

# RECORDS

OF THE

# SURVEY OF INDIA

Volume XIV

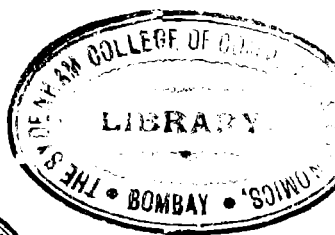
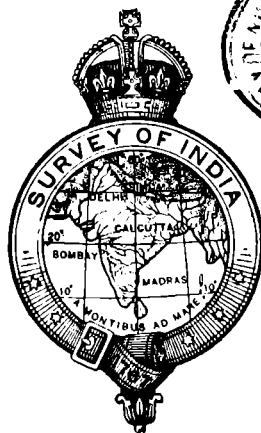
(Supplementary to General Report 1918-19)

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## ANNUAL REPORTS OF PARTIES AND OFFICES 1918-19.

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PREPARED UNDER THE DIRECTION OF  
Colonel C. H. D. RYDER, C. I. E., D. S. O., R. E.  
Surveyor General of India.



DEHRA DUN  
PRINTED AT THE OFFICE OF THE TRIGONOMETRICAL SURVEY  
1920

*Price Four Rupees or Eight Shillings.*



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(a) **THOSE SURVEYED AFTER 1905** are printed in colours, in sheets 23 INCHES × 19 INCHES, price ONE RUPEE per copy.

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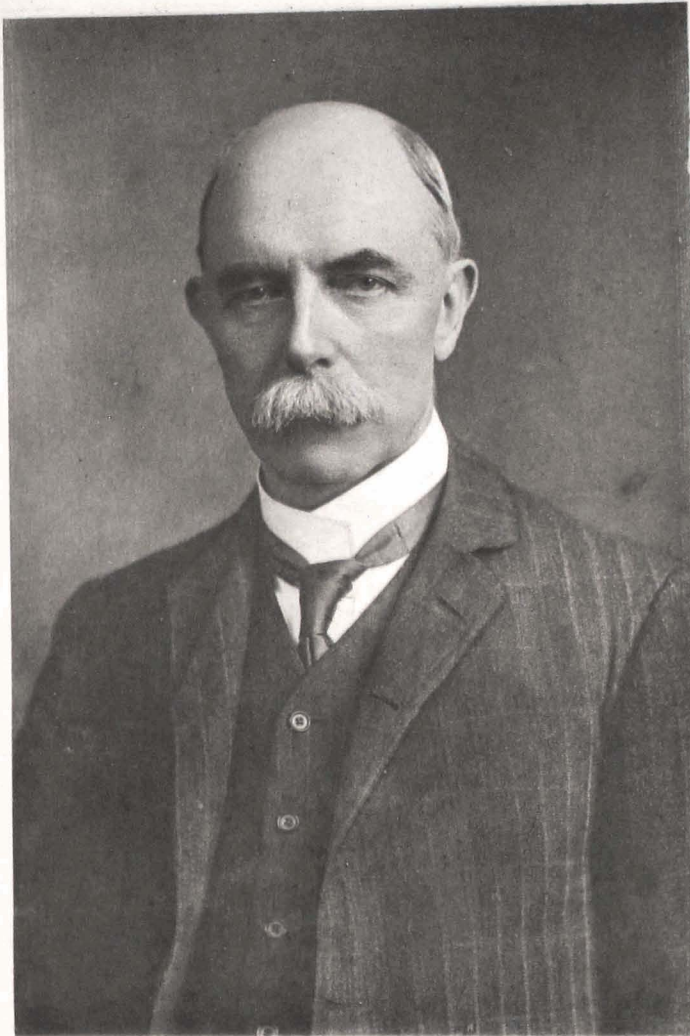
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8. **THE MAP RECORD AND ISSUE OFFICE** will be glad to give, free of charge, any further information.





Photography.

Survey of India Office, Calcutta, 1919.

COLONEL SIR SIDNEY GERALD BURRARD, K.C.S.I., R.E., F.R.S.,

Surveyor General, 1911-1919.



Roll of Honour.

Survey of India.

CAPTAIN W. P. HALES, M. B. E., I. A. R. O.





# Roll of Honour.

SURVEY OF INDIA.



LIEUTENANT (ACTING CAPTAIN) W. P. HALES, M.B.E., I.A.R.O.

Born 22nd July 1889.

Appointed to the Provincial Service, Survey of India, on 1st November 1907.

Received a Commission in the Indian Army Reserve of Officers on 19th June 1915.

DIED ON ACTIVE SERVICE IN PERSIA ON 1st NOVEMBER 1918  
WHILE SERVING WITH THE 3/124th BALUCHISTAN INFANTRY.



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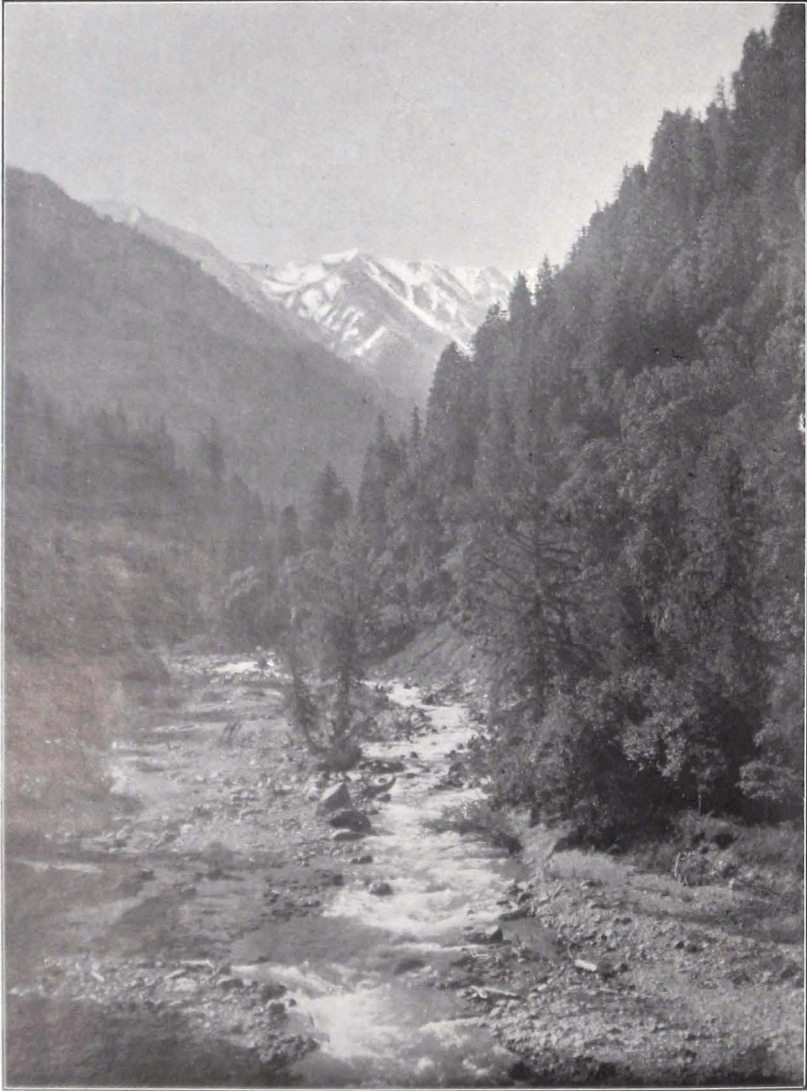
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THE HEAD OF THE SHAHĀBĀD GLEN (SOUTH KASHMĪR), ANANTNĀG TAHSĪL.  
ONE OF THE SOURCES OF THE JHELUM RIVER.

From a photograph by Mr. R. C. Hanson.

## PART I.—TOPOGRAPHICAL SURVEY. NORTHERN CIRCLE.

(Vide Index Map No. 1)

*Summary.*—This circle was under the superintendence of Lieutenant-Colonel E. A. Tandy, R. E., up to 29th November 1918 and of Lieutenant-Colonel R. T. Crichton, C. I. E., I. A. from 30th November 1918 to the close of the survey year. It comprised Nos. 1, 2 and 3 Topographical Parties, No. 3 Drawing Office and six special parties and detachments.

During the year Nos. 1, 2 and 3 Parties completed 591 square miles of detail survey on the 1-inch, 3-inch and 4-inch scales, besides 124 square miles on larger scales. No triangulation or traversing was done except 8 square miles of triangulation and 44 linear miles of traversing for large scale surveys.

The detail survey consisted of :—

	92	square miles of 1-inch original survey,
228	„ „ „	3-inch original survey,
82	„ „ „	4-inch revision survey,
189	„ „ „	4-inch original special forest survey.

The Punjab Riverain Party and the Sind-Sāgar Party continued special work in the Punjab for the Local Government. The latter carried out the rectangulation work in the Sind-Sāgar Doāb and the former the usual riverain surveys in the Punjab.

A survey party was formed from 1st October 1918 to work in East Persia. This party was disbanded from 30th September 1919.

A detachment called the Birjand Survey Detachment was formed from 2nd June 1919 to complete the work left unfinished in East Persia by the East Persia Party.

A survey party designated the North West Frontier Party was formed from 11th May 1919 for military service with the North West Frontier Force near Peshāwar and a survey detachment was formed in June 1919 for military service with the above Force near Quetta.

No. 4 Party was kept in abeyance as a topographical unit.

### No. 1 PARTY (PUNJAB).

BY BT: LIEUT.-COLONEL A. A. MCHARG, D.S.O., R. E.

The head-quarters of the party remained at Mussoorie throughout the year.

#### PERSONNEL.

##### *Imperial Officers.*

Bt. Lt.-Col. A. A. McHarg, D.S.O., R. E.,  
in charge from 1st April 1919.  
Captain W. E. Perry, M.C., R. E., in charge from  
1st October 1918 to 24th March 1919.

##### *Provincial Officers.*

Mr. H. H. B. Hanby, in charge from 25th to 31st  
March 1919.  
„ G. J. S. Rae.  
„ P. A. T. Kenny.  
„ A. M. Talati, L.C.E.  
„ R. C. Hanson.  
„ G. A. Norman.

##### *Upper Subordinate Service.*

Mr. Sher Jang, K. B.  
„ Paras Ram.  
„ Jamna Prasad, R. S.  
„ Jagdeesh Prasad Vastav.  
„ Afraz Gul Khan.  
„ Muhammad Khan.

##### *Lower Subordinate Service.*

24 Surveyors etc., inclusive of 9 Soldier  
Surveyors.

Field work in one camp was going on from the 1st of October 1918 until about the end of the month, in a second from about the 1st of December 1918 to the 10th of May 1919, and in a third during the month of April 1919 in Ferozepore and Lahore cities. The work in these two cities was delayed for a time owing to the riots, but was eventually completed.

The country in the Quetta-Pishin district consisted of an open cultivated valley at an altitude of about 5000 feet intersected by numerous generally dry water courses, with broken intricate hills, “*dāmān*” ground, and parts of the lower steep hills of the two ranges forming the valley; that in the Jhānsi district of an open cultivated plateau at an altitude of about 900 feet with a few hills, and that in the Mhow district of an open cultivated plateau at an altitude of about 2000 feet with a few isolated hills, and lastly of the congested city areas in both Ferozepore and Lahore cities.

The health of the party was good.

*Plane-tableing.*—An area of 91.8 square miles

of country was surveyed on the 1-inch scale viz : 15·9 for the Pāli-Pahāri Artillery Practice Camp in the Jhānsi district and 75·9 for the Killod Artillery Practice Camp in the Mhow district, and an area of 227·6 square miles for Artillery Practice Camps was surveyed on the 3-inch scale as follows :—

- 94·5 for Baleli Artillery Practice Camp in the Quetta-Pishin district.
- 72·4 for Pāli-Pahāri Artillery Practice Camp in the Jhānsi district, and
- 60·7 for Killod Artillery Practice Camp in the Mhow district.

In addition to this, an area of 2·19 square miles was surveyed on the sixteen-inch scale for Town Guide maps as follows :—

- 0·51 square mile in Ferozepore city and 1·68 square miles in Lahore city and environs.

The detail of the country has been described above.

The distribution of the party for carrying out the above programme was as follows :—

A camp of nine surveyors under Mr. P. A. T. Kenny during the month of October 1918 for the Baleli Artillery Practice Camp in sheets 34/J/parts of 15 and 16. Mr. Kenny and most of these surveyors were hurriedly transferred to the East Persia Survey Party about the 1st of November 1918 and the work was in consequence not particularly well tested by the camp officer, but as most of the surveyors were experienced and reliable, the work was probably good.

A second camp of one upper subordinate and one senior surveyor (as assistant instructors) and nine soldier surveyors undergoing their first field season under Mr. G. A. Norman for the Pāli-Pahāri Artillery Practice Camp in sheets 54/K/parts of 6, 7, 10, & 11 and Killod Artillery Practice Camp in sheets 46/N/parts of 10, 11, 14 and 15.

The Pāli-Pahāri work was thoroughly tested by the Officer in charge as well as the camp officer, and the Killod work by the camp officer. The country was easy and the work good.

A third camp under Mr. R. C. Hanson with one upper subordinate and two surveyors completed the Ferozepore city survey and four surveyors completed the Lahore city and environs survey. Material supplied by the General Staff and old surveys enlarged to the sixteen-inch scale were made use of for the Ferozepore city survey and reductions of Mr. A. J. Wilson's (late Survey of India) Lahore city survey on the scale of 500 feet to 1-inch to the 16-inch scale and material supplied by the General Staff were made use of for the Lahore city and environs survey.

The work in both cities was carried out during rather disturbed times and does not appear to be as accurate as it should be. This will be rectified.

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

	Three-inch	Baleli Artillery Practice Camp	Rs.	80·2
One and	do.	Pāli-Pahāri do.	„	182·8
One and	do.	Killod do.	„	117·6
	Sixteen-inch	Ferozepore Town Guide Map	}	... „ 2359·7
do.	Lahore	do.		

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

*Traversing.*—No traversing in advance was done for the ordinary programme of the party, but a supplementary traverse of 3·42 miles was run by Mr. Jagdeesh Prasad Vastav along the Ferozepore city circular road to assist the two surveyors making the survey of that city.

The cost-rate is included in that of the Town Guide maps.

*Recess Duties.*—During the field season Mr. Rae and Mr. Hanson (except during the month of April 1919) were employed at head-quarters with an average of 9 draftsmen and surveyors each, on fair-mapping sheets 43/O/8, 12, 16 and 43/P/5, 6, 7, 9, 10, 13, 14 on 1½-inch scale and the Yāru-Bostān and Baleli Artillery Practice Camps on 3-inch scale. During the recess Messrs. Rae, Hanson and Norman between them as section officers in charge, with an average of 10 men in each section, were employed on fair-mapping :—

On 1½-inch scale sheets 43/O/8, 12, 16, 43/P/5, 10, 11, 13, 14, 15, 53/A/1, 2, 3, 4, 6, 7, and on 3-inch scale Yāru-Bostān, Baleli, Pāli-Pahāri and Killod Artillery Practice Camps.



Mr. R. C. Hanson was transferred to the North West Frontier Survey Party on the 18th of May 1919 for field service, and retransferred to No. 1 Party from the 27th of August 1919, while Mr. Norman was transferred for field service to the East Persia Survey Party on the 15th of August 1919. These transfers have reacted adversely on the quantity and possibly on the quality also, of the fair-mapping, *e. g.*, the three-inch Yāru-Bostān Artillery Practice Camp survey was being fair-mapped without any one in the party (until Lt.-Colonel McHarg took over charge) actually knowing the country at all and the same partly applied, during Mr. Hanson's absence, to some of the Kashmīr sheets surveyed in 1917.

Mr. A. M. Talati with one upper subordinate and from 6 to 10 men from the 1st of July 1919 was preparing plane-tables for 1919-20 field season's work.

This work has been very troublesome for many reasons, some of which are given below:—

- (i) the different scales on which portions of sheets were originally surveyed.
- (ii) the difficulty of obtaining published editions of some of these surveys, the published stock having run out.
- (iii) the necessity for reductions and the consequent large amount of work entailed in taking out actual as well as reduced dimensions.
- (iv) the delays entailed in receiving reductions from the Dehra Office owing to the heavy rainy season this year.
- (v) the pasting up of reductions to form standard sheets and then returning them to the Dehra Office for reproduction.
- (vi) the necessity for thickening up the line work as well as the 250 and 500 feet contours on the large scale published sheets in order to obtain legible reductions.
- (vii) the difficulty in finding out by which party and on what scale, portions of sheets had been surveyed; where the original field sections were kept, and from which office published editions of the same were available.
- (viii) the difficulty in making the reductions fit as, in some instances, the original graticules seemed to have been carelessly drawn, so that the plotted points did not agree properly with the graticules, necessitating therefore, the redrawing of graticules from the plotted points.
- (ix) the labour entailed in extracting the triangulation data from a large number of volumes by sheets and in plotting points omitted on the published sheets.
- (x) the amount of correspondence entailed in obtaining certain triangulation computation volumes.

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

(i) 1-inch mapping	...	...	...	Total	1817 square miles.
(ii) 3-inch mapping					
Yāru-Bostān	...	...	...	...	209 square miles.
Baleli	...	...	...	...	111 " "
Pāli-Pahāri	...	...	...	...	46 " "
Killod	...	...	...	...	55 " "
				Total	421 " "
(iii) 16-inch mapping					
Ferozepore city	...	...	...	...	0·46 " "
Lahore city and environs	...	...	...	...	1·34 " "

Cost-rates per square mile were as follows:—

1-inch mapping	...	...	...	Rs. 16·2 per square mile.*
3-inch mapping	...	...	...	" 12·1 " "
16-inch mapping	...	...	...	" 607·7

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

1-inch sheets 43/O/12, 16, 43/P/5, 6, 7, 9, 11, 13,

3-inch Yāru-Bostān Artillery Practice Camp.

The following still remain to be submitted:—

1-inch sheets 43/O/8, 43/P/10, 14, 15, 53/A/1, 2, 3, 4, 6, 7.

Of these, four sheets are completed, but have still to be finally examined by the section officers.

\* This work was carried out by Soldier Surveyors whose pay has not been included in the cost.

3-inch Baleli Artillery Practice Camp  
 ,, Pali-Pahāri do.  
 ,, Killod do.  
 16-inch Town Guide maps  
 Ferozepore city  
 Lahore city and environs

All the computations and rough triangulation charts of the party for the Kashmir and Jammu work, which has been going on since 1909, have been handed into the Circle office, as well as all spare published charts and published triangulation pamphlets.

The only computations now with the party are those appertaining to the coming field season's work.

A great deal of work devolved on the Officer in charge of the party in sorting out old records relating to sheets which had already been sent into the Circle office and sending them for storage to the same office.

*Miscellaneous*.—During recess the Royal Air Force supplied the party with a mosaic of Lahore city and civil station, mounted on card board and rather indifferently cut into three parts for convenience in transit by rail, as well as spare prints of each photograph, also prints of the photographs for Ferozepore city and cantonment and the intervening country.

*Ferozepore*.—The average scale for about 20 of these prints of Ferozepore city and cantonment was worked out and found to be 8·605 inches to 1 mile.

Enlargements of the old 1870 edition Ferozepore cantonment and environs map, on the scale of 6 inches = 1 mile, in four sheets, were then obtained on the 8·605 inch scale, and the four sheets were pasted together but, owing to the originals having expanded unequally, this was rather difficult. The two northerly sheets eventually fitted fairly well, but the two southerly sheets *i. e.* the southern half of the cantonment portion did not fit. As all cantonment plans are kept up to date, this however was of no consequence.

The prints were then pasted in their correct positions, chiefly by making use of roads and recognisable points in the centres of the prints and superimposing them on the enlarged blue survey prints (black would have been better) over tracing glass. By cutting pieces off adjoining overlapping prints here and there, good connections were made, so that, eventually, a mosaic of Ferozepore city and the northern half of the cantonments with the intervening country was obtained.

The line work of this mosaic was then inked up in crimson lake. Owing to the difficulty in inking up on glazed prints, bromide prints would have been preferable.

A trace of the area north of the cantonment boundary showing all trees in their correct positions was made on tracing cloth, and copies of this trace, in blue on the six-inch scale, on mounted and rolled drawing paper, have been received from the Calcutta office. These will be taken out into the field during the coming field season, when the whole work will be classified and tested in the field. In addition to this, as there appeared to be some doubt about the accuracy of the field work of Ferozepore city surveyed on the twelve-inch scale during this last field season and drawn on the sixteen-inch scale during recess, an enlargement of the city area, on the sixteen-inch scale, from the tracing on tracing paper was obtained which, on being superimposed on the fair-drawn sheet did not agree satisfactorily.

It would seem therefore, that the mosaic based on the old 1870 work is more accurate than the recent survey of last field season.

This field work was based on a traverse run from one cantonment boundary pillar round the circular road and connected with a second cantonment boundary pillar. The traverse stations were computed in rectangular values, and plotted on the twelve-inch scale on a mounted plane-table.

Before taking the field, the detail on the photo prints supplied by the Royal Air Force was plotted on a blue survey print, on the twelve-inch scale, of the old 1870 edition Ferozepore and environs map, by means of proportional compasses. Traces of this resultant work were transferred and adjusted on the traverse work by the surveyors in the field, and the whole was then revised and classified by them.

The original photo prints supplied by the Royal Air Force were returned to them. It is difficult therefore to say where the error crept in, but was probably due to faulty transfer work.

The work, however, was checked by the section officer in the field who reported favourably on it. It is proposed, therefore, to check the city work, this ensuing field season, on a blue drawing print from the enlarged mosaic on the sixteen-inch scale, i. e. the same scale on which the fair sheet has been drawn this recess.

*Lahore.*—The average scale for about 20 prints of the Lahore city mosaic was found to be 8·822 inches to 1 mile.

Similar difficulties were found, as in the case of Ferozepore, in making the north-easterly sheet fit on to the others, but the eventual results were fair. The mosaic was made in a similar manner; and with the exception of two places, the photographs fitted, on the whole, very well.

The combined mosaic took in almost the whole area, subsequently asked for by the Government of the Punjab, to be surveyed on the scale of twelve inches = 1 mile. It was found that the photograph prints for the Lahore Railway Workshop area were on a slightly larger scale. These photographs had evidently been taken on a later flight, but they all agreed very well "inter se". For this area therefore, a separate mosaic was made and inked up as before. A trace was then made and enlargements were asked for on the twelve-inch scale.

The original mosaic measured about 60 inches from north to south and the same distance from east to west and the area enclosed was as follows:—from S. W. to N. E. a point on the down stream side of the Rāvi-Doāb canal, about 1 mile from the bridge leading from the Jail Road to Lahore cantonments, to the Railway Workshops bridge crossing this canal; thence, in a north-westerly direction, following the N. W. Railway line to the bridge over the Rāvi river; thence to a point on the Rāvi river (main river bed) due west of Anarkali's tomb and from this point in a straight line to the first point on the Rāvi-Doāb canal.

This mosaic was originally intended for reduction to the six-inch scale, on which scale the civil station and environs of Lahore for the Lahore Town Guide map were to be surveyed, but as the Punjab Government also required a survey of this area on the twelve-inch scale, light blue enlargements of the mosaic, in eleven sections, on the twelve-inch scale on rolled and mounted drawing paper have been asked for from the Calcutta office and it is proposed to revise and classify these eleven sections in the field.

Provided the blue enlargements are satisfactory and the surveyors are able to decipher them in the field, this system of obtaining blue enlargements direct from the mosaic will save a great deal of time.

If, on the other hand, they prove to be unsatisfactory, the only alternative is, to ink up the mosaic, make traces and obtain enlargements or reductions, as the case may be, and classify and revise these in the field.

The pasting up of the mosaic is a long and tedious job and is not one which can be left to a surveyor, nor can the mosaic supplied by the Royal Air Force be relied on, except as a general guide. In this case, the mosaic was pasted up by Lt.-Colonel McHarg who had the advantage of knowing Lahore city and civil station. One rather unintelligent surveyor was also employed in inking up the Ferozepore mosaic, but the work proved too much for him and Lt.-Colonel McHarg had also finally to wash out all his work and ink up the mosaic himself afresh. The mosaic graticule was laid off from the old enlargement.

From this it will be seen that all this initial work requires, anyway at present, at least a Provincial officer and the work is heavy, although it is undoubtedly possible to obtain a great deal of minute information which should simplify the eventual field work.

Lahore civil station is very well wooded. A station less wooded would give much better results.

It is proposed to plot all the trigonometrical data available on the 12-inch blue drawing prints and wherever these can be recognised, e. g. mosques etc., to check their position before taking the field.

The Lahore mosaic has proved some of the field work surveyed during the month of April 1919 in the Anarkali area to be faulty and it is very probably so in other places as well, outside the actual city area. This area was revised on reductions of Mr. A. J. Wilson's (late Survey of India) Lahore city survey on the scale of 500 feet = 1 inch and should be as accurate as is possible.

The fair-drawing of this portion, as well as possibly part of the railway area, will be accepted, but for the remainder, more accurate results will probably be obtained by accepting the work revised on these mosaic enlargements.

The procedure for the Lahore survey, excepting the actual city area, was similar to that of Ferozepore.

*Inspections.*—The Superintendent of the Circle inspected the party on several occasions during the recess.

## No. 2 PARTY (DELHI, UNITED PROVINCES AND RAJPUTANA).

By H. P. D. MORTON.

Owing to an urgent request having been received for the preparation of up-to-date Town Guide maps, the usual topographical programme of the party was postponed with the

### PERSONNEL.

#### *Imperial Officer.*

Major R. Foster. I. A., in charge from 16th May 1919 to 19th September 1919.

#### *Provincial Officers.*

Mr. H. P. D. Morton, in charge to 15th May 1919 and from 20th September 1919.

„ J. A. Calvert.

„ Duni Chand Puri.

#### *Upper Subordinate Service.*

Mr. Lakshmi Dutt Joshi.

„ Ghulam Hasan.

„ Daulat Ram Vohra.

#### *Lower Subordinate Service.*

23 Surveyors, etc.

lands, and the inhabited area of intricate details.

The head-quarters of the party opened in the field at Cawnpore on 18th November 1918, and closed on the 5th May 1919. The office reopened on the 14th May at its recess quarters in Mussoorie.

The party was employed on the revision surveys of the cities of Allahabad, Cawnpore and Benares on the scale of 16 inches=1 mile, Agra city on the scale of 13.2 inches=1 mile, and the cantonments, civil lines and environs of Allahabad, Agra, Lucknow, Cawnpore and Benares on scale of 16 inches=1 mile. (The city of Lucknow will be mapped on the 16-inch scale from the air-photographs taken for the purpose.)

In addition the second biennial revision survey of the 4-inch maps of Imperial Delhi and Delhi new cantonment was carried out.

The health of the party was remarkably good considering the insanitary conditions prevailing in Indian cities, and only a couple of cases of small-pox occurred amongst the menials.

*Plane-tabling.*—Mr. Calvert was in charge of the surveys of Imperial Delhi and Delhi new cantonment and of the towns of Cawnpore and Lucknow, and carried them out as follows:—

Revision survey of Imperial Delhi and Delhi new cantonment on the scale of 4 inches=1 mile, comprising an area of 64 square miles, and, in addition, 18 square miles of portions outside Imperial limits, on which 3 surveyors were employed the whole season.

Revision surveys of Cawnpore and Lucknow cantonments, civil lines, and environs, on the scale of 6 inches=1 mile, comprising areas of 15,691 and 22,842 acres respectively, employing thereon an average of 5 surveyors for 3½ months and an average of 8 surveyors for 2 months in each town.

Revision survey of Cawnpore city, on the scale of 16 inches=1 mile, comprising an area of 1,267 acres, employing 6 surveyors for 2 months.

exception of the second biennial revision survey of Imperial Delhi and Delhi new cantonment, and its activities were therefore mainly confined to town surveys.

