	+48	+40	+23	+7	−4	−10	−11	−11	−16	−18	−20	−19	−25
	Oct.	−15	−14	−13	−11	−9	−7	−6	−7	0	+16	+32	+43	+45	+36	+20	+7	−3	−9	−12	−16	−18	−19	−16	−15	−14
	Nov.	−17	−16	−14	−13	−12	−11	−7	−1	+9	+23	+36	+43	+38	+27	+14	+4	−1	−7	−9	−11	−17	−21	−21	−19	−14
	Dec.	−18	−15	−13	−10	−10	−7	−3	+4	+14	+22	+30	+35	+32	+23	+13	+5	−4	−7	−8	−11	−13	−17	−17	−16	−16
	Means	−15	−14	−12	−10	−10	−8	−6	−3	+5	+17	+29	+36	+36	+29	+17	+7	−2	−8	−9	−11	−14	−17	−16	−14	−15
Summer	April	−17	−16	−12	−12	−10	−8	−9	−7	+4	+24	+41	+51	+47	+38	+22	+6	−8	−15	−20	−22	−24	−23	−22	−18	−18
	May	−16	−14	−15	−14	−13	−13	−11	−5	+6	+22	+31	+41	+40	+35	+26	+12	−4	−13	−16	−15	−16	−17	−16	−17	−16
	June	−18	−16	−16	−16	−16	−16	−14	−7	+3	+18	+32	+41	+43	+37	+26	+13	−1	−12	−15	−14	−14	−15	−16	−17	−15
	July	−15	−13	−15	−15	−15	−13	−10	−5	+3	+16	+29	+39	+42	+37	+26	+13	−1	−12	−15	−14	−16	−15	−16	−15	−16
	Aug.	−23	−20	−19	−16	−17	−15	−14	−11	−3	+12	+27	+37	+41	+36	+28	+19	+6	−4	−7	−9	−12	−15	−12	−13	−13
	Sep.	−13	−14	−16	−13	−13	−11	−14	−17	−11	+7	+25	+38	+45	+42	+31	+17	+2	−6	−8	−10	−15	−17	−16	−15	−14
	Means	−17	−16	−16	−15	−14	−13	−12	−9	0	+16	+31	+41	+43	+37	+26	+13	−1	−11	−14	−14	−16	−17	−17	−16	−16

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 1917, 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.	691	691	691	691	691	691	691	690	690	684	674	669	673	681	684	687	688	685	686	689	689	690	691	691	691	687
	Feb.	691	692	692	691	691	691	691	691	691	685	677	671	665	672	677	682	685	686	685	688	689	689	690	691	692	686
	Mar.	693	693	694	693	693	693	695	694	689	679	671	668	669	675	683	687	687	685	685	688	689	689	690	692	693	686
	Oct.	687	687	687	687	687	687	690	690	683	672	666	663	665	671	676	679	679	678	681	683	683	684	686	687	688	681
	Nov.	687	687	687	687	687	687	687	687	687	683	678	675	675	674	674	676	679	680	682	684	683	684	686	687	688	683
	Dec.	690	690	690	690	690	690	689	688	690	691	688	685	680	676	676	679	683	684	684	687	687	687	688	690	690	686
Means		690	690	690	690	690	690	691	690	688	682	676	672	671	675	678	682	684	683	684	687	687	687	689	690	690	685
Summer	April	689	689	689	689	689	689	692	690	681	673	666	663	665	673	679	683	685	684	683	684	685	686	688	688	689	683
	May	698	699	699	699	699	700	703	700	694	685	681	681	684	689	693	697	700	698	695	694	695	696	697	698	699	695
	June	686	687	687	687	687	688	692	691	685	676	670	667	666	670	675	680	684	684	683	681	683	684	685	686	686	682
	July	684	684	684	684	684	686	690	687	679	671	664	662	662	665	669	676	680	681	680	678	680	682	683	684	684	678
	Aug.	689	689	690	690	690	691	695	690	681	670	661	658	658	663	672	680	685	686	684	683	685	686	688	689	689	681
	Sep.	688	688	688	688	688	689	695	690	678	665	658	655	659	669	678	685	685	681	680	683	684	685	686	687	688	681
Means		689	689	690	690	690	691	695	691	683	673	667	664	666	672	678	684	687	686	684	684	685	687	688	689	689	683

Diurnal Inequality of the Vertical Force at Toungoo in 1917, 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.	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	+ 3	+ 3	− 3	−13	−18	−14	− 6	− 3	0	+ 1	− 2	− 1	+ 2	+ 2	+ 3	+ 4	+ 4	+ 4	
	Feb.	+ 5	+ 6	+ 6	+ 5	+ 5	+ 5	+ 5	+ 5	+ 5	− 1	− 9	−15	−21	−14	− 9	− 4	− 1	0	− 1	+ 2	+ 3	+ 3	+ 4	+ 5	+ 6	
	Mar.	+ 7	+ 7	+ 8	+ 7	+ 7	+ 7	+ 9	+ 8	+ 3	− 7	−15	−18	−17	−11	− 3	+ 1	+ 1	− 1	− 1	+ 2	+ 3	+ 3	+ 4	+ 6	+ 7	
	Oct.	+ 6	+ 6	+ 6	+ 6	+ 6	+ 6	+ 9	+ 9	+ 2	− 9	−15	−18	−16	−10	− 5	− 2	− 2	− 3	0	+ 2	+ 2	+ 3	+ 5	+ 6	+ 7	
	Nov.	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	0	− 5	− 8	− 8	− 9	− 9	− 7	− 4	− 3	− 1	+ 1	0	+ 1	+ 3	+ 4	+ 5	
	Dec.	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	+ 3	+ 2	+ 4	+ 5	+ 2	− 1	− 6	−10	−10	− 7	− 3	− 2	− 2	+ 1	+ 1	+ 1	+ 2	+ 4	+ 4	
Means		+ 5	+ 5	+ 5	+ 5	+ 5	+ 5	+ 6	+ 5	+ 3	− 3	− 9	−13	−14	−10	− 7	− 3	− 1	− 2	− 1	+ 2	+ 2	+ 2	+ 4	+ 5	+ 5	
Summer	April	+ 6	+ 6	+ 6	+ 6	+ 6	+ 6	+ 9	+ 7	− 2	−10	−17	−20	−18	−10	− 4	0	+ 2	+ 1	0	+ 1	+ 2	+ 3	+ 5	+ 5	+ 6	
	May	+ 3	+ 4	+ 4	+ 4	+ 4	+ 5	+ 8	+ 5	− 1	−10	−14	−14	−11	− 6	− 2	+ 2	+ 5	+ 3	0	− 1	0	+ 1	+ 2	+ 3	+ 4	
	June	+ 4	+ 5	+ 5	+ 5	+ 5	+ 6	+10	+ 9	+ 3	− 6	−12	−15	−16	−12	− 7	− 2	+ 2	+ 2	+ 1	− 1	+ 1	+ 2	+ 3	+ 4	+ 4	
	July	+ 6	+ 6	+ 6	+ 6	+ 6	+ 8	+12	+ 9	+ 1	− 7	−14	−16	−16	−13	− 9	− 2	+ 2	+ 3	+ 2	0	+ 2	+ 4	+ 5	+ 6	+ 6	
	Aug.	+ 8	+ 8	+ 9	+ 9	+ 9	+10	+14	+ 9	0	−11	−20	−23	−23	−18	− 9	− 1	+ 4	+ 5	+ 3	+ 2	+ 4	+ 5	+ 7	+ 8	+ 8	
	Sep.	+ 7	+ 7	+ 7	+ 7	+ 7	+ 8	+14	+ 9	− 3	−16	−23	−26	−22	−12	− 3	+ 4	+ 4	0	− 1	+ 2	+ 3	+ 4	+ 5	+ 6	+ 7	
Means		+ 6	+ 6	+ 7	+ 7	+ 7	+ 8	+12	+ 8	0	−10	−16	−19	−17	−11	− 5	+ 1	+ 4	+ 3	+ 1	+ 1	+ 2	+ 4	+ 5	+ 6	+ 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 1917, 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.	9·7	9·6	9·5	9·6	9·5	9·5	9·4	9·3	9·2	8·6	7·7	7·0	7·2	7·9	8·4	8·9	9·2	9·2	9·2	9·6	9·6	9·7	9·7	9·5	9·6	9·0
Feb.	9·4	9·5	9·5	9·3	9·3	9·2	9·2	9·1	8·9	8·1	7·2	6·6	6·2	6·8	7·5	8·0	8·5	8·8	8·8	9·0	9·1	9·3	9·4	9·3	9·5	8·6
Mar.	9·4	9·3	9·4	9·2	9·3	9·3	9·3	9·2	8·5	7·2	6·0	5·4	5·5	6·2	7·3	8·1	8·5	8·5	8·6	8·8	9·0	9·1	9·2	9·3	9·6	8·3
Oct.	9·2	9·2	9·2	9·1	9·0	9·0	9·2	9·2	8·4	7·1	6·2	5·6	5·7	6·4	7·3	7·9	8·2	8·3	8·7	8·9	9·0	9·1	9·2	9·2	9·3	8·3
Nov.	9·1	9·0	9·0	8·9	8·9	8·9	8·7	8·6	8·2	7·5	6·7	6·3	6·4	6·7	7·1	7·6	8·0	8·2	8·5	8·7	8·8	9·0	9·1	9·1	9·0	8·2
Dec.	9·3	9·2	9·1	9·1	9·1	8·9	8·7	8·4	8·3	8·1	7·6	7·2	7·0	6·9	7·2	7·7	8·3	8·5	8·5	8·9	8·9	9·0	9·1	9·2	9·2	8·4
Means	9·4	9·3	9·3	9·2	9·2	9·1	9·1	9·0	8·6	7·8	6·9	6·4	6·3	6·8	7·5	8·0	8·5	8·6	8·7	9·0	9·1	9·2	9·3	9·3	9·4	8·5
Summer. April	9·4	9·3	9·2	9·2	9·1	9·1	9·3	9·1	8·1	6·9	5·8	5·3	5·6	6·4	7·4	8·2	8·8	8·9	9·0	9·2	9·3	9·3	9·5	9·3	9·4	8·4
May	10·0	10·0	10·0	10·0	10·0	10·1	10·2	9·8	9·0	7·8	7·2	6·9	7·2	7·7	8·2	9·0	9·8	9·9	9·8	9·7	9·8	9·9	9·9	10·0	10·1	9·2
June	9·0	9·0	9·0	9·0	9·0	9·1	9·3	9·0	8·2	7·1	6·2	5·7	5·6	6·0	6·8	7·6	8·3	8·7	8·7	8·5	8·6	8·7	8·9	8·9	8·9	8·1
July	8·9	8·9	8·9	8·9	8·9	9·0	9·2	8·9	8·0	7·0	6·0	5·6	5·5	5·9	6·5	7·4	8·2	8·6	8·7	8·5	8·7	8·8	8·9	8·9	9·0	8·0
Aug.	10·2	10·1	10·2	10·1	10·1	10·1	10·4	9·9	9·0	7·7	6·5	6·0	5·8	6·4	7·3	8·2	9·0	9·4	9·3	9·3	9·6	9·7	9·8	9·9	9·9	8·9
Sep.	9·2	9·2	9·3	9·2	9·2	9·2	9·8	9·5	8·4	6·9	5·8	5·1	5·2	6·0	7·0	8·0	8·5	8·5	8·5	8·7	9·0	9·1	9·1	9·2	9·2	8·2
Means	9·5	9·4	9·4	9·4	9·4	9·4	9·7	9·4	8·5	7·2	6·3	5·8	5·8	6·4	7·2	8·1	8·8	9·0	9·0	9·0	9·2	9·3	9·4	9·4	9·4	8·5

Diurnal Inequality of the Dip at Toungoo in 1917, 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.	+0·7	+0·6	+0·5	+0·6	+0·5	+0·5	+0·4	+0·3	+0·2	−0·4	−1·3	−2·0	−1·8	−1·1	−0·6	−0·1	+0·2	+0·2	+0·2	+0·6	+0·6	+0·7	+0·7	+0·5	+0·6	
Feb.	+0·8	+0·9	+0·9	+0·7	+0·7	+0·6	+0·6	+0·5	+0·3	−0·5	−1·4	−2·0	−2·4	−1·8	−1·1	−0·6	−0·1	+0·2	+0·2	+0·4	+0·5	+0·7	+0·8	+0·7	+0·9	
Mar.	+1·1	+1·0	+1·1	+0·9	+1·0	+1·0	+1·0	+0·9	+0·2	−1·1	−2·3	−2·9	−2·8	−2·1	−1·0	−0·2	+0·2	+0·2	+0·3	+0·5	+0·7	+0·8	+0·9	+1·0	+1·3	
Oct.	+0·9	+0·9	+0·9	+0·8	+0·7	+0·7	+0·9	+0·9	+0·1	−1·2	−2·1	−2·7	−2·6	−1·9	−1·0	−0·4	−0·1	0·0	+0·4	+0·6	+0·7	+0·8	+0·9	+0·9	+1·0	
Nov.	+0·9	+0·8	+0·8	+0·7	+0·7	+0·7	+0·5	+0·4	0·0	−0·7	−1·5	−1·9	−1·8	−1·5	−1·1	−0·6	−0·2	0·0	+0·3	+0·5	+0·6	+0·8	+0·9	+0·9	+0·8	
Dec.	+0·9	+0·8	+0·7	+0·7	+0·7	+0·5	+0·3	0·0	−0·1	−0·3	−0·8	−1·2	−1·4	−1·5	−1·2	−0·7	−0·1	+0·1	+0·1	+0·5	+0·5	+0·6	+0·7	+0·8	+0·8	
Means	+0·9	+0·8	+0·8	+0·7	+0·7	+0·6	+0·6	+0·5	+0·1	−0·7	−1·6	−2·1	−2·2	−1·7	−1·0	−0·5	0·0	+0·1	+0·2	+0·5	+0·6	+0·7	+0·8	+0·8	+0·9	
Summer. April	+1·0	+0·9	+0·8	+0·8	+0·7	+0·7	+0·9	+0·7	−0·3	−1·5	−2·6	−3·1	−2·8	−2·0	−1·0	−0·2	+0·4	+0·5	+0·6	+0·8	+0·9	+0·9	+1·1	+0·9	+1·0	
May	+0·8	+0·8	+0·8	+0·8	+0·8	+0·9	+1·0	+0·6	−0·2	−1·4	−2·0	−2·3	−2·0	−1·5	−1·0	−0·2	+0·6	+0·7	+0·6	+0·5	+0·6	+0·7	+0·7	+0·8	+0·9	
June	+0·9	+0·9	+0·9	+0·9	+0·9	+1·0	+1·2	+0·9	+0·1	−1·0	−1·9	−2·4	−2·5	−2·1	−1·3	−0·5	+0·2	+0·6	+0·6	+0·4	+0·5	+0·6	+0·8	+0·8	+0·8	
July	+0·9	+0·9	+0·9	+0·9	+0·9	+1·0	+1·2	+0·9	0·0	−1·0	−2·0	−2·4	−2·5	−2·1	−1·5	−0·6	+0·2	+0·6	+0·7	+0·5	+0·7	+0·8	+0·9	+0·9	+1·0	
Aug.	+1·3	+1·2	+1·3	+1·2	+1·2	+1·2	+1·5	+1·0	+0·1	−1·2	−2·4	−2·9	−3·1	−2·5	−1·6	−0·7	+0·1	+0·5	+0·4	+0·4	+0·7	+0·8	+0·9	+1·0	+1·0	
Sep.	+1·0	+1·0	+1·1	+1·0	+1·0	+1·0	+1·6	+1·3	+0·2	−1·3	−2·4	−3·1	−3·0	−2·2	−1·2	−0·2	+0·3	+0·3	+0·3	+0·5	+0·8	+0·9	+0·9	+1·0	+1·0	
Means	+1·0	+0·9	+0·9	+0·9	+0·9	+0·9	+1·2	+0·9	0·0	−1·3	−2·2	−2·7	−2·7	−2·1	−1·3	−0·4	+0·3	+0·5	+0·5	+0·5	+0·7	+0·8	+0·9	+0·9	+0·9	

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 1917, determined from all available days. Declination = W. 1° + tabular quantity.

Season	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.	31·3	31·3	31·2	31·3	31·4	31·5	31·7	31·6	31·5	31·1	31·5	32·1	32·3	31·9	31·5	31·1	30·8	31·0	31·2	31·0	31·1	31·3	31·3	31·3	31·4	31·4
	Feb.	31·7	31·7	31·7	31·8	32·0	32·1	32·2	32·2	31·8	31·2	31·0	31·4	31·8	32·2	32·2	32·1	31·8	31·7	31·8	31·7	31·6	31·6	31·8	31·8	31·7	31·8
	Mar.	32·0	31·9	32·0	32·0	32·1	32·3	32·3	31·9	31·5	31·5	31·9	32·5	33·0	33·1	32·9	32·2	31·9	32·0	32·1	32·1	32·0	32·1	32·1	32·2	32·1	32·2
	Oct.	35·3	35·3	35·4	35·5	35·6	35·6	35·3	34·8	34·5	34·9	35·5	36·1	36·2	35·9	35·5	35·3	35·0	35·2	35·5	35·4	35·4	35·5	35·5	35·5	35·3	35·4
	Nov.	35·8	35·8	35·9	35·9	36·1	36·4	36·6	36·9	36·4	36·3	36·3	36·4	36·2	35·7	35·6	35·6	35·6	35·8	35·9	35·7	35·7	35·8	35·8	35·8	35·8	36·0
	Dec.	35·8	35·9	35·9	36·1	36·3	36·6	36·8	37·5	37·3	36·6	36·1	35·6	35·4	35·1	35·1	35·3	35·4	35·5	35·8	35·7	35·7	35·8	35·9	35·9	35·8	36·0
	Means	33·7	33·7	33·7	33·8	33·9	34·1	34·2	34·2	33·8	33·6	33·7	34·0	34·2	34·0	33·8	33·6	33·4	33·5	33·7	33·6	33·6	33·7	33·7	33·8	33·7	33·8
Summer	April	32·6	32·4	32·4	32·5	32·5	32·5	32·1	31·4	31·4	31·8	32·2	32·8	33·6	33·9	33·6	33·1	32·5	32·3	32·4	32·7	32·8	32·8	32·7	32·7	32·6	32·6
	May	32·8	32·7	32·7	32·6	32·6	32·5	31·8	31·4	31·9	32·6	33·8	34·6	35·0	34·8	34·2	33·4	32·9	32·6	32·6	33·0	33·3	33·3	33·0	32·9	32·8	33·0
	June	33·4	33·3	33·2	33·3	33·2	33·1	32·4	31·6	31·5	32·2	33·1	34·3	34·9	35·0	34·7	34·2	33·7	33·6	33·3	33·8	33·9	33·8	33·7	33·6	33·5	33·4
	July	33·9	33·7	33·6	33·6	33·5	33·5	32·7	31·9	31·9	32·8	33·8	34·5	34·8	35·0	34·9	34·4	33·8	33·7	33·5	33·8	34·3	34·3	34·3	34·2	34·0	33·8
	Aug.	34·8	34·6	34·6	34·6	34·4	34·3	33·2	31·9	32·0	33·2	34·6	35·7	36·5	36·5	36·2	35·7	34·8	34·3	34·3	34·4	34·7	34·8	34·8	34·8	34·9	34·6
	Sep.	35·1	34·9	34·9	35·0	34·9	34·8	34·1	32·6	32·6	34·0	35·3	36·5	37·4	37·3	36·5	35·5	34·7	34·7	34·8	35·0	35·2	35·3	35·4	35·3	35·2	35·1
	Means	33·8	33·6	33·6	33·6	33·5	33·5	32·7	31·8	31·9	32·8	33·8	34·7	35·4	35·4	35·0	34·4	33·7	33·5	33·5	33·8	34·0	34·1	34·0	33·9	33·8	33·8

Diurnal Inequality of the Declination at Kodaikanal in 1917, deduced from the above Table.

Season	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.	+0·1	+0·1	+0·2	+0·1	0·0	−0·1	−0·3	−0·2	−0·1	+0·3	−0·1	−0·7	−0·9	−0·5	−0·1	+0·3	+0·6	+0·4	+0·2	+0·4	+0·3	+0·1	+0·1	+0·1	0·0	
	Feb.	+0·1	+0·1	+0·1	0·0	−0·2	−0·3	−0·4	−0·4	0·0	+0·6	+0·8	+0·4	0·0	−0·4	−0·4	−0·3	0·0	+0·1	0·0	+0·1	+0·2	+0·2	0·0	0·0	+0·1	
	Mar.	+0·2	+0·3	+0·2	+0·2	+0·1	−0·1	−0·1	+0·3	+0·7	+0·7	+0·3	−0·3	−0·8	−0·9	−0·7	0·0	+0·3	+0·2	+0·1	+0·1	+0·2	+0·1	+0·1	0·0	+0·1	
	Oct.	+0·1	+0·1	0·0	−0·1	−0·2	−0·2	+0·1	+0·6	+0·9	+0·5	−0·1	−0·7	−0·8	−0·5	−0·1	+0·1	+0·4	+0·2	−0·1	0·0	0·0	−0·1	−0·1	−0·1	+0·1	
	Nov.	+0·2	+0·2	+0·1	+0·1	−0·1	−0·4	−0·6	−0·9	−0·4	−0·3	−0·3	−0·4	−0·2	+0·3	+0·4	+0·4	+0·4	+0·2	+0·1	+0·3	+0·3	+0·2	+0·2	+0·2	+0·2	
	Dec.	+0·2	+0·1	+0·1	−0·1	−0·3	−0·6	−0·8	−1·5	−1·3	−0·6	−0·1	+0·4	+0·6	+0·9	+0·9	+0·7	+0·6	+0·5	+0·2	+0·3	+0·3	+0·2	+0·1	+0·1	+0·2	
	Means	+0·1	+0·1	+0·1	0·0	−0·1	−0·3	−0·4	−0·4	0·0	+0·2	+0·1	−0·2	−0·4	−0·2	0·0	+0·2	+0·4	+0·3	+0·1	+0·2	+0·2	+0·1	+0·1	0·0	+0·1	
Summer	April	0·0	+0·2	+0·2	+0·1	+0·1	+0·1	+0·5	+1·2	+1·2	+0·8	+0·4	−0·2	−1·0	−1·3	−1·0	−0·5	+0·1	+0·3	+0·2	−0·1	−0·2	−0·2	−0·1	−0·1	0·0	
	May	+0·2	+0·3	+0·3	+0·4	+0·4	+0·5	+1·2	+1·6	+1·1	+0·4	−0·8	−1·6	−2·0	−1·8	−1·2	−0·4	+0·1	+0·4	+0·4	0·0	−0·3	−0·3	0·0	+0·1	+0·2	
	June	0·0	+0·1	+0·2	+0·1	+0·2	+0·3	+1·0	+1·8	+1·9	+1·2	+0·3	−0·9	−1·5	−1·6	−1·3	−0·8	−0·3	−0·2	+0·1	−0·4	−0·5	−0·4	−0·3	−0·2	−0·1	
	July	−0·1	+0·1	+0·2	+0·2	+0·3	+0·3	+1·1	+1·9	+1·9	+1·0	0·0	−0·7	−1·0	−1·2	−1·1	−0·6	0·0	+0·1	+0·3	0·0	−0·5	−0·5	−0·5	−0·4	−0·3	
	Aug.	−0·2	0·0	0·0	0·0	+0·2	+0·3	+1·4	+2·7	+2·6	+1·4	0·0	−1·1	−1·9	−1·9	−1·6	−1·1	−0·2	+0·3	+0·3	+0·2	−0·1	−0·2	−0·2	−0·2	−0·3	
	Sep.	0·0	+0·2	+0·2	+0·1	+0·2	+0·3	+1·0	+2·5	+2·5	+1·1	−0·2	−1·4	−2·3	−2·2	−1·4	−0·4	+0·4	+0·4	+0·3	+0·1	−0·1	−0·2	−0·3	−0·2	−0·1	
	Means	0·0	+0·2	+0·2	+0·2	+0·3	+0·3	+1·1	+2·0	+1·9	+1·0	0·0	−0·9	−1·6	−1·6	−1·2	−0·6	+0·1	+0·3	+0·3	0·0	−0·2	−0·3	−0·2	−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 1917, from all available days. Horizontal Force = ·37000 C.G.S. + tabular quantity.