At the close of the field season, however, an urgent request was received from the Secretary, Public Works Department, Rajputana, for the survey on the scale of 24 inches=1 mile of the hill station of Mount Abu, and its extension as acquired on lease by the Government from the Sirahi Darbar, comprising an area of about 5500 acres; of which the leased portion consisted, for the most part, of rocky ground covered with scrub jungle and trees with some cultivated and grass

Mr. Duni Chand Puri was in charge of the survey of Allahābād and carried it out as below; after which he proceeded to Benares to advise and assist Mr. Daulat Ram Vohra in charge of the work there.

Revision survey of Allahābād cantonment, civil lines, and environs, on the 6-inch scale, comprising an area of 11,290 acres, and employing an average of 6 surveyors for 3 months.

Revision survey of Allahābād city on the 16-inch scale comprising an area of 2,706 acres and employing 7 surveyors for 2½ months.

Mr. Ghulam Hasan was in charge of the survey of Agra and carried it out as below; after which he proceeded to Lucknow to assist Mr. Calvert in charge of the work there.

Revision survey of Agra cantonment, civil lines, and environs, on the 6-inch scale, comprising an area of 10,862 acres, and employing an average of 7 surveyors for 1½ months.

Revision survey of Agra City, on the scale of 13·2 inches = 1 mile, comprising an area of 1,703 acres and employing 6 surveyors for 2½ months.

Mr. Daulat Ram Vohra was in charge of the survey of Benares and carried it out as follows:—

Revision survey of Benares cantonment, civil lines, and environs on the 6-inch scale comprising an area of 9,166 acres and employing an average of 4 surveyors for 2½ months.

Revision survey of Benares city, on the 16-inch scale, comprising an area of 1,875 acres and employing an average of 7 surveyors for 2½ months.

The out-turn and cost-rates of the foregoing are as follows:—

82 square miles	on the 4-inch scale	at Rs. 36·4	per square mile.
69,851 acres	on the 6-inch scale	at Rs. 5·0	per acre.
1,703	„ „ „ 13·2	„ „ „ 4·9	„ „
5,848	„ „ „ 16	„ „ „ 2·9	„ „

The 4-inch revision survey of the Delhi maps was carried out on vandyked blue prints pasted on Bristol boards of photographic reproductions of the previous biennial revision surveys. As town surveys were undertaken solely for the purpose of providing good Town Guide and not Property maps, no triangulation nor theodolite traversing was resorted to on which to base them. They were therefore carried out on vandyked blue prints, on Bristol boards, of photographic enlargements, reproductions or reductions, as the case required, of the most recent departmental and municipal maps available.

During the field season 1 unclassified surveyor, 1 traverser, 4 draftsmen and 14 pupils received instruction in plane-table traverse, which from its simplicity soon enabled them to take an active share in town surveys.

Mr. Vohra in charge, with two surveyors, started on the 25th June the detail survey of Mount Abu and leased area on the scale of 24 inches = 1 mile with 10 feet contours for the portion suitable for building sites and 50 feet contours for the rest of the area. He was joined by two more surveyors by the middle of July. The work is based on triangulation and traverse, which was specially executed for the purpose, with the exception of the cantonment area which is being revised on blue prints of the most recent map of that area.

The out-turn up to date is 584 acres, and the cost-rate works out at Rs. 4·9 per acre.

*Triangulation.*—This was carried out by Mr. Puri, shortly after his return to recess quarters for the special purpose of providing data for the Mount Abu survey. The work was based on 3 stations of the Mount Abu triangulation, executed in 1869-70, and an area of 5,000 acres was triangulated at a cost-rate of Rs. 138·7 per square mile.

*Traversing.*—With a view to testing the accuracy of the 16 inches = 1 mile blue print enlargements of a 4-inch survey of Lucknow city, on which framework it was decided to map all details from the air-photographs taken for the purpose, a plane-table traverse starting from a cantonment boundary pillar (one of the stations of the theodolite traverse on which the 4-inch survey was based) was run in circuits, over a distance of 24 linear miles, along the main streets and alleys. Two surveyors were employed on this work nearly a month and the cost-rate works out at Rs. 9·2 per linear mile.

A traverser was employed, for the special purpose of supplementing the triangulation data provided by Mr. Puri for the Mount Abu survey, in the congested and leased area where

41 linear miles of traverse was run with theodolite and by subtense bar and crinoline measurements at a cost-rate of Rs. 32·7 per linear mile.

*Recess Duties.*—Consisted of:—

- (a) Arrears of fair-mapping on 1½-inch scale of sheets 53/D/16, 54/A/9,13,14 and 63/M/4.
- (b) Arrears of fair-mapping on ¾-inch scale of sheets 54/A/NW, NE, SW, SE.
- (c) Fair-mapping of the Delhi revision survey on the 4-inch scale in 4 sheets.
- (d) Fair-mapping on 16-inch scale for publication on 12-inch scale of the towns of Agra, Allahābād, Benares and Cawnpore.
- (e) Fair-mapping on 6-inch scale for publication on 4-inch scale of the towns and environs of Agra, Allahābād, Benares and Cawnpore.

Owing to numerous changes, no officer had continuous charges of a section throughout the recess and the sections did not remain the same.

A drawing section was formed under Mr. D. C. Puri at Mussoorie on the 4th April to work off the arrears of 1-inch mapping of previous seasons; this was completed and sheets 53/D/16, 54/A/9,13,14 and 63/M/4 sent for publication.

Messrs. J. A. Calvert and D. C. Puri supervised the fair-mapping of half-inch sheets. The following sheets were taken up and it is hoped they will be completed by the end of the year:—

54/A/N.W., N.E. completed from original ½-inch survey and 1-inch published sheets and 54/A/S.E. completed from original ½-inch survey. Sheet 54/A/S.W. has also been commenced, but remains incomplete as 54/A/7 has not been surveyed.

Messrs. D. C. Puri and L. D. Joshi supervised the fair-mapping of the Delhi revision survey which comprised 4 sheets. As there were few alterations in the N.W. and N.E. sheets, these alterations were drawn on the original fair sheets of seasons 1912-13 and 1915-16 but the S.W. and S.E. sheets have been entirely redrawn. The N.W. and N.E. sheets have been submitted for publication but the other two will not be completed by the end of the season.

Messrs. H. P. D. Morton, L. D. Joshi, Ghulam Hasan and Daulat Ram Vohra supervised the fair-mapping of the 16-inch and 6-inch Town Guide maps.

The city areas are being mapped on the 16-inch scale for publication on the 12-inch scale and consist of the following sheets:—

Agra 3 sheets, Allahābād 2 sheets, Benares 2 sheets, and Cawnpore 2 sheets. The environment maps of the above towns are being drawn on the 6-inch scale for publication on the 4-inch scale and consist of 8 sheets (two for each town). The maps will be published on one sheet in all cases except the large scale map of Benares. The 16-inch maps of Agra and Allahābād only will be completed this season. The mapping of the remainder is backward for the following reasons:—

(a) Only pupil surveyors were employed on fair-mapping, and had to be taught and their work carefully supervised, the progress therefore was very slow.

(b) Final instructions for the fair-mapping of these maps were not received till late in the season.

The cost-rates of fair-mapping on the various scales dealt with during the year under report are as follows:—

16-inch scale for publication on 12-inch scale ...	Rs. 5·6	per acre.
6-inch do. do. 4-inch do. ...	Rs. 0·5	do.
4-inch do. do. do. do. ...	Rs. 70·4	per sq. mile.
¾-inch do. do. ½-inch do. ...	Rs. 3·3	do.

*Inspections.*—The party was inspected twice in the field and on several occasions during recess by the Superintendent.

## No. 3 PARTY (UNITED PROVINCES).

BY H. H. B. HANBY.

The head-quarters of the party remained at Mussoorie throughout the year, but a section

## PERSONNEL.

*Provincial Officers.*

- Mr. H. H. B. Hanby, in charge.  
 „ B. M. Berrill from 1st April 1919.  
 „ J. H. Johnson.  
 „ Moqimuddin from 13th January 1919.

*Upper Subordinate Service.*

- Mr. Paras Ram from 15th February to  
 30th June 1919.  
 „ A. A. S. Matlub Ahmad.

*Lower Subordinate Service.*

31 Surveyors, etc.

under a Provincial officer, assisted by an officer of the Upper Subordinate Service took the field during the first week of November to undertake forest surveys in the Dehra Dūn district (U.P.) and in parts of the Dhādi and Raingarh States (Punjab). The area covered by operations was hilly throughout and densely wooded.

Commencement of field work was delayed somewhat owing to influenza which was epidemic in November. Though there were some serious cases of pneumonia following influenza, there were only two deaths. The mortality would certainly have been much greater but for the personal attention

given by Mr. J. H. Johnson, the camp officer, to all the patients.

*Plane-tabling.*—The programme allowed for the survey of 189 square miles of reserved forest, on the scale of 4 inches = 1 mile, and this was completed by the middle of June. Mr. J. H. Johnson was assisted by Mr. Paras Ram, Sub-Assistant Superintendent in the conduct of field operations.

As there were only a few experienced hill surveyors available, and it was foreseen that the programme could not possibly be completed with this number, the field detachment was strengthened by the addition of some capable surveyors who had only experience of surveying in the plains. It was considered unfair that the Forest Department should be debited with the cost of training these surveyors in hill surveying, as progress would for a time be slow, so it was decided that the expenditure involved under this head should be borne by the Survey of India.

The cost-rate of the survey on the 4-inch scale works out to Rs. 115.4 per square mile exclusive of fair-mapping. The Forest Department allowed the party to decide along which boundaries a theodolite traverse was necessary. On account of this wise decision, a great saving was effected in time and expenditure and the whole area of survey was completed within a single field season.

*Triangulation and Traverse.*—Under these heads no fresh work was undertaken during the year under report.

*Recess Duties.*—The fair-mapping of all sheets was placed under Mr. Moqimuddin who joined the party during the second week in January. Mr. B. M. Berrill who was posted to the party in April assisted in the final examination of sheets. Owing to a small staff it has been found impossible to clear off arrears.

The following are the sheets dealt with:—

(a) For publication on 2-inch scale:—53/K/5 N & S., 53/K/9 N & S, 53/K/13 N & S, 53/K/14 N & S, 53/O/1 N & S, 53/O/2 N & S.

(b) For publication on 1-inch scale:—53/K/10, 53/O/3, 4, 7, 8. Of the sheets under (a) the following have been completed and await final examination by the officer in charge—53/K/5 N & S, 53/K/9 N, 53/K/13 N & S.

Of the sheets under (b) sheets 53/O/4, 3 have been submitted for publication, 53/O/3, 7 are under correction, and 53/K/10 awaits final examination.

Sheets 53/K/9 S and 53/K/14 N & S should be ready for final examination by the end of October.

Owing to the issue of fresh orders in connection with the preparation of Royal Artillery Practice Camp maps, the existing map of “Kutwa” may not meet requirements and may therefore have to be redrawn.

The cost-rate for fair mapping is Rs. 34.7 per square mile.

All arrears in computations were completed.

*Inspections.*—The party was inspected several times during recess by the Superintendent, Northern Circle, and visited once by the Superintendent of the Trigonometrical Survey and Superintendent, Map Publication respectively.

## SIMLA SURVEY DETACHMENT (PUNJAB).

BY W. H. STRONG, M. B. E.

The detachment took the field on 15th October 1918 for the purpose of preparing a large scale map of certain areas of the Simla Extension. The area embraced tracts in the vicinity of Potter's Hill, Jutogh Ridge, Prospect Hill, and Mashobra. The Mashobra area lies to the west of the Simla-Naldera Road between the old Toll Bar and the 8th mile-stone from Simla.

## PERSONNEL.

*Provincial Officer.*

Mr. W. H. Strong, M.B.E., in charge.

*Lower Subordinate Service.*

11 Surveyors, etc.

The health of the detachment was good on the whole during the influenza epidemic in November but one khalasi died.

*Plane-tabling.*—The total area surveyed amounts to 1551 acres. Of this, 1540 acres were surveyed on the scale of 125 feet = 1 inch, and 11 acres of the Jutogh Cantonment bazar, on the scale of 50 feet = 1 inch.

*Triangulation.*—Fifteen new stations were fixed by triangulation with the object of providing points to which subsequent traversing would be connected.

*Traversing.*—64 linear miles of traversing were run in connection with the entire area for survey.

*Recess Duties.*—On the completion of the field work, fair-mapping was taken in hand. During the year under report, 11 out of 19 sheets have been sent for publication. Of the remaining 8, 5 are well advanced and it is hoped they will be submitted for publication by the middle of October, the other three are in progress.

All computations have been completed, including those of about 1200 acres which will come under survey on the scale of 220 feet = 1 inch during next field season.

*Inspections.*—The Surveyor General inspected the detachment on 29th April 1919 and the Superintendent, Northern Circle on 20th December 1918.

## No. 4 PARTY (UNITED PROVINCES).

BY LIEUT.-COLONEL E. A. TANDY, R. E.

The charge of the party was taken over from Lieut.-Colonel McHarg on the 10th October 1918, by Lieut.-Colonel Tandy, who was then officiating as Superintendent Northern Circle, and who afterwards continued to hold charge of the party throughout the survey year.

## PERSONNEL.

*Imperial Officer.*

Lieut.-Colonel E. A. Tandy, R. E., in charge.

*Lower Subordinate Service.*

2 Clerks.

The topographical work of the party remained in abeyance, the officer in charge being employed on various special duties, which included the charge of a special records section, borrowed from other parties, for the purpose of assembling, sorting and storing all triangulation and traverse records of the Northern Circle, and dealing with the arrears of triangulation charts. The work of assembling, storing and indexing has now been completed, and the preparation of triangulation charts is in hand.



## SIND-SĀGAR PARTY (PUNJAB).

BY DHANI RAM VERMA.

The programme of the party undertaken in connection with the Punjab Government's Sind-Sāgar Canal and colonization project consisted of:—

## PERSONNEL.

*Provincial Service.*

Mr. Dhani Ram Verma, in charge.  
 „ J. C. C. Lears.  
 „ A. M. Talati, L.C.E., from 12th October 1918 to 30th June 1919.  
 „ Abdul Karim, B.A., from 3rd December 1918.  
 „ Moqimuddin, from 8th October 1918 to 12th January 1919.

*Upper Subordinate Service.*

Mr. Chuni Lal Kapur.  
 „ Nabidad Khan.

*Lower Subordinate Service.*

27 Surveyors, etc.  
 138 *Tahsildars, Naib Tahsildars, Kanungos, and Patwaris.*  
 (Revenue establishment).

(a). Traversing for the location of the corners of 4000-acre rectangles in country too thick to triangulate in parts of sheets 39/I/15 and 16; 39/J/13,14 and 15; 39/M/4; and 39/N/1 to 4.

(b). Location of the corners of 4000-acre rectangles from the triangulated and traversed points over the entire tract of the Doāb comprised in sheets 38/P/4,7,8,10,11,12,15,16; 39/I/15,16; 39/J/13 to 15; 39/M/1 to 16; 39/N/1 to 11,13; 43/D/3,4,7,8; and 44/A/1 to 4.

(c). Sub-demarcation of 4000-acre rectangles into 100-acre rectangles in the area comprised in sheets 38/P/4,7,8,10,11,12,15,16; 39/M/1,2,5,6,9,10,13,14; 43/D/3,4,7,8; and 44/A/1,2, by the patwari establishment, after receiving training in the first two months of the field season.

The locale of operations was the tract commonly known as the Sind-Sāgar Doāb situated between the Indus, Jhelum and Chenāb rivers and included parts of Miānwāli, Shāhpur, Jhang, and Muzaffargarh districts in the Punjab.

The general nature of the country is that of a vast rolling desert of sand dotted over with sand hillocks. A large portion is a treeless prairie 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 17th October 1918, and the field head-quarters opened at Miānwāli on the 24th October 1918. The office at Miānwāli was closed on the 7th May 1919 and the recess office was opened at Mussoorie on the 14th May 1919.

The opening of the field head-quarters at Miānwāli unfortunately synchronized with the outbreak of a virulent type of influenza epidemic, and although every effort was made to stem the tide of the disease, forty-one menials died. The Sub-Assistant Surgeon, who was wanted at the beginning of the field season, did not arrive till the 3rd November 1918 and the warm clothing which was to be supplied by the Indian Munitions Board was received very late, with the result that many sick khalasis had to be sent back to their homes. Mr. Moqimuddin was attacked with influenza and was compelled to take leave from 16th November 1918 to recoup his health. Surveyor Subhan Khan and unclassified draftsman Munshi Ram were also laid up for a fortnight. After the epidemic abated in November 1918, the health of the party became satisfactory.

At the commencement of the field season the party was divided into 4 camps, from the middle of December 1918 into 5 camps and from the middle of March 1919 again into 4 camps, as follows:—

*No. 1 Camp.*—Under Mr. J. C. C. Lears to 14th December 1918, with Mr. Nabidad Khan and 3 traversers and under Mr. Nabidad Khan from 14th December 1918, laid out 160 temporary marks by traverse near the 2000 and 4000-acre corners in parts of sheets 39/I/16; 39/J/13,14; 39/M/4; and 39/N/1 to 4. On completion of its work in the first week of March 1919 this camp was broken up. The traversers were transferred to No. 3 Camp and Mr. Nabidad Khan was transferred to No. 4 Camp. The detail of the traverse work is shown under the heading "Traversing".

*No. 2 Camp.*—Under Mr. A. M. Talati with 4 to 8 surveyors located 1600 actual 4000-acre and in some cases 2000-acre corners, embracing an approximate area of 7059 square miles in sheets 38/P/4,7,8,10,11,12; 39/I/15,16; 39/J/13,14; 39/M/1 to 3, 4 to 15,16; 39/N/1,2,3,4,5,6, 7 to 11,13; 44/A/1 to 4 and re-fixed 50 stations of the last year's preliminary triangulation. After completing the demarcation of main corners, this camp undertook 100-acre sub-demarcation

from the middle of March 1919 and laid out 380 100-acre corners on the long sides of the 4000-acre rectangles in sheets 39/M/2,6 and 860 100-acre corners inside the 4000-acre rectangles, embracing an area of 162·5 square miles in the latter sheet.

*No. 3 Camp.*—Under Mr. Chuni Lal Kapur with 6 to 10 surveyors located 230 actual 4000-acre and in some cases 2000-acre corners, embracing an area of 803·8 square miles, in sheets 38/P/15,16; 43/D/3,4,7,8 and laid out 3792 100-acre corners on the long side of 4000-acre rectangles, embracing an area of 3482 square miles, in sheets 38/P/4,7,8,10,11,12,15,16; 39/M/1,2,5,9,10,13,14; 43/D/3,4,7,8; and 44/A/1,2. After completing the allotted work, this camp, strengthened by two traversers from the middle of March 1919, undertook 100-acre sub-demarcation and laid out 2561 100-acre corners inside the 4000-acre rectangles, embracing an area of 432 square miles, in sheets 39/M/ 2,6,10,14 and 44/A/2.

*Nos. 4 and 5 Camps.*—According to arrangements made prior to taking the field it was expected that the revenue staff would join at the commencement of the field season but very few men were present when a training camp was formed under Mr. Chuni Lal Kapur for their instructions in laying out 100-acre corners in the open ground in the immediate vicinity of Kundiān Railway Station. The training continued till the 20th November 1918 when the patwaris were put on independent work under the supervision of a tahsildar assisted by naib-tahsildars and kanungos. The revenue staff was subsequently divided into two camps, viz., No. 4 Camp under Mr. J. C. C. Lears, who was recalled from the charge of Traverse Camp, and No. 5 Camp under Mr. Abdul Karim, who was transferred to this party from 3rd December 1918 to take the place of Mr. Moqimuddin, who had been invalided for the field. After personal representation of the officer in charge to the Director of Land Records at Lahore on the 6th January 1919, the revenue staff began to pour into Miānwāli from the 15th January and continued joining the party till the end of February 1919. As the men had joined at different times and were new to the work, considerable time was wasted in training them individually in the course of operations. The number of revenue men deputed to the party varied from 31 in November 1918 to 131 in April 1919.

The camp under Mr. J. C. C. Lears assisted by 1 tahsildar, 3 naib-tahsildars, 14 kanungos, and 46 patwaris laid out 7002 100-acre corners inside the 4000-acre rectangles, embracing an area of 1400·6 square miles, in sheets 38/P/4,7,8,10,11,12; 39/M/1,2,5,6,9,10. Mr. Nabadad Khan on completion of traverse work was attached to this camp from the 5th March 1919 to assist the camp officer in examining the work of the patwaris.

The camp under Mr. Abdul Karim assisted by 1 tahsildar, 3 naib-tahsildars, 16 kanungos, and 48 patwaris laid out 8271 100-acre corners inside the 4000-acre rectangles, embracing an area of 1619·3 square miles, in sheets 38/P/11,15,16; 39/M/10,13,14; 43/D/3,4,7,8 and 44/A/1,2. Surveyor Sher Gul who had joined the party on 2nd February 1919 on transfer from the Mesopotamian Survey Party was attached to this camp to assist the camp officer in examining the work of the patwaris. More details of demarcation are shown under the heading "Rectangulation".

In the earlier part of the field season, lower subordinates Partab Singh, Hari Singh and Abuzar were engaged in recruiting khalasis. The bulk of the menial establishment was recruited from Garhwāl, U. P. and the Punjab under great difficulties due to the heavy military recruitment and the prevalence of influenza. Some local men too were entertained but soon deserted. Their places were filled up by daily local labour.

*Nature of the country.*—The country rectangulated is locally known as "Thal" (sandy desert). The entire tract is sandy, studded with hillocks called "Tibbās" assuming generally a north-east and south-east direction and alternating with narrow strips of hard 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 north-east portion of the "Thal" is open and the rest is wooded in parts. The country is sparsely inhabited, the population being mostly pastoral. The northern part of the "Thal" is extensively cultivated with gram and the southern part has scattered wheat cultivation around wells in the "pattis". The people are generally willing and helpful. The water is brackish and bitter. The main transport is by camels.

*Triangulation ( Supplementary ).*—This was carried out to refix 15 points triangulated during the previous season which had not proved in computation and 50 points which could

not be found. As the area covered was in scattered portions it could not be calculated and as it had been credited to the area for last year's report, its cost has been included in that of the rectangular survey.

*Traversing.*—This was run with the theodolite and chain for the purpose of laying down temporary marks near the 2000 and 4000-acre corners in the country too thick to triangulate. 279.9 linear miles were traversed and connected with one secondary station and 5 principal stations of the Great Indus Series which skirts the western edge of the "Thal" and 13 azimuths were observed. The total area traversed was 405 square miles. The country covered by traverse consisted of sand hills and was thickly wooded with "Jand" trees and high grass which entailed very heavy line clearing and consequently made the progress very slow.

The computations were carried on as the work progressed and were completed in the field. The average angular error was 3" per station and the average linear error was 1 in 1000. The average cost-rate per linear mile of traverse including computation was Rs. 36.8.

83 rectangle plots of the area traversed were prepared and supplied to the main demarcation camp.

*Rectangulation.*—This, the chief programme, consisted of three successive operations:—(1) Location on the ground of the corners of 4000-acre rectangles. (2) Location on the ground of 100-acre corners on the long sides of the 4000-acre rectangles. (3) Sub-demarcation of the 4000-acre rectangles into 100-acre rectangles.

The actual main corners were laid out by the surveyors from the temporary marks near the corners of 4000-acre rectangles with theodolite and short and long chains and were marked by pyramidal topped monolith pillars, 7 inches square and 36 inches long, embedded 26 inches deep in the ground and 10 inches dressed portion exposed. 869 such pillars were embedded on the main corners of the 4000-acre rectangles in the agricultural or "Included Thal" and 430 double headed iron rails 75 lb. section and 6 to 8 feet long were embedded half length deep at the similar corners in the High or "Excluded Thal".

The 100-acre corners situated on the long sides of the 4000-acre rectangles were laid out by the surveyors by sub-dividing the long sides into 8 equal parts with theodolite and short and long chains and were marked by flat topped monolith pillars 6 inches square and 30 inches long, embedded 20 inches deep in the ground and 10 inches roughly dressed portion exposed. 4172 such pillars were embedded on the 100-acre corners situated on the long sides.

After the 100-acre corners had been marked on the ground on the long sides, the patwari establishment broke down the 4000-acre rectangles into 100-acre rectangles by sub-dividing the cross lines into 5 equal parts by long chain measurement and embedded 18694 flat topped monolith pillars on the 100-acre corners situated within the 4000-acre rectangles.

As the bulk of the revenue staff did not join the party till after the middle of the season, it was impossible for it to complete the programme of 100-acre sub-demarcation. The survey staff, having finished its work proper by the middle of March 1919, undertook inner sub-demarcation and laid out 3421 100-acre corners in the lower area of sheets 39/M/6,10,14, and 44/A/2, continuing field work till 2nd May 1919. The revenue staff carried on field work till 23rd April 1919.

The work was greatly hampered by violent sand storms which were frequent from the beginning of April 1919. The party although working under formidable difficulties from start to finish carried out its full programme except for 16 large rectangles left undemarcated in the lower part of sheet 39/M/2.

Rectangulation was carried out without much line clearing except in the very densely wooded portions of the country in sheets 43/D/7 and 39/M/1,2,5,6, but with the help of the optical square, much of this line cutting was avoided.

The men were made to work from the whole to the part, allowing a maximum error of 1 in 1000.

Nearly 73 per cent of the work was tested by 8221.2 linear miles partialled by the superior revenue staff and the survey officers. The total out-turn of rectangulation is shown in the annexed table.

Nature of work.	Number of corners located.	Number of 4000-acre rectangles demarcated.	Number of 100-acre rectangles laid out.	Area covered by main demarcation in square miles.	Area covered by sub-demarcation in square miles.
Location of main corners of 4000-acre rectangles.	1920 including 2000-acre corners.	1342 (partial and complete)	...	7863 (approximate)	...
Location of 100-acre corners on the long sides of 4000-acre rectangles.	4172	...	...	...	...
Sub-demarcation of 4000-acre rectangles into 100-acre rectangles.	18694	...	23324	...	3644.4
Total ...	24786	1342	23324	7863	3644.4

The traverse cost-rate of rectangulation executed, including computations, works out to Rs. 9.4 per corner and Rs. 63.9 per square mile or Re. 0.1 per acre.

In the course of operations the party replaced all the available stakes trigonometrically fixed in the previous season by monolith pillars having prismoidal tops with © engraved on them. They also replaced all those fixed by traverse, in the season of the year under report, by similar stones with × cut into the top, with a view to their preservation for future use.

The stakes marking the sites of 157 triangulated points of the previous season were lost. 50 points were refixed by triangulation and 90 by identification with old angles, the remaining 17, being near the 2000-acre corners, were not refixed.

*Recess Duties.*—In recess the strength of the party was much reduced. 6 men were transferred to Nos. 2 and 3 Parties and 6 men were lent to No. 3 Drawing Office to assist in fair-mapping. Mr. A. M. Talati on return from privilege leave was transferred to No. 1 Party.

The recess work was divided among three sections as follows:—

No. 1 Section.—Under Mr. J. C. C. Lears assisted by Mr. Nabadad Khan with 4 surveyors completed final computations of the points which were refixed in the season of the year under report and plotted more existing triangulation on the rough triangulation charts for Degree Sheets 38 P, 39 I, 39 M, 39 N, 43 D and 44 A which were prepared last year. On his proceeding on privilege leave on 1st August 1919, this section was amalgamated with No. 2 section, Mr. Nabadad Khan and one surveyor being transferred to the half-inch fair-mapping section.

No. 2 Section.—Under Mr. Chuni Lal Kapur with 4 to 6 surveyors completed the triangulation and traverse records of the Sind-Sāgar rectangular survey.

All computations have been completed and bound but no fair triangulation charts have been drawn for want of men.

No. 3 Section.—Mr. Abdul Karim was in charge of 6 pupils attached to the party from 2nd June 1919 for instruction in drawing. In addition, he supervised a section comprised of 1 Upper Subordinate and 5 surveyors etc. employed on the fair-mapping of 6 half-inch sheets 44/N/NW, NE, SW, SE, and 63/B/NW, NE, which were allotted to the party in the middle of the recess season. The first four were started in July, one more was taken up in August, and the last one in September. As the sheets will not be completed before the party leaves for the field, they will be made over to No. 3 Drawing Office for completion. For the same reason the out-turn and cost-rates of fair-mapping have not been calculated.

*Miscellaneous.*—With a view to employing the trained surveyors of the party on topographical surveys in the field season 1919-20, all but four of them will be transferred to other parties of the Northern Circle from 1st October 1919. To fill up the vacancies, 18 men suitable for rectangular survey were entertained from outside as purely temporary

traversers from the 15th September 1919. They have been given a training at Mussoorie in the rudiments of rectangular survey, but this preliminary instruction will be supplemented by a further training in the field before putting them on independent work.

*Inspections.*—The Superintendent, Northern Circle inspected the party in the field from 13th to 16th January 1919 and also during recess. The Superintendent, Map Publication accompanied by the Superintendent, Northern Circle inspected the half-inch fair-mapping of the party on 12th September 1919.

### RIVERAIN DETACHMENT (PUNJAB).

BY MAYA DAS PURI, RAI SAHIB.

The field season started on the 1st October 1918, and closed early in June 1919.

#### PERSONNEL.

##### Provincial Officer.

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

##### Upper Subordinate Service.

Mr. Paras Ram up to 14th February 1919.

" Ram Narayan Hastir.

" Lakshmi Dutt Joshi up to 21st July 1919.

" Vidya Dhar Chopra.

##### Lower Subordinate Service.

73 Surveyors, Traversers, etc.

3 Naib Tahsildars and 1 Kanungo (settlement establishment).

laid out by Lala Mul Raj, naib tahsildar.

The plotting section was mostly looked after by Mr. Vidya Dhar Chopra.

3. The detachment continued the work of traversing, and laying down base lines. 556 linear miles and 611 square miles of main circuits with 3,115 linear miles and 611 square miles of minor traverses were executed; 944 theodolite stations of the former, and 13,003 of the latter, were fixed in 179 villages; 1,026 corners of 342 squares were demarcated in 982 square miles with permanent mark-stones on both banks of the rivers Indus, Sutlej, Chenab, and Ravi in districts Dera Ghazi Khan, Muzaffargarh, Multan, and Bahawalpur State to serve as bases for the future survey and demarcation of boundaries and fields in the beds of the rivers; 2,034 plotted and 646 boundary *masavis* (settlement mapping sheets) on the scale of 1/2,640, and 41 four-inch sheets were traced and supplied in time to the settlement officers concerned. Three 4-inch sheets of the Chenab in districts Multan and Muzaffargarh were recompiled, owing to large differences in values between the old traverse done in season 1900-01 under Mr. R. B. Smart, and that now done by this detachment, and completed. In addition, 436 boundary *masavis* were partly compiled on the scale of 220 feet=1 inch for the next season's work, 190 miscellaneous traces were prepared and all the traverse stations marked during the year were plotted on 38 four-inch sheets. Some of the computation volumes still remain to be completed.

There was general scarcity of labour and transport especially towards the Bahawalpur side and much jungle cutting had to be done along the Indus and the Sutlej.

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

The office of the detachment remained at Jhelum till the 11th April 1919, after which it was shifted to Lahore where it remained till the close of the season.

2. Work on the Indus was divided into three camps, which were superxised by three upper subordinates, Messrs. Ram Narayan Hastir, Lakshmi Dutt Joshi, and Vidya Dhar Chopra.

The detail traversing on the 16 miles of the Chenab, in the Kabirwala *tahsil*, was carried under Mr. Paras Ram. The Sutlej work, main circuits; and the rectangulation were completed under the senior surveyor, Babu Ishwar Singh. The base lines on the Chenab and the Ravi, were

## FIELD WORK.

NAMES OF RIVERS, AND DISTRICTS AND SCALES.	MAIN-CIRCUIT.				MINOR TRAVERSE FOR DETAIL SURVEY.					BASE LINES.			REMARKS.
	Straight length in miles.	Number of square miles.	Number of linear miles.	Number of theodolite stations.	Straight length in miles.	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.	
<i>Indus River.</i> District Dera Ghāzi Khān and Bahāwalpur State. Scale 1/2,640.	...	...	...	...	60	405	1,705	6,774	72	309	103	508	* Portion of Indus between Muzaffargarh and Dera Ghāzi Khān had been completed in season 1917-18 with the exception of a few base lines which were laid out during the current season.
* Districts Dera Ghāzi Khān and Muzaffargarh. Scale 1/2,640.	...	...	...	...	60	...	30	126	...	108	36	...	
<i>Rāvi River.</i> District Multān (Kabirwāla tahsil). Scale 1/2,640.	...	...	...	...	40	...	78	372	...	231	77	119	
<i>Chenāb River.</i> Districts Multān (Kabirwāla tahsil) and Muzaffargarh. Scale 1/2,640.	...	...	...	...	10	43	253	992	20	78	26	77	
<i>Sutlej River.</i> District Multān (Mailsi tahsil) and Bahāwalpur State. Scale 1/2,640.	...	...	...	...	65	163	1,049	4,739	87	300	100	278	
<i>Sutlej River.</i> District Multān (Lodhrān and Shujābād tahsils) and Bahāwalpur State.	68	333	280	534	...	...	...	...	...	...	...	...	
<i>Chenāb River.</i> Districts Multān (Shujābād and Multān tahsils) and Muzaffargarh.	64	278	276	410	...	...	...	...	...	...	...	...	
Total ...	132	611	556	944	231	611	3,115	13,003	179	1,026	342	982	

## 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 of 4 inches = 1 mile.	Number of 4-inch sheets on which new work was plotted.
Indus ...	Dera Ghāzi Khān	1/2640	1,149	353	21	16
Sutlej ...	Multān ...	„	718	239	16	18
Chenāb ...	Multān ...	„	167	54	4	4
	Total	...	2,034	646	41	38

Besides these, 190 miscellaneous traces were prepared, and 436 boundary *masāvis* were partly compiled for the next season's work.

## OFFICE WORK DONE FOR THE 4-INCH COMPILATION OF RIVERAIN BOUNDARIES.

Name of river.	Name of series.	Number of sheets recompiled.	Number of sheets retyped.	Number of sheets finally examined and completed.
Chenāb ...	Multān Muzaffargarh	3	3	3
	Total	3	3	3

5. *The Multān rectangulation.*—At the request of the Settlement Officer, Multān, this work was undertaken during March, and was finished in April 1919, in 5 riverain villages of

the Sutlej in the Mailsi *tahsil*. The work was based on the Sutlej riverain traverse. 153 corners of 51 rectangles were demarcated with pegs in 22 square miles, forming 46 blocks. 176 stations were fixed with theodolite, and 34 linear miles traversed.

6. *The Jhelum town traverse.*—As asked for by the Deputy Commissioner, the Jhelum town traverse was commenced in March 1919, and was finished in April 1919. The work was based on the riverain traverse. 209 stations were fixed with theodolite and were permanently marked with stones; and 23 linear miles were traversed in 1,280 acres. Two plotted sheets, on the scale of 16 inches to a mile, were supplied during May to the Deputy Commissioner, Jhelum.

7. The riverain area under water action was usually broken and full of swamps, shrubs, high grass, and sand. The Indus which was over 12 miles broad, was cut into several small streams and creeks besides the two main channels, and was in places densely wooded, and contained large fertile cultivated tracts which had to be traversed. Portions of villages above the high banks were open, flat, and well inhabited.

8. The influenza attack was very virulent during October and November 1918, and retarded the progress of work seriously. Many men suffered. Several khalasis died but there were no deaths amongst the lower subordinates and officers of the detachment, for which much credit is due to Dr. Faqir Chand Bhandari, Sub-Assistant Surgeon. Plague was very bad in Jhelum during March and April 1919, due to which all the office hands were put to great inconvenience. For the remaining part of the year the health of the detachment was satisfactory.

9. The main circuits on the Sutlej were connected with Jhok T.S. XII, Nand Lal T.S. VIII, Hateji T.S. X, Godri T.S. XIV, Bakhiderā T.S. XVI, and Gaddan Platform Station XVIII; and those on the Chenāb with Shāh Mūsā Pole, and Khānpūr Dome.

10. The average errors were as follows:—

(a) Base lines and rectangles:—0·85 foot per corner of a riverain base line; and 0·66 foot per corner of a rectangle as compared with their theoretical values.

	Angular error per station in seconds.	Linear error in links per ten chains.
(b) Main circuits		
Sutlej ... ..	3·20	0·24
Chenāb ... ..	3·65	0·29
(c) Minor traverses		
Indus ... ..	8·15	0·93
Rāvi ... ..	7·58	0·56
Sutlej ... ..	9·41	0·81
Chenāb ... ..	7·68	0·69
Jhelum town ... ..	7·75	0·81

11. The total expenditure of the detachment from the 1st October 1918 to the 30th September 1919 was Rs. 1,17,074 as detailed below:—

Riverain survey	...	...	...	Rs. 1,14,938
Jhelum town traverse	...	...	...	„ 400
Multān rectangulation	...	...	...	„ 1,736

12. *Inspections.*—The detachment was inspected by the Superintendent, Northern Circle, during January 1919.

## SOUTHERN CIRCLE.

(Vide Index Map No. 1).

**Summary.**—This circle was under the superintendence of Colonel T. F. B. Renny-Tailyour, C. S. I., R. E. up to the 5th of March, under that of Major L. C. Thuillier, I. A. from the 6th to the 28th March and from the 29th March, under that of Lieut.-Colonel W. M. Coldstream, R. E. It comprised Nos. 5, 6, 7, 8 and 20 Parties, No. 4 Drawing Office, the Training Section, the Salonika Survey Detachment and the South-West Persia Survey Detachment.

The Salonika Survey Detachment returned to India in April.

During the year Nos. 5, 6, 7 and 8 Parties completed 7,263 square miles of detail survey on 2-inch and smaller scales, besides 33·5 square miles on larger scales, 3,367 square miles of triangulation and 591 linear miles of theodolite traversing.

The detail survey consisted of:—

	178 square miles of $\frac{1}{2}$ -inch original survey.
3,479	“ “ “ 1-inch original survey.
505	“ “ “ 1-inch revision survey.
2,852	“ “ “ 1-inch supplementary survey.
237	“ “ “ $1\frac{1}{2}$ -inch original survey.
12	“ “ “ 2-inch original survey.

No. 20 Party surveyed an area of 21,451 acres = 33·5 square miles in cantonments and military stations.

Owing to the shortage of supervising officers on account of the war, topographical survey operations were again considerably curtailed. Nos. 6 and 7 Parties took the field in comparatively weak strength and 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.

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

BY MAJOR L. C. THUILLIER, I. A.

This party took the field in reduced strength and completed the detail survey on the 1-inch scale of sheets 55/N/14 and 64/B/1, 2, 5, 6. The party also completed the triangulation of sheets 55/N/4, 8, 11, 12, 15, 15.

#### PERSONNEL.

##### *Imperial Officer.*

Major L. C. Thuillier, I. A., in charge from 29th March 1919.

##### *Provincial Officers.*

Mr. P. R. Anderson, in charge to 17th October 1918.

“ V. W. Morton, in charge from 18th October 1918 to 28th March 1919.

“ Haji Abdul Rahim, K. B.

“ F. C. Pilcher.

##### *Upper Subordinate Service.* ...

Mr. P. S. Vengsvami, from 1st October 1918.

“ Damodar Khadilkar. ...

“ Masud Khan, from 1st November 1918.

##### *Lower Subordinate Service.*

33 Surveyors, etc.

influenza on the 17th October 1918.

**Plane-tabling.**—The country surveyed is varied in nature. It comprises what is known as the plateau of the Sātpurā and consists of the mango studded plain around Mandlā and the rugged jungle covered jumble of hills which enclose the tortuous rock bound course of the Narbadā river in sheets 64/B/1, 2, 5, 6, and the Lakhnādon plateau, a well wooded rolling country of alternate ridges and hollows, in sheet 55/N/14.

The survey was done by 14 surveyors under Mr. F. C. Pilcher, who was assisted by Mr. Damodar Khadilkar and Mr. Masud Khan as assistant instructors to the young surveyors.

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

The field season opened on the 1st November 1918 and closed on the 31st May 1919. The head-quarters of the party remained at Bangalore throughout the year.

The health of the party in the field was not good. There was an outbreak of influenza among the field establishment soon after taking the field which greatly retarded work at the commencement of the field season. One surveyor and several khālās died and two surveyors had to be sent back to Bangalore as unfit for field work. Mr. P. R. Anderson who was in charge of the party died from



The 1-inch survey presented no great difficulties and the 1-inch revision survey was carried out as in former years on vandyked blue prints, on Bristol boards, of photographic reductions of previous 4-inch surveys.

A programme amounting to 1,442 square miles was completed. The total out-turn of 1-inch original survey and of 1-inch revision survey was 979 and 463 square miles respectively, the average monthly out-turn per man was 18·3 and 21·8 square miles, respectively, and the cost-rate per square mile was 23·3 and 22·9 respectively.

*Triangulation.*—The nature of the country triangulated is well-wooded, highly cultivated plains, interspersed with jungle covered hills which lie round the civil station of Seoni and fall in sheets 55/N/ 4, 8, 11, 12, 15, 16. An area of 1,652 square miles was completed by Mr. P. S. Vengusvami and the cost-rate per square mile was Rs. 6·4.

*Recess Duties.*—(a) The fair-mapping during the field season, owing to the shortage of officers at head-quarters, was under Mr. Haji Abdul Rahim, K. B. and consisted of half-inch sheets (compiled from 1-inch published sheets) 47/M/ s.w., 55/G/ N.E., 55/H/N.W., s.w., N.E., S.E., 55/K/ N.W., s.w., N.E., 55/L/ N.W., s.w., S.E. and the following 1-inch sheets not completed last recess.—55/C/ 11, 12, 15, 16.

Six ½-inch sheets (compiled from 1-inch published sheets) were taken over from No. 6 Party on its proceeding to the field, viz. 56/C/ N.E., S.E., 56/G/ N.W., s.w., N.E., S.E., and the officer in charge of the party personally supervised the fair-mapping of the two Royal Artillery Practice Camp maps of Kāpra and Rājankunti on the 3-inch scale.

On return of the parties from the field, the six ½-inch sheets were returned to No. 6 Party for completion and the fair-mapping of the party was divided into three sections as under:—

*No. 1 Section.*— Under Mr. V. W. Morton, ½-inch sheets (compiled from 1-inch published sheets) 47/M/ s. w., 55/H/ s. e. and 1-inch sheets 55/C/ 11, 55/N/ 14 and 64/B/ 5 and 6, also the 3-inch maps of Kāpra and Rājankunti.

*No. 2 Section.*— Under Mr. Haji Abdul Rahim, K.B., ½-inch sheets (compiled from 1-inch published sheets) 55/G/N.E., 55/H/N.W., s.w., 55/K/N.E., 55/L/s.w., and 1-inch sheet 55/C/12.

*No. 3 Section.*— Under Mr. F. C. Pilcher, ½-inch sheets (compiled from 1-inch published sheets) 55/H/N. E., 55/K/N.W., 55/L/N. w., s. e. and 1-inch sheets 64/B/1,2.

1-inch sheets 55/C/11, 12, 15, 16 were sent for publication during the year and the current season's 1-inch sheets, 55/N/14 and 64/B/1, 2, 5, 6, will also be sent for publication before the end of recess. The two Royal Artillery Practice Camp maps of Kāpra and Rājankunti and ½-inch sheet 55/K/ s. w. were sent for publication during the year. ½-inch sheets 47/M/ s. w. and 55/K/ N. w. will be submitted for publication before the end of the recess season. ½-inch sheets 55/G/N.E., 55/K/N.E. are also nearly ready for submission and may be completed before the party takes the field. ½-inch sheets 55/H/N. W., s. W., N. E., S. E. and 55/L/ N. w., s. w., s. e. are well on, but will not be completed this recess.

There will be no arrears of 1-inch fair-mapping by the end of the recess.

A total area of 2481·3 square miles was mapped by the party on the 1-inch scale, an area of 5489 square miles on the ½-inch scale and an area of 139·4 square miles on the 3-inch scale; the cost-rates per square mile being Rs. 4·5, Rs. 2·4, Rs. 18·2 respectively.

(b) All computations will be completed up to date and bound before the party takes the field. Owing to the dearth of officers no work was done on the preparation of data for triangulation charts and pamphlets.

The arrears of triangulation charts and pamphlets consist of the completion of degree sheets 46O and P.48K, 55H, I, J, K, L, M and O which have been prepared in old form but have to be resubmitted in new form, and degree sheets 55D and G have yet to be taken up.

## No. 6 PARTY (BOMBAY AND HYDERĀBĀD).

By J. O'B. DONAGHEY.

This party completed the detail survey on the  $\frac{1}{2}$ -inch scale of portions of the Hyderābād State in sheets 56/D/ 7, 8 on the 1-inch scale, of sheets 56/D/ 1 to 6 and parts of sheets 56/D/ 7, 8 and, on the  $1\frac{1}{2}$ -inch scale, of scattered areas of Hyderābād State reserved forests in sheets 56/H/ 1, 5, 6, 9, 10, 13, 14 and 56/L/1. The party also undertook the triangulation for the  $\frac{1}{2}$ -inch scale of sheets 56/O/1, 2, 5, 6, 9, 10.

## PERSONNEL.

*Provincial Officers.*

Mr. J. O'B. Donaghey, in charge.  
 „ E. A. Meyer.  
 „ Munshi Lal, B. A.  
 „ N. S. Harihara Iyer.

*Upper Subordinate Service.*

Mr. Eknath Battu.  
 „ K. Mandanna.  
 „ E. N. Natesan, B. A.

*Lower Subordinate Service.*

23 Surveyors, etc.

The reserved forest areas consist of hills covered with open forests, the remainder of the country is undulating and mostly cultivated.

The field season opened on the 25th November 1918 and closed on the 30th April 1919. The field head-quarters was at Bijāpur.

The health of the party was, on the whole, good, though, owing to influenza, the commencement of field work was considerably delayed; there were 15 deaths among the menials, eight being due to influenza.

*Plane-tabling.*—The nature of most of the country surveyed is open, undulating and highly cultivated, with some broken and hilly ground in the south-eastern corner. The reserved forest areas consist of wooded hills.

The work was divided among two camps as follows:—

*No. 1 Camp.*—Under Mr. Meyer, with one Provincial Officer, Mr. Harihara Iyer, one Upper Subordinate Officer, Mr. E. N. Natesan, B.A. and twelve surveyors, completed the original survey on the  $\frac{1}{2}$ -inch scale of parts of sheets 56/D/ 7, 8 and, on the 1-inch scale, of parts of sheets 56/D/ 3, 4, 5, 6, 7, 8 and the supplementary survey on the 1-inch scale of sheets 56/D/ 1, 2 and parts of sheets 56/D/ 3, 4, 5, 6, 7, 8.

*No. 2 Camp.*—Under Mr. Munshi Lal, B. A. with one Upper Subordinate Officer, Mr. K. Mandanna, and four surveyors, was employed on the special survey of scattered reserved forests of the Hyderābād State in sheets 56/H/ 1, 5, 6, 9, 10, 13, 14, and 56/L/ 1.

Owing to the reduced strength of the party, due to the transfer of members on field service, the delay caused through influenza in commencing field work, and the late receipt of permission from the Hyderābād State Government to carry on survey operations, the original programme of the party had to be reduced. A total of 2,359 square miles was completed. The out-turn of the  $\frac{1}{2}$ -inch original, 1-inch original, 1-inch supplementary and  $1\frac{1}{2}$ -inch original survey was 178, 274, 1,670 and 237 square miles, the average monthly out-turn per man 50·4, 32·0, 36·0 and 11·7 square miles, and the cost-rates per square mile Rs. 16·2, Rs. 21·7, Rs. 13·7 and Rs. 62·6 respectively. Of the total area surveyed 1,670 square miles are in the Bijāpur district of the Bombay Presidency, the remaining area, 689 square miles, being in Hyderābād.

*Triangulation.*—The nature of the country is hilly in sheet 56/O/ 1 and undulating, interspersed with rocky knolls, in the remaining sheets. There was only one triangulator, Mr. Eknath Battu, who completed an area of 1,699 square miles in sheets 56/O/ 1, 2, 5, 6, 9, 10 for survey on the  $\frac{1}{2}$ -inch scale.

The cost-rate per square mile was Rs. 8·4. The whole area is in the Hyderābād State.

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

*No. 1 Section.*—Under Mr. Meyer,  $\frac{1}{2}$ -inch sheets (surveyed in 1917-18) 56/C/N.E.S.E. and 56/G/N.W.S.W. and 56/C/S.W. which is being fair-mapped from published 1-inch maps, and 1-inch sheets (surveyed in 1918-19) 56/D/1, 2, 3, 4, 5, 6, 7, 8.

*No. 2 Section.*—Under Mr. Munshi Lal, B.A.,  $\frac{1}{2}$ -inch sheets (surveyed in 1917-18) 56/G/N.E.S.E. and the fair-mapping on the 2-inch scale of the reserved forests surveyed in the Hyderābād State as follows:—33 sheets of areas surveyed previously and 7 sheets of areas surveyed during the year.

The six  $\frac{1}{2}$ -inch sheets 56/C/N.E.S.E. and 56/G/N.W., S.W., N.E., S.E., which were commenced last year, have been completed and all have been submitted to the Circle office,

except 56/G/N.W. which has been kept back owing to references to local authorities, sheet 56/C/S.W., which is being drawn from component 1-inch maps published in 1918, is well in hand and, 1-inch sheets 56/D/1,2,3,4,5,6,7,8, will all be completed before the party takes the field; 19 2-inch special forest sheets have been completed and submitted for publication; 14 2-inch special forest sheets, which were commenced last year, have also been completed and will shortly be submitted for publication and the fair-mapping of the 7 2-inch special forest sheets surveyed during the year has been well advanced but it will probably not be possible to submit these for publication before the party takes the field. The arrears of fair-mapping are:—the ½-inch sheet of 56/G/N.W. and the fourteen 2-inch special forest sheets which were commenced last year.

The shortage of officers has been keenly felt in tackling the heavy fair-mapping programme during the year.

The cost-rates for fair-mapping are as follows:—

Rs.	5.4	per square mile for	½-inch.
„	3.8	„ „ „ „	1-inch.
„	16.0	„ „ „ „	2-inch.

The computations of the triangulation have not been completed. The arrears of computations are as follows:—about half of sheet 56H, a portion of sheet 56L, sheets 56/O/1,2,3,4,5,6,7,8,9,10,11,12,15,16, 56/P/1,5,9,13 and portions of sheets 56/P/2,3,4,5,6,9,10,13,14 which have been triangulated by this party.

No triangulation charts have been undertaken by the party and the preparation of triangulation charts 56 A,B,C,E,F,G and K has yet to be taken up.

#### No. 7 PARTY (MADRAS).

BY H. B. SIMONS.

This party completed the detail survey of sheets 57/M/9,10,12,13 to 16 and 66/A/3,4 on the 1-inch scale and also reserved forest areas in sheet 57/M/12 on the 2-inch scale.

##### PERSONNEL.

##### *Provincial Officers.*

- Mr. W. M. Gorman, in charge to 31st October 1918.
- „ C.E.C. French, in charge from 1st November 1918 to 30th May 1919.
- „ H.B. Simons, in charge from 31st May 1919.
- „ F.W. Smith.
- „ M.S. Ganesa Aiyar.

##### *Upper Subordinate Service.*

Mr. Pulin Behari Roy.

##### *Lower Subordinate Service.*

18 Surveyors, etc.

The nature of the country generally comprised open expanses of cultivated land, with isolated barren rocky hills standing out conspicuously from the plains and well distributed over the area.

The recess office of the party closed at Bangalore on the 25th October 1918 and the field head-quarters opened at Ongole on 1st November 1918. The office at Ongole was closed on 8th May 1919 and was opened in Bangalore on 16th May 1919.

During the month of November, work was considerably delayed owing to the north-east monsoons.

The health of the party was not good. Influenza and cholera, which were prevalent when the party took the field, broke out among the members: Surveyor Abdul Basit and 8 khalasis died, 5 from the former and 3 from the latter disease. In addition to the above casualties, two men died from natural causes.

*Plane-tabling.*—The country surveyed comprised highly cultivated undulations dotted over by isolated small groups of hills, mostly boulder strewn and covered with thorny scrub. A few disjointed hill ranges of 5 to 6 miles in length and from 1000 to 2000 feet in height, were met with in the north-west portion of the area, the most important being Podilikonda and Chimākurti.

The forest-clad areas comprised stretches of low scrub with few communications, the survey of which was completed by much laborious chaining.

The Paleru, the Mūsi, the Upputeru and the Gundlakamma are the principal rivers and flow from west to east.

There are numerous tanks for irrigation purposes, the largest being the Bavanāsi at Addanki in the Ongole taluk, which was recently completed, and irrigates an area of nearly 800 acres. The whole country is generally open and easy of survey except towards the sea where the ground is covered with numerous casuarina plantations, fringed with a dense belt of cocoanut palms, towards the extreme edge of the coast.

Difficulties were experienced with regard to supplies, water and labour. Scarcity prevailed in parts of the country owing to a deficient monsoon. Water is always bad, due to guinea worm, and the drying up in April of tanks, which form the main source of supply, made matters rather trying for surveyors towards the end of the season.

The party was divided into 2 camps, one under Mr. F. W. Smith and the other under Mr. M. S. Ganesa Aiyar.

*No. 1 Camp.*—Under Mr. Ganesa Aiyar, with 8 surveyors, completed an area of 1,144 square miles on the 1-inch scale in sheets 57/M/9,10,13,14. One pupil surveyor Ram Narayan Sharma (since dismissed) absconded during the field season.

*No. 2 Camp.*—Under Mr. F. W. Smith, with one upper subordinate, Mr. Pulin Behari Roy, and 5 surveyors, completed an area of 1,082 square miles on the 1-inch scale in sheets 57/M/12,15,16 and 66/A/3,4 and 12 square miles on the 2-inch scale of Pedairlapadu, Magalicherla, Ayyavaripalle and Pedacherlopalle reserved forests, falling in sheet 57/M/12.

A total area of 2238 square miles was surveyed. The total out-turn of the 2-inch survey and 1-inch survey was 12 and 2226 square miles respectively, the average monthly out-turn per man being 10.0 and 30.5 square miles, and the cost-rate per square mile Rs. 19.0 and Rs. 13.7 respectively.

*Triangulation.*—No triangulation was executed.

*Recess Duties.*—The fair-mapping was divided into two sections:—

*No. 1 Section.*—Under Mr. F. W. Smith, till the 23rd June 1919, and Mr. H. B. Simons, the officer in charge of party, from the 24th June 1919, assisted by Mr. Pulin Behari Roy, drew sheets 57/M/12,15,16 and 66/A/3,4 all of which will be sent for publication before the end of the recess.

*No. 2 Section.*—Under Mr. M. S. Ganesa Aiyar, drew sheets 57/M/9,10,13,14 which will also be sent for publication before the party takes the field.

The total out-turn of fair-mapping is 2,238 square miles and the cost-rate is Rs. 9.3 per square mile.

The arrears of computations of last season in 56 L and 57 I were completed during the field and early part of the recess seasons. The computations of the northern half of 57 J were taken in hand by computer Shaikh Subhan assisted by surveyor Saiyid Sulaiman in the beginning of June and should be completed by the end of the year. No progress was made with the fair triangulation charts of the party, as no officer was available for the work.

The following table shows the present state of work:—

*Computations.*—Current work—nil.

Arrears—57 J (northern half). Computations of intersected points.