Season	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.	614	615	613	616	615	617	616	618	634	658	680	687	679	658	639	627	626	625	620	616	614	614	615	618	616	630
	Feb.	624	627	629	620	631	630	631	637	651	674	694	706	702	690	672	656	649	644	639	633	629	627	627	625	625	648
	Mar.	627	631	632	632	633	632	631	645	674	709	738	748	735	701	671	653	647	650	647	636	632	629	627	627	627	658
	Oct.	642	644	646	649	650	649	649	660	687	719	740	746	736	717	697	674	671	663	653	647	645	642	640	642	643	671
	Nov.	650	652	653	653	654	655	658	669	686	707	720	721	716	708	696	689	680	671	663	655	652	649	651	653	652	672
	Dec.	649	650	654	653	654	656	659	669	681	692	700	701	706	704	701	692	680	672	662	657	653	652	649	648	650	671
	Means	634	637	638	639	640	640	641	650	669	693	712	718	712	696	679	665	659	654	647	641	638	636	635	635	636	659
Summer	April	632	633	634	636	636	634	635	648	679	715	736	737	720	694	669	653	649	644	639	633	631	629	630	630	631	657
	May	638	638	640	640	641	641	644	653	675	699	720	728	721	710	687	667	654	649	646	641	639	639	636	637	639	662
	June	638	640	641	642	641	640	646	647	662	692	718	732	733	717	705	684	664	652	650	646	644	641	641	640	641	665
	July	641	641	641	641	642	643	646	651	670	695	717	734	735	721	701	678	658	648	646	644	642	641	641	640	641	665
	Aug.	618	620	621	622	625	622	627	635	656	687	714	728	724	715	699	676	657	645	639	631	625	627	625	624	626	653
	Sep.	640	640	644	643	644	642	641	654	681	722	751	764	755	734	705	683	670	666	659	649	645	642	641	640	640	673
	Means	635	635	637	637	638	637	640	648	671	702	726	737	731	715	694	674	659	651	647	641	638	637	636	635	636	663

Diurnal Inequality of the Horizontal Force at Kodaikanal in 1917, deduced from the above Table.

Season	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.	−16	−15	−17	−14	−15	−13	−14	−12	+4	+28	+50	+57	+49	+28	+9	−3	−4	−5	−10	−14	−16	−16	−15	−17	−14
	Feb.	−24	−21	−19	−19	−17	−18	−17	−11	+3	+26	+46	+58	+54	+42	+24	+8	+1	−4	−9	−15	−19	−21	−21	−23	−23
	Mar.	−31	−27	−26	−26	−25	−26	−27	−13	+16	+51	+80	+90	+77	+43	+13	−5	−11	−8	−11	−22	−26	−29	−31	−31	−31
	Oct.	−29	−27	−25	−22	−21	−22	−22	−11	+16	+48	+69	+75	+65	+46	+26	+3	0	−8	−18	−24	−26	−29	−31	−29	−28
	Nov.	−23	−21	−20	−20	−19	−18	−15	−4	+13	+34	+47	+48	+43	+35	+23	+16	+7	−2	−10	−16	−21	−24	−22	−20	−21
	Dec.	−22	−21	−17	−18	−17	−15	−12	−2	+10	+21	+29	+30	+35	+33	+30	+21	+9	+1	−9	−14	−18	−19	−22	−23	−21
	Means	−25	−22	−21	−20	−19	−19	−18	−9	+10	+34	+53	+59	+53	+37	+20	+6	0	−5	−12	−18	−21	−23	−24	−24	−23
Summer	April	−25	−24	−23	−21	−21	−23	−22	−9	+22	+58	+79	+80	+63	+37	+12	−4	−8	−13	−18	−24	−26	−28	−27	−27	−26
	May	−24	−24	−22	−22	−21	−21	−18	−9	+13	+37	+58	+66	+59	+48	+25	+5	−8	−13	−16	−21	−23	−23	−26	−25	−23
	June	−27	−25	−24	−23	−24	−25	−19	−18	−3	+27	·53	+67	+68	+52	+40	+19	−1	−13	−15	−19	−21	−24	−24	−25	−24
	July	−24	−24	−24	−24	−23	−22	−19	−14	+5	+30	+52	+69	+70	+56	+36	+13	−7	−17	−19	−21	−23	−24	−24	−25	−24
	Aug.	−35	−33	−32	−31	−28	−31	−26	−18	+3	+34	+61	+75	+71	+62	+46	+23	+4	−8	−14	−22	−28	−26	−28	−29	−27
	Sep.	−33	−33	−29	−30	−29	−31	−32	−19	+8	+49	+78	+91	+82	+61	+32	+10	−3	−7	−14	−24	−28	−31	−32	−33	−33
	Means	−28	−28	−26	−26	−25	−26	−23	−15	+8	+39	+63	+74	+68	+52	+31	+11	−4	−12	−16	−22	−25	−26	−27	−28	−27

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 1917, 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.	915	914	913	914	914	914	916	914	911	902	893	884	886	891	897	901	904	904	906	910	910	910	913	913	915	906
	Feb.	919	920	921	920	920	919	920	921	920	916	907	899	896	897	898	902	906	908	911	915	915	916	918	918	920	913
	Mar.	926	928	927	926	927	927	930	929	923	914	904	893	887	891	899	909	912	914	917	919	920	921	923	925	927	916
	Oct.	952	952	952	952	953	954	957	955	947	938	928	924	925	923	924	928	932	936	941	944	946	947	948	952	952	942
	Nov.	952	952	952	951	952	953	953	955	954	952	950	950	946	940	935	934	935	938	944	946	947	947	950	951	952	947
	Dec.	954	954	956	954	955	956	956	953	954	955	956	955	950	943	933	932	937	940	945	949	950	950	951	952	954	950
Means		936	937	937	936	937	937	939	938	935	930	923	918	915	914	914	918	921	923	927	931	931	932	934	935	937	929
Summer	April	931	931	931	931	931	932	936	935	927	917	910	903	899	902	908	916	920	920	921	923	925	927	929	931	931	922
	May	938	938	939	938	939	940	943	942	936	927	916	912	909	911	914	919	925	928	929	930	932	935	936	937	939	930
	June	944	944	944	944	944	946	952	954	951	942	935	925	918	918	920	923	928	933	937	936	938	940	942	943	944	938
	July	941	942	942	942	943	944	949	946	940	931	924	916	913	912	915	920	925	930	933	933	936	938	940	941	942	933
	Aug.	950	9[illegible]1	950	951	951	952	958	951	937	926	917	911	913	915	917	922	930	934	938	939	940	944	946	947	949	937
	Sep.	957	957	959	958	958	960	966	958	941	928	918	910	910	917	925	931	936	940	944	946	949	951	954	956	957	943
Means		944	944	944	944	944	946	951	948	939	929	920	913	910	913	917	922	927	931	934	935	937	939	941	943	944	934

Diurnal Inequality of the Vertical Force at Kodaikanal in 1917, 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.	+ 9	+ 8	+ 7	+ 8	+ 8	+ 8	+10	+ 8	+ 5	− 4	−13	−22	−20	−15	− 9	− 5	− 2	− 2	0	+ 4	+ 4	+ 4	+ 7	+ 7	+ 9	
	Feb.	+ 6	+ 7	+ 8	+ 7	+ 7	+ 6	+ 7	+ 8	+ 7	+ 3	− 6	−14	−17	−16	−15	−11	− 7	− 5	− 2	+ 2	+ 2	+ 3	+ 5	+ 5	+ 7	
	Mar.	+10	+12	+11	+10	+11	+11	+14	+13	+ 7	− 2	−12	−23	−29	−25	−17	− 7	− 4	− 2	+ 1	+ 3	+ 4	+ 5	+ 7	+ 9	+11	
	Oct.	+10	+10	+10	+10	+11	+12	+15	+13	+ 5	− 4	−14	−18	−17	−19	−18	−14	−10	− 6	− 1	+ 2	+ 4	+ 5	+ 6	+10	+10	
	Nov.	+ 5	+ 5	+ 5	+ 4	+ 5	+ 6	+ 6	+ 8	+ 7	+ 5	+ 3	+ 3	− 1	− 7	−12	−13	−12	− 9	− 3	− 1	0	0	+ 3	+ 4	+ 5	
	Dec.	+ 4	+ 4	+ 6	+ 4	+ 5	+ 6	+ 6	+ 3	+ 4	+ 5	+ 6	+ 5	0	− 7	−17	−18	−13	−10	− 5	− 1	0	0	+ 1	+ 2	+ 4	
Means		+ 7	+ 8	+ 8	+ 7	+ 8	+ 8	+10	+ 9	+ 6	+ 1	− 6	−11	−14	15	−15	−11	− 8	− 6	− 2	+ 2	+ 2	+ 3	+ 5	+ 6	+ 8	
Summer	April	+ 9	+ 9	+ 9	+ 9	+ 9	+10	+14	+13	+ 5	− 5	−12	−19	−23	−20	−14	− 6	− 2	− 2	− 1	+ 1	+ 3	+ 5	+ 7	+ 9	+ 9	
	May	+ 8	+ 8	+ 9	+ 8	+ 9	+10	+13	+12	+ 6	− 3	−14	−18	−21	−19	−16	−11	− 5	− 2	− 1	0	+ 2	+ 5	+ 6	+ 7	+ 9	
	June	+ 6	+ 6	+ 6	+ 6	+ 6	+ 8	+14	+16	+13	+ 4	− 3	−13	−20	−20	−18	−15	−10	− 5	− 1	− 2	0	+ 2	+ 4	+ 5	+ 6	
	July	+ 8	+ 9	+ 9	+ 9	+10	+11	+16	+13	+ 7	− 2	− 9	−17	−20	−21	−18	−13	− 8	− 3	0	0	+ 3	+ 5	+ 7	+ 8	+ 9	
	Aug.	+13	+14	+13	+14	+14	+15	+21	+14	0	−11	−20	−26	−24	−22	−20	−15	− 7	− 3	+ 1	+ 2	+ 3	+ 7	+ 9	+10	+12	
	Sep.	+14	+14	+16	+15	+15	+17	+23	+15	− 2	−15	−25	−33	−33	−26	−18	−12	− 7	− 3	+ 1	+ 3	+ 6	+ 8	+11	+13	+14	
Means		+10	+10	+10	+10	+10	+12	+17	+14	+ 5	− 5	−14	−21	−24	−21	−17	−12	− 7	− 3	0	+ 1	+ 3	+ 5	+ 7	+ 9	+10	

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 1917, *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.	25·9	25·8	25·7	25·8	25·8	25·8	**26·0**	25·8	25·4	24·4	23·4	**22·6**	22·8	23·4	24·1	24·5	24·8	24·8	25·0	25·4	25·4	25·4	25·7	25·7	25·9	25·2
	Feb.	26·2	26·3	**26·3**	26·2	26·2	26·1	26·2	26·3	26·1	25·6	24·6	23·8	**23·6**	23·7	23·9	24·4	24·8	25·0	25·4	25·8	25·8	25·9	26·1	26·1	26·3	25·4
	Mar.	26·8	27·0	26·9	26·8	26·8	26·9	**27·1**	26·9	26·2	25·1	24·0	23·0	**22·5**	23·1	24·0	25·1	25·4	25·5	25·8	26·1	26·2	26·3	26·5	26·7	26·9	25·7
	Oct.	29·1	29·0	29·0	29·0	29·1	29·2	**29·5**	29·2	28·3	27·2	26·2	**25·8**	25·9	25·9	26·1	26·7	27·0	27·5	28·0	28·3	28·5	28·6	28·7	29·1	29·1	28·0
	Nov.	29·0	29·0	29·0	28·9	29·0	29·1	29·0	**29·1**	28·9	28·6	28·3	28·3	28·0	27·5	27·1	**27·1**	27·2	27·6	28·2	28·4	28·5	28·6	28·8	28·9	29·0	28·4
	Dec.	29·2	29·2	**29·3**	29·2	29·2	29·3	29·3	29·0	29·0	29·0	29·0	28·9	28·4	27·8	26·9	**26·9**	27·4	27·8	28·3	28·7	28·8	28·8	28·9	29·0	29·2	28·6
	Means	27·7	27·7	27·7	27·7	27·7	27·7	**27·9**	27·7	27·3	26·7	25·9	25·4	**25·2**	25·2	25·4	25·8	26·1	26·4	26·8	27·1	27·2	27·3	27·5	27·6	27·7	26·9
Summer.	April	27·2	27·2	27·2	27·2	27·2	27·3	**27·7**	27·5	26·5	25·4	24·6	23·9	**23·7**	24·2	24·9	25·7	26·1	26·1	26·3	26·5	26·7	26·9	27·1	27·2	27·2	26·3
	May	27·8	27·8	27·9	27·8	27·9	28·0	**28·2**	28·1	27·4	26·4	25·2	24·8	**24·6**	24·9	25·3	25·9	26·5	26·8	26·9	27·1	27·3	27·5	27·7	27·7	27·9	26·9
	June	28·4	28·3	28·3	28·3	28·3	28·5	29·0	**29·2**	28·8	27·8	27·0	26·0	**25·3**	25·4	25·7	26·1	26·7	27·3	27·6	27·6	27·8	28·0	28·2	28·3	28·3	27·6
	July	28·1	28·2	28·2	28·2	28·2	28·3	**28·8**	28·4	27·8	26·8	26·0	25·1	**24·9**	24·9	25·3	25·9	26·5	27·0	27·3	27·3	27·6	27·8	28·0	28·1	28·2	27·2
	Aug.	29·0	29·1	29·0	29·1	29·1	29·2	**29·7**	29·0	27·6	26·4	25·4	**24·7**	24·9	25·2	25·5	26·1	27·0	27·4	27·8	28·0	28·1	28·4	28·6	28·7	28·9	27·6
	Sep.	29·5	29·5	29·7	29·6	29·6	29·8	**30·3**	29·6	27·8	26·3	25·2	**24·4**	24·5	25·2	26·2	26·9	27·4	27·8	28·2	28·5	28·8	29·0	29·2	29·4	29·5	28·0
	Means	28·3	28·4	28·4	28·4	28·4	28·5	**29·0**	28·6	27·7	26·5	25·6	24·8	**24·7**	25·0	25·5	26·1	26·7	27·1	27·4	27·5	27·7	27·9	28·1	28·2	28·3	27·3

Diurnal Inequality of the Dip at Kodaikanal in 1917, *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.	+0·7	+0·6	+0·5	+0·6	+0·6	+0·6	+0·8	+0·6	+0·2	−0·8	−1·8	−2·6	−2·4	−1·8	−1·1	−0·7	−0·4	−0·4	−0·2	+0·2	+0·2	+0·2	+0·5	+0·5	+0·7
	Feb.	+0·8	+0·9	+0·9	+0·8	+0·8	+0·7	+0·8	+0·9	+0·7	+0·2	−0·8	−1·6	−1·8	−1·7	−1·5	−1·0	−0·6	−0·4	0·0	+0·4	+0·4	+0·5	+0·7	+0·7	+0·9
	Mar.	+1·1	+1·3	+1·2	+1·1	+1·1	+1·2	+1·4	+1·2	+0·5	−0·6	−1·7	−2·7	−3·2	−2·6	−1·7	−0·6	−0·3	−0·2	+0·1	+0·4	+0·5	+0·6	+0·8	+1·0	+1·2
	Oct.	+1·1	+1·0	+1·0	+1·0	+1·1	+1·2	+1·5	+1·2	+0·3	−0·8	−1·8	−2·2	−2·1	−2·1	−1·9	−1·3	−1·0	−0·5	0·0	+0·3	+0·5	+0·6	+0·7	+1·1	+1·1
	Nov.	+0·6	+0·6	+0·6	+0·5	+0·6	+0·7	+0·6	+0·7	+0·5	+0·2	−0·1	−0·1	−0·4	−0·9	−1·3	−1·3	−1·2	−0·8	−0·2	0·0	+0·1	+0·2	+0·4	+0·5	+0·6
	Dec.	+0·6	+0·6	+0·7	+0·6	+0·6	+0·7	+0·7	+0·4	+0·4	+0·4	+0·4	+0·3	−0·2	−0·8	−1·7	−1·7	−1·2	−0·8	−0·3	+0·1	+0·2	+0·2	+0·3	+0·4	+0·6
	Means	+0·8	+0·8	+0·8	+0·8	+0·8	+0·8	+1·0	+0·8	+0·4	−0·2	−1·0	−1·5	−1·7	−1·7	−1·5	−1·1	−0·8	−0·5	−0·1	+0·2	+0·3	+0·4	+0·6	+0·7	+0·8
Summer.	April	+0·9	+0·9	+0·9	+0·9	+0·9	+1·0	+1·4	+1·2	+0·2	−0·9	−1·7	−2·4	−2·6	−2·1	−1·4	−0·6	−0·2	−0·2	0·0	+0·2	+0·4	+0·6	+0·8	+0·9	+0·9
	May	+0·9	+0·9	+1·0	+0·9	+1·0	+1·1	+1·3	+1·2	+0·5	−0·5	−1·7	−2·1	−2·3	−2·0	−1·6	−1·0	−0·4	−0·1	0·0	+0·2	+0·4	+0·6	+0·8	+0·8	+1·0
	June	+0·8	+0·7	+0·7	+0·7	+0·7	+0·9	+1·4	+1·6	+1·2	+0·2	−0·6	−1·6	−2·3	−2·2	−1·9	−1·5	−0·9	−0·3	0·0	0·0	+0·2	+0·4	+0·6	+0·7	+0·7
	July	+0·9	+1·0	+1·0	+1·0	+1·0	+1·1	+1·6	+1·2	+0·6	−0·4	−1·2	−2·1	−2·3	−2·3	−1·9	−1·3	−0·7	−0·2	+0·1	+0·1	+0·4	+0·6	+0·8	+0·9	+1·0
	Aug.	+1·4	+1·5	+1·4	+1·5	+1·5	+1·6	+2·1	+1·4	0·0	−1·2	−2·2	−2·9	−2·7	−2·4	−2·1	−1·5	−0·6	−0·2	+0·2	+0·4	+0·5	+0·8	+1·0	+1·1	+1·3
	Sep.	+1·5	+1·5	+1·7	+1·6	+1·6	+1·8	+2·3	+1·5	−0·2	−1·7	−2·8	−3·6	−3·5	−2·8	−1·8	−1·1	−0·6	−0·2	+0·2	+0·5	+0·8	+1·0	+1·2	+1·4	+1·5
	Means	+1·0	+1·1	+1·1	+1·1	+1·1	+1·2	+1·7	+1·3	+0·4	−0·8	−1·7	−2·5	−2·6	−2·3	−1·8	−1·2	−0·6	−0·2	+0·1	+0·2	+0·4	+0·6	+0·8	+0·9	+1·0

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

No. 19 PARTY (BASE LINE).

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

Personnel.

Imperial Officers.

Major E.A. Tandy, R. E., in charge to 11th October 1917.
Major E.T. Rich, C.I.E., R.E., in charge from 14th January to 5th March 1918.
Major H. McC. Cowie, R.E., in charge from 6th March to 5th August 1918.
Captain W.E. Perry, M.C., R.E., in charge from 6th August to 30th Sept. 1918.

Provincial Officer.

Mr. E.C.J. Bond, in charge from 12th Oct. 1917 to 13th Jan. 1918.

Lower Subordinate Service.

2 Computers, &c.

No work was undertaken by this Party as a Party; the officers and establishment from time to time posted to it for administrative purposes were employed on miscellaneous work.

The Party remained at Head Quarters and did not take the field.

THE COMPUTING OFFICE.

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

PERSONNEL.

Imperial Officer.

Major H. McC. Cowie, R.E. in charge.

Provincial Officer.

Mr. Hanuman Prasad.

Upper Subordinate Service.

Mr. K.K. Das, B.A., from 1st June, 1918.

Computing Office.

Rai Sahib Ishan Chandra Dera, B.A., and 11 Computers; 4 Computers attached (4 Computers from field parties, 3 of them worked only for a portion of the year in Computing Office) and 7 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.—During the year under review the adjustment of the Akha Triangulation and the pendent portion of the Assam Valley Series was carried out. The secondary stations and intersected points of the following Geodetic Series were also adjusted:—Assam Longitudinal, Assam Valley, Nāga Hills, Kohīma and Cāchār, Manipur Longitudinal and Meridional, Mandalay Longitudinal and Meridional, and Gāro, Khāsi and Jaintiā Hills.

Levelling.—The dynamic and orthometric heights of new bench-marks between Meerut and Bareilly in the old line No. 64, relevelled in 1914-15, were computed and the new work adjusted to the values of the terminal bench-marks and the G. T. Tower Stations at Sirsa and Fatehganj. The adjustment was effected in four sections, *viz*, (1) Meerut to Sirsa, (2) Sirsa to Fatehganj, (3) Fatehganj to Bareilly and (4) B.M. 78/53 L to Bhatauli. In assigning new values of height to the old bench-marks use was made of the formula given on page 61 of the Records of the Survey of India, Vol. XI, 1916-17.

As was forecast in last year's report, the republication of the Burma heights in terms of the new mean-sea-level datum at Amherst was accomplished. A new edition of the Burma Pamphlets giving the revised heights has now been completed.

Miscellaneous Computations.—Computations were carried out in connection with Part II of the Auxiliary Tables of the Survey of India, 5th edition, 1918 and in connection with the investigation of Isostasy in India.

Triangulation Pamphlets.—Last year's progress was maintained in compiling data for the triangulation pamphlets, specially for trans-frontier areas. 115 degree sheets were compiled and compared during the year.

Printing Section.—The following were printed in the course of the year:—Vol. XI of the Records of the Survey of India 1916-17, Triangulation Pamphlets for 88 degree sheets (G. T. data only), Delhi Triangulation pamphlet, Bombay Island Triangulation pamphlet, Levelling pamphlets for sheets Nos. 84, 85 and 92 and Tide Tables for the Port of Basrah. The printing of Professional Paper No. 16 and Part II of the Auxiliary Tables of the Survey of India, 5th edition, was completed. In addition to these a pamphlet on the transliteration of place names was published.

In the Book-binding section the work dealt with comprised 4750 copies of triangulation and levelling pamphlets, 400 copies of Professional Paper No. 16, 406 copies of Tide Tables for the Port of Basrah, 500 angle books and 770 volumes of miscellaneous publications. The binding of 350 copies of the Records of the Survey of India Vol. XI, 1916-17, is in progress and will be shortly completed.

Workshops.—The work of this section consisted principally in the construction of a number of racks for the Computing Office and the Forest Map Office, the alteration of signals and the repairing of instruments for the Sind Sāgar Party and No. 3 Party and in the repairing and cleaning of instruments for issue to the Persian Survey Detachments.