The computations of 56 P and 57 M are completed and bound and awaiting detail survey. Those of 57 I are computed and have yet to be bound.

*Triangulation Charts and Pamphlets.*—

1. Submitted for publication.

48 L and P, 57 L and P, 66 D.

2. Remaining for preparation.

48 K, 57 H and N, 66 B, 57 O and 66 C (combined).

#### No. 8 PARTY (MADRAS).

By W. M. GORMAN.

This party, in reduced strength, took the field with its head-quarters at Aramboli and completed the survey on the 1-inch scale of

##### PERSONNEL.

###### Provincial Officers.

Mr. W. M. Gorman, in charge from 1st November 1918.

.. C. E. C. French, in charge up to 31st October 1918.

.. M. Mahadeva Mudaliar, M. A.

###### Upper Subordinate Service.

Mr. K. Narayanaswami Chetti.

.. H. Narasimhamurti Rao.

.. Shaikh Muhammad Salik.

###### Lower Subordinate Service.

87 Surveyors, etc.

.. **mad Wasil** died on the 15th March 1919.

.. completed the survey on the 1-inch scale of sheets 58/H/4,7,8,11,12,15,16, 58/L/3 and the traversing of sheets 58/K/13,14, 58/O/1,2.

The remaining members of the party with head-quarters at Bangalore, carried out the fair-mapping of 1-inch and ½-inch sheets.

The field season opened on the 21st November 1918 and closed on the 6th June 1919.

During the above period the health of the section was considerably affected for the first two months by the influenza epidemic, and throughout the season by fever while working in the hills. A khalasi succumbed to cholera and surveyor Muham-

The country surveyed comprises a portion of the Western Ghâts, mostly forest-clad, bold and rugged in its northern reaches, but losing much of its characteristic boldness and steepness as it approaches the sea on its southward trend to Cape Comorin. It divides the country on its flanks into undulating and low lying plains, intensely cultivated and dotted with numerous scattered huts and village sites and covered with a dense growth of palmyras.

*Plane-tableing.*—The high ground on the Travancore side of the Ghâts presented many difficulties to the surveyor in its thickly clad and intricate nature, lack of communications and transport, malarious climate, and the tendency to be enveloped in fog and cloud; while the lower slopes and undulating country at its base involved endless labour in the extensive cultivated valleys, dotted with numerous scattered huts and gardens and covered with a dense growth of palmyras, where the laborious process of traversing with plane-table and chain had to be resorted to.

On the Tinnevely side of the Ghâts, the hills rise abruptly from the plains, which slope almost imperceptibly to the sea, with red sand dunes along the coast. The wide expanse, being studded with numerous tanks and covered with a fairly open growth of palmyras and other trees, was found comparatively easy.

*No. 1 Camp.*—Under Mr. M. Mahadeva Mudaliar, assisted by Mr. K. Narayanasvami Chetti, with 13 surveyors, supplemented later on in the season by two others, completed a total area of 1,224 square miles on the 1-inch scale, of which 1,182 square miles were supplementary survey and 42 square miles revision survey. The monthly average out-turn per man for both classes of survey was 16·4 and 17·0 square miles, respectively, and the cost-rate was 17·6 and 14·6 square miles respectively.

For the above survey, 1-inch blue prints on Bristol boards, embodying the 1-inch prints supplied by the Madras Revenue Survey and areas previously surveyed on the 4-inch scale by the Survey of India, reduced to the 1-inch scale, were obtained from the Southern Circle Office. These prints were gone over on the ground and rigorously surveyed and the accurate detail contained in them considerably helped on the work.

*Triangulation.*—No triangulation was undertaken as the area triangulated in advance is sufficient for the next two seasons.

*Traversing.*—248 linear miles of theodolite traversing with heights, in sheets 58/K/13,14 and 58/O/1,2 were run by surveyor V. Varadaraju Nayadu, along the coast and inland, in flat featureless country with a fairly thick growth of palmyra trees. In order to supply data for the survey when undertaken, the traverses were connected with 13 trigonometrical stations and 43 azimuths were observed.

The cost-rate is Rs. 31·3 per linear mile.

*Recess Duties.*—

*No. 1 Section.*—The current season's work under Mr. M. Mahadeva Mudaliar, in sheets 58/H/4,7,8,11,12,15,16 and 58/L/3, is fairly advanced, considering the late arrival of the section from the field. Of the above, sheets 58/H/4,16, 58/L/3 have been completed and submitted for publication and the remainder will be ready before the party leaves for the field.

In addition, last season's fair-mapping of the party, together with fourteen sheets on the 1½-inch scale, made over by No. 7 Party, on their taking the field in November 1918, were completed and despatched for publication.

The total area under 1½-inch fair-mapping is 1,448·2 square miles and its cost-rate is Rs. 23·9 per square mile.

*No. 2 Section.*—Under Mr. K. Narayanasvami Chetti and, after his departure for the field, under Mr. Shaikh Muhammad Salik, carried on the fair-mapping of the following ½-inch sheets on the ¾-inch scale compiled from previous 1-inch published sheets, viz. 48/K/N.E., 57/N/S.E., 57/O/N.W., S.W., N.E., S.E., 57/P/N.W., S.W., N.E., S.E., 58/D/N.E., 58/G/S.W., 66/B/S.W. and 66/C/N.W., S.W. Of these, sheets 48/K/N.E., 57/P/N.W., S.W., N.E., S.E., 58/D/N.E., 66/B/S.W. and 66/C/N.W. have been submitted for publication and the remainder are well in hand.

The total area fair-mapped on the ¾-inch scale is 6,470·9 square miles and its cost-rate is Re. 0·8 per square mile.

The preparation of triangulation charts and computations was under the supervision of Mr. B. T. Wyatt, from the date of his transfer from the Salonika Survey Detachment to the date of his transfer to the Northern Circle. In this short period, chart 49 M was practically completed, leaving 58 A and 58 B as arrears.

Traverse computations, sufficient to meet the coming field season's programme, have been completed. Sheets 58/K/5,6,9,10, traversed in 1917-18, and sheets 58/K/13,14 of the current season, are arrears. These will be proceeded with during the coming field season and recess.

### No. 20 PARTY (CANTONMENT).

BY C. E. C. FRENCH.

During the year under report this party completed the survey of the cantonments and

#### PERSONNEL.

##### *Provincial Officers.*

Mr. B. R. Hughes, in charge to 2nd June 1919. A revision survey of the *bāzārs* of Secunderābād and  
 " O. E. C. French, in charge from 3rd June 1919. Bolārum on the scale of 50 feet to 1 inch is in pro-  
 " O. D. Jackson. gress of which about one-half is completed.

##### *Upper Subordinate Service.*

Mr. Dharmu. The triangulation and traversing of the follow-  
 " Jitendra Mohan Mukerji. ing cantonments etc. have been completed during  
 the year :—

##### *Lower Subordinate Service.*

22 Surveyors, etc.

Wellington, Cordite Factory at Aravanghāt, St. Thomas' Mount, Pallāvaram, Zone of Fort St. George, ground required for, (a) manufacturing water supply channel from Bairani stream to Cordite Factory boundary and (b) drinking water supply from Dodabetta to Cordite Factory boundary, Cordite Factory grounds at Kārteri and for the High Tension Line from Kārteri to Aravanghāt, Ketī cemetery (Rest Camp), Lovedale Estate for the Lawrence Memorial School, grounds on which the military buildings at Ootacamund are erected, West Hill (Calicut), Secunderābād and Bolārum.

Forty fair maps have been submitted for publication, forty-nine remain which will be submitted by the end of 1919.

The head-quarters of the party remained in Secunderābād during the season.

The health of the party has been indifferent during the year, several members suffering from malaria and influenza.

*Plane-tableing.*—The total area in acres surveyed on the 16-inch, 64-inch and 50-feet (revision) scales, is 20,865, 92 and 49½ acres, respectively, at a cost-rate of Rs. 0·99, 18·45 and 9·72 per acre, respectively.

The accuracy of the detail survey has been tested by Messrs. Hughes, French, Jackson and Dharmu by 75·40 linear miles and 352 *in situ* fixings.

*Triangulation.*—Mr. Dharmu and surveyor Gokul Chand were employed on the triangulation in Wellington and West Hill, where 13 stations and 18 intersected points were fixed over an area of 16 square miles at a cost-rate of Rs. 14·3 per square mile.

*Traversing.*—During the year Messrs. Dharmu and Mukerji and 4 surveyors have been employed on the traversing of Secunderābād, Wellington, Ootacamund, Pallāvaram, Fort St. George, St. Thomas' Mount, West Hill and Madras military lands (nearly completed) in which 343·37 linear miles have been run at a cost-rate of Rs. 53·01 per linear mile, the quality of which is good.

Steps are being taken to supply the local engineers with charts for the preservation of the theodolite points fixed.

*Levelling.*—56·15 miles of levelling have been run in Secunderābād, St. Thomas' Mount, Pallāvaram and Fort St. George and 26 bench-marks fixed, at a total cost of Rs. 487, or Rs. 8·67 per mile.

*Recess Duties.*—The fair-mapping for the season included the following cantonments :—Chaman, Drosh, Chitrāl, Thath, Delhi new cantonment, Agar, Erinpura, Jhānsi, Aurangābād, Ahmadnagar, Manora, Hosūr, Bellary, and comprised sixty-three sheets on scales of 16 and 64 inches to a mile.

Fair maps of the seven first named cantonments, also of Jatta, Zām, Jandola, Drazinda, Nasirābād and Ghairat, completed previously, comprising forty sheets, have been submitted for publication, the remainder will be despatched by December 1919.

The programme for season 1919-20 includes the detail survey of the military stations and lands of Wellington, Ootacamund, Pallāvaram, Fort St. George, St. Thomas' Mount, West Hill, Madras military lands as well as the traversing and survey of Bangalore, Civil and Military Station, Madras military lands and Cannanore.

## EASTERN CIRCLE.

(*Vide* Index Map No. 1)

*Summary.*—This circle was under the superintendence of Lieutenant-Colonel C. L. Robertson, C.M.G., R.E., throughout the year.

For the greater part of the year it comprised Nos. 9, 10, 11 and 12 Parties, and No. 5 Drawing Office. A Burma forest survey party was raised on 1st May.

During the year, the circle completed 9,914 square miles of detail survey, 6,245 square miles of triangulation and 758 linear miles of theodolite traversing. 19·8 square miles of large scale surveys were also completed.

The detail survey consisted of:—

	3,738	square miles of	$\frac{1}{4}$ -inch	revision survey.
	2,346	”	”	” $\frac{1}{2}$ -inch original survey.
	3,676	”	”	” 1-inch original survey.
	56	”	”	” 1-inch revision survey.
	98	”	”	” 2-inch original survey.

In addition to the four parties mentioned above, a detachment, called the Kūki Survey Detachment, was formed at the end of March for the purpose of revising parts of the existing  $\frac{1}{4}$ -inch maps of the areas in which the Kūki Punitive Measures Force operated, and, from 1st May, a new forest survey party was formed for the purpose of the execution of the survey of the reserved forests of Burma. This party has been given the designation of Special Burma Forest Survey Party. Financially it is a charge against the provincial revenues, though its personnel is entirely that of the Survey of India Department, and it is under the control of the Superintendent of the Eastern Circle in all respects.

The Kūki Survey Detachment remained in being for about 2½ months.

Nos. 10 and 11 Parties each detailed a surveyor earlier in the year to accompany the portion of the Kūki Punitive Measures Force which was operating from the side of Burma. These surveyors were placed under the orders of a military officer of the force.

### No. 9 PARTY (BENGAL).

By E. J. BIGGIE.

The sanctioned programme of the party for season 1918-19 had to be abandoned owing to an urgent call for Town Guide maps on the 12-inch scale of Barrackpore and Dum-Dum, and it was only near the end of the field season that the party was able to undertake the survey of sheets 79/B/1 and 5.

#### PERSONNEL.

##### *Provincial Officers.*

Mr. E. J. Biggie, in charge.  
 „ A. B. Hunter.  
 „ Amar Krishna Mitra.  
 „ H. T. Hughes from 17th July 1919.

##### *Upper Subordinate Service.*

Mr. Amalya Charan Ghosh.  
 „ Gopal Lal Mitra.

##### *Lower Subordinate Service.*

23 Surveyors, etc.

The areas surveyed, on both the 1-inch and 12-inch scales lay in Bengal. They are dead level, except where, near the river Hooghly, the ground slopes away gently towards its banks. The country is well cultivated and thickly populated, though the villages, in almost every instance, are hidden from view in dense woods. The one large and important river which flows due south through the work, is the Hooghly which divides sheet 79/B/5 into two almost equal parts. A belt of country, a few miles in width, on both banks of the river is very congested, there being several large towns and villages, centres of industry, situated on each bank. On the right bank are the ancient towns of Chinsura and Serampore and the French Settlement of Chandernagore, while on the left bank are situated the cantonment of Barrackpore, the towns of Naihati and Titagarh, the last named possessing the most extensive jute mills of the suburbs of Calcutta. In the south-east corner of sheet 79/B/5, Bariti Bil, one of the several large marshes or bils with which the Twenty-four Parganas, like other deltaic districts, are studded, occupies an area of 6½ square miles. There are excellent means of communication, the country being well served with a net-work of railways, besides a good number of first and second class roads which traverse the country in all directions.

The field season extended over a period of about 7 months from October 1918 to April 1919, but, practically this entire period was taken up by the large scale surveys of

which mention has already been made. The field office of the party opened at Dum-Dum on the 21st October 1918 and closed on the 24th April 1919, but Mr. A. B. Hunter remained out with his camp till near the end of May to complete sheet 79/B/1 which was started in the first week of April.

A section under Mr. A. K. Mitra remained at Shillong to deal with the arrears of one-inch and half-inch mapping.

The health of the party was anything but good. At the beginning of the season there was a great deal of sickness and eight menials died from malaria and influenza. During the season, surveyors and menials were, from time to time, ill with malaria and a pupil surveyor was compelled to take 3 months' leave to recuperate his health which had suffered from a severe attack of malaria.

*Plane-tabling.*—The area surveyed on the 12-inch scale covered the cantonments of Barrackpore, Ichāpur and Dum-Dum and country within a radius of about  $1\frac{1}{2}$  miles from cantonment limits, and, in the case of Barrackpore and Ichāpur, included a strip about 200 feet wide on the right bank of the river Hooghly.

In the cantonments of Barrackpore, Ichāpur and Dum-Dum supplementary surveys were carried out and, in the remainder of the area, an original survey. The supplementary surveys were executed on blue-print reductions on the 12-inch scale, which were obtained from the 16-inch cantonment maps of Barrackpore and Dum-Dum and from the 200 feet to the inch scale map of Ichāpur which was prepared in the previous season. The work was divided into two camps.

The wooded villages and clusters of trees in the area of 1-inch survey restricted the view, and plane-tabling by traversing, rather than by interpolation, had to be resorted to a great deal. At the start, the work on the 1-inch scale was for purely instructional purposes, four pupil surveyors being placed under training with a senior surveyor as instructor, who also helped in the completion of the detail survey. As the large scale surveys for the Town Guide maps claimed almost the entire attention of the party in the field, for convenience of supervision and instruction, two pupil surveyors each were allotted to Mr. E. J. Biggie and Mr. A. B. Hunter. As each surveyor completed his 12-inch work, he was put into one or other of the 2 camps, which were then dealing with the 1-inch work.

The party was organised in 2 camps throughout the field season, the personnel of which was varied from time to time as occasion required.

*No. 1 Camp.*—Under Mr. E. J. Biggie, surveyed 842 acres of supplementary survey in Dum-Dum, 4,293 acres (original) in Barrackpore and 950 acres (original) in Dum-Dum, also 122 square miles on the 1-inch scale in sheet 79/B/5.

*No. 2 Camp.*—Under Mr. A. B. Hunter surveyed 1,639 acres (supplementary) in Barrackpore and Ichāpur and 4,919 acres (original) in Barrackpore, also 426 square miles on the 1-inch scale in sheet 79/B/1.

Sheet 79/B/1 was started very late in the season and, to ensure its completion, the sheet had to be divided into several plane-table sections.

The average monthly out-turn per man for original survey on the 12-inch scale was 415.4 acres and, for supplementary survey on the same scale, 347.6 acres.

Plane-tabling on the 12-inch scale was carried out by direct measurements to detail from the stations of a theodolite traverse which were supplemented by a plane-table traverse, and by offsets from the chain lines. Where objects were sharply defined the method of fixing by intersection was also used.

The cost-rates for survey are—1-inch survey Rs. 31.8 per square mile.

12-inch original survey Re. 0.7 per acre.

12-inch supplementary survey Rs. 1.1 per acre.

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

*Traversing.*—A small section under Mr. A. B. Hunter consisting of 2 officers of the Upper Subordinate Service and 1 surveyor commenced a theodolite traverse early in October in advance of the 12-inch detail survey. This traverse had a length of 75.4 miles. The computations were carried out *pari passu* with the traversing and, on the completion of the latter, data were ready for plotting; in the meanwhile the surveyors were engaged on the supplementary surveys, mentioned in the report under the heading plane-tabling.

From the stations of this traverse, the greater number of which were only temporarily marked, 36 intersected points, such as chimneys, corners of buildings, lamp posts, flags on jetties and on rifle ranges were fixed.



In sheet 79/B/5 traverse stations and intersected points were found to be insufficient for the pupil surveyors who were employed on 1-inch plane-tabling, and an upper subordinate officer was told off to run a few supplementary tie-lines through the sheet totalling 69·3 linear miles. He observed at 303 traverse stations and from these fixed the positions of 47 intersected points such as trees, buildings and mile-stones. The traverse data obtained in previous years sufficed as a basis for the detail survey of sheet 79/B/1.

The cost-rates for traversing are Rs. 6·7 per linear mile for 1-inch survey.

Rs. 51·6 " " " " 12 " "

*Recess Duties.*—Mr. H. T. Hughes, who was transferred to the party from the Kūki Detachment, supervised the fair-mapping of the Town Guide maps which was carried out on the scale of 12 inches to the mile for publication on the same scale.

The Barrackpore map was drawn in 4 sheets, each sheet measuring 34·5 inches by 28·5 inches, while Dum-Dum was in 1 sheet, measuring 27 inches by 27 inches. The fair-mapping of these sheets was carried out by the direct-mapping process, blue prints for which were obtained from originals prepared in the following manner. The actual measurements of each sheet, taken from the plane-table sections, were laid out on a sheet of drawing paper. The rectangle thus projected was divided up into squares of 20 chains to correspond with the squares on the plane-table sections. Blue-print reproductions, on bankpost paper, of each plane-table section were obtained from the Photo-Litho Office. These prints cut up into squares of 40 chains or 20 chains, if necessary, were carefully pasted in their correct positions on the projected sheets which formed the originals. The actual measurements of each sheet were slightly larger than the true measurements and were reduced to the latter in the Photo-Litho Office. The blue-prints received from Calcutta, for direct-mapping were found to be very accurate. The area fair mapped is 8,850 acres at a cost-rate of Re. 0·7 per acre.

(a) There was only one section engaged on 1-inch and  $\frac{1}{2}$ -inch fair-mapping. This section, under Mr. A. K. Mitra, fair-mapped sheets 79/B/1,5 of the current season's survey and was also engaged in the completion of arrears of 1-inch mapping in sheets 79/A/3,4,7,8,10,11,13,14 and execution of half-inch mapping in sheets 83/J/N.W., 93/E/N.W., N.E., 94/B/N.E., S.E., 94/C/N.E., 94/E/N.W., N.E., S.W. and 95/K/N.W.

The fair-mapping of the 1-inch sheets was carried out by the direct-mapping method except for a small area in sheet 79/B/5 which was transferred by hand. The fair-mapping of sheet 79/B/1 was considerably delayed owing to the blue-prints, for direct-mapping, prepared in the Calcutta office, being unsatisfactory. Black-print enlargements on bank post paper to the scale of fair-mapping, from each plane-table section of sheet 79/B/1 were obtained from Calcutta and these prints were pasted in position within a graticule projected to the scale of fair-mapping on a sheet of drawing paper. This original sheet was prepared in the party and despatched to Calcutta for obtaining blue-prints on drawing paper for direct-mapping. The out-turn of fair-mapping on the  $1\frac{1}{2}$ -inch scale is 737 square miles, which comprises 329 square miles of the current season's and 408 square miles of arrears of mapping, that on the  $\frac{3}{4}$ -inch scale is 3,160 square miles of arrears of mapping.

The cost-rates of fair-mapping per square mile on different scales are as follows :—

1½-inch scale Rs. 12·0

$\frac{3}{4}$ -inch scale Rs. 3·0

Sheets 79/A/3,4,8,10,13 and 14 for publication on the 1-inch scale and sheets 93/E/N.W., 94/B/S.E., for publication on the  $\frac{1}{2}$ -inch scale were submitted during the year under report. In addition, sheets 79/A/7 and 94/E/N.W., N.E., S.W. for publication on the 1-inch and  $\frac{1}{2}$ -inch scales respectively, which were not reported last year, have also been submitted for publication.

(b) The computing section, under Mr. A. K. Mitra with 3 computers, was employed in the completion of the computations of the previous season's traversing. Owing to the small staff available, the party has not been able to take up the preparation of any of the fair degree charts.

*Inspections.*—The party was inspected in the field by the Superintendent, Eastern Circle in December 1918. During recess it was inspected once by the Surveyor General and, on several occasions, by the Superintendent, Eastern Circle.

## NO. 10 PARTY (UPPER BURMA).

BY M. C. PETERS.

The party continued the detail survey in the Myitkyinā and Putao districts, the area

## PERSONNEL.

*Provincial Officers.*

Mr. M. C. Peters, in charge.  
 „ W. G. Jarbo.  
 „ H. H. Creed.  
 „ D. N. Banerji, L. C. E.

*Upper Subordinate Service.*

Mr. Dharendra Nath Saha.  
 „ Ram Prasad, R.S.  
 „ Bhamba Rau.

*Lower Subordinate Service.*

27 Surveyors, etc.

surveyed extending over sheets 92/C/9 and parts of sheets 92/B/12,16, 92/C/13, 92/E/N.W., N.E., S.W., S.E. and 92/F/N.E. Triangulation in advance for detail survey on the 1-inch scale, and also for supplying a suitable number of well defined points for commencing and closing theodolite traverses for purposes of forest surveys on the four-inch scale, was extended over sheets 83/P/6,7,8,9,10,11,12,13,14, 15,16. The Forest Survey Detachment, constituted as a nucleus for the Special Burma Forest Survey Party, traversed boundaries, and, where necessary, interior lines, of forest reserves in sheets 83/P/9,10, 13,14, 92/D/1, 93/D/5,6, and surveyed part of 93/D/6.

The existing survey comprising an area of 367 square miles of portions of sheets 83/K/11,14,15,16 and 83/O/2,3,7 was revised provisionally on the  $\frac{1}{4}$ -inch scale by the surveyor deputed to accompany the Kūki Punitive Measures Force operating near the Burma-Assam frontier.

The country under survey ranges in altitude from 400 feet at Homalin on the bank of the Chindwin river to 19,000 feet on the mountain range forming the divide between the Irrawaddy and Brahmaputra rivers. The country is almost covered with dense forest with a heavy undergrowth of cane and thorny creepers. Work was considerably retarded in the early months of the season by a heavy mist which obscured trigonometrical points and made plane-table fixings by interpolation impossible until about 11 o'clock in the morning. Heavy jungle clearing was also necessary before the plane-table could be set up at suitable places.

The field season opened on 29th October 1918 and closed about 1st June 1919; but a camp of 6 surveyors under a Provincial officer remained in the Putao district during the rainy season. The Forest Survey Detachment took the field on 1st December 1918.

There were 21 deaths among Hazārībāgh khalasis as a result of influenza.

*Plane-tabling.*—The total area surveyed on various scales was 3,516 square miles including 367 square miles of  $\frac{1}{4}$ -inch revision survey. Of this total 1,416 square miles have been dealt with in another report.

*No. 1 Camp.*—Under Mr. D. N. Banerji, with 8 surveyors, completed an area of 1,163 square miles on the  $\frac{1}{2}$ -inch scale in sheets 92/E/N.W., N.E., S.W., S.E. and 92/F/N.E. The centre of gravity of this camp lay at a distance of about 30 marches from the head-quarters of the party at Myitkyinā, whence all rations, other than rice, had to be transported on mules. With the exception of two surveyors who returned to recess quarters, the *personnel* of this camp remained in the area during the rainy season to complete the survey of the very high hills usually under snow during the winter.

*No. 2 Camp.*—Under Mr. D. N. Saha, with 6 surveyors, completed an area of 515 square miles on the 1-inch scale in sheets 92/B/12, 16 and 92/C/9, 13. Mr. Ram Prasad, R. S., on transfer to the party towards the end of the field season, was attached to this camp. The area embraced the upper drainage of the Mogaung Chaung, which flows into the Irrawaddy at Sinbo, and is covered with dense forest; it extended to the limits of the Myitkyinā district where it adjoins the unadministered area known as the Hukawng valley. The existing notification defining the boundary between Myitkyinā district and unadministered territory in this area is based on old reconnaissance maps and could not be reconciled with the positions of features as depicted in the modern survey. As a result, the headmen of villages on either side were consulted during the course of the survey, and an alignment separating the areas of their respective jurisdictions was mutually agreed upon. An amended draft notification defining this boundary for a length of about 74 miles was forwarded to the Deputy Commissioner, and now awaits the approval of the Local Government.

*Forest Survey Detachment.*—Under Mr. Jarbo with 7 pupil surveyors completed an area of 55 square miles of 2-inch special forest survey in the Myittha reserve, in sheet 93/D/6. This detachment was formed on 1st December 1918 as a nucleus of the Special Burma Forest Survey Party and its *personnel* was increased by transfer from other parties, and by entertainment of purely temporary hands. The area surveyed was additional to the programme, as it was found that the pupils could be employed on independent work after a fortnight's further training in the method of carrying out forest surveys. The detachment was transferred to the Special Burma Forest Survey Party which was formed on 1st May 1919. The expenditure incurred by this detachment is debitable to the Forest Department.

The area surveyed by the surveyor who was attached to the Kūki Punitive Measures Force, was 367 square miles as already mentioned. It was on the  $\frac{1}{4}$ -inch scale and was revision work.

The out-turns and cost-rates are as follows :—

2-inch original survey,	55 square miles	at Rs. 153·8	per square mile.
1-inch do.	748	do.	Rs. 37·6 do.
$\frac{1}{2}$ -inch do.	2,346	do.	Rs. 23·6 do.
$\frac{1}{4}$ -inch revision survey,	367	do.	Rs. 9·3 do.

The cost-rates for one-inch and half-inch surveys are less than those of last year which were Rs. 48·7 and Rs. 24·7 per square mile, respectively. The cost-rate for two-inch survey is above the average and is due to the survey being executed at a slow rate by pupils.

*Triangulation.*—Mr. H.H. Creed triangulated an area of 1,700 square miles for detail survey on the 1-inch scale in sheets 83/P/6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16. The country surveyed consists of well wooded hills with broad valleys at an average elevation of 3,000 feet above sea-level. The cost-rate of triangulation works out to Rs. 8·6 per square mile.

*Traversing.*—Mr. W.G. Jarbo was in charge of the traverse camp, which formed part of the Forest Survey Detachment, and, with Mr. Bhamba Ram and 7 traversers, traversed an area of 254 square miles, representing 273 linear miles, in advance for special forest surveys on the 4-inch and 2-inch scales, in sheets 83/P/9, 10, 13, 14, 92/D/1, 93/D/5,6. The traversing comprised the whole area of Hwelit, Nansaung and Myittha reserves, and parts of Modé, Chaunggyibya, Mezabya, Yebokson and Pyinnyaung reserves, falling in Mansi, Kathā and Meiktila Forest Divisions. Traverse lines were carried out along all forest reserve boundaries; in addition, interior lines were run to sub-divide the larger forests into blocks of suitable size for purposes of starting and closing plane-table traverses for the detail survey. The area is well wooded and fairly free from undergrowth, but the narrow serrated ridges forming portions of the boundaries of the Myittha and Modé reserves proved an obstacle to rapid work. The out-turns and cost-rates of traversing are as follows :—

For 4-inch special forest survey,	117 square miles	at Rs. 91·6	per square mile.
For 2-inch do.	137 square miles	at Rs. 91·4	per square mile.

The cost of this traversing is debitable to the Forest Department.

*Recess Duties.*—Mr. D. N. Saha was in charge of the fair-mapping of the season's out-turn of survey contained in three 1-inch sheets and one  $\frac{1}{4}$ -inch sheet. Work was also undertaken on three  $\frac{1}{2}$ -inch sheets partly surveyed and mapped last year whose surveys were completed during the current year. The direct-mapping system was adopted and appreciably expedited progress of work. Owing to 6 surveyors being employed during the recess season on detail survey in the Putao district, the drawing power of the party was much reduced, and it was not possible to finish the current fair-mapping. Sheets 92/F/s.w., 92/C/6, 10, 14 were submitted for publication during the year under report. All fair-mapping in hand at the close of the recess season will be made over to the Maymyo Drawing Office for completion.

The out-turns and cost-rates of fair-mapping are as follows :—

1-inch fair mapping,	356 square miles	at Rs. 11·7	per square mile.
$\frac{1}{2}$ -inch do.	814	do.	Rs. 7·3 do.

The computations of the season's triangulation were completed during the recess by Mr. Ram Prasad, R.S.

*Inspection.*—The Superintendent, Eastern Circle, inspected the party during recess.

## No. 11 PARTY (LOWER BURMA).

By J. O. GREIFF.

The party was employed in Lower Burma, in the districts of Mergui and Tavoy, in continuation of the previous season's work. The drawing office remained up at Maymyo. One surveyor was employed with the Kûki Punitive Measures Force, in Upper Burma.

## PERSONNEL.

*Provincial Officers.*

Mr. J. O. Greiff, in charge.  
 „ O. J. H. Hart.  
 „ E. M. Kenny.  
 „ C. O. Picard.  
 „ A. V. Dickson from 23rd October 1918.

*Upper Subordinate Service.*

Mr. P. C. Sen Gupta, B. Sc.

*Lower Subordinate Service.*

26 Surveyors, etc.

The area surveyed was 2,323 square miles, distributed as follows:—

1-inch original survey 1217 square miles, in sheets 95/P/1 (part), 8 (part), 96/I/13 (part), 96/M/1, 5, 9 in Mergui, and in sheet 95/J/1 (part) in Tavoy.

1-inch revision survey 26 square miles, in sheets 95/P/3 (part), 7 (part), Mergui.

$\frac{1}{4}$ -inch revision survey (provisional), 1,080 square miles, in degree sheets 83 K (part), L (part), O (part),

embracing parts of the Upper Chindwin district and adjoining unadministered territory in Burma, and of Manipur in Assam.

The field season extended from the 12th November 1918 to the 17th June 1919. In Mergui the season was prolonged owing to abnormal rain in the latter part of May and the beginning of June. The health of the party was only fairly good. There was much fever. Surveyor Muhammad Yusuf Khan, who rejoined the party from the East Africa Detachment, on the 21st January, died of malarious fever on the 3rd June. His death is a great loss to the party, as he was a very promising all round surveyor. One menial also died of fever.

Influenza also broke out among the menials at Rangoon, some of whom were detained there for nearly a month and eleven of the senior men succumbed to pneumonic-influenza.

The country surveyed in the Mergui district, comprised the basin of the Little Tenasserim river, and two of its principal tributaries the Kyein Chaung and Theinkun Chaung. The river and its tributaries have their source in the main watershed, which forms the international boundary between India and Siam. From the village of Letpanthaung on the Little Tenasserim, up to which point big boats ply, to Thëbyu village, the country is more or less undulating meadow land, interspersed with cultivation and patches of open forest growth, encircled by densely wooded irregular hills. From Thëbyu to the Maw-daung pass on the main watershed, the valley rapidly closes in, the hills and ranges are more defined and rise to an elevation of over 2,000 feet. It is probable that the site of the old village of Jelinga, from which the journey to Ayuthia, the ancient capital of Siam, used to be done in carts and dhoolies was on this route.

*Plane-tabling.*—The party was divided into three camps as follows:—

*No. 1 Camp.*—Directly under the Officer in charge of party, consisted of four surveyors. It completed the survey on the 1-inch scale of 305 square miles in sheets 95/J/1 (part), 95/P/1 and 96/I/13 (part). Also the revision survey on the same scale of 26 square miles in sheets 95/P/3 (part), 7 (part).

*No. 2 Camp.*—Mr. Dickson in charge with ten surveyors completed the survey, on the one-inch scale, of 912 square miles in sheets 95/P/8 (part), 12 (part), 96/I/13 (part), 96/M/1, 5, 9.

The average out-turn per surveyor per month of twenty-four working days is 20.7 square miles. The out-turn is small, and during the first part of the field season did not average more than 16 square miles per man. But progress throughout the season was considerably impeded by the unwillingness on the part of the villagers to render any assistance. There was considerable difficulty in procuring local labour even at the high rate of Rs. 1/4/-per day. The area surveyed is inhabited chiefly by Shans, mostly emigrants from the Shan areas of Siam. Their villages are congregated in the low ground lying between the Kyein Chaung and Theinkun Chaung, where these streams debouch from the hills and join the Little Tenasserim. They were most averse to leaving their homes, for long periods at a time, to work in wild uninhabited parts. They are by nature extremely lazy and addicted to dissipation and gambling, and though impressed for service by the local official, provided with supplies and advances of pay, frequently deserted the surveyors in large numbers, thereby considerably hindering progress.

Another factor which militated against rapid progress was the density of forest growth and the large areas of low-lying ground, necessitating a very large amount of plane-table traversing. In these areas fixed points were not visible, and numerous *machāns* had to be built, some times at heights of nearly 150 feet above the ground, in order to interpolate points on which to close the traversing. Arrangements to guard against accidents to men climbing up to these *machāns* were necessary and their provision was another cause tending to hinder progress.

*No. 3 Camp.*—Formed a training camp round Maymyo. It was directly under the supervision of Mr. P. C. Sen Gupta and under the general supervision and inspection of Mr. E. M. Kenny. Four pupil surveyors were under training, and surveyed between them an area of 25 square miles on the two-inch scale. All the pupils except one showed good promise as plane-tableers. The camp was in the field from the beginning of December 1918 to about the middle of May 1919. The area surveyed does not form part of the out-turn area for which the party takes credit.

One surveyor from the party was attached to the Kūki Punitive Measures Force for the purpose of correcting the existing  $\frac{1}{4}$ -inch map of the Somra tract, lying to the north-west of the Upper Chindwin district. The original programme was not adhered to by the military authorities and the surveyor was, at the beginning of the season, directed to carry out the survey of an area in Manipur, Assam, for which no data had been supplied. The positions of prominent peaks in this area were pricked off from the old quarter-inch maps, on to the plane-table section, and the survey based on these. The whole of the area so surveyed will now need to be adjusted on to the fixed points. There was also delay in providing escorts and coolies. The surveyor had a chance of carrying out his original orders later in the season, but the revision of the survey of the whole of the Somra tract was not completed. The survey is based on the triangulation data of old No. 6 Party, North-East Frontier. The country is said to be densely wooded, rising from 400 feet, on the banks of the Chindwin river, to over 9,000 feet on the main watershed. It is well inhabited chiefly by Kūkis and Nāgās. As it is an area which will come under systematic survey on the  $\frac{1}{2}$ -inch scale in the course of a few years, it has been treated as provisional and has not been included in the survey during the year for which credit has been taken by the Eastern Circle.

*Triangulation.*—Triangulation was continued by Mr. Picard in the southern portion of the district in parts of sheets 96/I/11,12,15,16, 96/J/9,13, 96/M/3,4,7,8 and in sheet 96/N/1, covering an area of 1,810 square miles.

The country triangulated consists of irregular forest-clad hills, rising to over 2,000 feet in elevation along the Siam border, with a fringe of dense mangrove jungle along its western limits, cut up by creeks and estuaries. Mud flats along this coast render parts of it unapproachable by steamers.

The out-turn of triangulation for the season cannot be regarded as satisfactory. The original programme was not completed. In the last two months of the field season, practically no work was done, owing to all the transport mules having died. There was also much trouble in procuring local labour for hill clearing. Due to these facts the cost-rate of the triangulation is double that of previous seasons.

*Traversing.*—In the Tavoy district the traversing of 28 linear miles of the boundary of the Heinze and Kaleinaung forest reserve, remaining over from the previous season, was completed. The portion of the boundary lies in the extreme north of the district, away from all habitation, and without facilities of access. Consequently much time was lost in marching and clearing paths. The actual number of working days was 53.

The cost-rates for the different classes of work are :—

1-inch original survey	Rs. 68·8 per square mile.
1-inch revision	Rs. 43·5 do.
Triangulation	Rs. 14·3 do.
Traversing two-inch	Rs. 80·2 per linear mile.

*Recess Duties.*—In recess the party was divided into three sections :—

*No. 1 Section.*—With Mr. Kenny in charge, completed the fair-mapping of 366 square miles in sheets 95/O/3, 4, 95/P/1, 8, 12, 96/M/9. The section also completed the mapping of 7 forest boundary plots, on the four-inch scale, of the forest areas surveyed in Amherst district, in season 1917-18.

*No. 2 Section.*—Of which Mr. Picard was in charge, completed the computations of the season's triangulation, revised part of the computations done by Mr. Dalbir Rai in season

1916-17, and made good progress in the preparation of degree triangulation charts 95 L, 95 O, 95 P, 96 I, 96 M. The first three charts have practically been completed, and wait final examination and correction in certain details, in order to make them conform to recent orders. Mr. Dickson was also attached to this section. He was employed in fully completing the field sections of the current season's work, and assisting in the computations.

*No. 3 Section.*—The personnel of this section was almost identical with that of No. 3 Camp. It was under Mr. P. C. Sen Gupta. Five pupils were under instruction in drawing, plotting, typing, hand-printing, etc. Mr. Gupta also completed the computations of part of the previous season's and the current season's traversing, and started the preparation of the four-inch boundary plots of the Heinze and Kaleinaung forest reserve.

*Drawing Office Section.*—This was maintained throughout the year in Maymyo for the purpose of dealing with 1-inch,  $\frac{1}{2}$ -inch and  $\frac{1}{4}$ -inch mapping of Burma and was under Mr. O. J. H. Hart. The area mapped on each of these scales was, 602 square miles in 1-inch sheets 95/J/1, 5, 95/K/15, 16, 95/P/6, 96/M/5; 5,379 square miles in  $\frac{1}{2}$ -inch sheets 92/D/N.W., N.E., 92/E/N.E., N.W., 92/G/N.E., 93/A/N.E., S.E., 93/E/S.W., 93/I/N.W., 93/O/S.W., 95/J/S.W.; 1,000 square miles in  $\frac{1}{4}$ -inch sheets 93 E, 93 J. About 30 square miles of re-mapping was also done in 1-inch sheets 95/P/3, 4, 7 due to errors in the original survey of these sheets. This area of mapping has not been taken credit for in the total area of 1-inch mapping done by the drawing office.

The following sheets were sent for publication in the year under report:—1-inch sheets 95/K/15, 16, 95/O/3, 4, 95/P/6, 7;  $\frac{1}{2}$ -inch sheets 92/D/N.W., 92/D/N.E., 92/G/S.E., 93/A/N.E., 93/A/S.E., 93/E/S.W., 93/I/N.W. and  $\frac{1}{4}$ -inch sheets 93 E, 93 J.

The area of 1-inch mapping done by the party is small, due to the party having returned from the field late in the season, and to a fairly large amount of odd pieces of work done in 1-inch sheets drawn in previous seasons. There are practically no arrears of mapping in the party. The greater portion of sheets 95/J/1, 5, 95/P/8, 12 was surveyed in season 1917-18, but the survey of these sheets was completed last season. The mapping of these sheets has been completed, and only the final examination remains. It is hoped that it will be possible to despatch the sheets for publication before the party takes the field again.

The cost-rates for the different classes of mapping are:—

One-inch	...	...	Rs. 11·0 per square mile.
Half-inch	...	...	Rs. 2·1 do.
Quarter-inch	...	...	Rs. 2·8 do.

These cost-rates are in excess of the previous season, due to officers on large salaries, and some of the senior surveyors of the party being attached to the drawing office during the field season.

*Miscellaneous.*—The ground surveyed last season in one-inch sheets 96/M/1, 5, 9 is of great historical interest as through this area passed the once famous overland route which for centuries played so important a part in the commerce and history of the ancient kingdom of Siam. It was one of the main channels of her trade, ensured her commercial activities during all seasons, and made Tenasserim one of the first marts for trade in the East. From about the close of the thirteenth century, the time of the founding of the capital of Ayuthia, till the year 1767, Siam had established her sovereignty over the province of Tenasserim, and during this period constructed and maintained this route as one of the principal means of developing her trade. It was along this route that ambassadors and envoys, from the courts of Europe, and principalities of India, and foreign adventurers travelled. The East India Company used this route for their letters to Europe, addressing them 'Via Tenasserim.' There was also another route, which falls in sheet 95/P/1 surveyed last season, and which was along the Sarwa Chaung, and crossed the main watershed at the Tsa-raw or Sarwa pass, now known as the Palan-daung pass. This route was said to be even shorter than the southern route, but owing to the great difficulties to be encountered was chiefly used by pedestrians. This route is still used by the Karens who inhabit the north-east of the district; it is practicable for mules from the junction of the Palan-Chaung with the Sarwa-Chaung to the pass. The principal route, however, was the southern one, and it is around this route that past and present interests centre. The present village of Tenasserim was in the days of Siamese rule, the capital of the province, and the seat of the Governor. Large sized craft came up the river to Tenasserim, where freight and passengers were discharged. From here the journey was continued in small boats, 'dugouts', up the Little Tenasserim river to the village of Jelinga, whence they proceeded overland, either in carts or dhoolies or on elephants,

to the east coast of the Gulf of Siam, where they again transferred to boats, and proceeded up the Menam river to Ayuthia. This route was permitted to fall into disuse and decay during the period of Burmese rule. When the province became British no attempt was made to reopen and maintain these old routes. But, within recent years interest in this once famous route has been awakened and there has been much speculation as to its identity, and that of the site of the old village of Jelinga. In the accounts on record, descriptive of the journey from Tenasserim to Jelinga by boat, there is a general agreement that the duration of the journey was from six to seven days. Doctor Anderson in his book, "English Intercourse with Siam in the seventeenth century" is disposed to place Jelinga on the banks of the big Tenasserim about seventy-six miles up stream. This would bring one to the neighbourhood of the Sarwa route. The whole of this country has now been mapped, and during my tours, I devoted much time to tracing the existence of Jelinga and the overland road. But nowhere along the banks of the Tenasserim is there any evidence of there ever having been any road suitable for wheeled traffic. The physical features of the country are absolutely against such a probability. Such a road could only have been constructed at the cost of tremendous labour and expenditure, and would require much engineering skill. Had such a road ever been constructed, beyond doubt there would, even to this day, exist evidences of it. On the other hand, there is ample proof, physical, material, and traditional, of such a road having at one time existed along the Theinkun Chaung, the main branch of the Little Tenasserim river. During my tour last season, I made it a point to travel by this route up to the Maw-daung pass on the main watershed. A six to seven days' journey by small boats from Tenasserim would take one past the junction of the Kalin kwan Chaung with the Theinkun, into the neighbourhood of three deserted sites, within easy reach of each other, known as Htawng Mwu, Leik-pok-Hkun, Naungbwa. All great physical obstructions to wheeled traffic terminate here. The hill sides descend in gentle slopes to the banks of the Theinkun Chaung, the valley opens out, and the journey from this point to the pass is along practically level ground with an almost imperceptible ascent. The alignment of the path from here conveys also the impression of its having been laid out with some skill, and all along the route, abundant evidences are met with, of how closely populated this part of the district must once have been. Undoubtedly Jelinga must have been in this locality, and in my opinion was identical with the site of Naungbwa. It is the largest of the three sites, an open clearing with a ruined pagoda, toddy palms and domestic vegetation. Both Shan and Siamese villagers testify to its once having been a large important place, from where, even to this day during the rains, men and goods travel by raft or small boats. The description of the village of Jelinga given by M.de Bourges, historian to the French Bishop Berythe, who travelled by this route to Siam in 1662, appears to correspond with the site of Naungbwa. Mr. Leal, Interpreter to Captain Burney's Mission to Bangkok in 1826, in the account of his journey from Siam by this route states, "the next day" (that is after having crossed the watershed and starting from the site of a pagoda) "the march was continued "along a good road to the banks of the Tenasserim river, where the party constructed seventy-five rafts, for the purpose of completing the journey to Mergui". Doctor Thomas Oldham in his papers on the mineral products of Mergui, published in 1852, refers to Naungbwa as the spot from which he proceeded 12 miles along a good road towards the administrative boundary. The map of Lieut. Bagge R. E. compiled for the settlement of the boundary between the kingdom of Siam and the British province of Tenasserim, published in 1868, shows the site of a village in the same locality, and a road proceeding from it across the Maw-daung pass to Siam.

The consensus of evidence is undoubtedly in favour of Naungbwa being identical with the old village of Jelinga. A day's march from this spot are the ruins of the village formerly called Menam, now known as Mainam-wat-yo-so. The site is marked by the ruins of what was at one time a big pagoda. The platform is about 150 feet square strewn with many broken images of the Buddha cut in stone. The size of the bricks, the class of mortar and style of ornamentation, point to its construction being concurrent with that of the town of Tenasserim, built in 1373. The Maw-daung pass (Siamese Khow-maun) is about two hours march from Mainam-wat-yo-so.

*Inspections.*—The Superintendent of the circle inspected the party in the field between the 22nd and 29th January, and again in recess at Maymyo on the 10th August.

## No. 12 PARTY (ASSAM).

BY CAPTAIN F. B. SCOTT, I. A.

During the field season 1918-19 the party carried out original and revision survey on the 1-inch scale of sheets 83/I/3 (part), 4 (part), 6 (part), 7, 8(part), 10 (part), 11 (part) and 14 (part) in the Lakhimpur and Sibsāgar districts and the Sadiyā frontier tract of Assam, and original 2-inch survey of two reserved forests.

## PERSONNEL.

*Imperial Officer.*

Captain F. B. Scott, I. A., in charge from 23rd April 1919.

*Provincial Officers.*

Mr. H. W. Biggie, in charge up to 28th February 1919.

„ E. G. Hardinge, in charge from 1st March to 22nd April 1919.

„ Pramadaranjan Ray, R.S.

„ Prafulla Chandra Mitra, B.A.

„ K. S. Gopalachari, B.A.

*Upper Subordinate Service.*

Mr. Girija Sonker Bagehi,

*Lower Subordinate Service.*

25 Surveyors, etc.

Triangulation and traversing in advance of detail survey were also undertaken in sheet 83 C. The country generally is covered with dense jungle and the plains are subject to inundation.

The field season extended over a period of about seven months, commencing on the 21st October 1918 and closing on different dates between the 1st May and 9th June 1919.

The party did not take the field in full strength owing to war conditions.

The health of the party was not good. Influenza broke out among the Hazārībāgh khalasis on their arrival at Dibrugarh and Shillong, resulting in thirteen deaths out of about 40 cases.

One surveyor was attacked with influenza in March, and another was gored by a buffalo. The health of all those who remained in the field after the commencement of the rains in April suffered.

*Plane-tabling.*—The country in which detail survey was carried out is a flat area, mostly covered with dense jungle consisting of trees, cane brakes and tall grass. It is subject to inundation during the rains, and rivers and “*bils*”, or swamps, are numerous. Villages and patches of cultivation are scattered through the area. The foot hills of the Himālayas, rising to about 3,000 feet, came into sheet 83/I/10. The main rivers are the Subansiri, Ghunā Suti, Kherkutiā Suti, Sisi and Koran. There are a few cart tracks which can be used in dry weather only, and footpaths in the forest areas.

The party was divided into two camps.

*No. 1 Camp* under Mr. Hardinge up to the 16th February 1919, when Mr. P. Ray, R. S., took charge, with seven surveyors and four pupil surveyors surveyed 822 square miles of original and 30 square miles of revision survey on the 1-inch scale and 23 square miles of reserved forests on the 2-inch scale in parts of sheets 83/I/3,4,6,10,11,14. The revision survey was undertaken in the area previously surveyed in 1916-17 on account of changes caused by riverain action.

*No. 2 Camp* under Mr. K. S. Gopalachari, with three surveyors up to the 25th February 1919, and five surveyors and two pupil surveyors after that date, surveyed 341 square miles on the 1-inch scale in sheets 83/I/2 (part), 6 (part), 7,11 (part), of which Mr. Gopalachari himself surveyed 57 square miles. The work, except in the small portion of hills falling in the area, was carried out by plane-table traversing.

The total area surveyed by both camps on the 1-inch scale was 1,193 square miles, including 30 square miles of revision survey, and 23 square miles on the 2-inch scale. The respective cost-rates are Rs. 37·1 and Rs. 73·4 per square mile and the combined cost-rate Rs. 37·8.

*Triangulation.*—Triangulation was carried out by Mr. P. C. Mitra in sheets 83/C/2,3, 4(part), 6,7,8 (part), 10,11,12,15,16 and reconnaissance by Mr. K. S. Gopalachari in sheets 83/C/5,6,10,14. The country consists of hills rising to 5,000 feet partly open and partly covered with dense jungle. These hills rise very steeply from the plains to the south, and, on the north, descend gradually in a series of flat-topped elevations, necessitating a large amount of jungle clearing, to enable observations to be made. Labour and supplies are both scarce, and coolies the only means of transport. Smoke haze interfered with the work in March and heavy rains in April and May. An area of 2,735 square miles was triangulated, the cost-rate being Rs. 5 per square mile.

*Traversing.*—Traversing was carried out in the plains portions of sheets 83/I/3 and 83/C/4,8 and along portions of the artificial boundaries of reserved forests in the hills. The



country is similar to that described under "plane-tabling" and "triangulation" in the plains and hills respectively. One traverser was employed in 83/I/3 and two in 83/C/4,8. The out-turn was 258 linear miles covering an area of 410 square miles. 1,776 stations were fixed, of which 126 were permanently marked and 61 were marked with zinc cylinders. The cost-rates per linear mile for 246 linear miles of traversing for 1-inch survey, and, for 12 linear miles of traversing for 2-inch survey are Rs. 36.4 and Rs. 98.8 respectively. The combined cost-rate is Rs. 39.3 per linear mile. The high cost-rate for forest boundary traversing was due to the difficult nature of the ground, entailing much line clearing.

*Recess Duties.*—A drawing section of six surveyors and one Sub-Assistant Superintendent under Mr. P. Ray, R. S., till the middle of February, and under the officer in charge of party after that date, remained at Shillong during the field season, and carried out a portion of the fair-mapping of the 1-inch sheets 95/J/s. E., 83/F/s. E., 93/O/s. E., and special contour sheets of 83/B/N.E., N.W. This work was delayed on account of having to wait for material.

During recess the party was divided into three sections:—

*No. 1 Section*, under Mr. Hardinge with nine surveyors carried out the fair-mapping of 1-inch sheets 83/I/7,8, of part of  $\frac{1}{2}$ -inch sheet 95/J/s. E., and of the special contour sheet of 93/J/s. E., and took over the mapping of sheets 83/I/4,6 (parts) from Mr. Gopalachari on his transfer to the Trigonometrical survey on the 1st September 1919.

*No. 2 Section*, under Mr. P. C. Mitra with one Sub-Assistant Superintendent and eight surveyors, carried out the fair-mapping of sheets 83/I/10 (part), 11,14 (part) and of  $\frac{1}{2}$ -inch sheets 83/F/s. E. and 93/O/s. E. including their special contour sheets.

*No. 3 Section*, under Mr. K. S. Gopalachari and 4 surveyors carried out the fair-mapping of sheets 83/I/4,6 (parts). Mr. Gopalachari handed over to Mr. Hardinge on the 1st September 1919.

An area of 1,366 square miles for publication on the 1-inch scale, at a cost-rate of Rs. 14.9 per square mile, has been fair-mapped. Sheet 83/I/4 will not be submitted for publication this year, as a small portion remains to be surveyed. 2,011 square miles of  $\frac{1}{2}$ -inch work have also been fair-mapped at a cost-rate of Rs. 3.3 per square mile.

Mr. P. C. Mitra, with one computer, completed the computation of the triangulation carried out during the field season, and four computers and traversers completed the traverse computations and the 4-inch boundary plots of artificial boundaries of reserved forests.

*Miscellaneous.*—The smoke haze, which obscures all distant points, interfered with the triangulation during March and until rain commenced in April. The heavy rains which came in April and May this year, and the consequent sickness among officers and their squads prevented the completion of both triangulation and traverse programmes. The party's elephants were of great assistance in North Lakhimpur and were the only means of transport, off the cart tracks. In 83/C/12 there are no villages except along the southern fringe and the only communications are wild elephant paths. A local man employed as a khalasi was taken by a man-eating tiger in this area. Leeches caused some trouble, and leech proof socks were issued, and proved very useful in preventing bites. The unsettled state of the boundaries was again a source of delay and necessitated numerous references.

*Inspections.*—The Surveyor General inspected the party on the 23rd July 1919. The Superintendent, Map Publication visited the party during October 1918.

### SPECIAL BURMA FOREST SURVEY PARTY (UPPER BURMA).

By H.W. BIGGIE.

This party, which was formed on the 1st May 1919, took over and carried on the work of the Burma Forest Survey Detachment which had, up till then, constituted a section of No. 10 Party. The report deals with the operations of the unit as a party.

#### PERSONNEL.

##### *Provincial Officers.*

Mr. H.W. Biggie, in charge from 8th May 1919.  
 „ W.G. Jarbo, in charge from 1st to 7th May 1919.

##### *Upper Subordinate Service.*

Mr. Bhamba Ram.

##### *Lower Subordinate Service.*

9 Surveyors, etc.

The *raison d'être* of the party is amply suggested by its designation. Work has started in reserved forests in the Northern and Southern Forest Circles. The staff at present is the same as that which formed the nucleus, and needs to be considerably reinforced to enable it to deal fully with the work ahead.

The country over which traverse and detail survey operations were carried out consists of well-wooded hills.

The field season closed on the 31st May 1919.

Owing to sickness, one surveyor employed on traversing in the Northern Forest Circle was not able to do any work during the month of May. Another surveyor similarly employed in that area had to close work on account of fever in the middle of the month. The health of the rest of the party in the field during May was good, but nearly all suffered from periodical attacks of malaria after their return to recess quarters at Maymyo.

*Plane-tabling (Southern Forest Circle).*—This was carried out in sheet 93/D/6 in wooded hills rising from 2,000 to 5,000 feet in the eastern portion of the Meiktila Forest Division in the district of the same name, where it borders on the Southern Shan States.

The work was under Mr. Jarbo with six pupils. The out-turn during the month of May was 19·9 square miles of detail survey on the 2-inch scale in the Myittha forest reserve.

The cost-rate, based on the one month's out-turn, is Rs. 92·7 per square mile.

*Triangulation.*—Nil.

*Traversing (Northern Forest Circle).*—The country traversed in sheets 83/P/9, 14 consists of well-wooded hills, fringed on the east by the Minwun range, starting from the extreme northern limit of Kathā, east of the Taungthonlon hill, and running down the centre of the district to its southern boundary.

Mr. Bhamba Ram and three traversers were employed on the work. This section was not inspected during May, but the arrangements for closing its work about the beginning of June were delegated to Mr. Bhamba Ram.

27·4 linear miles of traversing, covering an area of 27·8 square miles in the Modé and Chaunggyibya reserves in the Mansi Forest Division was carried out.