Requisitions.—85 requisitions for data were received from departmental and non-departmental officials. In some cases these requisitions were met by the supply of printed publications; in others it was necessary to extract the required information from manuscript records.

Miscellaneous.—The Omori Seismograph was in operation throughout the year and the usual meteorological observations were taken. A satisfactory record was obtained of the destructive earthquake which occurred on 8th July 1918 in Assam and was sent to the Director of the Geological Survey in compliance with his request.

The photo.-helio. observatory continued its work as in past years.

The following statements show the earthquakes recorded and the number of days on which Solar photographs were taken :—

Earthquakes recorded during 1917-18.

Serial No.	Month and Date	Time of beginning (corrected)		Duration	Distance of Epicentre in miles		Intensity
		Dehra	Simla (from W.R.)		Dehra	Simla (from W.R.)	
		Hrs. Mts.	Hrs. Mts.	Mts.			
1	31-1-18*	2 58	2 57	27	2800	3000	moderate
2	14-2-18	11 45	11 45	86	2730	3000	do.
3	25-3-18	5 52	5 54	30	1540	1000	slight
4	13-4-18	6 29½	6 30	85	3570	1500	do.
5	4-7-18	12 33½	12 33	70	4550	4000	moderate
6	8-7-18	15 54	15 55	110	840	1000	great (Assam earthquake)
7	15-8-18 }	11 8½	...	67	3430	...	severe
	do. }	17 56	17 57	220	3640	2500	do.
8	7-9-18	22 57	...	260	4410	...	do.
9	12-9-18	15 11	15 11	18	400	400	slight

Note :—No earthquakes were recorded during the months of October, November and December 1917.

SOLAR PHOTOGRAPHY.

Statement showing the number of days on which Solar Photographs were taken during the year 1917-18.

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 1917	26	47	...	1	...	5	April 1918	30	52	...	2	...	...
November „	30	56	...	3	...	..	May „	31	57	...	4	...	...
December „	30	52	...	1	...	1	June „	29	49	...	1	...	1
January 1918	30	54	...	2	...	1	July „	30	47	...	1	...	1
February „	26	48	...	3	...	2	August „	27	44	...	1	...	4
March „	29	52	...	2	...	2	September „	30	54	...	2	...	...
							Totals ...	348	612	...	23	...	17

CALCUTTA SURVEY OFFICES ON ARMISTICE DAY.

From a photograph by Mr. T. Chorlton.

Photo-engraved & printed at the Offices of the Survey of India, Calcutta, 1919.

PART III.—SPECIAL REPORTS.

PHOTO.-LITHO. OFFICE, CALCUTTA.

BY MAJOR F. J. M KING, R. E.

The year 1917-18 has again witnessed a very large increase in the demand for maps by the military authorities. The greater part of this demand consisted of maps required for mobilisation purposes and entailed the concentration of all our resources on it for some months and the employment of constant overtime.

As a result of the war the Government of India experienced difficulty in obtaining supplies of Treasury Bills and Promissory Notes from England, and this office was consequently called upon to print large numbers of complete Treasury Bills and of the background design of the Promissory Notes, the type matter on the latter being subsequently surprinted by the Superintendent, Government Printing. These Promissory Notes were used as scrip for the Second Indian War Loan.

The Powder Process.—In the Records Volume for 1916-17 it was mentioned that the Powder Process would probably be taken into use again in the office. This process was formerly used here for the preparation of reversed negatives which were required in connection with the preparation of " dust-on " blue prints for hill shading before the present method of making these blue prints was introduced ; it has now been taken into use again but for quite a different purpose.

Space having been found by a rearrangement of the glass and negative storage accommodation, a new section was formed to work this process which is now used for the preparation of all the negatives of the line work on our modern coloured maps. The Powder Process enables any number of reversed copies of a negative to be made at a trifling cost.

Until this new section was formed the Negative Section had to make four negatives of the outline original and one of the hill original of every modern coloured map, whereas the Negative Section now has to make only one negative of the outline and one of the hills, these negatives being made " direct ", that is without the use of a prism on the lens of the camera. These " direct " negatives are given a full exposure in the camera and developed; the intensification subsequent to development is, however, not carried so far as was formerly the case, a comparatively " thin " negative being all that is required, as any required amount of density can be obtained when making the reversed duplicates by the Powder Process, and over-intensification of the camera negative causes fine work to close up and become broken. The small amount of intensification given enables all the minute details of the finest drawing to be preserved. The direct outline and hill negatives are then sent down to the Powder Process Section where four reversed copies are made of the outline negative and one of the hills and it is on these reversed duplicates that the duffing for colours is subsequently done.

Though the Powder Process itself is a very old one it is only lately that its possibilities in connection with our work were realised, and, as it is a process which is so little known, a description of it is given below under " Methods and Processes ". Its introduction has improved the quality of our maps, considerably lightened the work of the Negative Section which was rapidly becoming congested, and reduced the cost of reproduction of coloured maps. Without it it would have been impossible to cope with all the demands for reprints of our maps for mobilisation purposes in anything like as short a time as that in which the work was actually carried out.

By this means a very notable economy has also been effected. The Process was taken into use in February 1918. The average cost of negatives from October 1st 1917 to January 31st 1918 works out at Rs. 1-2-9 per 100 square inches, while from February 1st 1918 to September 30th 1918 the average cost comes to only Rs. 0-10-8 or a saving of Rs. 0-8-1 per 100 square inches. The total area of negatives made during the year under report comes to 2,589,557 square inches, so that the saving on a whole year's working amounts to about

Rs. 12,000. This process has also been found very useful for preparing negatives for the layer plates of our layered maps. Instead of making in the camera the whole set of negatives for the layers of a map, only one is now made, as many duplicates of it as are necessary being made by the Powder Process.

It has been stated above that the introduction of the Powder Process entails using the camera "direct", *i.e.*, with no prism on the lens. Hitherto our cameras have been arranged for use with prisms and it has now been necessary to alter two of them for direct use. Our largest camera has not as yet been so altered as in this case some arrangement will have to be made whereby this camera can be used either direct or with a prism, as much of our largest work is in one colour only in which case no Powder Process negative is made and the camera negative is the one used from which to make the helio. The alterations necessary to this large camera are not very great but it has been thought inadvisable to ask the Mathematical Instrument Office to undertake the work in war time when they are so busy with munition work. The alterations will be undertaken as soon as the Mathematical Instrument Office can spare the time to do them.

Our largest camera is the only one which will carry our best lens—a large one by Zeiss: we are therefore at present unable to use our best lens on our highest class of work which is the reproduction of our modern maps in colours.

METHODS AND PROCESSES.

I. The Powder Process.

1. By means of the Powder Process it is possible to make any number of reversed duplicates of a negative,—it is a means of making a negative *from* a negative.

2. *Sensitising.*—A clean piece of glass is coated with the following solution:—

Glucose	30 gms.
Gelatine	4 gms.
Gum arabic	8 gms.
Ammonium Bichromate	15 gms.
Water	240 c.c.

The coating of the glass is carried out as follows:—The glass, which should be thoroughly clean, is laid on a flat table and a small quantity of the solution is poured on to the centre of the glass and distributed over its surface by means of a rubber roller. Only sufficient solution should be poured on as will cover the glass with a very thin film when it is spread out by the action of the roller. The best type of roller to use is of the type sold for use with the "Cyclostyle" duplicating apparatus. The rolling is continued both backwards and forwards and across until the glass is covered with a thin even film and the solution begins to get tacky when the rolling should be stopped. Most of the old text books which deal with this process recommend flowing the solution over the glass and draining it, or flowing it on and whirling it. Both these methods were tried here but it was always found that the resulting negatives were a mass of pinholes; coating with a rubber roller obviates this great defect. The coating of the glass up to this stage can be done safely in daylight as the solution is not sensitive to light until it is dry.

3. *Drying.*—The coated glass is now dried in a specially constructed light-tight drying box, the drying being effected by means of heat.

4. *Exposing.*—When thoroughly dry the sensitised glass is removed from the drying box in a yellow light and placed, film to film, with the negative to be copied in a pneumatic printing frame, and an exposure made. The exposure should be given, if possible, in direct sunlight in order to obtain the sharpest results. The length of exposure necessary in Calcutta is about 1½ minutes at mid-day in strong sunlight, longer exposures of course being necessary when the light is weaker or the sun is obscured.

5. *Developing.*—The printing frame is now taken into the developing room, the exposed glass removed from the frame in a yellow light and allowed to stand exposed to the damp atmosphere of the room for a few minutes in order that it may absorb moisture from the air. If this process were to be worked in a very dry climate it might be necessary to provide for this purpose a special damping box in which the air could be kept more or less laden with moisture by some means. The atmosphere of Calcutta is, however, sufficiently moisture-laden

to render any special arrangement of this sort unnecessary. The glass is now placed, film side up, on the top of a developing box, which consists in the main of an ordinary wooden box with a light inside it and with a thick glass lid, the interior of the bottom and sides of the box being painted white. Fine lamp black powder is then dusted gently over the film side of the exposed glass with a tuft of cotton wool; by means of gentle rubbing the image gradually appears and can be brought to any degree of density required provided the exposure is correct. Over-exposure leads to a difficulty in getting sufficient density of image, while under exposure gives extreme density with a "veiling" or blackening of the lines of the image which should remain clear.

6. *Varnishing.*—When sufficient density has been obtained the surplus powder is dusted off and the negative is varnished in the same way as is done in the case of ordinary wet plate negatives.

7. *Washing out the bichromate.*—In some cases the Ammonium Bichromate in the sensitising solution imparts a yellowish tinge to the clear lines. If such is the case, the negative, after development and before varnishing, is exposed to daylight to thoroughly harden the film; it is then thoroughly washed under a tap until the bichromate is dissolved out, thus causing the yellowish tinge to disappear from the clear lines of the image. The negative is then allowed to dry, after which it can be varnished.

8. *Explanation of the process.*—The two main factors in the sensitising formula are the ammonium bichromate and the glucose. The sensitising solution when spread on the glass by the roller and dried by heat is not in a sticky or "tacky" state, but if exposed to damp air it absorbs moisture and becomes sticky. The action of light on the dried film on the other hand destroys that power and so hardens the film that it cannot absorb moisture and become sticky. This light-sensitive film when exposed under a negative will become hardened only on the portions to which the light has access, that is to say, on those parts under the clear lines of the image of the original negative; the portions under the opaque parts of the original negative on the other hand are not acted on by light and still retain the power of absorbing moisture and so becoming sticky. The development with lamp black is purely mechanical and involves no chemical action. The powder will only stick to those portions which are sticky and have not been hardened by light, and will not adhere to those portions which have been so hardened. The resulting negative is therefore a reversed duplicate of the original negative.

II. Improvements in the preparation of Layer Plates.

Some developments have been made during the year with a view to simplifying the preparation of plates for the layer colouring of our maps by the new photographic method which was described in the Records Volume for 1916-17.

The making of half-tone negatives for this purpose is a somewhat complicated business, and there are many factors which require constant attention such as "screen distance", stops, exposure, etc., as any errors in these respects may be the cause of unsatisfactory results.

At Mr. Vandyke's suggestion the special "X" shaped stop, referred to in last year's Records Volume, was replaced by a stop formed of a single slit, the slit sloping at 45 degrees to the horizontal and parallel to one set of lines of the screen. Half the exposure is made with the stop in one position, and the other half with the stop reversed so that the slit is at an angle of 90 degrees to its position during the first half of the exposure. During the first half of the exposure the layer original is on the plan board and single lines at 45 degrees to the horizontal are produced on those portions of the negative corresponding to the white portions of the layer original; the black portions of the layer original produce no action on the negative so that lines are not formed on those parts of the negative corresponding to the blacks of the layer original. During the second half of the exposure, the stop having been reversed, the layer original is covered over with white paper. Lines crossing the former lines at 90 degrees are thus formed all over the negative. On development, a negative prepared in this fashion will show single lines all over those portions corresponding to the black portions of the layer original and crossed lines all over those portions corresponding to the white portions of the layer original.

The helio plates prepared from negatives prepared in this way were found more satisfactory than those from negatives made with the X stop as the dots forming the light tint were large but definitely isolated. The lines forming the dark tint were also more satisfactory as there is not the same tendency for single line tints to close up in printing as is the case with cross-lined tints.

Mr. Vandyke's next development was the substitution of a single lined screen with lines at 45° to the horizontal for the ordinary half-tone screen. A screen of this sort was ruled in a ruling machine and consisted of fine clear lines cut through an opaque ground which was laid on the glass. This screen is carried in the ordinary screen carrier in the camera but is used without any screen distance—*i.e.*, close up to the plate,—and a large stop is used in the lens, thus entailing a shorter exposure than was the case with the "slit" stop. After the first half of the exposure has been given the dark slide is closed, the screen rotated through 90°, so that the lines run at right angles to their former direction, and the second half of the exposure made, white paper being placed over the original as was done when using the "slit" stop. The elimination of the screen distance renders this method very simple and the use of a screen with a somewhat coarse ruling makes the subsequent printing much easier.

APPENDIX I.

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THE PROBLEM OF THE HIMALAYA AND THE GANGETIC TROUGH.

By Dr. A. Morley Davies.

"The Attraction of the Himalaya Mountains upon the Plumb-line in India."—Major S. G. Burrard, R. E. Survey of India: Professional Paper No. 5. (1901).

"Pendulum Observations in India, 1903-07."—Major G. P. Lenox-Conyngham, R.E. Survey of India: Professional Paper No. 10. (1908).

"Investigation of the Theory of Isostasy in India."—Major H.L. Crosthwait, R.E. Survey of India: Professional Paper No. 13. (1912).

"On the Origin of the Himalaya Mountains."—Colonel S. G. Burrard, C.S.I., R.E., F.R.S. Survey of India: Professional Paper No. 12. (1912).

"Notes on the Relationship of the Himalayas to the Indo-Gangetic Plain and the Indian Peninsula."—H.H. Hayden, C.I.E., F.G.S. *Records Geol. Surv. India,* **43,** 108-167. (1913).

"The Origin of the Himalayan Folding."—Sir Thomas H. Holland, K.C.I.E., A.R.C.S., F.R.S. *Geol. Mag.,* Dec. 5, **10,** 167-170. (1913).

"Note in Reply to Mr. Hayden's Paper . . ."—Lieut.-Colonel G. P. Lenox-Conyngham, R.E. *Records Surv. India,* **5,** 161-164. (1914).

Presidential Address to Section C, Brit. Assoc. (Australian Meeting).—Sir Thomas H. Holland, K.C.I.E., A.R.C.S., D.Sc., F.R.S. *Geol Mag.,* Dec. 6, **1,** 411-418, 457-464 (1914); and *Rep. Brit. Assoc.,* Australia, 1914; (1915), 344-358.

"On the Effect of the Gangetic Alluvium on the Plumb-line in Northern India."—R. D. Oldham, F.R.S. *Proc. Roy. Soc.,* A, **90,** 32-41. (1914).

"On the Origin of the Indo-Gangetic Trough, commonly called the Himalayan Foredeep."—Colonel Sir Sidney Burrard, K.C.S.I., R.E., F.R.S. *Proc. Roy. Soc.,* A, **91,** 220-238. (1915).

"The Structure of the Himalayas and of the Gangetic Plain, as elucidated by Geodetic Observations in India."—R. D. Oldham, F.R.S. *Mem. Geol. Surv. India,* **42,** pt. 2, 1-153. (1917).

and other papers.

The literature of the famous Himalayan problem has been enriched in recent years by a series of important papers which need collective notice. Scattered over a wide range of official publications, and demanding for their appreciation an equal knowledge of Geology and Geodesy, an introduction to their study is required; and it is as such an introduction, rather than as a critical judgment of the problem in its present phase, that this notice is written.

The great alluvial plains of Northern India, which slope so gently upward from the Bay of Bengal and the Arabian Sea that the indistinct watershed north of Delhi is less than 1000 feet above the sea-level, separate two regions of higher land that are in striking contrast, physically and geologically. To the south, the Peninsula is an almost earthquake-free area of ancient crystalline rocks, freshwater sediments, and immense horizontal sheets of lava. Its geological relationships are with South Africa and Australia, fragments of a continent which for long ages remained highly stable and free from compressive stress. To the north, the Tibetan plateau, the snowy Himalaya, the Lesser Himalaya and the Siwalik Hills form four parallel belts which show evidences of strong transverse compression in late geological periods, the last of them being still the seat of origin of violent earthquakes. In the two northern belts crystalline rocks are associated with the uplifted deposits of an ancient ocean, while the Siwaliks are composed of sediments like those of the alluvial plains, though slightly older in geological time.

The plains themselves are formed of material brought down by streams from the high ground, especially from the north. On their southern margin the rocks of the peninsula slope gently away beneath them, frequently projecting through them like islands; but on the northern margin the Himalayan rocks plunge abruptly down to unknown depths. What geological structure is hidden beneath this northern part of the plains?

When Everest in 1847 finished measuring that part of the Great Arc of India which crosses the plains from the central station of Kalianpur to Kaliana near the foot of the mountains, he found that the latitude of the latter place, as determined by direct astronomical observation, was less by more than 5 seconds of arc than the latitude as measured geodetically. This was interpreted as due to the attraction of the Himalayas, which by deflecting the plumb-line falsified the astronomical observations, and Pratt (*Phil. Trans.*, **145** (1855), p. 53) set out to verify this by an elaborate calculation. He came to the disconcerting result that the deviation of the plumb-line ought to be three times as great as it actually was. Airy (*Ibid.*, p. 101) at once pointed out that if the Earth (as then generally believed) had a thin solid crust supported by flotation on a liquid central mass, every protuberance must be supported by a downward displacement of the liquid, just as with an iceberg or a floating cork; that therefore there ought to be a defect of gravity beneath a mountain-chain or plateau which would diminish the deflection of the plumb-line caused by the protuberant mass. Pratt, however, rejected the idea of flotation of a thin crust (*Phil. Trans.*, **149** (1859), p. 746), but accepted that of a sub-montane defect of gravity, believing this to be due to deep-seated chemical changes, which actually caused the rising of the surface. He showed also that there was a deflection of the plumb-line towards the ocean at Indian coast-stations, so that there must be an excess of gravity beneath the ocean hollows. To this relation between surface features and deep-seated variations of gravity he applied the term "compensation".

Here we see a double divergence of view: Pratt for a rigid Earth, Airy for a fluid globe with thin crust; Pratt for a deep-seated tumefaction (like the rising of dough) as the cause of mountains and plateaux, Airy for their formation by some immense surface accumulation of matter of which a very large part sank into the supporting fluid. Airy indeed expressed no view as to how the accumulation came about, and to complete the double contrast we must go forward to 1881, when Osmond Fisher ('Physics of the Earth's Crust,' pp. 142–150) combined Airy's principle of flotation with the geological principle of mountain origin by tangential compression in his theory of mountain "roots," according to which every upward wrinkle was accompanied by a much larger downward wrinkle displacing the more or less fluid sub-crust.

J. D. Dana ('Manual of Geology') put forward the principle of compensation as evidence for the permanence of oceanic and continental areas through geological time; but otherwise little notice seems to have been taken of it by geologists in their theories of upheaval and mountain formation, until Dutton * in 1889 brought it into prominence and proposed the term *Isostasy*. This term was scarcely a happy one, since Dutton's great service was that he took a principle which in the hands of geodesists had been simply static, and made it dynamic by introducing the idea of constant adaptation through geological time. Dutton's paper was a stop-gap, not originally intended for publication, but its effect on geological thought was remarkable.

Isostasy may be defined as a condition of approximate equilibrium in a heterogeneous earth, such that variations in the actual surface from that of the ellipsoid of rotation compensate for (or are compensated by) differences in the density of the crust beneath them. The maintenance of isostasy in face of the geological changes that are known to have taken place in the crust implies some degree of plasticity in the sub-crust, though it is not necessary to adopt the crude idea of a thin crust on a liquid sub-crust.† "The continents will be floated, so to speak, because they are composed of relatively light material; and, similarly, the floor of the ocean will......be depressed because it is composed of unusually dense material."

"The adjustment of the material towards this condition, which is produced in nature by the stresses due to gravity, may be called the *isostatic adjustment*......The compensation of the excess of matter at the surface (continents) by the defect of density below, and of the surface defect of matter (oceans) by excess of density below, may be called the *isostatic compensation*."

* "On some of the Greater Problems of Physical Geology," *Bull. Phil. Soc. Washington*, **11**, 51–64 (1892).

† The modern geological conception is perhaps best expressed by Prof. Barrell's "Asthenosphere"—"a thick earth-shell marked by a capacity to yield readily to long-enduring strains of limited magnitude," though transmitting earthquake-waves like a rigid body. "The Strength of the Earth's Crust," *Journ. Geol.* (Chicago), **22, 23** (1914-15), numerous references.

These quotations are from a memoir by Hayford,* who in the early years of the century devised an ingenious modification of the "compartment" method which Pratt had invented for his Himalayan calculations, making it possible by comparatively simple calculations to determine the "topographic deflection" for any station. This may be defined as the deflection of the plumb-line which would be produced by the irregular distribution of the masses corresponding to the known irregularities of the surface, assuming the non-existence of any isostatic compensation. By the same method may be determined the "correction for isostasy" at any station, that is the correction to be made in the topographic deflection on the assumption that the Earth is in perfect isostatic equilibrium. If the deflection so calculated and corrected does not agree with the observed deflection (as shown by the difference between the astronomical and geodetic latitudes of a station) the difference is the "residual deflection" (or "anomaly"), and is the measure of the imperfection of isostasy at the station, unless it can be shown to be due in part to imperfect geodesy (for instance, the use of an inexact spheroid as basis).

Isostatic equilibrium is, of course, very far from being real equilibrium. The plumb-line is still deflected locally, because the compensating excesses and defects of mass are at unequal distances from it; and there are lateral strains set up in the Earth itself. Elevated areas are not saved from denudation nor seas from sedimentation by compensation in the depths, and the effect of these geological actions as well as of those movements under tangential pressure to which the folding and overthrusting of rock-masses bear witness is to disturb isostasy continually. If, therefore, there is even an approximation to isostasy in the Earth, it is good evidence that isostatic adjustment has been taking place during the past.

Hayford and his colleagues of the U. S. Coast and Geodetic Survey showed by the smallness of the "residual deflections" that there was approximate isostasy in the United States. The residuals were smallest if isostatic compensation were assumed to be complete at a depth of about 113·7 (afterwards recalculated as 122) km. The mass under any given area, from sea-level down to this depth of complete compensation, is the "supporting column" of that area. Hayford mapped the distribution of residuals, but could find no general explanation of them. Gilbert † pointed out that Hayford assumed a uniform distribution of the compensating defect or excess throughout the supporting column, and calculated that heterogeneity of the column might produce results comparable to the actual residuals, but that variation in the isostatic level would not. Barrell ‡ came independently to the conclusion that vertical variations of density are a real cause, but not the major cause of anomalies.

Meanwhile much work was being done in India. Burrard (1901) published the results of the previous six years' work in a volume which may well be taken as a classical example of scientific progress by the method of trial and error, as first one and then another explanation of the plumb-line anomalies is tried and abandoned. We need only refer to the final result, the chief of which is that a "hidden mountain chain" or region of excessive density crosses India, parallel to the Himalayas, and about 400 miles from their southern boundary, from near Calcutta through Kalianpur to near Karachi, and that this masks the effect of the Himalayas on the plumb-line. Another small area of high density occurs in the midst of the Punjab alluvium between Multan and Lahore.

These results of plumb-line observations were confirmed by Lenox-Conyngham's pendulum observations (1908).

Crosthwait (1912) applied Hayford's methods to India, and showed that there was a far wider divergence from isostasy in India than in the United States. Burrard had divided India into regions according to the direction and amount of the local deflections. Ardent believers in isostasy may have hoped that these distinctions would vanish when "correction for isostasy" had been made; but they still persist. Thus in region 1 (Himalayas) all residuals are negative (northward deflection), and all but one have high values, 13″ to 24″. Region 2 (plains at foot of Himalayas) is a region of rapid transition: there are only four stations, and the residuals range from −11″ to +7″. Regions 3, 4, and 5 (all the rest of the plains, and the peninsula roughly north of the Tropic of Cancer) include 37 stations, of which 34 have positive residuals, the other three having 0, 0, and −1″ respectively. Further south, on the other side of the "hidden range" negative values again prevail except in the

* J. F. Hayford, 'The Figure of the Earth and Isostasy,' U. S. Coast and Geodetic Survey (Washington, 1909), and 'Supplementary Investigation' (1910).

† "Interpretation of Anomalies of Gravity," U. S. Geol. Surv., Professional Paper 85 C (1913).

‡ *Op. cit.*, **22**, 313 (1914).

extreme south, where there is a transition towards positive.* There is thus evidence of a defect of gravity under the plains and an excess under the northern part of the peninsula, not accounted for by either topography or isostatic compensation. Crosthwait (anticipating Gilbert's conclusion) suggested that residuals might be due in part to unequal distribution of mass in the "supporting columns." He regarded the less perfect isostasy of India as due to the much greater disturbances of the crust in late geological times, as compared with North America. "The Earth's crust in India is in a process of settling down and may be, comparatively speaking, in a state of strain." On this Barrell † commented that "upheavals cannot exceed the strength of the crust; and in India, therefore, perhaps may be better observed than in the United States the maximum strains which the Earth is competent to endure;" and as a result of his elaborate studies concluded that the Earth's crustal strength is "twenty, fifty, or even a hundred times greater than that advanced in recent years by the leading champions of high isostasy." Thus we see the pendulum of opinion swinging between belief in fluidity and rigidity in the Earth.

Following on Crosthwait's publication, Burrard (1912) propounded his theory of the origin of the Himalayas. He postulates a sub-crust, contracting as it cools and cracking. The sides of the crack (or series of cracks) move apart. The crust overlying the shrinking northern side is compressed by this movement of the sub-crust, the mountain-folds of the Himalayas being thus produced. The rift is gradually filled with alluvium of low density. Further shrinkage and cracking causes some of this alluvium to be folded, producing the Siwalik Hills.

This theory was so contrary to accepted geological ideas that controversy soon rose over it. If the sub-crust is so plastic that complete isostatic compensation may take place within a depth of 75 miles, can it be so rigid as to form, under tension, a wide rift to a depth of 20 miles? This is one difficulty, but the direction of thrust that folded the Himalayan rocks is another. It had been generally considered by geologists that the direction of pressure in a folded area could be judged (1) by the inclination of the axes of asymmetric folds, which appear as though their upper end had been pushed farther than the lower; (2) by the relative position of more or less horizontally displaced masses, it being assumed that an overthrust is more easily produced than an underthrust; (3) by the curvature in the trend of the folds in plan, it being assumed that the pressure must have come from the concave side of the arc. On all these grounds the Himalayas are usually regarded as having been subject to a pressure from the north. Suess, who led the way in the broad treatment of mountain systems, regarded the whole of Asia as subject to a push outwards from a centre in Siberia, mountains being thrust up in a series of arcs along the continental margin. The greatest resistance to this outward movement was offered by the rigid peninsula of India, and this dammed back the advancing earth-waves so that they reached the greatest elevation on the Earth. The alluvium of the plains filled up a great downward buckle or trough in front of the main upfold, a "fore-deep" analogous to the Tuscarora deep in front of the arc of Japan. While Suess's detailed views are not universally accepted among geologists, they do express in broad outline the general opinion. Burrard's idea of an elevation of the Himalayas by a *northward* movement of the sub-crust was therefore a most subversive suggestion. Suess in his latest pronouncement on the Himalayas ‡ (1909) took small account of isostasy, preferring to treat crust and sub-crust as practically rigid, and suggesting that the great mass of alluvium of low density filling the Indo-Gangetic "fore-deep" was sufficient to account for the gravity anomalies.

An attempt to reconcile the geodetic observations with isostasy was made by Hayden (1913). He showed that by taking variable depths of isostatic compensation for different stations the residuals could be reduced to a series of vanishing points. This pretty statistical card-castle collapsed under the criticism of Lenox Conyngham (1914) who pointed out that the whole of Crosthwait's calculations were based on the assumption of a uniform depth of compensation, and that you could not assume different depths of compensation for the same compartment according to whether you were calculating its effect on this station or that. Lenox Conyngham, however, appears to adopt too rigid an attitude in refusing to admit any variation in the depth of compensation: such a variation is accepted as possible by Hayford, Barrell, and other American investigators.

* All these residuals are for meridional deflections only. The observations of east and west (prime vertical) deflections are too few for generalization.

† *Op. cit.*, **22**, 318 (1914).

‡ 'Das Antlitz der Erde,' vol. 3 (2), pp. 705-708; English translation, 'The Face of the Earth,' vol. 4, pp. 611-614.

Holland (1913) reviewed Burrard's theory not unfavourably, though with caution, briefly pointing out several "geological and physical considerations that debatably seem to fall into line" with it. Chief of these are (1) the existence of numerous tension-faults in the northern part of the peninsula parallel to the supposed rift, and (2) the great depth at which megaseisms (world-shaking earthquakes) originate, which may seem to justify the belief in a very deep-seated rift.

Oldham (1914) made calculations as to the effect on the plumb-line of a mass of low density such as the Gangetic alluvium appears (on geological evidence) to be—assuming it to fill a trough 100 miles wide with depth increasing from 0 on the south to about 3½ miles on the north (with other possible dimensions considered, as a check). He found that the effects were commensurate with the actual Crosthwait residuals. On the other hand such a rift as Burrard seemed to postulate—5 miles wide and 20 miles deep—would give very different figures. Oldham's calculations however were confined to two groups of stations extending for no great distance north and south of the Himalayan margin. He also assumed that the observed meridional deflections were the meridional components of a real deflection at right angles to the trend of the range; and justified this by reference to Dehra Dun, where observations have been taken both in the meridian and prime vertical, and the resultant (residual) deflection is actually transverse to the local trend. Unfortunately there is a station, Jalpaiguri, in his second group where also prime vertical observations have been made, and here the resultant residual (as taken from Crosthwait's map) is 15″ in the direction E. 26° S., whereas Oldham takes it as 7″ normal to the range, which would be about E. 68° S.

Holland (1914) expanded his ideas on the formation of tension-faults in the northern part of the peninsula, remarking that "during the secular subsidence of the northern shore-line of Gondwanaland, accompanied by the slow accumulation of sediment near the shore and the gradual filing away of land above sea-level, there must have been a gradual creep of the crust in a northerly direction," which produced a state of tension and a series of faults parallel to the ancient shore-line (or to the modern Himalaya). He also expressed the opinion "that the break-up of Gondwanaland and the tectonic revolutions that followed show how isostasy can defeat itself in the presence of a sub-crustal magma actually molten or ready to liquefy on local relief of pressure. It is possible that the protracted filing off of Gondwanaland brought nearer the surface what was once the local level of no strain and its accompanying shell of tension." From these quotations we may infer that he regards the Gangetic trough rather as the effect of sinking of the crust under tension accompanied by the rise of liquefied sub-crust, than of a tension-rift in a rigid sub-crust as supposed by Burrard.

Burrard (1915) returned to the subject in a paper which is largely taken up with a criticism of the view that the Gangetic trough has been actually produced by the weight of the sediment deposited at the foot of the mountains. To this he urges several objections, the first of which is absolutely conclusive:—If alluvium of density 2·1 has pressed down a floor of density 2·7 to a depth of 20,000 feet, its upper surface should be far higher than it actually is. There has certainly been very loose thinking on the part of some geologists on the subject of sediment-loading and isostatic adjustment. There are well-known cases of masses of sediment of enormous thickness (for instance, the Coal Measures) which show evidence throughout of having been deposited in very shallow water. These have been explained by supposing the weight of sediment to force down the substratum persistently to an extent equal to its own thickness; but this is quite impossible unless the yielding zone below, which allows of isostatic adjustment, is exactly equal in density to each new layer added, and that is precisely what it is not, *ex hypothesi*, least of all under a depressed area. Similarly with the rising of mountains from isostatic adjustment *pari passu* with their denudation. Both processes give an infinite series in geometrical progression with a finite sum; they cannot continue at a uniform rate. If therefore any one holds the view that the Gangetic trough has been produced by the weight of alluvium that now fills it, he is believing a mathematical impossibility. What is possible is that the loading has helped a depression due to other causes. Even this view may come under another of Burrard's criticisms. He points out that the load of alluvium is not uniformly spread, but is piled up at the points of debouching of the Himalayan rivers into the Plains. The depth of the trough however is not similarly localized, but its deepest part (according to Captain Couchman's pendulum observations) is opposite Nepaul, where the rivers are not the largest. But if the floor on which the sediment has accumulated is a northward extension of the Indian Peninsula, it would itself have an uneven surface, and would be sufficiently rigid to bear the unequal loading by strains in its own substance and transmit it in an equalized form to the yielding sub-crust.

Another interesting point made by Burrard is the analogy between the Gangetic trough and the Tuscarora Deep (off Japan), which has sunk to a depth of 27,500 feet without the help of any load of sediment. This argument would be more convincing if there were better evidence that the Gangetic trough had once been occupied by the sea; but the upraised Siwalik strata that were first deposited in it include no marine sediments, and the chief evidence has hitherto been the existence of closely allied species of freshwater dolphins in the lower reaches of both Indus and Ganges. Burrard refers to the "swatches of no ground" or very deep channels off the mouths of Indus and Ganges as submarine continuations of the rift. That in the Arabian Sea is in line with the Indus depression, but that in the Bay of Bengal is rather parallel to the Gangetic trough than a continuation of it.

In the further part of his paper Burrard explains more fully his own theory, and by not insisting on a depth of 20 miles and width of 5 for his rift, brings the latter more into harmony with what geologists would regard as probable. He incorporates a note by de Graaff Hunter on the conditions of a cooling earth, in which it is argued that there must be a zone or shell contracting more than the zones either above or below it, and therefore in a state of tension: the cracking of this zone and consequent adjustment to it of the crust above are regarded as causes of deformation in the latter. The criticisms which the geologist would make on this argument would be, firstly, that variations in physical conditions, such as density and, above all, thermal conductivity, of different zones of the sub-crust must modify this simple argument; and, secondly, that it has to be shown that the zone of tension is sufficiently rigid to crack, instead of yielding by plastic deformation.

Oldham, in a memoir just received, makes a very elaborate study of the whole question. In this, after a preliminary discussion of the problems awaiting solution and the nature of geodetic methods, he calculates the effects of an imaginary range of simple step-like form, sufficiently near the form of the real Himalaya to give approximately the same gravity-effects. From this he proceeds to determine the real form of the Gangetic trough on the geodetic evidence, and concludes that it is about 20,000 feet deep between 80° and 84°, and again in the Upper Punjab, but not more than 15,000 feet in the longitude of Delhi. This shallowing is probably not due to unequal sinking but to the continuation, across the trough-floor, of the Aravalli Mountains, which appear also to enter into the Himalayas beyond. The greatest depth is not necessarily close to the Himalayan margin, but may be some distance further south. Thus his cross-section of the trough comes to resemble more nearly that given by Burrard. As to the lateral extension of the trough, Oldham finds it to continue to Assam on the east and the Salt Range in the north-west, its southern edge being for the most part concealed under alluvium towards these two extremes: it does not therefore bend round as do the alluvial plains, which overlap it towards the Arabian Sea and Bay of Bengal, but is bounded by a hidden rock-barrier beneath them, the geological evidence here confirming the geodetical. For these reasons Oldham speaks of it as the Gangetic, not the Indo-Gangetic trough.

He then proceeds to discuss the support of the Himalayas, and concludes that there is over-compensation in the Central Himalayas and under-compensation in the outer region, the strains thus produced being well within the limit which the rigidity of the crust can support, on Barrell's calculations. To a further alternation of over- and under-compensated areas under the plains and northern Peninsula respectively, he attributes the geodetic anomalies of the "hidden range" of Burrard. Evidently, however, this provides us with a generalization on the anomalies, rather than with an explanation of them. Finally, after considering every theory yet proposed to explain the tangential pressures that produce the mountain-folds, he dismisses all as inadequate.

Here for the present the matter rests. It cannot be said that there is any agreement as to how the Himalayas were raised or the Gangetic trough formed, and yet there seem to be signs of reconciliation between divergent views. Much remains to be discovered before a settlement can be reached. More geodetic observations are needed—more among the high Himalayas as urged by Oldham; new observations at pairs of stations near in position but differing greatly in altitude as suggested (among other proposals) by Barrell; more prime-vertical observations to combine with those in the meridian. All this the Indian Survey will give us in time, and geodesists in other countries will deal with other mountain ranges. Meanwhile geologists will find scope for the scientific imagination in devising new theories of mountain-formation, since none of the old seems to have survived criticism; and areas of tension as well as areas of compression will need study, in which geodetic results must be given the attention they deserve.

When we consider the high level of ability shown by this group of authors whose work we have tried to summarize, and remember that all are or have been in the service of the Government of India, we may express the hope that the reputation of the Indian Surveys may be maintained in the future, and that neither the pressing need for investigations of immediate practical value nor the desire for economy may prevent the continuation of work upon these broad problems—work which will assuredly prove eventually to be not devoid of practical importance.

APPENDIX II.

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GEOLOGICAL INTERPRETATIONS OF GEODETIC RESULTS.

A CRITICAL EXAMINATION OF MR. R. D. OLDHAM'S RECENT TREATISE ON HIMALAYAN STRUCTURE

BY

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The alluvial plains of the Ganges conceal from our view a deep "trough" that has been formed in the Earth's crust. The "trough" is bounded on the north by the Himalayan mountains and on the south by an ancient table-land. This "trough" was called by Suess the Himalayan Foredeep; its origin and its relationship to the mountains are among the unsolved problems of geology and geophysics.

For many years the Trigonometrical Survey of India has been taking geodetic observations over both hills and plains: it has determined the direction and the intensity of gravity at numerous places. During its operations its chiefs have frequently had the benefit of consultation with foreign delegates at International Geodetic Conferences, and with successive directors of the Geological Survey of India. The gap between geology and geodesy is however difficult to bridge: the students of the two branches of science have been differently trained, and the best hope of future progress lies in personal collaboration.

Mr. R. D. Oldham, F. R. S. has lately published a memoir* entitled,

"The Structure of the Himalayas, and of the Gangetic Plain, as elucidated by "Geodetic Observations in India."

When a book dealing with geodetic results is written by a professional geologist it starts on its career with the keen interest of geodesists. But Mr. Oldham's treatise will do nothing towards bridging the gap; its attempts to lower the standard of geodetic accuracy will be resented. As a book it is difficult to follow; for though its language is that of positive assertion, its meanings are frequently obscure. Individual sentences may be strongly worded, yet in the aggregate their collective meaning is uncertain.

The imaginary range.

In his geodetic calculations Mr. Oldham's first step is to discard the Himalaya mountains of nature and to substitute for them an "Imaginary Range", the dimensions and contour of which he has designed; he says that the method of geodesy is too laborious. He therefore decides to ignore "the complicated contour of the actual Himalayas." He also assumes in his calculations that his imaginary range has an east and west direction, whereas the true Himalaya extend over 7 degrees of latitude.

Mr. Oldham tries to show that his imaginary range is similar to the true Himalaya in its powers of attraction. The safest way of making such a comparison would be to test the attraction of the imaginary mountains *uncompensated* against the attraction of the true mountains *uncompensated*. But this test is not faced; both the imaginary and the true

* Memoirs, Geological Survey of India, Vol. XLII, part 2, 1917.

mountains are assumed to be wholly compensated by underlying deficiencies of matter, and the resultant attractions are thus reduced to small quantities. The attraction of a mountain mass causes deflections of the plumb-line, but if the mass be assumed wholly compensated by underlying deficiencies of matter, its positive attraction will become nullified by the negative attraction, and the deflections will tend to vanish. The deflection of the plumb-line caused at the station of Kaliana by the positive attraction of the true Himalaya is 58″; that caused by the Imaginary Range is 6″. The discrepancy is no less than 52″, but by taking compensation into account, Mr. Oldham reduces the Himalayan effect from 58″ to 3″, and the effect of his Imaginary Range from 6″ to 2″ (page 42). He then compares 3″ with 2″ and argues that a discrepancy of 1″ is admissible.

If we are dealing with a large deflection such as 58″, a discrepancy of 1″ denotes an error less than 2 per cent. But when the large deflection has been reduced by compensation to 3″ a discrepancy of 1″ denotes an error of 33 per cent. Mr. Oldham states that the attraction of the Imaginary Range (compensated) exceeds that of the true range at all stations, but there are mistakes in his computations (table 5). At Lambatach in the mountains the effect of the imaginary range (compensated) is 55 per cent. *larger* than that of the true range: whilst at Kaliana, 41 miles distant from the foot of the mountains, the effect of the imaginary range is 33 per cent. *smaller* than that of the true range; errors such as these prove that the imaginary range is not suitable for geodetic investigations.

It is true that when Mr. Oldham first introduces his imaginary range (page 36) he excuses it on the grounds that it is intended for the preliminary stages and not for the final calculations of the investigation. But he fails to adhere to this stipulation: at the end of his book he arrives at final and positive conclusions concerning the compensation of the Himalaya mountains (pages 112, 114) and he claims to have discovered the form of the underground floor of the whole Gangetic trough, (page 119); these conclusions are all based on the Imaginary Range.

The use of the word "trough."

We use the word "trough" for want of a better. The word conveys the idea of a long rock hollow filled with loose alluvium. But at moderate depths alluvium becomes compacted into solid rock: and at greater depths it may become metamorphosed. Mr. Oldham describes the Gangetic "trough" as though it were a simple depression in the rock-surface filled with alluvium, and as though the alluvium were 16,000 feet deep (pages 7, 8, *et seq.*). This value of the depth is obtained from Middlemiss's measurements of exposed strata at the foot of the Himalaya in Kumaun, north-east of Delhi. (Geological Survey of India, XXIV, page 29). But Middlemiss shows that these strata are built up of the following thicknesses:—

	Feet
Siwalik conglomerate	3,000
Sand-rock	8,000
Sand-stone	6,000

Thus the trough is not a rock-basin containing loose alluvium; it is a basin constructed of ancient rocks in which tertiary rocks have been consolidated. The dividing line between the northern wall and its solid contents can only be discovered by a geologist. Geodesists have used the word "trough" to denote the crustal zone throughout which the rock is of lower density than normal: and they take the depth of the trough to be the depth to which deficiency of density extends, independently of the kind or age of the rocks involved.

The depth of the Gangetic trough.

We have now to consider this problem:—if the sides and floor of a trough have been formed of ancient rocks, and if its contents consist of tertiary rocks, can a pendulum be utilised to determine the depth of the lowest tertiary rocks?

If at any place a pendulum is observed to be swinging at a slower rate than normal, a deficiency of rock in the underlying crust is indicated: whereas if a pendulum is observed to oscillate rapidly, the inference is warranted that the underlying crust is unusually dense. These variations in the rate of swing at different places signify variations in the force of gravity, and constitute what are known as local "gravity anomalies". Wherever a gravity anomaly is observed to be negative, the crust is abnormally light, and wherever a gravity anomaly is positive the crust is dense.

An excess or defect of matter may be near the surface of the crust, or it may be hidden at a great depth. Geodesists have met with difficulties in dealing with this problem of depth: they can prove the existence of an excess of matter in the crust, but they are unable to determine whether the excess is superficial or deep*.

Observations have shown that the density of the crust is different in different regions, and varies from place to place, and that these unceasing variations extend downwards to great depths, (perhaps 70 miles).

If a pendulum station is situated above the light tertiary rocks of the Gangetic trough, the gravity anomaly will have a tendency to be negative. But the deeper rocks will affect the pendulum also: and if they are unduly light they will *accentuate* the negative tendency, whereas if they are dense, they will *counteract* that tendency. A gravity anomaly is due to both surface and deep-seated rocks, and the difficulty is to disentangle their respective effects.

By means of a sounding-line we can discover the depth of water, and by boring we may discover the depth of alluvium, but a pendulum is not a sounding nor a boring instrument, and observations of gravity do not determine depths of sea or alluvium.

I do not contend that a pendulum can never be used to determine the depth of a particular rock. I will give an instance in which I think it might be so utilised. The Mysore Gold Mines are situated in a small patch of heavy rock (Dharwar schist, density 3·00) which is lying in a surface hollow of the Mysore plateau (gneiss, density 2·67).

The patch of heavy rock containing the gold is only 4 miles wide; if pendulum observations on the gneiss surrounding the patch give a constant gravity anomaly, and if the anomaly at once becomes larger at stations on the patch, the increase in the intensity of gravity may be fairly attributed to the excessive density of the patch. No complete investigation has yet been made, but Lenox-Conyngham found that the gravity anomaly on the patch was 0·034 greater than at Bangalore (Professional Paper 15, page 24, Survey of India): he has calculated that this anomaly would denote a depth of about 13,500 feet for the heavy schist of the patch. The gold mining operations have now reached a depth of 5,000 feet. The reason, which would justify us in this case in attributing the increase in the gravity anomaly to the patch, would be that the pendulum stations on and off the patch being so near together (*i.e.*, within 2 to 3 miles) the cause of the increase would appear to be local.

The Gangetic alluvium presents a different problem: its area is great and we cannot attribute anomalies to any local cause such as the lightness of alluvium. The geodetic observations have led us to believe that the Earth's crust north of the alluvium is deficient in density to a great depth, and that south of the alluvium the density of the crust is excessive†. The junction of the two different densities occurs in the crust underlying the alluvium.

Mr. Oldham considers that the depth of the trough is about 16,000 feet at the northern edge and that it gradually decreases from north to south (pages 82, 119). All gravity anomalies that can be made to fit this hypothesis he interprets as due to the lightness of alluvium. But anomalies that do not fit he interprets as due to deep-seated rocks ***below*** the alluvium.

On page 81 he writes of the station Monghyr:—

"Though situated close to the southern edge of the alluvium it gives a Bouguer "anomaly of—·031, and a Hayford of—·024 dyne, and, as it is difficult to believe that there "can be a thickness of over 4,000 feet of alluvium under this station, we must fall back "on the supposition that the anomaly is due to a more deep-seated deficiency of density. "A similar, though smaller defect of density at the station of Sasaram, suggests that in "both cases the anomaly may be due to a deep-seated defect of density in the rocks below "the alluvium".

The fact that the anomalies at Monghyr and Sasaram have to be rejected as untrustworthy measures of the depth of surface alluvium raises the question,—What security is there that other anomalies give reliable measures? There is no security; a gravity anomaly is a measure of the density of the Earth's crust, and not of the uppermost layer only.

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* Colonel Burrard's paper on the Gangetic Trough, Proc. Royal Society A, Volume 91, pages 230, 233.

† Under the Himalaya the density of the crust is below normal: south of the trough there is a zone of excessive density known as the "hidden range." (page 124).