The cost-rate per linear mile is Rs. 106·0.

*(Southern Forest Circle).*—The country traversed in this forest circle, in sheets 93/D/5, 6 is as described under the head of *Plane-tabling*, except that a lower elevation, 1,200 feet above sea-level, was reached.

27·5 linear miles of traversing, covering an area of 15 square miles, in the Pyinnyaung and Yebokson reserves of the Meiktila Forest Division was carried out.

The cost-rate per linear mile is Rs. 91·2. The combined cost-rate per linear mile for traversing in the Northern and Southern Forest Circles is Rs. 98·6.

As in the case of plane-tabling, the cost-rates of traversing have been based on a single month's out-turn.

*Recess Duties.*—(a) The fair-drawing of the party consisted of the drawing on the scale of survey, on the out-line sheet, only, of 74·4 square miles of detail survey on the 2-inch scale completed during 1918-19 by this and No. 10 Party. The surveyed area lies in two sheets, 93/D/6 N and 93/D/6 S, in both of which additional survey has to be undertaken in seasons 1919-21, so the drawing of the hill sheets has been held in abeyance until vandyke prints of the entire outline areas to be drawn can be obtained. The outline drawing was done by transfer from hand traces prepared from the field sections.

The establishment employed on fair-drawing, or instruction in drawing, under Mr. Jarbo consisted of six surveyors and pupils. Of these only two were found qualified to do fair-drawing. The rest were kept under instruction in both outline and hill drawing and were, later in the season, put under instruction in computations in which they made satisfactory progress and were able to help to further the work.

The out-turn of fair-mapping is estimated to be 25·3 square miles, and the cost-rate per square mile is Rs. 41·1.

(b).—Other recess duties included the computations of the season's traversing by four lower subordinates under the supervision of Mr. Jarbo, assisted by Mr. Bhamba Ram. The lower subordinates had to be instructed before their services could be profitably utilised.

The work comprised the computations of 133 linear miles of traversing in the Northern Forest Circle for detail survey on the 4-inch scale and 129 linear miles of traversing in the Southern Forest Circle for detail survey on the 2-inch scale, the cost-rates per linear mile being Rs. 31·4 and Rs. 33·2 respectively, and the combined cost-rate per linear mile Rs. 32·3.

The cost-rate per linear mile for traversing and computations will therefore be the addition of Rs. 98·6 and Rs. 32·3 or Rs. 130·9.

*Miscellaneous.*—The cost-rates for all classes of work are high. This is due to organizing and equipping a new party, entailing abnormal expenditure which is debitable to the short period reported on, during which only small out-turns were obtainable from a staff, composed mostly of pupils and purely temporary hands, recruited in an emergency. All of these men had to be put under instruction and the results of their actual work are much below the average. In recess also, a great deal of time and labour had to be spent on instructing them before their services could be utilised to further the progress of the work. As already stated, the present establishment of the party is the same as that which formed the nucleus which existed as a detachment, but the out-turns of the party are burdened for the period under report with the expenditure of a major charge. All the expense incurred on the journey to their homes in India of the menial establishment, instead of being debitable to the out-turns of half a field season, are a charge against work done in the month of May alone, which gives an average of only 17 working days for traverse and detail survey.

Administrative sanction to the erection of an office for the party has been accorded by the Local Government at a cost of Rs. 40,000 and it is hoped that the building will be ready by the beginning of next recess. Mr. C. G. Rogers, C.I.E., Chief Conservator of Forests has very kindly placed five elephants at the disposal of the party, which have been purchased for its use at a total cost of Rs. 20,000.

A scheme for training Burmans as surveyors is at present under consideration.

*Inspection.*—The Superintendent, Eastern Circle inspected the party during the recess season.

#### KŪKI SURVEY DETACHMENT.

BY H. T. HUGHES.

The detachment was formed at the end of March 1919 at the request of the General Officer Commanding the Kūki Punitive Measures Force with the object of revising on the  $\frac{1}{4}$ -inch scale as much as possible of the existing maps of the areas in which the Force had been, and then was, operating.

##### PERSONNEL.

##### *Provincial Officer.*

Mr. H. T. Hughes, in charge.

##### *Lower Subordinate Service.*

3 Surveyors.

The triangulation on which it was necessary to base the detail revision survey at the commencement of operations was weak and it was proposed that the officer in charge of the detachment should carry out a supplementary triangulation as soon as he had completed the arrangements for the plane-tablers.

This however he found himself unable to do and the whole area of revision survey, amounting to 2,291 square miles, has had to rest on such points of the existing triangulation of the area dealt with as could be found by the plane-tablers.

The out-turn rate of plane-tabling has averaged 19 square miles per working day and, though in some parts there has been a good deal of generalization, the resulting survey constitutes a great advance on the existing maps of the area.

The area surveyed comprised the southern portion of the Manipur State and small portions of the Chin Hills and Lushai Hills along the northern boundaries of these areas. It falls chiefly in sheet S3 H, but takes in also small portions of sheets 83 D, 84 A and E.

As these areas will come under systematic survey on the  $\frac{1}{4}$ -inch scale in the course of the next few years, the work of the detachment has been considered as provisional and has not been taken credit for as progress accomplished.

The country surveyed was hilly, rising, from about 375 feet above sea-level in the valleys on the western edge, to 6,675 feet on the Kailam Range, and for the most part was forest clad. Water was plentiful but supplies, other than a small amount of rice, unprocureable locally. The surveyors and khalasis were rationed under the same arrangements as were made for the Military Police with which they were working; and the general health was good. This may have been accounted for partly by the fact that the season was a dry one and that work had practically closed when the rains broke on 8th June.

Much help was received from the Political Agent, Manipur and from the officers of the Military Police operating in the country.

TABLE I.

## OUT-TURNS OF PLANE-TABLING 1918-19.

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.
¼-inch	Revision Survey (Provisional)	E	No. 10	Upper Burma ...	367	587·2	0·1	0·2
		E	No. 11	Upper Burma ...	1,080	296·8	0·2	
		E	Kāki Det.	Assam ...	2,291	19·0*		
½-inch	Original Survey	S	No. 6	Hyderābād ...	178	50·4	7·6	
		E	No. 10	Upper Burma ...	2,346	77·7	0·4	1·1
1-inch	Original Survey	S	No. 5	Central Provinces...	979	18·3	12·9	3·6
		S	No. 6	Hyderābād ...	274	32·0	12·8	
		S	No. 7	Madras ...	2,226	30·5	8·5	2·0
		E	No. 9	Bengal ...	548	20·9	7·3	19·2
		E	No. 10	Upper Burma ...	748	20·0	0·9	8·6
		E	No. 11	Lower Burma ...	1,217	20·7	1·0	7·9
		E	No. 12	Assam ...	1,163	18·1	0·2	19·6
		N	No. 1	United Provinces & Central Provinces...	92			
1-inch	Revision Survey	S	No. 5	Central Provinces...	463	21·8	5·3	9·6
		S	No. 8	Madras ...	42	17·0	5·0	2·3
		E	No. 11	Lower Burma ...	26	18·2	1·0	8·7
		E	No. 12	Assam ...	30	18·1	0·2	19·6
1-inch	Supplementary Survey	S	No. 6	Bombay ...	1,670	36·0	9·4	
		S	No. 8	Madras ...	1,182	16·4	5·0	11·3
1½-inch	Original Survey	S	No. 6	Hyderābād ...	237	11·7	19·8	3·8
2-inch	Original Survey	S	No. 7	Madras ...	12	10·0	15·8	18·3
		E	No. 10	Upper Burma ...	55	2·1	8·9	136·9
		E	No. 12	Assam ...	23	8·1	...	43·3
		E	Special Burma Forest	Upper Burma ...	20	4·1	3·6	56·8
3-inch	Original Survey (Military)	N	No. 1	United Provinces, Central India and Baluchistān ...	228	6·5	40	

\* Per working day.

TABLE I.—*Concluded.*OUT-TURNS OF PLANE-TABLING 1918-19.—*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.	<i>In situ</i> (by resection).	Plane-table traverse.
4-inch	Original Survey (Special Forest)	N	No. 3	United Provinces and Punjab ...	189	3·1	71·3	
4-inch	Revision Survey	N	No. 2	Delhi Province ...	82	10·7	39·4	
6-inch	City Survey	N	No. 2	United Provinces ...	109·2	1,329·6 acres	...	185·6
12-inch	Original Survey	E	No. 9	Bengal ...	15·9	415·4 acres		
12-inch	Supplementary Survey	E	No. 9	Bengal ...	3·9	347·6 acres		
13·2-inch	City Survey	N	No. 2	United Provinces ...	2·6	147·4 acres	...	2·5 per acre
16-inch	Original Survey	S	No. 20	Bellary and Secunderābād ...	32·6	0·44 acre		
16-inch	City Survey	N	No. 1	Punjab ...	2·2	0·53	...	1,009
		N	No. 2	Punjab ...	9·1	203·2 acres	...	2·2 per acre
24-inch	Original Survey (Special)	N	No. 2	Rājputāna ...	0·9	90·0 acres	...	4·4 per acre
64-inch	Original Survey	S	No. 20	Secunderābād ...	0·1	0·03 acre		
50-feet to 1-inch	Correction of existing plans	S	No. 20	Secunderābād and Bolārum ...	0·8	0·07 acre		

TABLE II  
DETAILS OF TRIANGULATION AND TRAVERSING 1918-19.

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.	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.
16-inch	City Survey	N	No. 1	Punjab	...	...	...	...	...	...	...	...	...	3.42	17	...	...
24-inch	Original Survey	N	No. 2	Rajputana	6	8	0.1(a)	0.1(a)	5	9.0	0.60	68	0.54	41	360	7.7	2.1
1-inch	Original and Revision Survey.	S	No. 5	Central Provinces	6	1,652	6.8	6.8	31	12.9	0.28	213	2.4	...	...	...	...
4-inch	Original Survey	S	No. 6	Hyderabad	6	1,699	(b)	(b)	(b)	(b)	(b)	(b)	(b)	...	...	...	...
1-inch	Supplementary and Revision Survey.	S	No. 8	Madras	...	...	...	...	...	...	...	...	...	248	964	14.1	2.0
16-inch	Original and Revision Survey.	S	No. 20	Wellington	6	16	0.7	2.0	10	15.7	0.3	14	0.5	79	2,867	5.8	1.3
16-inch	Original Survey	S	No. 20	Secunderabad	...	...	...	...	...	...	...	...	...	165	1,766	3.1	0.4
16-inch	Original Survey	S	No. 20	St. Thomas' Mount	...	...	...	...	...	...	...	...	...	99	1,260	4.4	0.3
1-inch	Original Survey	E	No. 9	Bengal	...	...	...	...	...	...	...	...	...	69.3	303	4.0	0.7
12-inch	Original Survey	E	No. 9	Ditto	...	...	...	...	...	...	...	...	...	75.4	919	4.5	0.3

(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 1918-19.—*Concluded.*

Scale.	Class of Survey.	Circle.	Party.	Locality.	TRIANGULATION.							TRAVERSING.						
					Diameter of theodolite in inches.	Area in square miles.	Number of square miles to each point trigonometrically fixed.	Number of square miles to each height.	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	Original Survey	E	No. 10	Upper Burma	6	1,700	9.7(a)	9.7(a)	19	14.9	0.17	157	0.53	...	...	...	...	
2-inch	Ditto	E	No. 10	Ditto	...	...	...	...	...	...	...	...	...	137	...	...	...	
4-inch	Ditto	E	No. 10	Ditto	...	...	...	...	...	...	...	...	...	117	273	5,972	(c)	
1-inch	Ditto	E	No. 11	Lower Burma	6	1,810	12.9(a)	12.7(a)	10	9.6	0.26	130	0.43	...	27.5	739	5.2	4.6
1-inch and 2-inch	Triangulation	E	No. 12	Assam	6	2,735	17.2(a)	16.4(a)	9	8.2	0.31	150	0.60	...	...	...	...	...
1-inch and 2-inch	Traversing	E	No. 12	Ditto	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2-inch	Original Survey	E	Special Burma Forest Survey	Upper Burma	...	...	...	...	...	...	...	...	...	43	258.2	1,776	5.0	1.6
					...	...	...	...	...	...	...	...	...	43	55	1,062	7.0	5.5

(a) Additional points, previously fixed, will also be used in this area.  
 (c) Computations will be carried out by the Special Burma Forest Survey Party.

TABLE III.  
COST-RATES OF SURVEY 1918-19.

COST-RATES, RUPEES, PLANE-TABLING, PER SQUARE MILE.												REMARKS.	Total cost of party. Rs.											
COST-RATES, RUPEES.														Total plane-tabling out-turns on all scales, square miles.										
TRAVELING PER MILE PER MILE.		TRIANGULATION PER SQUARE MILE.		TOPOGRAPHICAL.		FOREST BOUNDARY.		RE-MAPPING, PER SQUARE MILE.		Total plane-tabling out-turns on all scales, square miles.														
1-inch original survey.	1-inch original survey.	1-inch supplementary survey.	14-inch original survey.	2-inch original survey.	3-inch original survey (military).	4-inch special forest original survey.	4-inch revision survey.	6-inch city survey.	12-inch original survey.	12-inch supplementary survey.	13-inch city survey.	16-inch original survey.	16-inch city survey.	24-inch original survey (special).	64-inch original survey.	50 feet to 1 inch correction of plans.	Triangulation per square mile.	Topographical.	Forest boundary.	Re-mapping, per square mile.	Total plane-tabling out-turns on all scales, square miles.	Includes a sum of Rs. 5,333 debitable to the Secretary, P. W. D., Rajpūtāna, and a sum of Rs. 166 debitable to the Forest Department, U. P.  Includes a sum of Rs. 16,420 debitable to the Forest Department, U. P.	75,152  74,556  92,051  70,716  78,232	
16-221.7	1-inch original survey.	1-inch revision survey.	13-762.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...			...
23-322.9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...			...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...			...
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...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...			...

(c) For 2-inch. (d) For 3-inch. (e) For 4-inch. (f) For 6-inch. (h) For 16-inch. (i) For 24-inch. (j) These entries refer to acres. (k) Additional points previously fixed will



TABLE III.—Concluded.  
COST-RATES OF SURVEY 1918-19.—Concluded.

e. Party.	Locality.	COST-RATES, RUPEES, PLANE-TABLING, PER SQUARE MILE.														COST-RATES, RUPEES.			REMARKS.												
		COST-RATES, RUPEES, PLANE-TABLING, PER SQUARE MILE.														COST-RATES, RUPEES.															
		4-inch revision survey (provisional).	4-inch original survey.	4-inch original survey.	4-inch revision survey.	1-inch original survey.	1-inch supplementary survey.	1-inch original survey.	1-inch original survey.	2-inch original survey.	2-inch original survey (military).	4-inch special forest original survey.	6-inch city survey.	6-inch original survey.	12-inch original survey.	12-inch supplementary survey.	13-2-inch city survey.	16-inch original survey.		16-inch city survey.	24-inch original survey (special).	24-inch original survey.	30 feet to 1 inch correction of plans.	Triangulation per square mile.	Topographical.	Forest boundary.	Fair mapping per square mile.	Total plane-tabling out-turns on all scales, square miles.	Total cost of party.	Rs.	
No. 7	Madras	...	13-7	...	...	...	...	...	19	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9-3	2,239	56,234	Includes Rs. 4,635, the cost of computations of triangulations of previous years, the cost-rate of which is Re. 0-8 per square mile.		
No. 8	Madras	...	...	14-6	17-6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0-8 (a) 23-9 (b)	1,224	68,758			
No. 20	Rellary, Secunderabad, Wellington, St. Thomas Mount	...	...	...	...	...	...	...	...	...	...	...	...	...	...	100	...	...	...	...	...	18-4 (j)	9-7 (i)	14-3	53-0	...	0-4 (j)	33-5	54,391		
No. 9	Bengal	...	...	...	...	...	...	...	...	...	...	...	...	0-7	1-1 (i)	...	...	...	...	...	...	...	...	...	...	...	3-0 (n) 12-0 (b) 0-7 (g) (j)	548	61,019		
No. 10	Upper Burma	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7-3 (a) 11-7 (b)	3,516	1,45,668	Includes Rs. 31,686 debitable to the Forest Department on account of special forest surveys.	
No. 11	Upper and Lower Burma	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2-1 (a) 11-0 (b)	2,233	1,52,587	Includes cost of Mayunyo Drawing Office.	
No. 12	Assam	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3-3 (e) 14-9 (b)	1,216	96,907		
Special Burma Forest Survey Party. Kahi Survey Detachment.	Upper Burma	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	20	19,871	
Assam	Assam	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2,291	10,057	Refer to plane-tabling only.

(a) For 4-inch, (b) For 1-inch, (c) For 2-inch, (d) For 3-inch, (e) For 4-inch, (f) For 6-inch, (g) For 12-inch, (h) For 15-inch, (i) For 24-inch, (j) These entries refer to acres. (k) Additional points usually fixed will also be used.



NUN KUN PEAKS FROM THE KRISH VALLEY, KASHMIR. PHOTO TAKEN AT 14,000 FEET.

From a photograph by Mr. R. C. Hanson.

Photo-engraved & printed at the Offices of the Survey of India, Calcutta, 1920.

## PART II.—GEODETIC AND SCIENTIFIC OPERATIONS.

### TRIGONOMETRICAL SURVEY.

#### ASTRONOMICAL LATITUDES.

No latitude operations were carried out during the year under report and the personnel of this party was employed at the Head Quarters Office of the Trigonometrical Survey.

#### PERSONNEL OF NO. 13 PARTY.

##### *Imperial Officers.*

Major H. McC. Cowie, R. E. in charge up to 11th  
May 1919.  
Major C. M. Thompson, I. A., in charge from 12th  
May to 31st August 1919.  
Major M. O'C. Tandy, O. B. E., D. S. O., R. E.  
in charge from 1st to 16th September 1919.  
Bt.-Major C. G. Lewis, R. E., in charge from 17th  
September 1919.

##### *Lower Subordinate Service.*

2 Computers, etc.

#### PENDULUM OPERATIONS.

No pendulum operations were carried out during the year under report and the personnel of this party was reduced to a minimum and employed in miscellaneous work.

#### PERSONNEL OF NO. 14 PARTY.

##### *Imperial Officers.*

Major H. McC. Cowie, R. E., in charge up to 8th  
May 1919.  
Major C. M. Thompson, I. A., in charge from 9th  
May 1919.

##### *Lower Subordinate Service.*

1 Clerk, etc.

#### TRIANGULATION.

The party did not take the field during field season 1918-19.

#### PERSONNEL OF NO. 15 PARTY.

##### *Imperial Officers.*

Major R. Foster, I. A. in charge from 30th April  
1919 to 15th May 1919.  
Bt.-Major C. G. Lewis, R. E., in charge from 16th  
May 1919 to 26th May 1919.  
Major R. H. Thomas, D. S. O., R. E., in charge  
from 16th August 1919 to 30th September 1919.

##### *Provincial Officers.*

Mr. H. G. Shaw, in charge from 1st October 1918  
to 30th April 1919 and from 27th May 1919  
to 15th August 1919.  
" C. S. McInnes.  
" Abdul Karim, B. A.

##### *Lower Subordinate Service.*

9 Computers, etc.



## TIDAL OPERATIONS.

By O. C. OLLENBACH.

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

## PERSONNEL OF No. 16 PARTY.

*Provincial Officers.*

Mr. O. C. Ollenbach, in charge.  
Khan Sabib Syed Zille Haasnain.

*Lower Subordinate Service.*

20 Computers, etc.

In addition to the above work, the predictions of high and low water for the year 1918 at Bhaunagar, Chittagong and Akyab were compared against actual readings of high and low water supplied by the Port Officers concerned. These readings were taken during day-light on tide-poles throughout the year. The object of the above comparisons was to see whether the predictions which were based on tidal observations taken some years ago still maintained the required degree of accuracy.

## TIDAL OBSERVATIONS AT BASRAH.

Tidal observations on an ordinary wooden tide-gauge at Basrah were taken by the Military authorities, a copy of which was supplied to this department by the Director of Inland Water Transport, Mesopotamia. The observations for the year commencing 1st January 1918 were reduced by the method of harmonic analysis and the constants thus deduced were used in the computation of data for the Basrah tide-tables for 1920. These data were forwarded on 30th April 1919 to the Director, National Physical Laboratory Teddington, England, for the preparation of the tide-tables with the aid of the tide-predicting machine.

The tide-tables have not yet been received.

## 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 observations	Date of closing of observations.	Number of Years of observations.	REMARKS.
1	Suez ... ..	Automatic	1897	1903	7	
2	Perim ... ..	"	1898	1902	5	
3	Aden ... ..	"	1879	Still Working	40	
4	Maskat ... ..	"	1893	1898	5	
5	Bushire ... ..	"	1892	1901	8	
6	Karāchi ... ..	"	{ 1868 1881	1880 Still Working	{ *13 39 } 52	* Small tide-gauge working.
7	Hanstal ... ..	"	1874	1875	1	Tide-tables not published. Year 1904-05 is excluded.
8	Navānar ... ..	"	1874	1875	1	
9	Okha Point ... ..	"	{ 1874 Restarted	1875	1	
10	Porbandar ... ..	Personal	1893	1906	1	Years 1898, 1899 & 1902 are excluded.
10 A	Porbandar ... ..	Automatic	1898	1902	2	
11	Port Albert Victor (Kāthiāwār).	Personal	1881	1882	1	
11 A	Port Albert Victor (Kāthiāwār).	Automatic	1900	1903	4	
12	Bhaunagar ... ..	"	1889	1894	5	
13	Bombay (Apollo Bandār)	"	1878	Still Working	41	
14	Bombay (Prince's Dock)	"	1888	"	31	
15	Marmagao (Goa) ... ..	"	1884	1889	5	
16	Kārwar ... ..	"	1878	1883	5	
17	Beyppore ... ..	"	1878	1884	6	
18	Cochin ... ..	"	1886	1892	6	
19	Tuticorin ... ..	"	1888	1893	5	
20	Minicoy ... ..	"	1891	1896	5	
21	Galle ... ..	"	1884	1890	6	
22	Colombó ... ..	"	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	1890 Still Working	{ 10 24 } 34	
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	38	
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	1881 1888	5	Year 1880-81 is excluded.
38	Rangoon ... ..	"	1880	Still Working	39	
39	Amherst ... ..	"	1880	1886	6	
40	Moulmein ... ..	"	{ 1880 Restarted	1886	{ 6 10 } 16	
41	Mergui ... ..	"	1909	Still Working	10	
42	Port Blair ... ..	"	1889	1894	5	
43	Basrah ... ..	Personal	1880	Still Working	39	Observations taken on a tide-pole.
			1916	"	3	

## WORKING OF THE OBSERVATORIES.

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

Khan Sahib Syed Zille Hasnain inspected the observatories at Karāchi, Bombay (Apollo Bandar), Bombay (Prince's Dock), and Madras.

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

- (a) Checking the working zero of the tide-gauge and comparison of the same with the true zero.
- (b) Testing the stability of the tide-gauge by check levelling between its bed plate and the bench-mark of reference.
- (c) Testing the zero of the graduated staff with reference to the zero of the tide-gauge.
- (d) Thoroughly cleaning and overhauling all the instruments and putting them in perfect working order.
- (e) Final adjustment of the tide-gauge and the working zero after cleaning the whole apparatus.
- (f) Examination and cleaning of the observatory well and the inlet holes and securing free communication between the sea and the well.
- (g) General examination of the observatory cabin with the object of getting any repairs done, if necessary.

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

*Aden.*—The inspection of this observatory was withheld during the past year chiefly owing to the difficulty of travelling to Aden and back on account of the war. From the reports and the tidal diagrams which are being regularly received from the observatory it appears that the tide-gauge has been working satisfactorily. An early opportunity will be taken to inspect this observatory during the ensuing field season.

*Karāchi.*—During the past year there have been twelve minor interruptions in the tidal registrations of this observatory owing to the inlet hole being temporarily blocked. With this exception, the tide-gauge has worked satisfactorily.

*Bombay (Apollo Bandar).*—The tide-gauge at this observatory has worked without a break throughout the past year.

*Bombay (Prince's Dock).*—Since last year the working of this observatory has considerably improved. The vexatious breaks in the tidal registrations due to the stoppage of the driving clock or the breaking of the pencil wire which used to occur very frequently in former years have practically disappeared. This is chiefly due to the care and attention bestowed by the present observatory clerk on his work.

*Madras.*—The working of this observatory during the past year has been continuous and thoroughly satisfactory.

*Kidderpore.*—The tide-gauge has worked very well during the year under report.

*Rangoon.*—There have been no breaks in the working of this observatory since the last report.

*Moulmein.*—The tide-gauge at this observatory has worked well, but the clerk in charge of the observatory was found to be grossly negligent in submitting the daily reports, tidal diagrams and other periodical returns to the office of the tidal operations at Dehra Dūn. The matter was brought to the notice of the Port Officer who eventually changed the observatory clerk and since then the reports and diagrams have been regularly received.

*Port Blair.*—The tidal registrations at this observatory have been very satisfactorily carried out. The bottom section of the iron cylinder had got worn out and in consequence the inlet holes had become larger than their original size and several other holes in the cylinder had sprung up, with the result that the rush of the water inside the cylinder was too much for the smooth and accurate registration of the tides. The Engineer and Harbour Master of Port Blair was requested to have the bottom section of the cylinder renewed which was done in February last. The tidal curves registered on the diagrams have since assumed normal shape and been quite satisfactory.

## 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 1918 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 of Inland Water Transport for the year 1918 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 ( $\zeta$ ) at the various stations; they also give the values of  $H$  and  $K$  which are connected with  $R$  and  $\zeta$ , 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.