If the gravity anomalies at alluvial stations were wholly due to the lightness of surface alluvium, they would everywhere be negative; but at several stations on the alluvium the gravity anomalies are positive. On page 81, Mr. Oldham writes of two stations on the alluvium, at which gravity is in excess:—

"The high positive anomaly at Kisnapur is evidently the result of a deep-seated "excess of density in the rock underlying the alluvium, but its magnitude, and the smaller "positive anomaly at Chatra, show that the alluvium cannot have any great thickness, "comparable to that in the Gangetic trough, for if there were any great thickness of alluvium "the negative effect of the defect in density would more largely neutralise the deep-seated "excess of density in one case, and in the other would make the anomaly negative, instead "of positive".

This argument is incorrect; the positive anomalies merely show that there is an excess of matter in the crust, notwithstanding the surface alluvium; they furnish no evidence as to the depth of alluvium.

The gravity anomaly at Mian Mir on the alluvium is +0·040 dyne, showing that gravity is in excess. On page 85, Mr. Oldham writes:—

"The positive anomaly at Mian Mir shows that the alluvium cannot have any great "thickness here".

The positive anomaly at Mian Mir merely denotes that the lightness of the surface alluvium is more than counterbalanced by the density of the deeper rock: it is no proof that the alluvium is shallow.

To illustrate the risks of using gravity anomalies as measures of depth, I will refer to Hecker's observations of gravity over the ocean*. When Hecker was vertically over the Tonga Deep he found that the deficiency of gravity was—0·245 dyne. If Hecker had adopted Mr. Oldham's method, he would have deduced the depth of the Tonga Deep to be 13,300 feet: the sounding lead showed that the true depth was 27,800 feet.

When Hecker's steamer crossed the Tonga plateau, he found that the gravity anomaly was +0·264 dyne. If then he had used the argument that a positive anomaly denotes shallow depth, he would have concluded that the Tonga plateau could not be far below the surface of the sea. The soundings showed that it was 8,800 feet deep.

The density of alluvium at depths.

If an observation for gravity is taken over the ocean, the presence of water can be allowed for as its density is known. But the density of alluvium when compressed and compacted at moderate and great depths is an uncertain quantity. Mr. Oldham has assumed the average density of the Gangetic alluvium from the surface to a depth of 4 miles to be 2·16. The rock-walls of the trough have a density of 2·67, and he assumes that the contents of the deep trough have a density of 20 per cent. less than the rock walls.

General Sorsbie, author of Geology for Engineers, estimates that the mean density of the Gangetic deposits, loose and solid, shallow and deep, would be about 2·4. Mr. Hunter has determined the density of exposed Siwalik sandstone at Hurdwar and Mohan, and has found it vary from 2·35 to 2·60, and these specimens were broken from weathered scarps and were possibly less compact than when buried and compressed by the weight of miles of superincumbent strata. He has determined the density of khankar (carbonate of lime) dug from the surface of the alluvial plains, and has found it to average 2·34. Barrell in his investigations of *the Strength of the Earth's Crust* assumes 2·5 as the density of the deposits of the Nile and the Niger (Journal of Geology, XXII, page 43).

There are thus reasons for doubting whether Mr. Oldham's assumption of density=2·16 is justifiable, and it will be useful to show the effects upon his results if a density-value of 2·4 be substituted.

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* Gravity determinations on the Ocean, Berlin, 1910. Hecker assumed the Ocean to be isostatically compensated.

Station. (See pages 84 and 90).		Distance from northern edge of trough in miles.	DEPTH OF ALLUVIUM AS DEDUCED FROM GRAVITY ANOMALY:	
			Density 2·16 according to Oldham.	If density 2·4 be substituted.
			Feet.	Feet.
Rajpore	...	0	15,000	30,000
Dehra Dun	...	2	12,000	24,000
Roorkee	...	25	13,000	26,000
Nojli	...	38	12,000	24,000
Pathankot	...	1	23,000	46,000

Mr. Oldham claims (pages 91, 119) that his geodetic values of depth *at the northern edge* of the plains agree with the geological value, namely 16,000 feet.

My table shows that his claim can only be established if an unduly low density is assumed for the alluvium. The adoption of the density 2·4 produces a great discrepancy between the so-called geodetic and geological values.

It must not be supposed that I am putting forward the depths in the last columns of these tables as probably correct: they are, I think, based on more reasonable assumptions than the figures in the third columns, but the lesson they teach is that the method adopted of deducing depths of surface alluvium from gravity anomalies is unreliable. The magnitudes of the quantities in the last column support the view that the negative anomalies over the Gangetic trough are partly due to the attenuation of the rock that is *below* the tertiary deposits.

On page 119, Mr. Oldham writes:—

Mr. Oldham's conclusions.

"We have also found complete confirmation of the geological deduction that the "depth of the alluvium along the outer edge of "the Himalayas is great, amounting to about "15,000 to 20,000 feet towards the northern boundary of the alluvial plain, figures which are "in complete accord with those deduced from the geological examination of the Siwalik "hills. This agreement, between the results of two wholly independent and different lines of "research, leaves little room for doubt that we have reached a correct interpretation of the "underground form of the Gangetic trough from near its northern limit to the southern "boundary, and that its maximum depth is about 15,000 to 20,000 feet, possibly more on "some sections probably less on others, but in most cases lying within the limits named."

In this summary Mr. Oldham claims to have discovered the underground form of the Gangetic trough from north to south, and from east to west. The average width of the trough from north to south is 150 miles; its length from east to west is 1,000 miles: it occupies an area of 150,000 square miles. Mr. Oldham claims to have interpreted the underground form of this great alluvial area by means of the "agreement between the results of two wholly inde-"pendent and different lines of research".

Let us consider upon what grounds are these claims based. The geological deduction from exposed strata is that the depth of the trough *at one point* near its northern edge is 16,000 feet (page 6): there is no geological evidence of depth east, or west of this point, and there is no geological evidence anywhere as to the maximum depth of the trough, or as to the distance from the edge at which the maximum depth occurs (page 8). The geological "line of research" is thus limited to *one point* in a trough 1,000 miles long and 150 miles broad. Certain geodetic results can be brought into approximate agreement with this one geological deduction by the adoption of a particular value of surface density.

But even the alleged agreement itself "between the two wholly independent lines of "research" is not clearly indicated. The geological deduction was made in the foot-hills of Kumaun south of the Ganges, where no geodetic stations exist; in the foot-hills just north of the Ganges there are two geodetic stations, Rajpore and Dehra Dun. In order to confirm Mr.

Oldham's geological conjecture that deep alluvium exists under Rajpore and Dehra Dun, negative anomalies were required (page 107), and these were obtained by the aid of the Imaginary Range (page 90). But the anomalies as calculated by the Trigonometrical Survey are positive, and this result has placed Mr. Oldham in a predicament (page 91). He writes that "these stations cannot be used with any degree of safety in determining the form "of the trough". Thus the agreement between the different lines of research can only be maintained, if two of the most important geodetic results are excluded from the investigation.

The Himalayan Pendulum Station at Moré.

From 1866 to 1870 Captain Basevi observed the pendulum at several places in India: he was a careful observer, but in his day no method had been devised of determining the sway of the pendulum stand. When a pendulum is swinging, its stand is swayed by it: and this swaying tends to increase the time of the pendulum's oscillation; consequently if no correction is applied, the deduced value of gravity will be too small; the greater the "flexure" of the stand the greater the error in the observed result.

For his observations in India Basevi used a heavy braced stand. In 1870 he decided to swing his pendulums at a high altitude in Ladak, and in order to lighten his loads and to facilitate transport he introduced a special light stand. This light stand he used in his observations at the Indian Station of Mian Mir, and he then transported it across the Himalaya mountains to the station of Moré (height 15,427 feet). In Ladak he died and it is not known what became of the light pendulum stand.

In 1903 Colonel Lenox-Conyngham commenced his modern series of pendulum observations, and during his first tour he visited four of Basevi's stations. His observations gave larger values of g than Basevi had obtained, the discrepancies varying from 0·027 at Bombay to 0·044 at Madras and to 0·103 at Dehra Dun. These discrepancies were attributed by Lenox-Conyngham to the omission of the "flexure correction" by Basevi*.

Other stations of Basevi's were visited in subsequent years. In 1906 Lenox-Conyngham observed at the station of Mian Mir where Basevi had used his special light stand; at this station the discrepancy between the old and the new results was 0·112.

Basevi's pendulum observations have thus been superseded; they served their purpose well, and their supersession is the inevitable fate of all observations which have been rendered obsolete by modern instrumental improvements. His more important stations have been revisited and their results revised. Eighteen of Basevi's stations have not as yet been revisited by modern observers, but in their stead 108 new pendulum stations have been established in India.

If it had not been for the war, the station of Moré would have been revisited by a British observer in 1915 or 1916. Commander Alessio of the Filippi expedition (1913), endeavoured to observe the pendulum at Moré, but the attempt had to be made too early in the year and was frustrated by heavy snow.

Basevi's results were included in Helmert's compilations for the International Geodetic Association. After Lenox-Conyngham had completed his observations at Mian Mir, the International Association in 1909 deduced from them a "flexure correction" for Moré. Helmert was constructing a formula that would give the normal value of gravity in any latitude, and the Association wished to show how this formula agreed with observed results. The Association did not intend to convey to geologists the idea that they would now be justified in building far-reaching theories upon the Moré result.

Unfortunately Professor Borrass who compiled the report made the mistake of assuming that Basevi's light stand had been used at *two* stations in India, and that its flexure correction had remained *the same* at both places†. He thought that the light stand had been used at Dehra Dun as well as at Mian Mir and Moré. Believing that Dehra Dun and Mian Mir should be classed together and finding that the two corrections were accordant, he adopted a mean correction and applied it at Moré.

Borrass stated his flexure corrections as follows:—

Deduced at Dehra Dun	+0·103
Deduced at Mian Mir	+0·112
Mean	+0·107 ± 0·004

* Survey of India, Narrative Reports, 1903-04, para. 139.

† Report, 16th International Geodetic Conference. 1911, page 236.

At Dehra Dun the pendulum had been swung on the heavy stand and at Mian Mir on the light one. The agreement between the corrections deduced by Borrass was fortuitous; Borrass's mean value and his probable error being based on misapprehension have thus no weight.

In September 1916 an article by Mr. Oldham on Basevi's pendulum observations appeared in the Geographical Journal, in which the author expressed the opinion that the flexure correction for Basevi's results could be estimated. This had already been done, but such an estimate cannot be made with sufficient accuracy. It is a question of the standard of accuracy required. Basevi omitted the flexure correction, and nothing now can raise his results to the modern standard of accuracy.*

The flexure of Basevi's heavy stand was apt to vary from station to station, and even the modern stand shows variations of flexure sufficiently great to necessitate a redetermination whenever the apparatus is re-erected. As to the behaviour of Basevi's light stand we know but one fact, namely, that his Mian Mir result requires a correction of $+0 \cdot 112$.

Mr. Oldham assumes that Basevi's flexure correction was the same at Moré as at Mian Mir. Basevi recorded that at Mian Mir the stand was erected on a "floor of solid paka "masonry": at Moré he recorded that the soil was "very loose and sandy". Between Mian Mir and Moré the stand had to be carried on men's backs for hundreds of miles over high mountains and passes: at Moré the stand was exposed to conditions of temperature, pressure, humidity and wind, totally different from those of Mian Mir.

When Mr. Oldham's article appeared I did not understand its purport. No one had been criticising Basevi, and his pendulum results were being replaced and extended by the modern series. In his memoir however Mr. Oldham makes the surprising statement (page 110) that the Moré results having been discredited have been reinstated. He gives no explanation, no references. I know the history of the Moré discussion well, but I know of no discredit, nor reinstatement. I can only conclude that by "reinstatement" Mr. Oldham means the article he wrote himself in the Geographical Journal.

In his memoir (page 111) Mr. Oldham estimates the anomaly for Moré as $-0 \cdot 434$, and compares it with Borrass's result $-0 \cdot 433$, published in 1911. He writes:—

"The two values of anomaly differ by only ·001 dyne and we may take it that the "deficiency at Moré is not far from ·43 dyne".

It is hardly necessary for me to point out that the agreement of these two results is no evidence of accuracy. These two results are both derived by the same method from the same observation.

The new Theory.

Mr. Oldham's new theory seems to be based upon the anomaly at Moré namely $-0 \cdot 434$; this is certainly a large negative value, but all anomalies at high altitudes, if deduced on Bouguer's hypothesis, have negative values. Bouguer's hypothesis was that mountains were being supported by the rigidity of the crust. It has been recognised for many years that isostatic compensation must be taken into account, and Hayford's method based on the theory of isostasy has now superseded Bouguer's. The substitution of the theory of isostasy for that of extreme rigidity has had the effect of converting the negative anomalies which formerly obtained at high Himalayan altitudes into positive anomalies.

Instead of deducing the Hayford anomaly by clear steps, Mr. Oldham mixes in the same paragraph two geodetic hypotheses (Bouguer and Hayford) and two systems of mountains, the imaginary and the real (page 111); and then out of this obscurity he draws the conclusion that "in the Central Himalaya compensation is in excess" (pages 112, 114). Having produced no evidence, he writes—

"It is evident that the defect of compensation has disappeared" (page 112).

One assumption leads to another, and his next step is to assume that as the compensation is in excess at Moré, the whole extensive mountain area of the Inner and Higher Himalayas must be over-compensated, buoyant and light. (It might be just as fairly assumed that the gravity anomaly observed at Geneva is applicable to the whole area of Pyrenees, Alps and Carpathians).

Finally Mr. Oldham proceeds to the further assumptions that as this great Himalayan area is buoyant, it must be rising (page 115); that the Earth's crust is being uplifted here

* A note by Colonel Lenox Conyngham on this subject, giving a full explanation, has recently been published in the *Records, Survey of India, Vol. XI, p. 97.*

by its buoyancy, and that owing to its uplift the crust to the south is being tilted downwards and is creating the Gangetic trough (page 123). In this way his reinstatement of the Moré result has led up to his theory of the origin of the Gangetic trough.

The Trigonometrical Survey of India has benefited in the past from the collaboration of men who were not professional geodesists, notably, Archdeacon Pratt and Osmond Fisher. These distinguished investigators were endeavouring to utilise the geodetic data for unravelling the secrets of Nature. The welcome that was extended to them was awaiting Mr. Oldham; but his attitude towards geodesy has been different. He has considered it admissible to alter scientific data and to create new data from imaginary ranges. In the same table (pages 77 and 90) he combines true geodetic data with figures of his own, and an uninitiated reader will never realise that the quantities given under the heading of "Hayford compensation" have not been deduced by Hayford's method.

Mr. Oldham's reference to the Aravalli mountains is equally inaccurate. This range traverses Rajputana in a north-easterly direction, and terminates near Delhi as a small ridge which is an insignificant topographical feature. Mr. Oldham recalls a geological suggestion made many years ago that this range may once have extended across the Gangetic trough into the Himalaya. He now quotes the deflections of the plumb-line at three stations as evidence in support of this suggestion (page 97). Two of these deflections however furnish no evidence on the point, whilst the evidence of the third (Sarkara) is adverse*. Yet Mr. Oldham sums up as follows:—

"The geological structure has suggested the possibility of an original extension of the "Aravalli range into what is now the Himalayan region; the geodetic observations have "supported this suggestion and converted what was only a bare possibility into something "more than a probability"

So mistaken indeed are Mr Oldham's ideas of geodetic principles and accuracy, that when he found his calculation of the depth of the alluvium at Agra was not in accord with the depth obtained by boring, he attributed the disagreement not to his own hypotheses but to the geodetic data. (Page 80) He avoided this disagreement not by reconsidering his own assumptions, but by altering the observed results. On page 112 he says he found it "necessary to apply a correction of — ·02 dyne" to the pendulum results as the latter did not give the depth of the alluvium correctly: and he even suggested that this Agra correction might be applied to Basevi's observations at Moré. The scientific precautions taken in the observation of pendulums become useless, if the results, obtained by labour and care, are to be treated as they are in this memoir.

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* Any reader can check my criticism by examining the map attached to the memoir. If the Aravalli axis is produced it will pass north-west of Sarkara; this will not diminish the northerly deflection at Sarkara.

APPENDIX III

List of Survey of India Publications

(Corrected up to 30th September 1918)

PUBLICATIONS

OF THE

SURVEY OF INDIA

SYNOPSIS

A—HISTORY AND GENERAL REPORTS.

B—GEODETIC WORKS OF REFERENCE.

C—CATALOGUES AND INSTRUCTIONS.

D—MISCELLANEOUS PAPERS.

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 1900-1918 (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.
XII—Notes on Survey of India Maps and the modern development of Indian Cartography. *By Lt.-Col. W.M. Coldstream, R.E., Supdt. Map Publication.* } Calcutta, 1919. *Price Rs. 3 or 4s.*
XIII—**1917-18**—Annual reports of parties and offices ... Dehra Dūn, 1919.

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. (Out of print).

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.)

EVERESTS' 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

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, Hurīlāong 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 Triangulation 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.

Appendix No. 6. The Errors of the Trigonometrical values of Heights of stations of the principal triangulation.

Appendix No. 7. The effect on the spheroidal correction of employing Theoretical instead of Observed values of Gravity and a discussion of different formulæ giving variation of Gravity with Latitude and Height.

Appendix No. 8. On the discrepancy between the Trigonometrical and spirit-level values of the difference of height between Dehra Dūn and Mussooree.

XIXA—**Bench-Marks** on the **Southern** Lines of Levelling. Dehra Dūn, 1910.
Price Rs. 5 or 6s-8d.

XIXB—**Bench-Marks** on the **Northern** Lines of Levelling. Dehra Dūn, 1910.
Price Rs. 5 or 6s-8d.

SYNOPTICAL VOLUMES—giving charts, descriptions of stations, and full synopses of coordinates and heights of all stations and points fixed by Principal and Secondary **Triangulation**.*

Price Rs. 2 or 2s-8d per volume unless otherwise stated.

Italic figures are in chronological order and refer to the Index Chart of the G. T. Survey.

North-West Quadrilateral

Vol. I—The Great Indus Series (*32*). Dehra Dūn, 1874.

II—The Great Arc—Section 24°-30° (*6*). Dehra Dūn, 1874.

III—The Karachi Longitudinal Series (*25*). Dehra Dūn, 1874.

IV—The Gurhāgarh Meridional Series (*23*). Dehra Dūn, 1875.

V—The Rahūn Meridional Series (*33*). Dehra Dūn, 1875.

VI—The Jogi-Tila Meridional Series (*37*). and the Sutlej Meridional Series (*45*). Dehra Dūn, 1875.

VII—The N. W. Himālaya Series (*22*) and the Triangulation of Kashmīr (*36*). Dehra Dūn, 1879.

VIIA—The Jodhpore Meridional Series (*62*) and the Eastern Sind Meridional Series (*64*). Dehra Dūn, 1887.

* Special charts can be supplied of those series for which no Synoptical Volumes are available, *viz.* :— all Burma, Chittagong and Baluchistān triangulation, the Assam Longitudinal, the Sambalpur Meridional, and the Gilgit Series, with a few recent secondary series in India.

SYNOPTICAL VOLUMES—(*Continued*).

South-East Quadrilateral

Vol. VIII—The Great Arc—Section 18°-24° (*8*). Dehra Dūn, 1878.
IX—The Jabalpur Meridional Series (*53*). Dehra Dūn, 1878.
X—The Bider Longitudinal Series (*43*). Dehra Dūn, 1880.
XI—The Bilāspur Meridional Series (*58*). Dehra Dūn, 1880.
XII—The Calcutta Longitudinal Series (*5*). Dehra Dūn, 1880.
XIII—The East Coast Series (*24*). Dehra Dūn, 1880.
XIIIA—The South Pārasnāth (*1*) and the South Malūncha Meridional Series (*17*) Dehra Dūn, 1885.

North-East Quadrilateral

Vol. XIV—The Budhon Meridional Series (*2*). Dehra Dūn, 1883.
XV—The Rangīr Meridional Series (*4*). Dehra Dūn, 1883.
XVI—The Amua Meridional Series (*3*) and the Karāra Meridional Series (*12*). Dehra Dūn, 1883.
XVII—The Gurwāni Meridional Series (*19*) and the Gora Meridional Series (*15*). Dehra Dūn, 1883.
XVIII—The Hurīlāong Meridional Series (*21*) and the Chendwār Meridional Series (*14*). Dehra Dūn, 1883.
XIX—The North Pārasnāth (*27*) and the North Malūncha Meridional Series (*13*). Dehra Dūn, 1883.
XX—The Calcutta Meridional (*16*) and the Brahmapūtra Meridional Series (*56*). Dehra Dūn, 1883.
XXI—The East Calcutta Longitudinal (*48*) and the Eastern Frontier Series—Section 23°-26° (*44*). Dehra Dūn, 1883.
XXII—The Assam Valley Triangulation, E. of Meridian 92° (*55*). Dehra Dūn, 1891. (Out of print.)
XXXV—The North-East Longitudinal Series (*20*) with the volume of charts. Dehra Dūn, 1909. *Price Rs. 5 or 6s-8d.*

Southern Trigon

Vol. XXIII—The South Konkan Coast Series (*11*). Dehra Dūn, 1891.
XXIV—The Mangalore Meridional Series (*49*). Dehra Dūn, 1891.
XXV—The South-East Coast Series (*63*). Dehra Dūn, 1891.
XXVI—The Bombay Longitudinal Series (*7*). Dehra Dūn, 1892.
XXVII—The Madras Longitudinal Series (*54*). Dehra Dūn, 1892.
XXVIII—The Madras Meridional and Coast Series (*46*). Dehra Dūn, 1892.
XXIX—The Great Arc Meridional Series—Section 8°—18° (*9*). Dehra Dūn, 1899.

South-West Quadrilateral

Vol. XXX.—The Abu Meridional Series (*26*) and the Gujarāt Longitudinal Series (*29*). Dehra Dūn, 1892.
XXXI—The Khānpisura Meridional Series (*18*). Dehra Dūn, 1893.
XXXII—The Singi Meridional Series (*10*). Dehra Dūn, 1893.
XXXIII—The Cutch Coast Series (*35*). Dehra Dūn, 1893.
Addendum to the Cutch Coast Series, (*Indus delta*) (separate pamphlet). Dehra Dūn, 1902.
XXXIV—The Kāthiāwār Meridional Series (*28*). Dehra Dūn, 1894.

TRIANGULATION PAMPHLETS with charts, are now being issued for every square degree, giving the results of all minor triangulation, as well as that shown in Synoptical Volumes. *Price Re. 1 or 1s-4d per pamphlet.* *Vide* page 123.

LEVELLING PAMPHLETS—giving heights and descriptions of all **Bench-marks,** fixed by levelling of Precision in India and Burma. Each pamphlet embraces an area of 4° × 4° and the numbering is the same as that of the corresponding sheets of the 1/M map of India. Each is illustrated by a map of the area. *Price Rs. 2 or 2s-8d per pamphlet except where otherwise stated.*

Pamphlet	Nos.	Latitude.	Longitude.	Published	Pamphlet	Nos.	Latitude.	Longitude	Published.
India	34	28°–32°	64°–68°	Dehra Dūn, 1916.	India	44	28°–32°	72°–76°	Dehra Dūn, 1912.
"	35	24°–28°	64°–68°	" 1911.	"	45	24°–28°	72°–76°	" 1911.
"	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.
"	40	24°–28°	68°–72°	" 1911.	"	48	12°–16°	72°–76°	" 1912.
"	41	20°–24°	68°–72°	, 1913.	"	49*	8°–12°	72°–76°	" 1911.
"	43	32°–36°	72°–76°	" 1913.	"	52	32°–36°	76°–80°	" 1912.
"	"	Addendum		" 1915.	"	53	28°–32°	76°–80°	" 1912.