1918

Tide Symbol	ADEN				KARACHI				BOMBAY (Apollo Bandar)			
	$A_0=5.849$				$A_0=7.339$				$A_0=10.286$			
	R	$\zeta$	H	$\kappa$	R	$\zeta$	H	$\kappa$	R	$\zeta$	H	$\kappa$
Short Period		°		°		°		°		°		°
$S_{2_1}$	0.089	166.14	0.089	166.14	0.093	174.49	0.093	174.49	0.060	179.14	0.060	179.14
$S_{2_2}$	0.665	250.36	0.665	250.36	0.977	323.82	0.977	323.82	1.576	5.78	1.576	5.78
$S_{2_4}$	0.004	280.18	0.004	280.18	0.009	19.98	0.009	19.98	0.018	207.59	0.018	207.59
$S_3$	0.007	231.07	0.007	231.07	0.009	305.15	0.009	305.15	0.005	151.19	0.005	151.19
$S_3$	0.002	9.46	0.002	9.46	0.003	161.57	0.003	161.57	0.004	115.94	0.004	115.94
$M_1$	0.075	3.46	0.039	61.05	0.083	18.17	0.044	76.51	0.096	14.66	0.051	73.19
$M_2$	1.557	316.05	1.548	231.37	2.614	17.11	2.599	293.92	3.990	54.32	3.967	331.52
$M_3$	0.018	161.06	0.018	214.04	0.034	284.91	0.034	340.12	0.071	328.90	0.071	24.71
$M_4$	0.011	168.38	0.011	359.03	0.014	157.81	0.014	351.43	0.112	107.35	0.110	301.76
$M_6$	0.007	270.94	0.007	16.91	0.045	89.02	0.045	199.45	0.019	277.80	0.019	29.42
$M_6$	0.002	96.01	0.002	117.30	0.003	127.41	0.002	154.65	0.008	347.01	0.008	15.84
$O_1$	0.645	328.00	0.648	40.11	0.655	333.31	0.658	46.97	0.632	335.26	0.635	49.34
$K_1$	1.299	197.35	1.303	36.45	1.321	207.22	1.325	46.26	1.374	206.81	1.378	45.84
$K_2$	0.182	30.83	0.188	249.03	0.256	102.05	0.263	320.13	0.392	141.31	0.403	359.36
$P_1$	0.416	223.12	0.416	32.91	0.407	233.51	0.407	43.37	0.400	232.14	0.400	42.02
$J_1$	0.087	24.49	0.086	24.50	0.076	38.45	0.076	37.60	0.083	44.61	0.083	43.53
$Q_1$	0.139	131.23	0.140	46.59	0.141	138.73	0.141	56.39	0.130	142.73	0.131	61.01
$L_2$	0.025	328.04	0.032	209.03	0.043	7.65	0.055	249.33	0.067	11.77	0.086	253.63
$N_2$	0.433	107.48	0.430	226.00	0.625	157.58	0.621	278.39	0.982	193.94	0.976	315.36
$\nu_2$	0.158	237.86	0.157	223.20	0.221	287.14	0.219	274.65	0.304	320.67	0.303	308.76
$\mu_2$	0.092	9.33	0.091	199.97	0.086	71.12	0.085	264.74	0.238	117.52	0.235	311.94
$T_2$	0.045	314.09	0.045	315.42	0.123	349.06	0.123	350.45	0.209	31.51	0.209	32.91
$(MS)_1$	0.009	260.43	0.009	175.75	0.039	38.97	0.039	315.78	0.101	106.56	0.101	23.77
$(2SM)_2$	0.010	32.25	0.010	116.93	0.013	37.79	0.012	120.98	0.052	42.79	0.052	125.53
$2N_2$	0.080	220.21	0.079	181.93	0.079	267.81	0.079	232.61	0.137	322.14	0.136	287.76
$(M_2N)_1$	0.010	212.01	0.010	245.85	0.018	328.57	0.018	6.19	0.028	196.18	0.028	234.81
$(M_2K_1)_3$	0.015	54.60	0.015	169.02	0.005	163.18	0.005	279.03	0.068	109.86	0.067	226.10
$(2M_2K_1)_3$	0.009	327.93	0.009	319.47	0.022	1.33	0.022	355.90	0.071	65.28	0.071	60.67
Long Period		°		°		°		°		°		°
$Mm$	0.056	215.12	0.055	11.92	0.049	98.60	0.048	254.60	0.048	95.07	0.047	250.86
$Mf$	0.049	63.42	0.050	14.51	0.039	21.37	0.040	330.86	0.003	147.63	0.003	96.68
$MSf$	0.019	163.79	0.019	218.46	0.038	98.67	0.038	181.86	0.036	16.45	0.036	99.24
$Sa$	0.339	58.75	0.339	338.96	0.209	146.18	0.209	66.32	0.185	58.93	0.185	339.05
$Ssa$	0.101	276.60	0.101	117.01	0.158	303.53	0.158	143.82	0.094	322.86	0.094	163.11

1918

Tide Symbol	BOMBAY (Prince's Dock)				MADRAS				KIDDERPORE			
	$A_0=8.302$				$A_0=2.222$				$A_0=10.318$			
	R	$\zeta$	H	$\kappa$	R	$\zeta$	H	$\kappa$	R	$\zeta$	H	$\kappa$
Short Period		°		°		°		°		°		°
$S_1$	0.077	183.06	0.077	183.06	0.028	77.61	0.028	77.61	0.102	198.21	0.102	198.21
$S_2$	1.625	4.33	1.625	4.33	0.454	268.85	0.454	268.85	1.511	97.87	1.511	97.87
$S_3$	0.024	209.57	0.024	209.57	0.001	246.80	0.001	246.80	0.092	107.57	0.092	107.57
$S_6$	0.001	153.44	0.001	153.44	0.001	284.04	0.001	284.04	0.004	86.01	0.004	86.01
$S_2$	0.002	95.19	0.002	95.19	0.001	254.75	0.001	254.75	0.006	298.97	0.006	298.97
$M_1$	0.097	11.75	0.051	70.29	0.008	3.62	0.004	62.41	0.041	121.54	0.021	180.60
$M_2$	4.104	53.05	4.080	330.26	1.101	322.30	1.095	240.01	3.765	136.36	3.744	54.62
$M_3$	0.067	329.19	0.066	25.00	0.003	318.01	0.003	14.58	0.023	278.63	0.023	336.02
$M_4$	0.108	136.33	0.107	330.75	0.005	336.30	0.005	171.72	0.756	193.61	0.747	30.12
$M_6$	0.010	51.05	0.010	162.68	0.007	344.83	0.007	97.96	0.154	195.37	0.151	310.14
$M_3$	0.007	62.49	0.006	91.33	0.001	110.56	0.001	141.40	0.072	231.75	0.070	264.77
$O_1$	0.645	334.09	0.648	48.16	0.095	248.01	0.096	322.61	0.216	300.22	0.217	15.39
$K_1$	1.388	205.77	1.392	44.80	0.295	137.04	0.296	336.05	0.414	213.81	0.417	52.80
$K_2$	0.392	140.80	0.402	358.85	0.126	50.21	0.129	268.22	0.436	234.97	0.448	92.93
$P_1$	0.402	231.55	0.402	41.42	0.095	164.98	0.095	334.87	0.165	235.86	0.165	45.77
$J_1$	0.083	40.89	0.083	39.81	0.018	284.74	0.018	283.37	0.023	357.98	0.023	356.30
$Q_1$	0.137	140.39	0.138	58.68	0.002	115.20	0.002	34.28	0.027	100.34	0.027	20.28
$L_2$	0.078	8.68	0.100	250.54	0.036	21.21	0.046	263.31	0.189	171.37	0.241	53.72
$N_2$	1.009	193.12	1.003	314.54	0.247	112.78	0.245	234.97	0.723	281.20	0.719	44.23
$\nu_2$	0.298	322.05	0.297	310.15	0.076	245.98	0.076	234.82	0.316	33.23	0.314	22.86
$\mu_1$	0.241	115.07	0.238	309.49	0.043	1.36	0.042	196.79	0.301	335.06	0.297	171.57
$T_2$	0.217	28.01	0.217	29.42	0.040	302.81	0.040	304.23	0.215	136.64	0.215	138.09
$(MS)_1$	0.130	121.21	0.129	38.42	0.004	9.46	0.004	287.17	0.691	153.47	0.687	71.73
$(2SM)_2$	0.046	35.47	0.046	118.26	0.024	137.05	0.024	219.33	0.070	281.86	0.070	3.60
$2N_2$	0.149	325.28	0.148	290.91	0.037	226.55	0.037	193.22	0.030	325.82	0.030	293.62
$(M_2N)_4$	0.006	234.35	0.006	272.98	0.005	131.91	0.005	171.81	0.275	341.87	0.272	23.15
$(M_2K_1)_3$	0.071	85.22	0.071	201.46	0.011	63.44	0.011	180.16	0.152	259.44	0.151	16.68
$(2M_2K_1)_3$	0.081	73.57	0.080	68.97	0.001	45.00	0.001	41.42	0.041	328.77	0.041	326.29
Long Period		°		°		°		°		°		°
$Mm$	0.041	93.47	0.040	249.26	0.110	216.78	0.108	12.30	0.263	201.67	0.258	356.90
$Mf$	0.012	97.86	0.012	46.92	0.041	71.66	0.042	20.17	0.252	91.18	0.256	39.10
$MSf$	0.042	12.23	0.042	95.02	0.026	279.48	0.026	1.77	0.748	324.14	0.744	45.88
$Sa$	0.163	56.98	0.163	337.11	0.503	313.14	0.503	233.24	2.136	227.09	2.136	147.17
$Ssa$	0.076	329.34	0.076	169.59	0.367	293.53	0.367	133.74	0.858	110.14	0.858	310.31

1918

Tide Symbol	RANGOON				MOULMEIN				PORT BLAIR			
	$A_0=10.377$				$A_0=8.921$				$A_0=4.901$			
	R	$\zeta$	H	$\kappa$	R	$\zeta$	H	$\kappa$	R	$\zeta$	H	$\kappa$
Short Period		o		o		o		o		o		o
$S_1$	0.129	136.82	0.129	136.82	0.119	147.28	0.119	147.28	0.032	67.90	0.032	67.90
$S_2$	2.116	166.83	2.116	166.83	1.442	141.96	1.442	141.96	0.961	313.55	0.961	313.55
$S_3$	0.088	262.97	0.088	262.97	0.055	208.71	0.055	208.71	0.003	181.85	0.003	181.85
$S_6$	0.009	21.08	0.009	21.08	0.013	175.43	0.013	175.43	0.003	311.82	0.003	311.82
$S_{11}$	0.003	263.09	0.003	263.09	0.001	289.98	0.001	289.98	0.004	356.01	0.004	356.01
$M_1$	0.037	81.91	0.020	141.23	0.033	69.20	0.017	128.57	0.008	311.46	0.004	10.66
$M_2$	5.858	210.18	5.824	128.96	4.013	189.44	3.989	108.32	2.037	359.88	2.025	278.43
$M_3$	0.027	91.11	0.026	149.29	0.028	119.72	0.027	178.05	0.006	317.12	0.006	14.96
$M_4$	0.531	326.86	0.525	164.44	0.966	319.95	0.954	157.73	0.016	271.88	0.016	109.00
$M_6$	0.265	330.63	0.260	86.99	0.093	50.55	0.091	167.20	0.003	299.48	0.003	55.14
$M_8$	0.106	60.80	0.193	95.95	0.073	60.43	0.072	95.98	0.002	24.78	0.002	59.00
$O_1$	0.302	309.42	0.304	25.14	0.243	329.72	0.244	45.55	0.151	225.54	0.152	301.02
$K_1$	0.686	194.63	0.688	33.59	0.460	196.97	0.461	35.93	0.402	127.30	0.403	326.27
$K_2$	0.578	308.61	0.594	166.53	0.383	284.81	0.393	142.72	0.257	90.52	0.264	308.46
$P_1$	0.176	241.45	0.176	51.39	0.129	243.75	0.129	53.69	0.131	146.78	0.131	316.71
$J_1$	0.013	31.72	0.013	29.74	0.018	1.90	0.018	359.85	0.025	291.37	0.025	289.51
$Q_1$	0.025	131.88	0.025	52.66	0.027	155.56	0.027	76.49	0.018	346.76	0.018	267.17
$L_2$	0.428	254.56	0.547	137.16	0.316	243.49	0.404	126.13	0.058	12.23	0.075	254.72
$N_2$	1.066	352.87	1.060	116.71	0.754	328.70	0.730	92.70	0.400	150.08	0.398	273.57
$\nu_2$	0.459	124.76	0.456	115.17	0.329	103.14	0.327	93.69	0.135	277.34	0.134	267.41
$\mu_2$	0.495	90.36	0.490	287.94	0.333	74.01	0.329	271.79	0.107	95.30	0.106	292.41
$T_2$	0.274	179.22	0.274	180.69	0.238	157.45	0.238	158.92	0.110	329.84	0.110	331.30
(MS) $_2$	0.486	291.80	0.484	210.59	0.771	279.57	0.766	198.46	0.006	171.72	0.006	90.28
(2SM) $_2$	0.173	331.49	0.172	52.70	0.157	307.09	0.156	28.21	0.024	85.24	0.024	166.68
$2N_2$	0.169	23.33	0.168	352.23	0.075	353.77	0.074	322.88	0.056	295.50	0.056	263.92
(M $2N$ ) $_2$	0.194	119.85	0.192	162.48	0.328	104.47	0.324	147.35	0.007	36.16	0.007	78.20
(M $2K_1$ ) $_3$	0.187	307.68	0.186	65.44	0.199	314.98	0.198	72.83	0.024	105.45	0.024	222.98
(2M $2K_1$ ) $_3$	0.113	51.50	0.112	50.11	0.100	58.41	0.099	57.22	0.004	201.04	0.004	199.18
Long Period		o		o		o		o		o		o
Mm	0.150	228.56	0.147	23.50	0.338	215.71	0.332	10.60	0.042	193.05	0.041	348.12
Mf	0.119	112.33	0.121	59.67	0.305	114.75	0.310	61.99	0.038	67.27	0.039	14.86
MSf	0.488	322.78	0.485	43.99	1.222	322.53	1.215	43.65	0.016	356.75	0.016	78.20
Sa	1.280	228.73	1.280	148.80	2.794	227.46	2.794	147.52	0.150	277.74	0.150	197.81
Ssa	0.155	74.49	0.155	274.62	0.682	83.87	0.682	283.99	0.137	357.19	0.137	197.33



## 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 1922, ready for use for the tide-predicting machine.
- (b) Values of the tidal constants for the tide-tables for Basrah for the year 1920.
- (c) Actual values of high and low water during 1917 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 1917, 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 1918, 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 were stopped but the times and heights of high and low water were 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 1918.*

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.	692	37	41	8	9	5	
Karāchi	"	703	35	40	12	10	3	
Bhaunagar	T. P.	365	76	24	0	0	0	
Bombay	(Apollo Bandar)	Auto.	699	38	50	6	4	2
	(Prince's Dock)	"	703	41	43	8	6	2
Madras	"	705	34	44	10	8	4	
Kidderpore	"	704	29	43	13	12	3	
Chittagong	T. P.	365	45	34	10	9	2	
Akyab	"	365	100	0	0	0	0	
Rangoon	Auto.	705	35	48	9	6	2	
Moulmein	"	705	31	41	12	12	4	
Port Blair	"	70	55	38	4	2	1	

## No. 2.

*Percentages and amounts of the errors in the predicted times of low water at the various tidal stations for the year 1918.*

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.	691	36	42	9	8	5
Karachi ...	"	704	32	40	12	11	5
Bhaunagar ...	T.P.	365	72	28	0	0	0
Bombay { (Apollo Bandar)	Auto.	690	35	51	8	5	1
	" (Prince's Dock)	701	37	47	8	6	2
Madras ...	"	704	28	48	9	9	6
Kidderpore ...	"	704	23	48	13	12	4
Chittagong ...	T.P.	365	39	31	11	12	7
Akyab ...	"	365	100	0	0	0	0
Rangoon ...	Auto.	706	28	39	16	14	3
Moulmein ...	"	706	20	32	13	19	16
Port Blair ...	"	705	53	41	3	3	0

## No. 3.

*Percentages and amounts of the errors in the predicted heights of high water at the various tidal stations for the year 1918.*

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.	692	6.7	93	7	0	0
Karachi ...	"	703	9.3	66	29	5	0
Bhaunagar ...	T.P.	365	31.4	80	18	1	1
Bombay { (Apollo Bandar)	Auto.	690	13.9	74	22	4	0
	" (Prince's Dock)	703	13.9	62	31	6	1
Madras ...	"	705	3.5	82	17	1	0
Kidderpore ...	"	704	11.7	36	24	16	24
Chittagong ...	T.P.	365	13.3	33	29	21	17
Akyab ...	"	365	8.3	80	19	1	0
Rangoon ...	Auto.	706	16.4	50	28	17	5
Moulmein ...	"	706	12.7	33	27	19	21
Port Blair ...	"	705	6.6	85	14	1	0

No. 4.

Percentages and amounts of the errors in the predicted heights of low water at the various tidal stations for the year 1918.

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.	691	6.7	95	5	0	0
Karāchi ...	"	704	9.3	83	16	1	0
Bhaunagar ...	T.P.	365	31.4	78	19	2	1
Bombay { (Apollo Bandar)	Auto.	699	13.9	74	21	4	1
	" (Prince's Dock)	701	13.9	08	25	7	0
Madras ...	"	704	3.5	76	20	4	0
Kidderpore ...	"	704	11.7	44	24	10	22
Chittagong ...	T.P.	365	13.3	20	23	21	36
Akyab ...	"	365	8.3	87	12	1	0
Rangoon ...	Auto.	706	16.4	38	30	19	13
Moulmein ...	"	706	12.7	36	24	18	22
Port Blair ...	"	705	6.6	98	2	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 1918.

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.
<i>Open Coast.</i>								
Aden ...	Auto.	6.7	11	11	0.025	0.025	2	2
Karāchi ...	"	9.3	11	11	0.036	0.027	4	3
Bhaunagar ...	T.P.	31.4	4	4	0.008	0.008	3	3
Bombay { (Apollo Bandar)	Auto.	13.9	9	9	0.018	0.018	3	3
	" (Prince's Dock)	13.9	9	9	0.024	0.024	4	4
Madras ...	"	3.5	11	12	0.071	0.071	3	8
Akyab ...	T.P.	8.3	0	0	0.030	0.020	3	2
Port Blair ...	Auto.	6.6	6	6	0.025	0.025	2	2
General Mean	...	...	8	8	0.030	0.027	3	3
<i>Riverain.</i>								
Kidderpore ...	Auto.	11.7	12	1	0.064	0.057	9	8
Chittagong ...	T.P.	13.3	9	12	0.050	0.081	8	18
Rangoon ...	Auto.	16.4	9	12	0.025	0.036	5	7
Moulmein ...	"	12.7	11	18	0.052	0.059	8	9
General Mean	...	...	10	14	0.048	0.058	8	9

*Summary for 1918.*

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	88	82	97	97	97	96
2 "	Tide-pole	100	100	99	98	100	100
3 Riverain	S. R. Tide-gauge	76	63	65	65	90	89
1 "	Tide-pole	79	70	62	43	93	73

COMPARISONS OF THE PREDICTIONS FOR THE YEAR 1918 WITH THOSE FOR THE  
PREVIOUS YEAR.

On comparing the tidal predictions at the nine working stations for the year 1918 against those for the year 1917, it appeared that the predictions of times for 1918 at Aden and Port Blair had improved in accuracy since the previous year. The predictions of times at the other stations and of heights at all the stations were practically of the same standard of accuracy as those for the year 1917.

The greatest difference between the actual and predicted heights of low water for 1918 at the riverain ports was as follows:—

Kidderpore ... 3 feet 1 inch on 22nd October 1918, actuals being lower.  
Rangoon ... 2 feet 2 inches on 6th November 1918, actuals being lower.  
Moulmein ... 4 feet 10 inches on 28th May 1918, actuals being higher.

## TIDE-TABLES.

The tide-tables for the year 1919 were received from England on 30th October 1918 and were immediately distributed to the various people requiring them.

The tide-tables for the year 1920 have not yet been received from England.

The tide-tables for Basrah for 1919 were printed at the office of the Trigonometrical Survey at Dehra Dūn and despatched to the Director of Inland Water Transport Basrah on 22nd October 1918. The tide-tables for Basrah for the year 1920 are being printed in England and will be supplied to the Basrah authorities as soon as received.

The amount realized on the sale of tide-tables during the year ending 30th September 1919 is Rs. 1,989/5/-.

## PROGRAMME FOR SEASON 1919-20.

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



LEVELLING

By H. G. SHAW.

*Levelling in the Punjab.*

PERSONNEL of No. 17 PARTY.

*Provincial Officers.*

- Mr. H. G. Shaw, in charge. Retired: in temporary employ from 21st February 1919.
- „ O. N. Pushong, from 1st April 1919 to 20th July 1919.
- „ D. H. Luxa, from 1st May 1919.
- „ J. McCracken, M. B. E., from 1st May 1919 to 14th September 1919.
- „ T. F. Kitchen, from 15th March 1919 to 5th July 1919
- „ K. S. Gopalachari, B. A., from 15th September 1919.
- „ N. N. Chuckerbutty, L. C. E., from 26th May 1919.

*Upper Subordinate Service.*

- Mr. K. E. Das, B. A., from 7th December 1918.
- „ S. C. Mukerjee, from 1st May 1919.

*Lower Subordinate Service.*

- 6 Computers.
- 5 Recorders
- 1 Clerk.

One double detachment, consisting of 2 officers (Messrs. Pushong and Kitchen), 3 Recorders and 33 menials, was employed in April and May 1919 on the revision of the line from Pathānkot to Dharmkot hill (Dharmśāla). The out-turn amounted to 56 miles of "simultaneous double levelling" (old system) in the course of which the heights of 9 primary and 65 secondary bench-marks were redetermined. Full details of the out-turn of work are given in Table I attached.

The health of the detachment was on the whole very good.

This revision was undertaken in order to ascertain whether the seismic disturbance which occurred in that locality in the summer of 1916 had had any effect in the relative levels of the hills and plains. The test was made possible by the existence of carefully selected bench-marks laid down in April and May 1910 with a view to such a contingency.

This line was originally levelled in April and May 1910 under the old system of "simultaneous double levelling" and in order to make the two levellings as strictly comparable as possible, the revision of 1919 was carried out under the same system, confining the operations to the same time of the year and as far as feasible reproducing the conditions of 1910.

From Pathānkot, 1081 feet above mean sea level, the road rises gradually for the first 14 miles and then ascends the hill to Nūrpur Fort, 894 feet above Pathānkot; it then alternately rises and falls up to Chambi bridge which is about 1088 feet above Pathānkot and distant 44 miles from it; from this point it ascends steadily and rapidly 4967 feet, in a distance of 12 miles to the terminal mark at Dharmkot hill (Dharmśāla) 7136 feet above mean sea level.

Using the formula  $\pm 0.6745 \sqrt{\frac{\sum d^2}{4M}}$  given in G. T. S. Volume XIX, the probable accidental error per mile of the original levelling in 1910 works out to  $\pm 0.007$  ft. and that of the revisionary levelling in 1919 to  $\pm 0.004$  ft.

Table III shows the discrepancies between the old and new values of bench-marks, from which it will be seen that except where the bench-marks have been disturbed by traffic *etc.*, the discrepancies are very small indeed. The greatest discrepancy between any two bench-marks occurs between those at miles 35.7 and 39.9, *i. e.*,  $-0.066$  ft. in 4.2 miles, and if we use the test formula for identity of bench-marks  $x = \sqrt{16(y^2 + y_1^2)M + (0.003)^2 M^3}$  given in the Records of the Survey of India Volume XI, we obtain  $\pm 0.067$  ft. as the value of  $x$ , so that this discrepancy is fairly attributable to accidental and systematic errors. The formula  $\sqrt{y^2 M + (0.00034)^2 M^3 + \lambda^2 D^2}$  from G.T.S. Volume XIX, expresses the probable error of the terminal result of a line  $M$  miles long, where  $D$  is the difference in height between the starting and the terminal points,  $y$  is the probable accidental error per mile, and  $\lambda$  is the probable error per foot of the mean length of the staves. If the line be revised then the probable error of the discrepancy between the original and the revised levelling is the square root of the sum of the squares of the probable errors of the original and the revised levelling respectively which is expressed as  $\sqrt{(y^2 + y_1^2) M + 2(0.00034)^2 M^3 + 2(0.00021)^2 D^2}$  where  $y$  and  $y_1$  are the probable errors per mile respectively of the original and the revised levellings. The terminal discrepancy between the results of the 1910 and the 1919 levellings was found to be  $-0.246$  of a foot, of this amount, (i)  $-0.097$  ft. was generated in the first 44 miles from Pathānkot, in which the rise is 1088 feet, and (ii) the remaining  $-0.149$  ft. in the last 12 miles, in which there is a steady rise of 4967 feet. For the purpose of determining

the probable error of the discrepancy between the original and the revised levellings, it has been considered advisable to divide the line into the above two parts so that each part is practically uniform in the nature of the gradients encountered.

Part (i). From B.M. No. 21/43 P (initial bench-mark) to B.M. No. 27/52 D, where  $M=43.7$  miles,  $D=1088$  ft.,  $y=\pm 0.007$  ft.,  $y_1=\pm 0.004$  ft. and  $\lambda=0.000021$  from G.T.S. Volume XIX, we get the probable error of the discrepancy  $\pm 0.066$  ft. The actual discrepancy at B.M. No. 27/52 D is  $-0.097$  ft., but from a comparison of the discrepancies at flanking bench-marks it is evident that this mark has suffered a small subsidence of roughly  $0.030$  ft., so that the actual discrepancy, after neglecting  $0.030$  ft., hits off, almost exactly, the probable error above determined.

Part (ii). From B.M. No. 27/52 D to B.M. No. 53/52 D (terminal bench-mark), where  $M=12$  miles,  $D=4967$  ft. and the other factors are the same as in part (I), we get the probable error of the discrepancy  $=\pm 0.151$  ft. The actual discrepancy is  $-0.149$  ft.

It is also worthy of note that the total difference between the results of the two levellers amounted to  $0.214$  ft. in 1910, and to  $0.248$  ft. in 1919. These quantities are very nearly equal to the total discrepancy between the mean results of the 1910 and the 1919 observations. The result by one of the levellers of 1910 was practically identical with that of one of the levellers of 1919.

It is therefore safe to conclude that the discrepancy of  $0.246$  ft. is due to the errors, accidental and systematic, which are inherent in the conditions of mountain levelling and that no measurable change has resulted from the earthquake of 1916.

#### *Levelling of Mesopotamia.*

For administrative purposes the personnel of the levelling detachments, as shown in

##### PERSONNEL.

Tigris Detachment.

*Provincial Officer.*

Mr. D. H. Luxa.

*Upper Subordinate Service.*

Mr. S. C. Mukerjee.

*Lower Subordinate Service.*

3 Computers.

Euphrates Detachment.

*Provincial Officers.*

Mr. J. McCracken, M. B. E.

„ N. N. Chuckerbutty, L. C. E.

*Lower Subordinate Service.*

2 Computers.

1 Recorder.

the margin, were transferred to the Mesopotamia Survey Party for levelling operations in Mesopotamia, but the work was carried out under the supervision of the Officer in charge, No. 17 Party (Levelling), and on the completion of the work they were re-transferred to No. 17 Party.

The detachments left Dehra Dūn on 20th September 1918 and arrived at Basrah on 4th October 1918, and returned to recess quarters, Mussoorie, on 12th May 1919.

The out-turn amounted to 956 miles, including branch-lines, of "simultaneous double levelling" in the course of which the heights of 26 primary (Standard), 406 secondary and 467 tertiary bench-marks were determined. Full details of the out-turn of work are given in Table I attached.

The health of the detachments was on the whole good. Two *khalāsis* died, one from fever and the other from dysentery.

The object of the levelling was primarily to provide trustworthy bench-marks for the use of Irrigation Engineers, and to serve as a frame-work on which the several schemes of irrigation emanating from the Tigris and the Euphrates could be based, but should geodetic operations be undertaken in Mesopotamia these lines of levels will be of value. This levelling was undertaken by the Survey of India at the request of the Director of Irrigation, Mesopotamia.

The levelling was carried out on the system of "simultaneous double levelling of precision" which was in use in India from 1858 to 1913. This system was adopted instead of the present system of independent "fore and back double levelling of precision" on account of the prevailing war conditions and transport difficulties.

The lines run were:—

- (1) From Basrah to Nasiriyah, along the railway, thence northwards *via* Sumāwah to Hilla along the Hilla branch of the Euphrates, and finally, leaving the Euphrates, to Baghdad. Distance 410 miles.

- (2) From Baghdad to Kut-el-Amara and thence to Shaikh Sa'ad where a junction was made with a good line run in 1916-17 up the Tigris from Basrah by a party of levellers sent from India by the Public Works Department. Distance 147 miles.
- (3) From Kut-el-Amara *via* Hai along the Shatt-al-Gharráf to Suwaij and thence by road to Nasiriyah. Distance 130 miles.
- (4) From Baghdad to Ramádi *via* Feluja. Distance 66 miles.
- (5) From Baghdad to Table Mountain along the railway line. Distance 71 miles.
- (6) From Baghdad to Baiji (Rail head) along the railway line. Distance 132 miles.

Lines (1), (2) and (3) form two circuits, namely:—

- (a) Basrah—Nasiriyah—Kut-el-Amara (*via* Hai)—Shaikh Sa'ad—Basrah. Length 526 miles. In this circuit the line from Shaikh Sa'ad to Basrah, a distance of 227 miles, was done by the Public Works Department in 1916-17 as mentioned previously. The closing error of this circuit amounted to  $-0\cdot593$  ft. The circuit includes several river crossings and the closing error though greater than would be expected from the length of the lines is on the whole tolerably satisfactory.
- (b) Nasiriyah—Sumāwah—Hilla—Baghdad—Kut-el-Amara—Nasiriyah. Length 482 miles. The closing error of this circuit amounted to  $+0\cdot141$  ft.