* Price Re. 1 or 1s-4d.

LEVELLING PAMPHLETS—(*Continued*).

Pamphlet	Nos.	Latitude.	Longitude.	Published.	Pamphlet	Nos.	Latitude.	Longitude.	Published.
India	54	24°–28°	76°–80°	Dehra Dūn, 1914.*	India	78	24°–28°	88°–92°	Dehra Dūn, 1912.
"	55	20°–24°	76°–80°	" 1912.	"	"† Addendum			" 1916.
"	56	16°–20°	76°–80°	" 1912.	"	79	20°–24°	88°–92°	" 1912.
"	57	12°–16°	76°–80°	" 1912.	"		Addendum		" 1916.
"	58	8°–12°	76°–80°	" 1914.	"	83	24°–28°	92°–96°	" 1912.‡
"	63	24°–28°	80°–84°	" 1911.	Burma	84	20°–24°	92°–96°	" 1918.§
"	64	20°–24°	80°–84°	" 1912.	"	85	16°–20°	92°–96°	" 1917.§
"	65	16°–20°	80°–84°	" 1913.	"	92	24°–28°	96°–100°	" 1918.§
"	66	12°–16°	80°–84°	" 1912.	"	93	20°–24°	96°–100°	" 1917.§
"	72	24°–28°	84°–88°	" 1912.	"	94	16°–20°	96°–100°	" 1916.§
"	73	20°–24°	84°–88°	" 1913.	"	95	12°–16°	96°–100°	
"	74	16°–20°	84°–88°	" 1913.					

* 2nd Edition (enlarged). † Price Re. 1 or 1s.-4d. ‡ Heights on pages 45 & 46 revised in 1918. § Heights revised.

TIDE TABLES—

Since 1881 Tidal predictions based on the observations of the Survey of India have been published annually by the India Office, London. The tables give the time and height of high and low water for every day in the year at each port, and are published early in the previous year. Current tables are available for the following 41 ports :—

Western Ports—

Suez (Egypt)—Basrah—Perim—Aden—Maskat—Būshire—Karāchi—Okha Point and Bet Harbour (Gulf of Cutch)—Porbandar—Port Albert Victor (Kāthiāwār)—Bhaunagar—Bombay (Apollo Bandar)—Bombay (Prince's Dock)—Mormugao (Goa)—Kārwār—Beypore (near Calicut)—Cochin—Minicoy (Indian Ocean)—Tuticorin—Pāmban Pass (Island of Rāmeswaram).

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.

The Tide Tables are issued in the following forms :—

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(iii) **Pamphlets**—giving separately the tables for individual ports or for small local groups of ports—*Price varying from As. 8 or 8d to Rs. 1-8 or 2s per pamphlet.*

C—CATALOGUES AND INSTRUCTIONS.

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

DEPARTMENTAL ORDERS.—

From 1878 to 1885 the Surveyor General's orders were all issued as "*Circular Orders.*" Since then they have been classified as follows :—

From 1885 to 1904 as:
- 1—**Government of India Orders** (called "*Circular Orders*" up to 1898.)
- 2—**Departmental Orders (Administrative)**.
- 3—**Departmental Orders (Professional)**.

In 1904 the various orders issued since 1878 were reclassified as follows :—

	Number to date.
1.—**Government of India Orders**—	707
2.—**Circular Orders (Administrative)**.—	382
3.—**Circular Orders (Professional)**.—	195
4.—**Departmental Orders**. (appointments, promotions, transfers, etc.)	

These are numbered serially and had reached the above numbers by September 1918. *Government of India Orders and Circular Orders (Administrative)* are bound up in volumes from time to time, as shown below, while *Circular Orders (Professional)* are gradually incorporated in the Survey Hand-books. Besides the above, temporary orders have been issued since 1910 in the form of "**Circular Memos.**" These either lapse or become incorporated in some more permanent form, and are therefore only numbered serially for each year. Bound volumes of orders are available as follows:—

1. **Government of India Orders (Departmental) 1878-1903.—Calcutta, 1904.
   Ditto ditto 1904-1908.—Calcutta, 1909. (Out of print).
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DEPARTMENTAL ORDERS—(*Continued*).

2. *Circular Orders (Administrative) 1878-1903.—Calcutta, 1904.
Ditto ditto 1904-1908.—Calcutta, 1909.
Ditto ditto 1909-1913.—Calcutta, 1915.

3. * Regulations on the subject of Language Examinations for Officers of the Survey of India. Calcutta, 1914.

4. * Map Publication Orders 1908-1914 (*Superintendent, Map Publication's Orders.*)—Calcutta, 1914.

5. Specimens of papers set at Examinations for the Provincial Service.—Dehra Dūn, 1903.—(Out of print).

CATALOGUES AND LISTS.

1. **Catalogue of Maps** published by the Survey of India. Corrected to 1st October 1917 Calcutta, 1918. *Price Re. 1 or 1s-6d.*

NOTE.—Lists are issued quarterly of new maps published during each quarter, and similar lists for each month appear in the monthly NOTES OF THE SURVEY OF INDIA.

2. **Catalogue of Maps** of the Bombay Presidency, Calcutta, 1913. *Price As. 4 or 4d.*

3. **List of the publications of the Survey of India** (published annually)—Dehra Dūn. *Gratis.*

4. **Price List of Mathematical Instrument Office.** Calcutta, 1913. *Gratis.*

5. Catalogue of Books in the Head-Quarters Library, Calcutta, 1901. (Out of print).

6. Catalogue of Scientific Books and Subjects in the Library of the Trigonometrical Survey Office. Dehra Dūn, 1908. *Price Re. 1 or 1s-4d.*

7. Catalogue of Books in the Library of the Trigonometrical Survey Office. Dehra Dūn, 1911. (Out of print.)

8. **Green Lists**—PART I—List of officers in the Survey (*half yearly to dates 1st January and 1st July*)—Calcutta. *Price As. 6 or 6d.*
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(Nos. 8 and 9 are stocked in the Surveyor General's Office, Calcutta).

TABLES AND STAR CHARTS.

1. **Auxiliary Tables**—to facilitate the calculations of the Survey of India. Fourth Edition, revised. Dehra Dūn, 1906. *Price Rs. 4 or 5s-4d in cloth and calf, or Rs. 2 or 2s-8d in paper and boards.*

2. **Auxiliary Tables**—of the Survey of India. Fifth Edition, revised and extended by J. de Graaff Hunter, M.A. In parts—
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3. Tables for Graticules of Maps. Extracts for the use of **Explorers.** Dehra Dūn, 1918. *Price As. 4 or 4d.*

4. * Metric Weights and measures and other Tables. Photo-Litho Office. Calcutta, 1889. (Out of print.)

5. Logarithmic Sines and Cosines to 5 places of decimals. Dehra Dūn, 1886. (Out of print).

6. Logarithmic Sines, Cosines, Tangents and Cotangents to 5 places of decimals. Dehra Dūn 1915. (Out of print).

7. Common Logarithms to 5 places of decimals 1885. *Price As. 4 or 4d.*

8. Table for determining Heights in Traversing. Dehra Dūn, 1898. *Price As. 8 or 8d.*

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15. * Rainfall from 1868 to 1903, measured at the Trigonometrical Survey Office. Dehra Dūn. (Out of print.)

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2. Ditto ditto ditto. Second Edition. London, 1855. (Out of print).

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4. **Hand-book, Revenue Branch.** Calcutta, 1893. *Price Rs. 2-8 or 3s-4d.*

SURVEY OF INDIA HAND-BOOKS.

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5. *Report on the Working of the Light Field Litho Press (experimental) in November and December 1910 with Appendices. *By Lieutenant A. A. Chase, R. E.*, Calcutta, 1911.

(1) Notes on some of the Methods of Reproduction suitable for the Field.

(2) Suggested Equipment Tables for the Light Field Litho Press (experimental).

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12. Instructions for the Survey and Mapping of Town Guide Maps.

D—MISCELLANEOUS PAPERS.

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13. Report on the Treatment and use of Invar in measuring Geodetic Bases. *By Capt. H. H. Turner, R. E.* London, 1907. *Price As. 8 or 8d.*

Projections.

14. On the projection used for the General Maps of India. Dehra Dūn, 1903. (Out of print).

15. *On the deformation resulting from the method of constructing the International Atlas of the World on the scale of one to one million. *By Ch. Lallemand. Translated by J. Eccles, M.A.*, together with tables for the projection of 1/M Maps on the International system. Dehra Dūn, 1912. (Out of print).

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Mapping.

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17. *A Note on the representation of hills. *By Major C. L. Robertson, C.M.G., R.E.* Dehra Dūn, 1912.
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1. Philosophical Transactions, Series A, Volume 186, 1895. India's Contribution to Geodesy, *by General J. T. Walker, R.E., C.B., F.R.S., LL.D.*
2. Philosophical Transactions, Series A, Volume 205, pages 289-318, 1905. On the Intensity and Direction of the Force of Gravity in India, *by Lieutenant-Colonel S.G. Burrard, R.E., F.R.S.*
3. Proceedings, Series A, Volume 90, pages 32-40, 1914. On the effect of the Gangetic Alluvium on the Plumb-Line in Northern India, *by R. D. Oldham, F.R.S.*
4. Proceedings, Series A, Volume 91, pages 220-238, 1915. On the origin of the Indo-Gangetic trough, commonly called the Himalayan Foredeep, *by Colonel Sir S. G. Burrard, K.C.S.I., R.E., F.R.S.*

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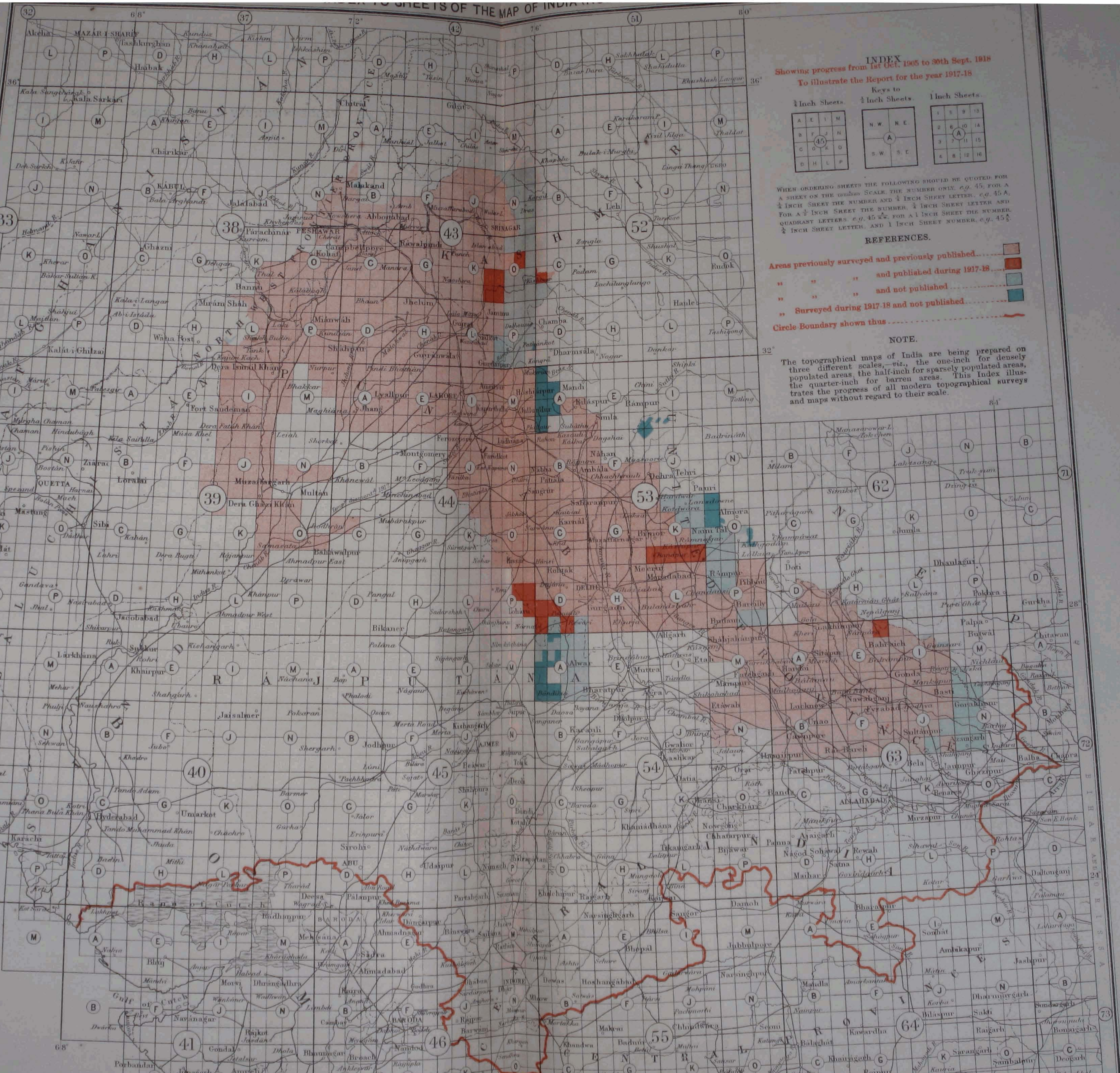
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
A	f	f					f	d 1912	ac 1916		f	d 1911		f	S	f	a 1918	
B	f	f					f	d 1912	ac 1916		f	d 1913	f	f	S	f	a 1918	
C	a 1918	a 1918					f	d 1912	ac 1916		f	ac 1915	ac 1915	f	S	d 1911	a 1918	
D	a 1918	f					a 1918	d 1912	ac 1916	S	d 1912	f		S	S	d 1912	a 1918	
E	f	f					f	d 1912	ac 1916		f	d 1911		f	S	f	a 1918	
F	f	f					f	d 1912	ac 1916		f	d 1913	f	a 1918	S	f	a 1918	d 1911
G	a 1918	a 1918					f	d 1912	ac 1916		a 1918	d 1914		f	S	f	a 1918	
H	a 1918	f					f	d 1912	ac 1916	S	d 1912	d 1911		S	S	d 1911	bc 1916	
I	f	f					f	d 1912	ac 1916		f	d 1911	d 1915	a 1918	S	f	a 1918	bc 1915
J	f	a 1918					f	d 1912	ac 1916	f	f	d 1913		a 1918	S	f	a 1918	
K	f	a 1918					f	d 1913	ac 1916		a 1918	d 1914		d 1914	S	f	bc 1916	
L	a 1918	f					f	d 1912	ac 1916	S	a 1918	d 1911		a 1918	S	f	bc 1916	a 1918
M	f	a 1918					f	d 1912	f	f	f	d 1911		a 1919	ac 1916	f	a 1918	
N	f	f					f	d 1912	ac 1916	f	f	d 1914		a 1918	S	f	a 1918	
O	f	a 1918					f	d 1912	ac 1916	f	f	f		a 1918	S	f	ac 1916	a 1918
P	a 1918	a 1918					a 1918	d 1912	ac 1916	S	d 1912	d 1911		a 1918	S	d 1911	d 1913	f

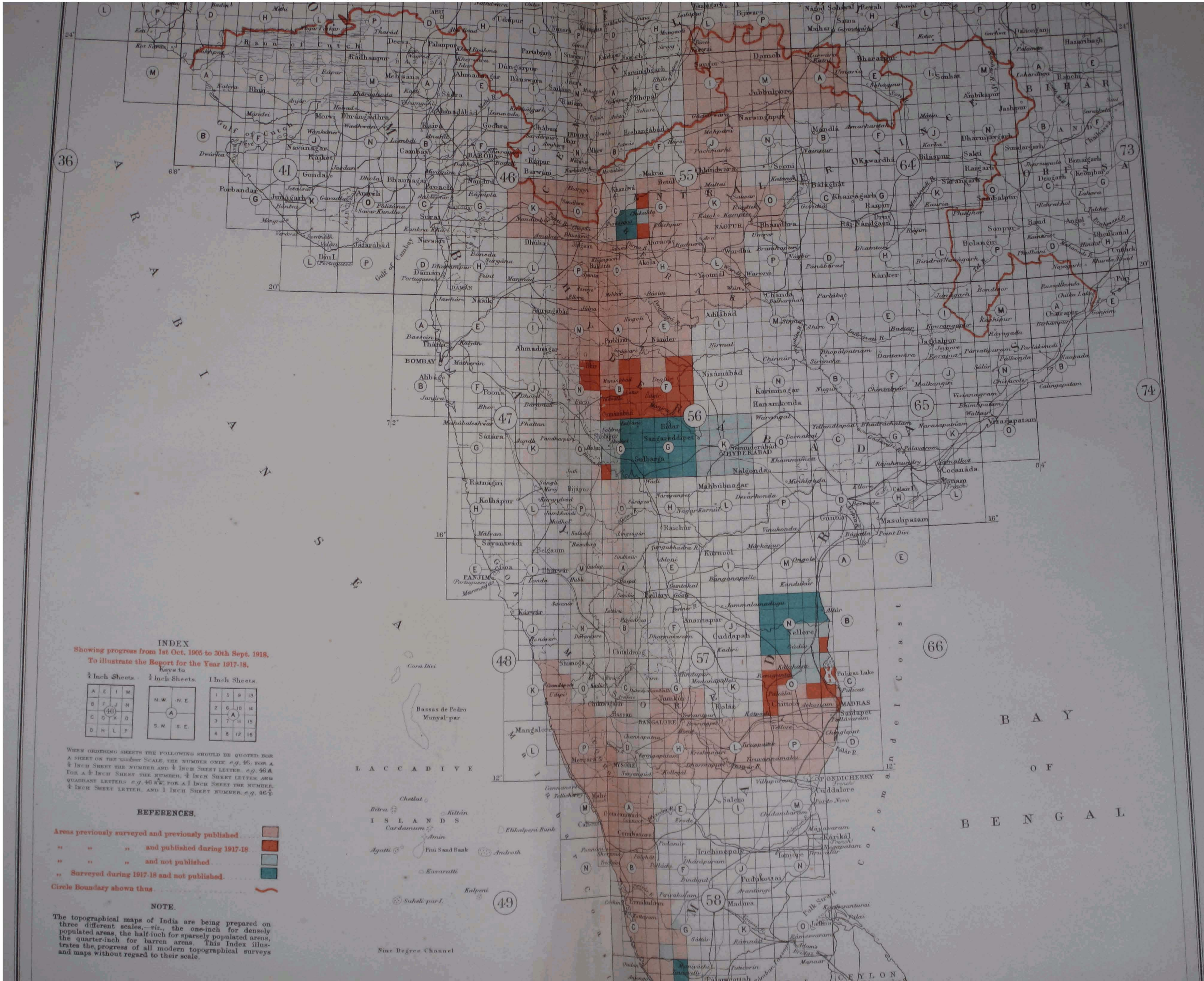
	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	
A	ac 1916	ac 1916	f	d 1911	ac 1916	ac 1916	ac 1916	ac 1917	S	S			d 1911	ac 1917	ac 1917	ac 1917	ac 1915	ac 1916			f	d 1911	ac 1917	ac 1916	A
B	ac 1916	ac 1916	f	ac 1917	ac 1916	ac 1916	ac 1916	ac 1917	S	S			d 1911	ac 1917	ac 1917	ac 1916	ac 1916	ac 1916	ac 1916		f	d 1911	ac 1917	ac 1917	B
C	ac 1916	S	d 1911	ac 1917	ac 1916	ac 1916	ac 1916	S	S	S		d 1911	d 1911	ac 1917	ac 1917	ac 1917	ac 1916	ac 1916	ac 1916		f	d 1911	ac 1917	ac 1917	C
D	ac 1916	S	d 1911	d 1912	ac 1916	ac 1916	ac 1916	S	S	S		d 1911	ac 1918	ac 1917	ac 1917	ac 1918	ac 1916	ac 1915	ac 1916		d 1912	f	ac 1917	ac 1917	D
E	ac 1916	ac 1917	f	d 1911	ac 1916	ac 1916	ac 1916	ac 1916	ac 1916	S		f	d 1911	ac 1917	ac 1917	ac 1916	ac 1918	ac 1916	ac 1916		f	d 1911	ac 1917	ac 1917	E
F	ac 1916	ac 1917	f	d 1911	ac 1916	ac 1916	ac 1916	ac 1916	S	S			d 1911	ac 1917	ac 1917	ac 1915	ac 1915	ac 1916	ac 1916		f	d 1911	ac 1917	ac 1917	F
G	ac 1916	ac 1916	d 1911	d 1913	ac 1916	ac 1916	ac 1916	ac 1916	S	S			d 1911	ac 1917	ac 1917	ac 1915	ac 1916	ac 1917	ac 1915		f	d 1911	ac 1917	ac 1917	G
H	ac 1918	S	d 1911	ac 1917	ac 1916	ac 1916	ac 1916	ac 1916	S	S			ac 1918	ac A 1917	ac 1917	ac 1918	ac 1916	ac 1915	ac 1916		d 1912	d 1911	ac 1917	ac 1917	H
I	ac 1916	ac 1917	d 1911	d 1911	ac 1916	ac 1916	ac 1916	ac 1916	ac 1916	S			d 1911	ac 1917	ac 1917	ac 1918	bc 1918	ac 1916	ac 1916		f	d 1911	f	ac 1917	I
J	ac 1916	ac 1916	d 1911	d 1911	ac 1916	ac 1916	ac 1916	ac 1916	ac 1916	S		f	d 1911	ac 1917	ac 1917	ac 1916	ac 1918	ac 1916	ac 1916		f	d 1912	ac 1917	ac 1917	J
K	ac 1918	ac 1917	ac 1915	d 1911	ac 1916	ac 1916	ac 1916	ac 1916	ac 1916	S		f	d 1911	ac 1917	ac 1917	ac 1918	ac 1916	ac 1916	ac 1916			d 1911	ac 1917	ac 1917	K
L	ac 1918	ac 1916	ac 1915	d 1911	ac 1916	ac 1916	ac 1916	ac 1916	ac 1916	S		d 1911	d 1911	ac 1917	ac 1915	ac 1918	ac 1916	ac 1915	ac 1915		d 1912	d 1911	ac 1917	ac 1917	L
M	ac 1916	ac 1916	d 1911	d 1911	ac 1916	ac 1916	ac 1916	ac 1916	ac 1916	ac 1916		f	d 1911	ac 1917	ac 1917	ac 1918	bc 1918	ac 1916	ac 1916		f	d 1911	f	ac 1917	M
N	ac 1916	ac 1916	d 1911	d 1911	ac 1916	ac 1916	ac 1916	ac 1915	ac 1916	bc 1917		f	d 1911	ac 1917	ac 1917	ac 1915	ac 1918	ac 1916	ac 1916		f	d 1911	ac 1917	ac 1917	N
O	ac 1916	ac 1916	ac 1915	d 1911	ac 1916	ac 1916	ac 1916	ac 1916	ac 1916	S			d 1911	ac 1917	ac 1917	ac 1918	ac 1916	ac 1915	ac 1915		f	d 1911	ac 1917	ac 1917	O
P	ac 1916	ac 1917	d 1911	d 1911	ac 1916	ac 1916	ac 1916	ac 1916	ac 1915	S		d 1911	d 1911	ac 1917	ac 1917	bc 1918	ac 1916	ac 1916	f		d 1912	f	ac 1917	ac 1917	P

	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
A	bc 1915	ac 1917	ac 1916			f	d 1912	f	ac 1918	ac 1918	ac 1918						
B	ac 1917	ac 1917	ac 1915			f		f	ac 1917	ac 1916	ac 1918						
C	ac 1917	ac 1917	ac 1915				f	bc 1916	ac 1918	ac 1918	S			d 1913	d 1912		
D	ac 1917	ac 1917	ac 1915				f	bc 1916	ac 1918	ac 1918	S				d 1912	S	
E	ac 1917	ac 1917	ac 1916			f	f	f	ac 1918	ac 1918	a 1918					d 1912	
F	ac 1917	ac 1917	S			f	f	f	ac 1918	ac 1916	S						
G	ac 1917	ac 1917	S				f	bc 1916	ac 1918	ac 1918	S			d 1913			
H	ac 1917	ac 1917	S			f	f	bc 1916	ac 1918	ac 1919	S					S	
I	ac 1917	ac 1917	S			f	f	f	ac 1918	ac 1918	ac 1918						
J	ac 1917	ac 1917	S			f	f	f	ac 1918	ac 1918	S						
K	ac 1917	ac 1917	S				f	bc 1916	ac 1918	ac 1918	S			d 1913			
L	ac 1917	ac 1917	S			f	f	bc 1916	ac 1916	ac 1918	S			d 1913		S	
M	ac 1917	ac 1917	S			f	f	f	ac 1918	ac 1918	S				bc 1916		
N	ac 1916	ac 1917	S			f	f	f	ac 1918	ac 1918	S				bc 1915		
O	ac 1916	ac 1917	S			f	f	bc 1916	ac 1918	ac 1918	S			d 1913			
P	ac 1917	S	S			f	f	bc 1916	ac 1916	ac 1918	S			d 1913	d 1912	S	

	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	
A					S	S		S							S	S										A
B					S	S		S							S	S										B
C					S			S				ac 1917			S	S										C
D					S			S							S	S						d 1913				D
E						S										S										E
F							S								d 1913											F
G					S		S	S														d 1911				G
H					S			S							S	S										H
I					d 1913		S	S																		I
J			ac 1915			S	S	S																		J
K							S	S																		K
L				d 1913		S	S	S																		L
M							S	S						bc 1916												M
N						S	S	S					d 1912													N
O						S	S	S																		O
P						S	S	S																		P

a Pamphlet with G.T. data available at Trigonometrical Survey Office. *b* Pamphlet with G.T., if any, and Topo. data received from parties. *c* Data with chart.
d Data published in the old style (chart form). *f* No data available at Trigonometrical Survey Office. *S* Area falling in the sea. *A* Addendum in a separate pamphlet.


TO SHEETS OF THE MAP OF INDIA
INDEX
Showing progress from 1st Oct. 1905 to 30th Sept. 1918
To illustrate the Report for the year 1917-18
Keys to
¼ Inch Sheets.
½ Inch Sheets.
1 Inch Sheets.
When ordering sheets the following should be quoted: for a sheet on the million Scale, the number only, e.g. 45; for a ¼ Inch Sheet the number and ¼ Inch Sheet letter, e.g. 45 A. For a ½ Inch Sheet the number, ¼ Inch Sheet letter and quadrant letters, e.g. 45 A/N.W. for a 1 Inch Sheet the number, ¼ Inch Sheet letter, and 1 Inch Sheet number, e.g. 45 A/5.
REFERENCES.
Areas previously surveyed and previously published
" " " and published during 1917-18
" " " and not published
" Surveyed during 1917-18 and not published
Circle Boundary shown thus
NOTE.
The topographical maps of India are being prepared on three different scales,—viz., the one-inch for densely populated areas, the half-inch for sparsely populated areas, the quarter-inch for barren areas. This Index illustrates the progress of all modern topographical surveys and maps without regard to their scale.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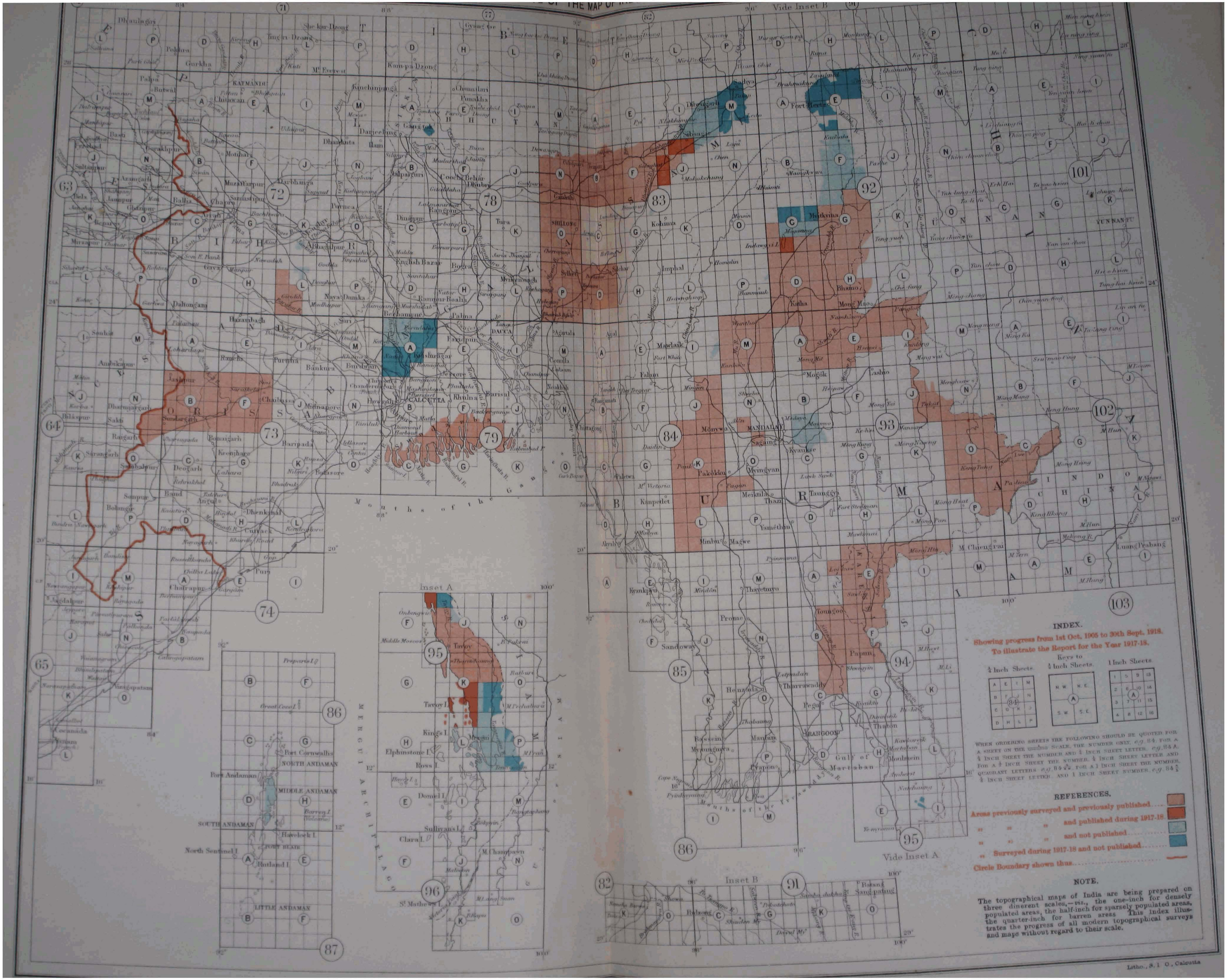
Showing progress from 1st Oct. 1905 to 30th Sept. 1918.
To illustrate the Report for the Year 1917-18.
Keys to
¼ Inch Sheets.
½ Inch Sheets.
1 Inch Sheets.
When ordering sheets the following should be quoted: for a sheet on the quarter Scale, the number only, e.g. 46; for a ¼ Inch Sheet the number and ¼ Inch Sheet letter, e.g. 46 A. For a ½ Inch Sheet the number, ¼ Inch Sheet letter and quadrant letters e.g. 46 A/N.W.; for a 1 Inch Sheet the number, ¼ Inch Sheet letter, and 1 Inch Sheet number, e.g. 46 A/5.
REFERENCES.
Areas previously surveyed and previously published
" " " and published during 1917-18
" " " and not published
" Surveyed during 1917-18 and not published.
Circle Boundary shown thus
NOTE.
The topographical maps of India are being prepared on three different scales,—viz., the one-inch for densely populated areas, the half-inch for sparsely populated areas, the quarter-inch for barren areas. This Index illustrates the progress of all modern topographical surveys and maps without regard to their scale.
ARABIAN SEA
BAY OF BENGAL
LACCADIVE ISLANDS
Coromandel Coast
CEYLON
Nine Degree Channel
BOMBAY
MADRAS
HYDERABAD
NAGPUR
BANGALORE
PONDICHERRY
CENTRAL PROVINCES
BIHAR AND ORISSA
36
41
46
47
48
49
55
56
57
58
64
65
66
73
74



INDEX.
Showing progress from 1st Oct. 1905 to 30th Sept. 1918.
To illustrate the Report for the Year 1917-18.
Keys to
¼ Inch Sheets
½ Inch Sheets
1 Inch Sheets
REFERENCES.
Areas previously surveyed and previously published
" " " and published during 1917-18
" " " and not published
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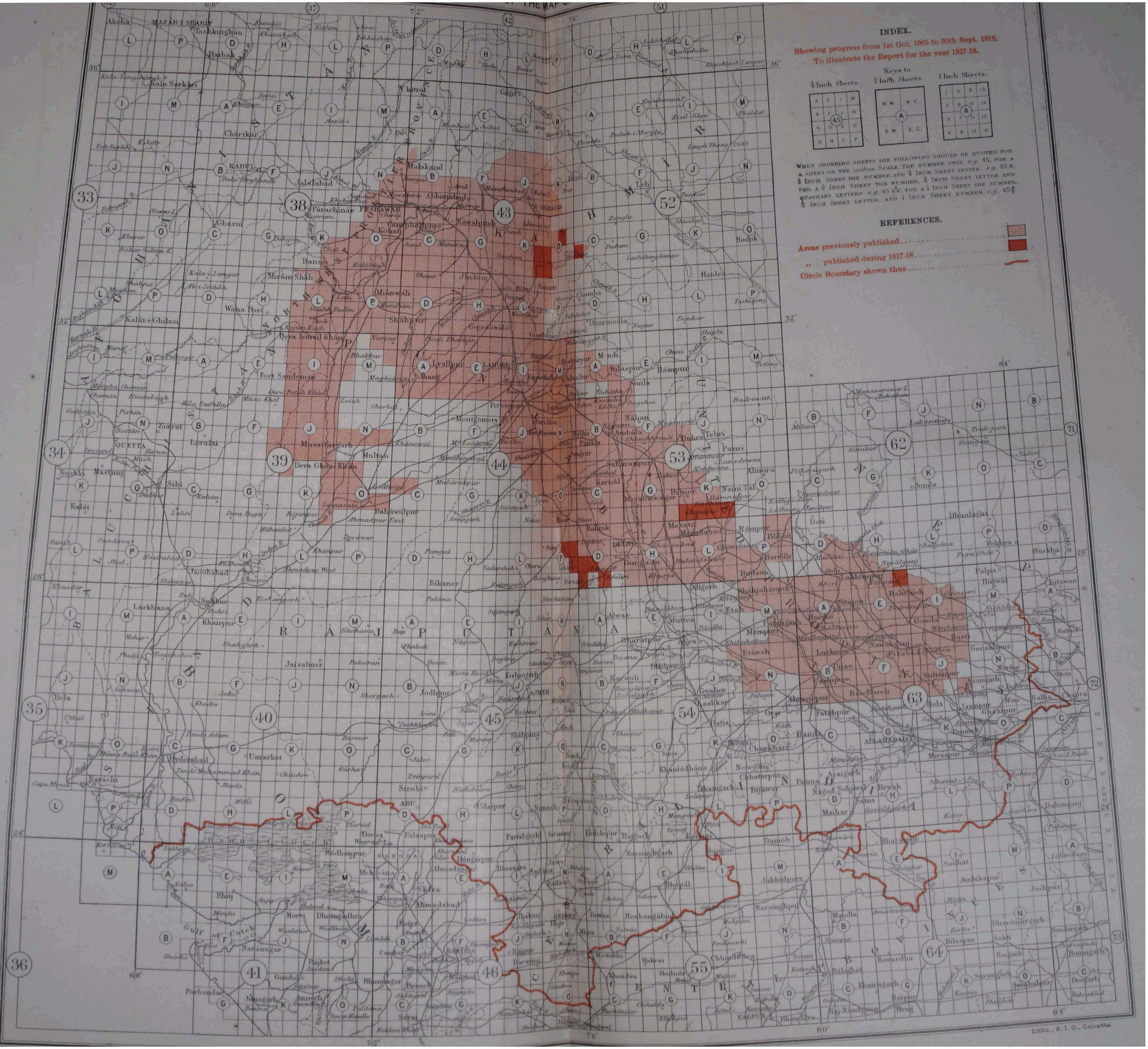
The topographical maps of India are being prepared on three different scales,—viz., the one-inch for densely populated areas, the half-inch for sparsely populated areas, the quarter-inch for barren areas. This Index illustrates the progress of all modern topographical surveys and maps without regard to their scale.
Litho., S. I. O., Calcutta
Vide Inset B
Vide Inset A
Inset A
Inset B
KATMANDU
CALCUTTA
DACCA
MANDALAY
RANGOON
SHILLONG
YUNNANFU
Mouths of the Ganges
Mouths of the Irrawaddy
Gulf of Martaban
MERGUI ARCHIPELAGO
NORTH ANDAMAN
MIDDLE ANDAMAN
SOUTH ANDAMAN
LITTLE ANDAMAN


INDEX.
Showing progress from 1st Oct. 1905 to 30th Sept. 1918.
To illustrate the Report for the year 1917-18.
Keys to
¼ Inch Sheets.
½ Inch Sheets.
1 Inch Sheets.
N. W.
N. E.
S. W.
S. E.
When ordering sheets the following should be quoted: for a sheet on the 1/1,000,000 Scale, the number only, e.g. 45; for a ¼ Inch Sheet the number and ¼ Inch Sheet letter, e.g. 45 A. For a ½ Inch Sheet the number, ¼ Inch Sheet letter and quadrant letters e.g. 45 A/N.W.; for a 1 Inch Sheet the number, ¼ Inch Sheet letter, and 1 Inch Sheet number, e.g. 45 A/5.
REFERENCES.
Areas previously published
" published during 1917-18
Circle Boundary shown thus
KASHMIR
PUNJAB
RAJPUTANA
BALUCHISTAN
CENTRAL PROVINCES
UNITED PROVINCES
NORTH WEST FRONTIER PROVINCE
Litho., S. I. O., Calcutta.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Showing progress from 1st Oct. 1905 to 30th Sept. 1918.
To illustrate the Report for the year 1917-18.
Keys to
¼ Inch Sheets.
½ Inch Sheets.
1 Inch Sheets.
When ordering sheets the following should be quoted: for a sheet on the Scale, the number only, e.g. 46, for a ¼ Inch Sheet the number and ¼ Inch Sheet letter, e.g. 46 A, for a ½ Inch Sheet the number, ¼ Inch Sheet letter and quadrant letters e.g. 46 A/N.W., for a 1 Inch Sheet the number, ¼ Inch Sheet letter, and 1 Inch Sheet number, e.g. 46 A/5
REFERENCES.
Areas previously published
" published during 1917-18
Circle Boundary shown thus
ARABIAN SEA
BAY OF BENGAL
LACCADIVE ISLANDS
BOMBAY
MADRAS
HYDERABAD
NAGPUR
BANGALORE
PONDICHERRY
CEYLON
Nine Degree Channel
36
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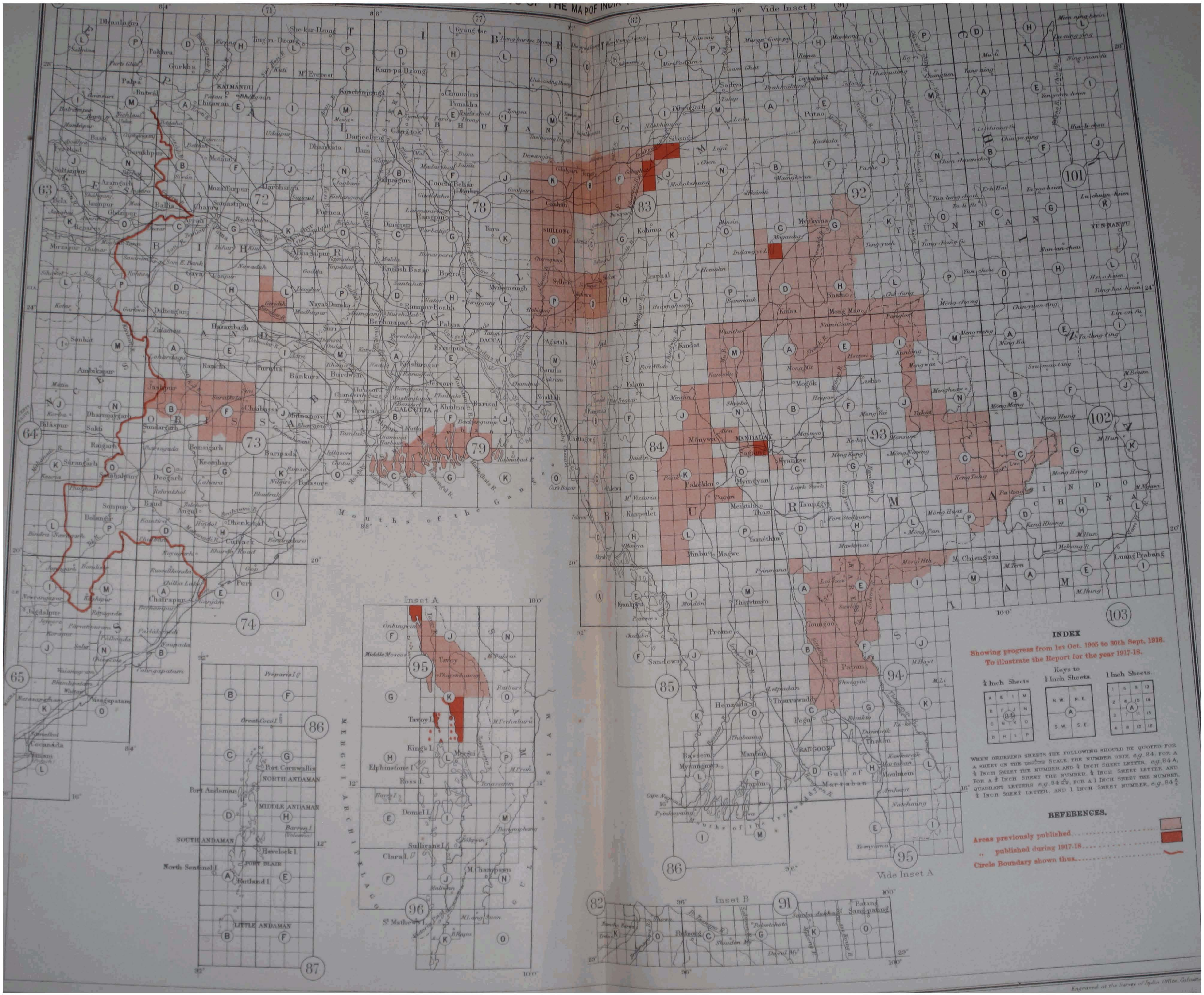
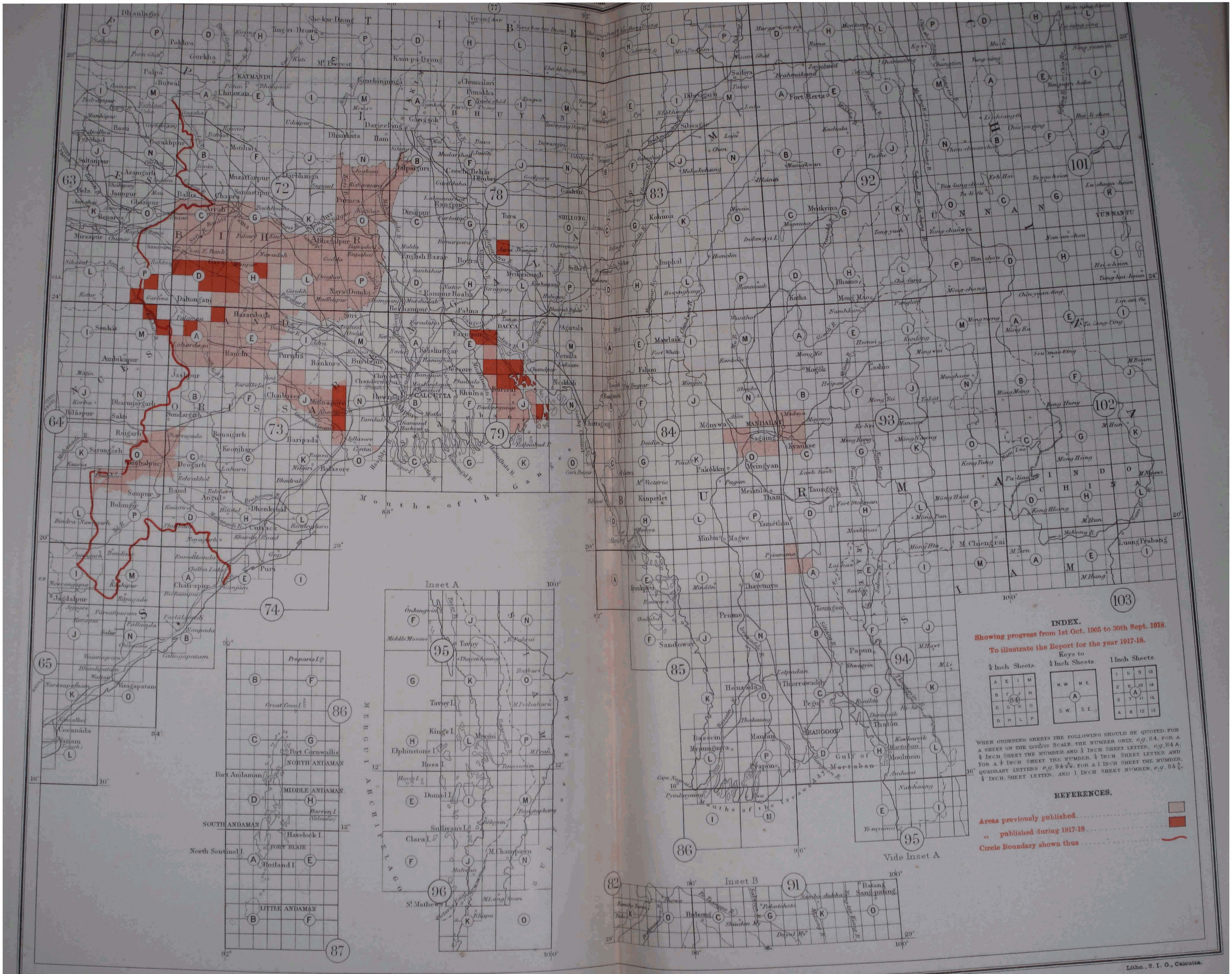
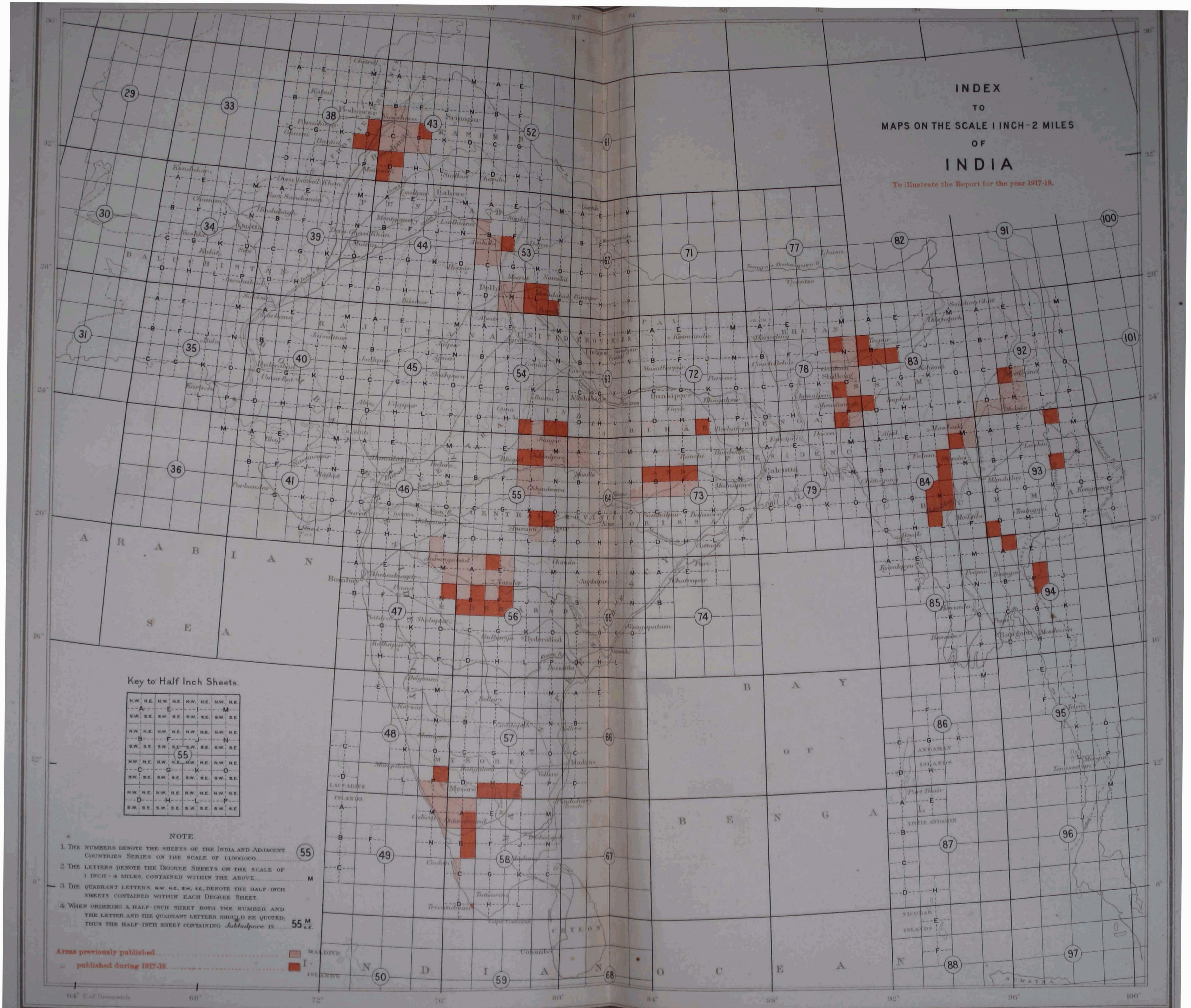

OF THE MAP OF INDIA
Vide Inset B
Inset A
Inset B
Vide Inset A
INDEX
Showing progress from 1st Oct. 1905 to 30th Sept. 1918.
To illustrate the Report for the year 1917-18.
¼ Inch Sheets
Keys to ½ Inch Sheets.
1 Inch Sheets.
When ordering sheets the following should be quoted for a sheet on the 1/1000000 scale the number only, e.g. 84; for a ¼ inch sheet the number and ¼ inch sheet letter, e.g. 84 A; for a ½ inch sheet the number, ¼ inch sheet letter and quadrant letters e.g. 84 A/N.W.; for a 1 inch sheet the number, ¼ inch sheet letter, and 1 inch sheet number, e.g. 84 A/5
REFERENCES.
Areas previously published
" published during 1917-18
Circle Boundary shown thus
Engraved at the Survey of India Offices, Calcutta


INDEX.
Showing progress from 1st Oct. 1905 to 30th Sept. 1918.
To illustrate the Report for the year 1917-18.
Keys to
¼ Inch Sheets
½ Inch Sheets.
1 Inch Sheets.
When ordering sheets the following should be quoted: for a sheet on the ... scale, the number only, e.g. 45; for a ¼ Inch Sheet the number and ¼ Inch Sheet letter, e.g. 45 A; for a ½ Inch Sheet the number, ¼ Inch Sheet letter and quadrant letters e.g. 45 A/N.W.; for a 1 Inch Sheet the number, ¼ Inch Sheet letter, and 1 Inch Sheet number, e.g. 45 A/5.
REFERENCES.
Areas previously published
„ published during 1917-18.
Circle Boundary shown thus
RÁJPUTÁNA
KASHMIR
BALUCHISTAN
NORTH WEST FRONTIER PROVINCE
CENTRAL PROVINCES
UNITED PROVINCES
BOMBAY
PESHAWAR
LAHORE
DELHI
AJMER
ALLAHABAD
INDORE
NAGPUR
QUETTA
KABUL
Litho., S. I. O. Calcutta



Litho., S. I. O., Calcutta.



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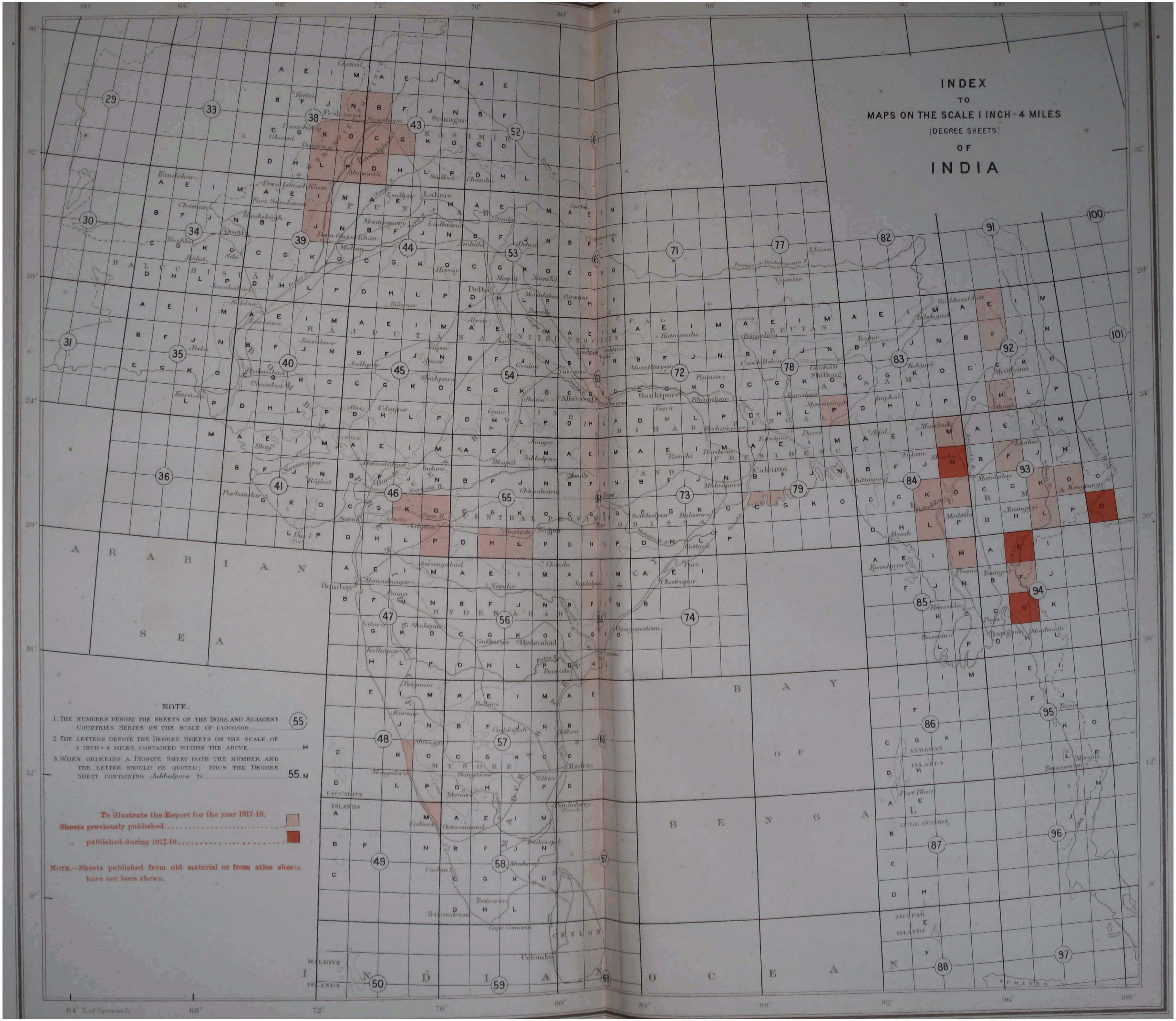
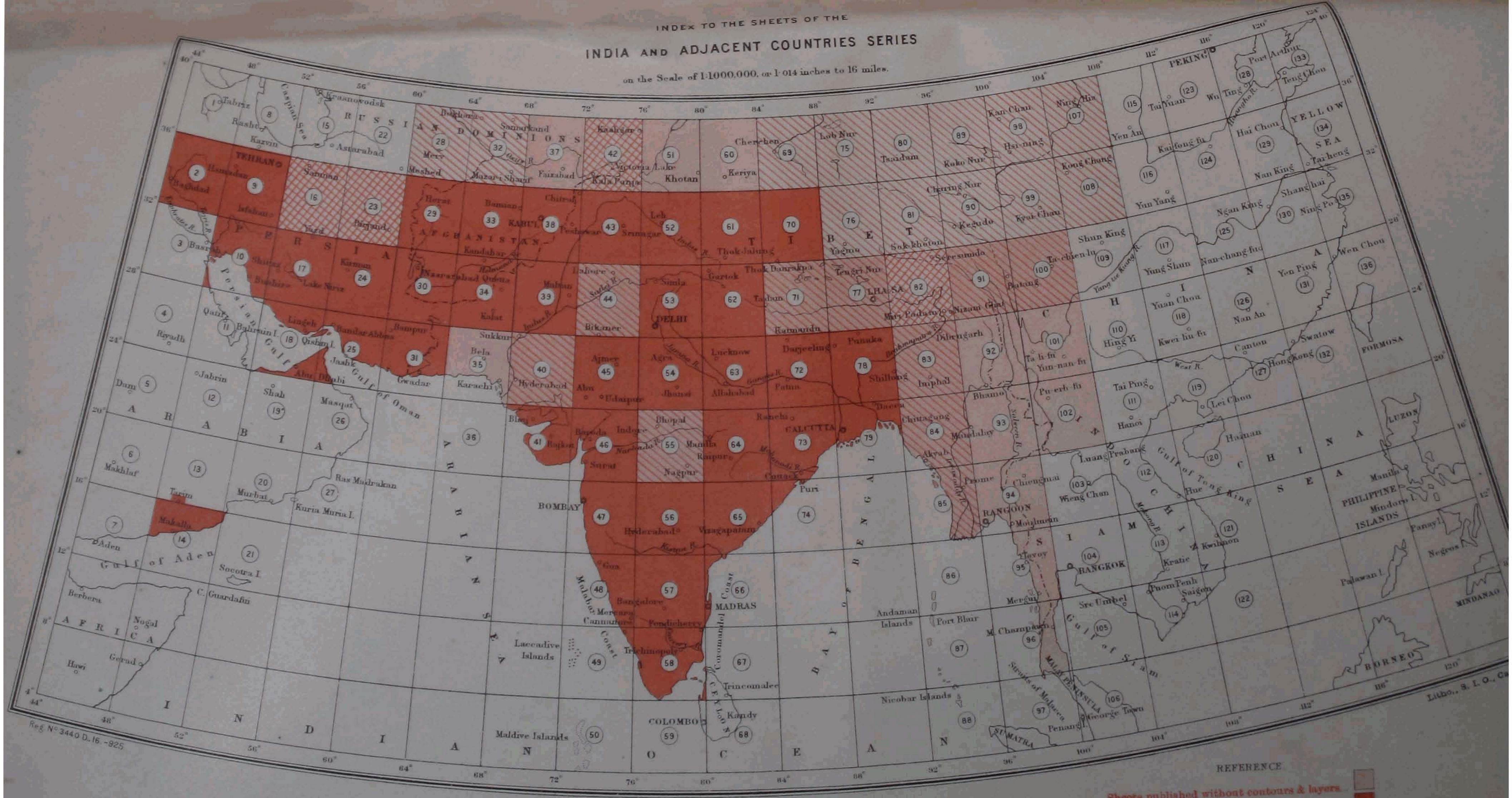
TO
MAPS ON THE SCALE 1 INCH - 2 MILES
OF
INDIA
To illustrate the Report for the year 1917-18.
Key to Half Inch Sheets.
NOTE.
1. The numbers denote the sheets of the India and Adjacent Countries Series on the scale of 1:1,000,000 55
2. The letters denote the Degree Sheets on the scale of 1 inch - 4 miles, contained within the above .... M
3. The quadrant letters, N.W., N.E., S.W., S.E., denote the half-inch sheets contained within each Degree Sheet.
4. When ordering a half-inch sheet both the number and the letter and the quadrant letters should be quoted, thus the half-inch sheet containing Jubbulpore is .... 55 M S.E.
Areas previously published
" published during 1917-18
ARABIAN SEA
BAY OF BENGAL
INDIAN OCEAN


INDEX
TO
MAPS ON THE SCALE 1 INCH = 4 MILES
(DEGREE SHEETS)
OF
INDIA
NOTE.
1. The numbers denote the sheets of the India and Adjacent Countries Series on the scale of 1:1,000,000 55
2. The letters denote the Degree Sheets on the scale of 1 inch = 4 miles, contained within the above .... M
3. When ordering a Degree Sheet both the number and the letter should be quoted; thus the Degree Sheet containing Jubbulpore is 55.M
To illustrate the Report for the year 1917-18.
Sheets previously published ....
" published during 1917-18 ....
Note.—Sheets published from old material or from atlas sheets have not been shewn.
ARABIAN SEA
BAY OF BENGAL
INDIAN OCEAN
64° E. of Greenwich

INDEX TO THE SHEETS OF THE

INDIA AND ADJACENT COUNTRIES SERIES

on the Scale of 1:1000,000, or 1·014 inches to 16 miles.



Scale $\frac{1}{30,000,000}$

Miles 200 0 200 400 600 800 Miles

REFERENCE

Sheets published without contours & layers

" " with contours & layers

" under publication

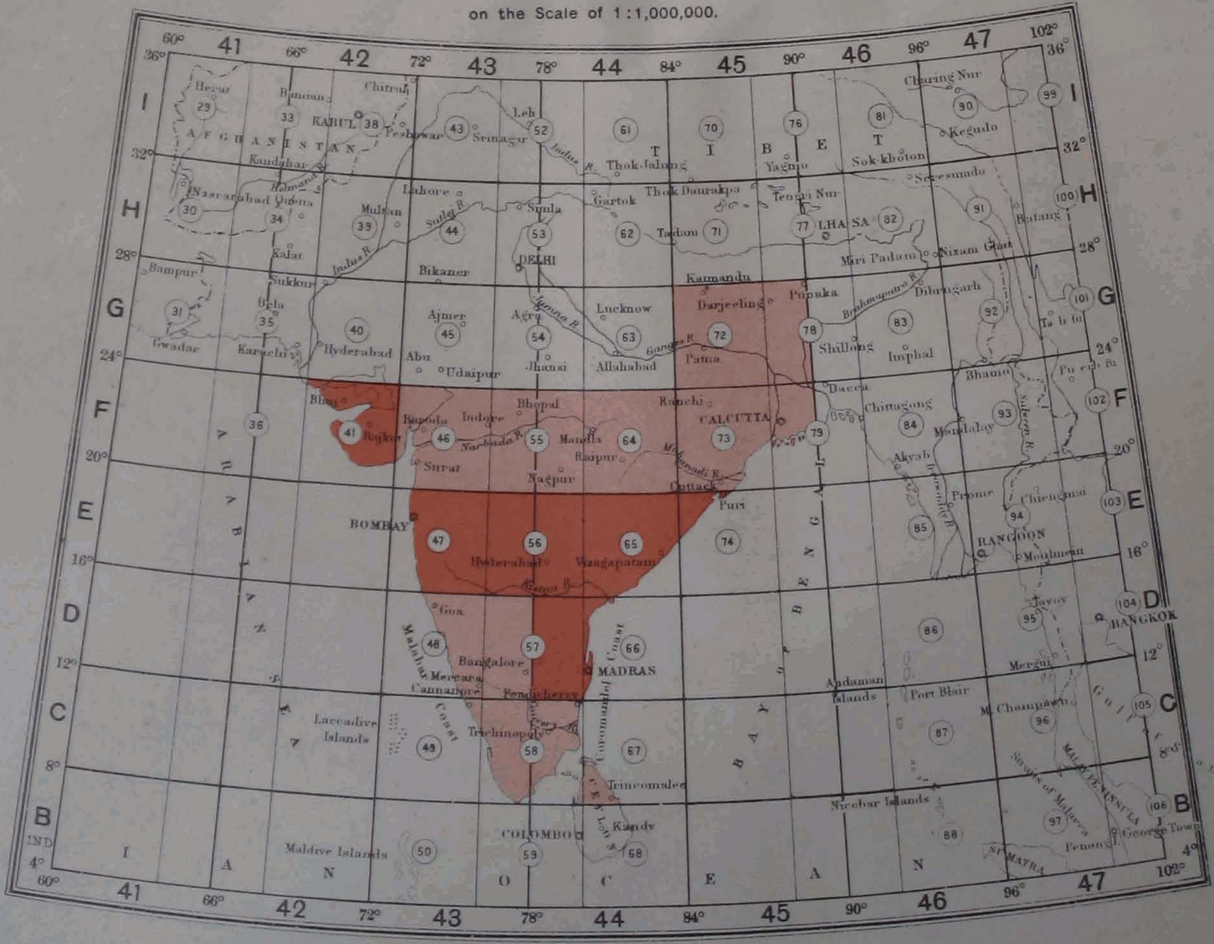
" in hand

To illustrate the Report for the year 1917-18.

INDEX TO THE SHEETS OF THE

CARTE INTERNATIONALE DU MONDE

on the Scale of 1:1,000,000.



The thick lines show the margins of the sheets of the International Map of the World, Scale 1:1,000,000. Each sheet is designated by the letter N (Northern hemisphere), followed by the marginal letter and number corresponding to its position, *e.g.*, the sheet which includes Bombay is N.E-43.

The figures in circles are the numbers of the sheets of the India and Adjacent Countries Series on the Scale of 1:1,000,000.

Scale 50,000,000.

Miles 200 0 200 400 600 800 Miles

REFERENCE.

Sheets published ....

" under publication ....

" in hand ....

To illustrate the Report for the year 1917-18.

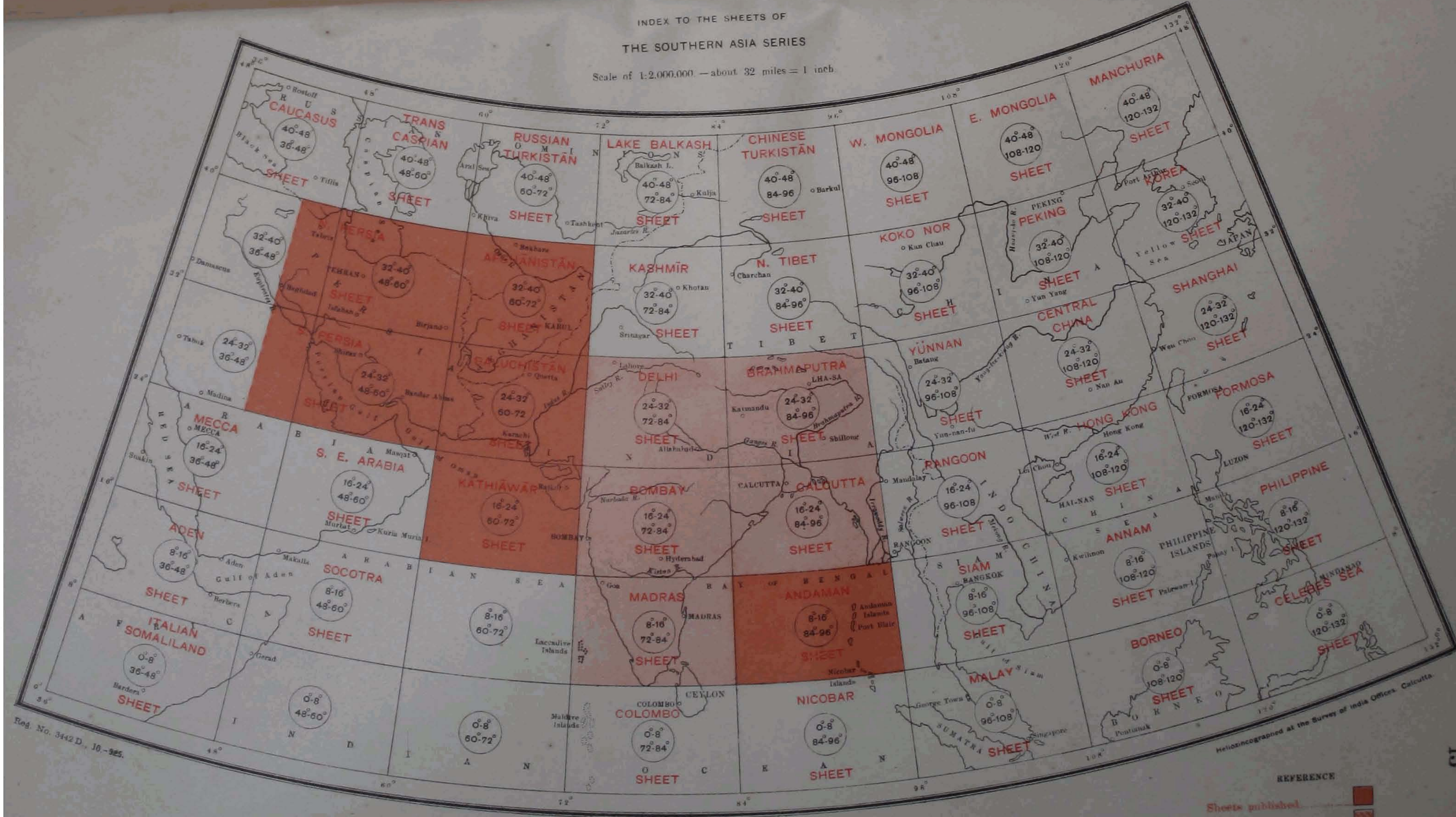
Litho., S. I. O. Calcutta

Reg. No. 3441 D., 16.

INDEX TO THE SHEETS OF

THE SOUTHERN ASIA SERIES

Scale of 1:2,000,000. — about 32 miles = 1 inch.



Scale $\frac{1}{40,000,000}$

Miles 200 0 200 400 600 800 1000 Miles

REFERENCE

Sheets published

" under publication

" in hand

To illustrate the Report for the year 1917-18