This result is very good. The probable error of the circuit as calculated by the formula which has been found applicable to the Indian work is  $\pm 0\cdot186$  ft.

Mean Sea Level at Fāo has been accepted and employed as the datum for the heights of all bench-marks in Mesopotamia. The height of this datum above the zero of the Tide Gauge at Fāo was deduced from the readings of the Tide Gauge at the Tidal Observatory at Fāo set up under the direction of Sir G. Buchanan. The observations for mean sea level at this Tidal Observatory extended over several months *viz.*, from 8th July to 1st December 1916. A line of levels was run from this observatory to Basrah in 1916-17 by the Public Works Department levellers, connecting the bench-mark on the landing of the masonry steps on the west bank of the Shatt-al-'Arab opposite Messrs. Gray Mackenzie & Co., (Willcocks' bench-mark) *i. e.*, bench-mark No. 30 in the Line A (Fāo to Basrah) given in page 4 of the Mesopotamia Levelling Pamphlet published in 1919. This levelling was done with great care and there is evidence that the degree of accuracy attained was high, it was, therefore, decided to accept the height of this bench-mark as correct and it was made the initial point of the levelling of precision in Mesopotamia.

Primary or Standard bench-marks were erected at important towns at about 40 to 60 miles apart. The sites of such bench-marks are well away from railway lines and above flood level. Secondary or embedded bench-marks were also built and connected at towns of lesser importance and in the vicinity of conspicuous tombs and buildings, at distances of about 10 miles apart, these were supplemented by tertiary or inscribed bench-marks on buildings, culverts and bridges established at intervals of  $\frac{1}{2}$  mile to 2 miles apart. Full details of the construction and build of all the different kinds of bench-marks in Mesopotamia are given in the Levelling Pamphlet published in 1919.

As the nature of the soil at Basrah is not such as to offer much certainty of stability in the bench-marks built there, a standard bench-mark and four auxiliaries were built in the neighbourhood of Zubair, where the ground is safe from inundation and where good stability may be expected, and a good connection was made between the Basrah bench-marks and this Zubair group. Repetitions of this short line Zubair-Basrah made from time to time will show whether the ground round about Basrah is moving or not. This standard bench-mark near Zubair is to be regarded as the Bench-mark of reference for the whole of Mesopotamia.

Most of the country traversed was flat, featureless and liable to inundation. The portion near Ramádi is undulating with low gravel hills. From Shahrabān to Table Mountain and from Samarra to Baiji the ground gradually ascends to the hills. In many places the soil is impregnated with saltpetre which, when slightly heated, caused the atmosphere to boil and made the observations difficult on account of radiation.

32° N. Latitude has been adopted as the central latitude for the orthometric corrections for the levelling in Mesopotamia.

TABLE I.—Tabular statement of out-turn of work, season 1918-19.

Detachment	Lines.	Months.	NUMBER OF MILES OF DOUBLE LEVELLING.			Total.	Total number of feet (Mean Line).		Number of stations at which instruments were set up.	NUMBER OF BENCH-MARKS CONNECTED.												REMARKS.
			Main Line.	Extras and branch-lines.	Total.		Rises.	Falls.		Primary.	Secondary.	Tertiary.	Rock-cut.	Embedded.	Rock-cut.	Inscribed.	Embedded in cement concrete.	Inscribed.	Iron spikes full or concrete embedded in the ground.	Iron bolts embedded in culverts.		
Punjab	Pathankot to Dharmkot Hill (Dharmasals)	April 1919	Mls. Chs. Ls.	Mls. Chs. Lks.	Mls. Chs. Lks.	2997.714	1674.496	876	9*	1*	33*	31*	...	...	...	...	...	...	* Old bench-marks.			
		May 1919	13 07 08	0 27 26	13 34 34	5153.712	421.117		672	9	1	33	31	...	...	...	...	...				
		Grand Totals	55 63 10	0 33 18	56 06 28	8151.426	2096.613	1548	18	2	66	62	...	...	...	...	...					
	Kut-el-Amara	October 1918	15 57 84	...	15 57 84	92.403	106.315	164 758 138 5	...	...	...	...	...	...	...	...	...	...	70			
		November 1918	79 51 06	2 12 32	81 63 38	202.989	236.682		...	4	...	...	10	16	...	...	...					
December 1918	14 77 96	...	14 77 96	45.568	50.841	...	...		...	...	...	...	...	...	...	...	...	...				
March 1919	...	0 22 64	0 22 64	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...			
Totals	110 26 86	2 34 96	112 61 82	340.970	393.318	1065	...		4	...	...	10	16	...	...	...	...	...				
Kut-el-Amara to Shaik Sa'ad	December 1918	31 60 20	...	31 60 20	65.411	77.676	298	...	...	...	...	...	...	...	...	...	...	8				
	Totals	31 60 20	...	31 60 20	65.411	77.676		...	...	...	...	...	...	...	...	...	...		...			
	December 1918	9 44 18	...	9 44 18	53.342	92.914		92	...	...	...	...	...	...	...	...	...		...			
Table Mountain	January 1919	59 01 62	0 34 00	59 35 62	244.808	321.214	552 30	...	...	...	...	...	...	...	...	...	...	200				
	March 1919	...	2 38 28	2 38 28	...	...		...	...	...	...	...	...	...	...	...	...		...			
	Totals	68 45 80	2 72 28	71 38 08	297.650	414.128		674	...	...	...	...	10	36	...	...	...		...			
Nasiriyah to Baghdad	January 1919	3 78 46	0 51 14	4 49 60	49.975	49.119	54	...	...	...	...	...	...	...	...	...	...	4				
	Totals	3 78 46	0 51 14	4 49 60	49.975	49.119		54	...	...	...	...	...	...	...	...	...		...			
Baghdad to Baiji	January 1919	26 05 62	...	26 05 62	121.416	103.102	266 928	...	...	...	...	...	...	...	...	...	...	29				
	February 1919	104 71 88	1 08 10	105 79 98	934.534	690.375		...	...	...	...	...	...	...	...	...	...		...			
	Totals	130 77 50	1 08 10	132 05 60	1055.950	793.477		1194	...	...	...	...	...	...	...	...	...		...			
Basrah to Nasiriyah	March 1919	3 67 18	...	3 67 18	20.654	17.255	38	...	...	...	...	...	...	...	...	...	...	3				
	Totals	3 67 18	...	3 67 18	20.654	17.255		38	...	...	...	...	...	...	...	...	...		...			

1919



TABLE II.—PUNJAB DETACHMENT.

*Results of comparison of staves with Standard Steel Tape No. 4, season 1918-19.*

Place and date of comparison.	DIFFERENCE OF LENGTH OF STAFF FROM 10 FEET.				Remarks.
	Number of staff.				
	19 A.	19 B.	I.	OI.	
	Foot.	Foot.	Foot.	Foot.	
Pathankot 8-4-1919 ...	-0.0016437	-0.0018310	-0.0006637	-0.0024387	Clear, slight breeze.
Nürpur 15-4-1919 ...	-0.0022297	-0.0019547	-0.0011905	-0.0029287	Cloudy, slight breeze.
Kotla 25-4-1919 ...	-0.0017754	-0.0011313	-0.0010113	-0.0028599	Bright & hot, clouds on all horizons, scattered clouds overhead.
Chambi bridge 1-5-1919 ...	-0.0021848	-0.0024713	-0.0011968	-0.0034718	Light scattered clouds and light cool breeze.
Dharmśūla Kachahri 6-5-1919	-0.0018087	-0.0023905	-0.0013429	-0.0031988	Cloudy, thundering.
McLeodganj bazar 12-5-1919	-0.0017056	-0.0019120	-0.0010120	-0.0024183	Cloudy and cool.

TABLE II—(Continued).—TIGRIS DETACHMENT.

*Results of comparison of staves with Standard Steel Tape No. 2, season 1918-19.*

Place and date of comparison.	DIFFERENCE OF LENGTH OF STAFF FROM 10 FEET.				Remarks.
	Number of staff.				
	25 A.	25 B.	23 B.	22 B.	
	Foot.	Foot.	Foot.	Foot.	
Kut-el-Amara 21-10-18 ...	+0.00003	-0.00140	+0.00071	+0.00005	Clear and dry.
Diylāh 31-10-18 ...	-0.00078	-0.00304	-0.00034	-0.00120	Strong cool breeze, dusty.
Lajj 7-11-18 ...	-0.00152	-0.00422	-0.00105	-0.00274	Raining, cloudy and cool breeze.
Aziziyah 15-11-18 ...	-0.00024	-0.00227	+0.00031	-0.00050	Clear and cool breeze.
Shidhaif 23-11-18 ...	+0.00094	-0.00129	+0.00153	+0.00068	Light scattered clouds, cool breeze.
Imām Mahdi 30-11-18 ...	+0.00064	-0.00177	+0.00086	+0.00001	Light scattered clouds.
Kut-el-Amara 7-12-18 ...	+0.00089	-0.00160	+0.00108	0.00000	Scattered clouds, cool breeze.
Marching Post No. 10 (Fūahiyah) 15-12-18	+0.00057	-0.00197	+0.00080	+0.00024	Cloudy.
Shaiḥ Sa'ad 19-12-18 ...	+0.00077	-0.00180	+0.00069	+0.00014	Light scattered clouds with sudden gusts of cold breeze.
Baghdad 27-12-18 ...	+0.00127	-0.00166	+0.00144	+0.00022	Foggy.
Abū Jisrah 3-1-19 ...	+0.00140	-0.00140	+0.00138	+0.00058	Light scattered clouds, cool breeze.
Coningham's Post 10-1-19 ...	+0.00173	-0.00107	+0.00196	+0.00100	Light scattered clouds and cool breeze.
Baghdad 20-1-19 ...	+0.00297	+0.00020	+0.00279	+0.00207	Cloudy, damp and cold breeze.
Tāji 27-1-19 ...	+0.00176	-0.00027	+0.00184	+0.00151	Clear and cool breeze.
Sūmaichah 4-2-19 ...	+0.00174	-0.00039	+0.00173	+0.00127	Light scattered clouds, cool breeze.
Istabulat 11-2-19 ...	+0.00291	+0.00025	+0.00252	+0.00200	Light scattered clouds, sudden gusts of strong cool breeze.
Daur 19-2-19 ...	+0.00181	-0.00044	+0.00166	+0.00162	Scattered clouds.
Baiji 28-2-19 ...	+0.00138	-0.00028	+0.00182	+0.00169	Clear overhead, scattered clouds on N horizon.
Ṭanūmah (Basrah) 21-3-19 ...	+0.00109	-0.00098	+0.00100	+0.00109	Clear and cool breeze.

TABLE II.—(Continued).—EUPHRATES DETACHMENT.  
Results of comparison of staves with Standard Steel Tape No. 5, season 1918-19.

Place and date of comparison.	DIFFERENCE OF LENGTH OF STAFF FROM 10 FEET.				Remarks.
	Number of staff.				
	24 A.	24 B.	12 A.	12 B.	
	Foot.	Foot.	Foot.	Foot.	
Tanumah 13-10-18 ...	-0.00383	-0.00165	+0.00154	+0.00229	Clear and cool breeze.
Zubair 26-10-18 ...	-0.00623	-0.00466	+0.00011	+0.00109	Light scattered clouds and cool breeze.
Ghabshiyah 6-11-18 ..	-0.00695	-0.00499	-0.00138	+0.00068	Scattered clouds and cool breeze.
Tel-al-Lahm 18-11-18 ...	-0.00487	-0.00368	+0.00101	+0.00177	Clear.
Khidhr 2-12-18 ...	-0.00575	-0.00413	-0.00010	+0.00077	Clear and cool breeze.
Rumaithah 15-12-18 ...	-0.00524	-0.00331	+0.00052	+0.00102	Cloudy and cool breeze.
Abu Shanawah 1-1-19 ...	-0.00440	-0.00284	+0.00110	+0.00144	Cloudy, rained in the morning and overnight.
Mahmūdiyyah 15-1-19 ...	-0.00362	-0.00281	+0.00080	+0.00188	Light clouds and cool breeze.
Feluja 31-1-19 ...	-0.00383	-0.00232	+0.00206	+0.00217	Light scattered clouds.
Kut-el-Amara 14-2-19 ...	-0.00381	-0.00262	+0.00121	+0.00224	Clear and strong cool breeze.
Karrādi 4-3-19 ...	-0.00322	-0.00215	+0.00212	+0.00306	Light clouds and strong breeze.
Nasiriyyah 15-3-19 ...	-0.00481	-0.00327	+0.00144	+0.00192	Clear and cool breeze.

TABLE III.—REVISION LEVELLING.—PUNJAB DETACHMENT.  
Discrepancies between the old and new heights of bench-marks.

Bench-marks of the original levelling that were connected during the revisionary operations.		Distance from starting bench-mark.	Observed heights, above (+) or below (-) the starting bench-mark.			Difference (Revision—Original). The sign + denotes that the height was greater and the sign - less in 1919 than when originally levelled.	Remarks.
Number.	Degree sheet.		Description.	From original levelling.	Date of original levelling.		
			Miles.	Feet.		Feet.	
<i>Revision of line Pathankot-Dharmśāla. Part of line No. 56 B (Lahore-Dharmśāla).</i>							
21	43 P	Embedded ...	0.00	0.000	1909-10	0.000	...
22	"	Station platform...	0.23	+ 7.128	"	+ 7.126	-0.002
23	"	Mile pillar ...	1.41	+ 48.418	"	+ 48.467	+0.049
24	"	Mile pillar ...	2.43	+ 90.036	"	+ 90.038	+0.002
25	"	Mile pillar ...	3.43	+ 118.088	"	+ 118.083	-0.005
26	"	Mile pillar ...	4.44	+ 156.657	"	+ 156.650	-0.007
27	"	Mile pillar ...	5.45	+ 189.314	"	+ 189.291	-0.023
28	"	Bridge ...	...	...	...	...	Destroyed.
29	"	Bridge ...	7.48	+ 199.773	"	+ 199.774	+0.001
30	"	Bridge ...	8.76	+ 244.338	"	+ 244.319	-0.019
31	"	Bridge ...	10.30	+ 291.177	"	+ 291.154	-0.023
32	"	Bridge ...	11.58	+ 313.157	"	+ 313.122	-0.035
33	"	Bridge ...	12.47	+ 353.479	"	+ 353.466	-0.013
34	"	Bridge ...	12.98	+ 365.752	"	+ 365.741	-0.011
35	"	Bridge ...	13.94	+ 402.485	"	+ 402.473	-0.012
36	"	Bridge ...	...	...	...	...	Destroyed.
37	"	Rock ...	15.30	+ 750.111	"	+ 750.105	-0.006
38	"	Rock ...	15.68	+ 894.074	"	+ 894.041	-0.033
39	"	Rock ...	16.25	+ 809.455	"	+ 809.419	-0.036
40	"	Rock ...	16.72	+ 750.688	"	+ 750.667	-0.021
41	"	Rock ...	17.40	+ 854.538	"	+ 854.504	-0.034
42	"	Rock ...	18.21	+ 894.982	"	+ 894.942	-0.040
43	"	Bridge ...	19.21	+ 882.079	"	+ 882.045	-0.034
44	"	Rock ...	19.83	+ 861.895	"	+ 861.855	-0.040
45	"	Mile pillar ...	21.31	+ 1003.552	"	+ 1003.477	-0.075
46	"	Bridge ...	22.42	+ 866.806	"	+ 866.768	-0.038
47	"	Embedded stone ...	23.31	+ 899.759	"	+ 899.715	-0.044
48	"	Rock ...	24.74	+ 1074.124	"	+ 1074.097	-0.027

TABLE III.—REVISION LEVELLING.—(Continued).

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

Bench-marks of the original levelling that were connected during the revisionary operations.			Distance from starting bench-mark.	Observed heights, above (+) or below (-) the starting bench-mark.			Difference (Revision-Original). The sign + denotes that the height was greater and the sign - less in 1919 than when originally levelled.	Remarks.
Number.	Degree sheet.	Description.		From original levelling.	Date of original levelling.	From revision 1919.		
			Miles.	Feet.		Feet.	Feet.	
<i>Revision of line Pathānkot-Dharmśāla. Part of line No. 56 B (Lahore-Dharmśāla).—(Contd.)</i>								
1	52 D	Rock	26.33	+ 978.475	1909-10	+ 978.449	- 0.026	
2	"	Rock	27.10	+ 784.162	"	+ 784.154	- 0.008	
3	"	Marble Memorial	28.50	+ 689.790	"	+ 689.782	- 0.008	
4	"	Rock	...	...	...	...	...	Destroyed.
5	"	Plinth of temple...	29.10	+ 635.711	"	+ 635.709	- 0.002	
6	"	Bridge	29.91	+ 640.076	"	+ 640.071	- 0.005	
7	"	Rock	31.03	+ 683.940	"	+ 683.939	- 0.001	
8	"	Bridge	32.04	+ 735.781	"	+ 735.793	+ 0.012	
9	"	Rock	...	...	...	...	...	Destroyed.
10	"	Bridge	32.64	+ 771.211	"	+ 771.210	- 0.001	
11	"	Rock	33.07	+ 899.362	"	+ 899.357	- 0.005	
12	"	Bridge	34.26	+ 1180.201	"	+ 1180.197	- 0.004	
13	"	Rock	35.00	+ 1214.871	"	+ 1214.853	- 0.018	
14	"	Rock	35.75	+ 1252.342	"	+ 1252.311	- 0.031	
15	"	Mile pillar	36.33	+ 1391.937	"	+ 1392.535	+ 0.598	Reconstructed.
16	"	Rock	...	...	...	...	...	Destroyed.
17	"	Boulder	...	...	...	...	...	Not found.
18	"	Bridge	38.81	+ 1550.570	"	+ 1550.454	- 0.116	Slight subsidence
19	"	Mile pillar	39.31	+ 1478.630	"	+ 1479.069	+ 0.439	Reconstructed.
20	"	Big Boulder	39.86	+ 1405.272	"	+ 1405.175	- 0.097	
21	"	Boulder	40.10	+ 1381.142	"	+ 1381.040	- 0.102	
22	"	Rock	40.83	+ 1323.059	"	+ 1322.964	- 0.095	
23	"	Rock	41.87	+ 1285.803	"	+ 1285.729	- 0.074	
24	"	Mile pillar	42.33	+ 1247.573	"	+ 1247.495	- 0.078	
25	"	Rock	42.51	+ 1231.222	"	+ 1231.158	- 0.064	
26	"	Rock	42.82	+ 1220.283	"	+ 1220.217	- 0.066	A possible subsidence as boulder is near bed of river surrounded by wet soil and water channels.
27	"	Boulder	43.69	+ 1088.369	"	+ 1088.272	- 0.097	
28	"	Boulder	45.07	+ 1401.875	"	+ 1401.815	- 0.060	
29	"	Boulder	46.13	+ 1632.384	"	+ 1632.298	- 0.086	
30	"	Bridge	47.06	+ 1734.221	"	+ 1734.155	- 0.066	
31	"	Boulder	47.20	+ 1766.364	"	+ 1766.299	- 0.065	
32	"	Rock	48.14	+ 2091.765	"	+ 2091.664	- 0.104	
33	"	Rock	49.20	+ 2334.121	"	+ 2334.008	- 0.113	
34	"	Rock	50.19	+ 2753.460	"	+ 2753.312	- 0.148	
35	"	Rock	...	...	...	...	...	Destroyed.
36	"	Roof over spring	51.40	+ 3366.499	"	+ 3366.316	- 0.183	
37	"	Bridge	51.58	+ 3455.547	"	+ 3455.362	- 0.185	
38	"	Rock	51.72	+ 3471.600	"	+ 3471.422	- 0.178	
39	"	Rock	51.83	+ 3640.127	"	+ 3639.940	- 0.187	
40	"	Rock	52.22	+ 3816.546	"	+ 3816.388	- 0.158	
41	"	Rock	52.48	+ 3940.064	"	+ 3939.893	- 0.171	
42	"	Rock	52.72	+ 4131.543	"	+ 4131.385	- 0.158	A slight subsidence of the boulder has taken place.
43	"	Boulder	52.94	+ 4310.610	"	+ 4310.416	- 0.194	
44	"	Rock	53.43	+ 4736.105	"	+ 4735.978	- 0.127	
45	"	Rock	53.53	+ 4810.650	"	+ 4810.510	- 0.140	
46	"	Rock	54.00	+ 5161.553	"	+ 5161.381	- 0.172	
47	"	Rock	54.29	+ 5363.000	"	+ 5362.816	- 0.184	A slight subsidence in this bench-mark.
48	"	Boulder	54.48	+ 5523.838	"	+ 5523.578	- 0.260	
49	"	Rock	54.82	+ 5747.518	"	+ 5747.305	- 0.213	
50	"	Rock	54.94	+ 5816.421	"	+ 5816.200	- 0.221	
51	"	Rock	54.97	+ 5835.513	"	+ 5835.290	- 0.223	
52	"	Rock	55.42	+ 6016.141	"	+ 6015.907	- 0.234	
53	"	Rock	55.66	+ 6054.955	"	+ 6054.709	- 0.246	



TABLE IV.

*Differences between levellers.*

Detachment.	Section.	Difference. First - Second.
Punjab	Line Pathānkot to Dharmkot hill	At 10th mile +0·038
	Ditto	„ 20th „ +0·042
	Ditto	„ 30th „ +0·047
	Ditto	„ 40th „ +0·010
	Ditto	„ 44th „ -0·020
	Ditto	„ 50th „ -0·124
	Ditto	„ 56 miles or end of line -0·248
Tigris	Line E, Kut-el-Amara to Shaikh Sa'ad	At 14th mile -0·026
	Ditto	„ 25th „ -0·013
	Ditto	„ 32 miles or end of line -0·019
	Line F, Baghdad to Kut-el-Amara	„ 25th mile +0·036
	Ditto	„ 50th „ +0·076
	Ditto	„ 75th „ +0·059
	Ditto	„ 100th „ +0·024
	Ditto	„ 110 miles or end of line +0·001
	Line H, Table Mountain to Baghdad	„ 24th mile -0·033
	Ditto	„ 50th „ -0·027
	Ditto	„ 69 miles or end of line -0·041
	Line I, Baghdad to Baiji	„ 25th mile +0·040
	Ditto	„ 50th „ -0·042
	Ditto	„ 75th „ +0·006
	Ditto	„ 100th „ 0·000
Ditto	„ 131 miles or end of line +0·027	
Euphrates	Line C, Basrah to Nasiriyah	At 50th mile +0·024
	Ditto	„ 100th „ +0·037
	Ditto	„ 139 miles or end of line -0·024
	Line D, Kut-el-Amara to Nasiriyah	At 52nd mile -0·018
	Ditto	„ 100th „ -0·031
	Ditto	„ 130 miles or end of line -0·032
	Line G, Nasiriyah to Baghdad	„ 51st mile +0·018
	Ditto	„ 101st „ -0·013
	Ditto	„ 150th „ +0·013
	Ditto	„ 199th „ +0·058
	Ditto	„ 238th „ +0·047
	Ditto	„ 242 miles or end of line +0·021
	Line J, Baghdad to Ramādi	„ 48th mile -0·016
Ditto	„ 66 miles or end of line +0·020	



## MAGNETIC SURVEY.

By E. C. J. BOND.

## PERSONNEL of No. 18 PARTY.

*Provincial Officers.*

Mr. E. C. J. Bond, V. D., in charge.  
 „ N. R. Mazumdar.

*Upper Subordinate Service.*

Mr. B. B. Shome.

*Lower Subordinate Service.*

2 Magnetic Observers.  
 12 Computers etc.

The present report on the work of the magnetic party in 1918-19 comprises:—

- I.—An account of the work during the field and recess seasons.
- II.—A note on each of the observatories.
- III.—Tables of the mean values of the magnetic elements, dates of magnetic disturbances and hourly means and diurnal inequality of the magnetic elements at observatories in 1918.

## I.—WORK DURING THE FIELD AND RECESS SEASONS.

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

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

No field work was undertaken during the year.

The staff of the party was employed on the computation and tabulation of the preliminary reduction of the observations at observatories and in the reduction of observations at detail stations to the epoch 1909·0.

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 1918 have been completed. The mean values of these elements for the year, derived from the measurement of traces of all available days, excluding those of great disturbance, are given in the table at the end of this report.

The reduction of the observations of the detail survey was completed during the early part of the recess season and the computations for investigating the disturbance effects in the detail survey areas are in hand.

*Special observations.*—In response to a request from Dr. L. A. Bauer, Director of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, to all countries for co-operation in special simultaneous magnetic observations in connection with the Total Solar Eclipse of the 29th May 1919, observations of the three magnetic elements were taken at the Dehra Dūn observatory on the 28th, 29th and 30th May 1919, in accordance with the programme issued by the Director. Observations were required at observatories situated both inside and outside the zone of visibility of the eclipse. The Dehra Dūn observatory fell outside this zone. No unusual changes were noticed in the magnetic elements at Dehra Dūn during the three days' observations, but it is hoped that even a result of this nature will be of use to Dr. Bauer in his investigation of the effects of the eclipse on the Earth's magnetism.

The observations were commenced at 2 P. M. in natural light and had to be continued with artificial light to 10 P. M. Electric lights were employed as these were easier to manipulate than oil lamps or candles and there was no difficulty in having the observatory connected with the mains. Before using the electric lights, however, a trial was made to find out whether the electric current would have any action on the magnets, no effect was produced as was indeed to be expected as the current is an alternating one.

3. *Programme for 1919-20.*—Observations at Repeat Stations were last taken in field season 1914-15 and as it has been decided that observations are to be repeated every fifth year for determining reliable values of the annual changes in the magnetic elements, three detachments will be employed in the coming field season to take magnetic observations at the 75 Repeat Stations distributed over India, Burma and Ceylon: these stations are shown in map No. 10 in this report.

The reduction of the observations at the Repeat Stations will be taken in hand during the next recess season and the secular changes derived from these for the period 1915 to 1920 will be utilized in reducing the values of the magnetic elements at all stations to a new epoch and in preparing revised editions of the maps of the magnetic elements.

In addition to this and to the usual computations for the reduction of the year's observations at the observatories, the computations for investigating the disturbance effects at the detail stations will be continued.

## II.—THE OBSERVATORIES IN 1918-19.

### Dehra Dun Observatory.

1. The magnetographs have worked satisfactorily during the year, except that the V. F. clock went out of order on two occasions and had to be cleaned and adjusted.

The mirror of the V. F. magnet system has become dull, probably from the effects of the dampness of the underground room, and the magnet lines on the magnetograms are in consequence somewhat faint. A new mirror will be substituted early in the coming field season.

The declination magnetograph was adjusted on the 1st April 1919 on account of the magnet line on the magnetogram approaching too close to the base line, owing to the gradual shift in the direction of the magnet due to secular change.

The underground observatory was free from inundation during the rainy season this year. There have been frequent heavy showers of rain but these were not continuous beyond a day or two and the subsoil water did not probably have time to accumulate in sufficient quantity in the boulder trench to cause enough pressure for the percolation of water into the observatory.

As electric lights had proved so satisfactory for taking the absolute observations during the total solar eclipse of the 29th May 1919, a further trial was made with them in the underground observatory with a view of introducing such lights for the magnetographs in place of oil lamps which often smoke and foul the air in the observatory. The lights were switched on and off at intervals but gave no indication whatever of any action of the electric current on the sensitive magnets of the magnetographs; it has therefore been considered advisable to install electric lights in the observatory in place of the existing oil lamps as soon as it is possible to procure a suitable form of electric lamp for use with the magnetographs.

2. *Mean values of the declination and H. F. constants.*—The table below gives the mean monthly values of the magnetic collimation, the distribution constants  $P_{1,2}$  and  $P_{2,3}$ , 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. The values of 'm' are higher than the previously accepted value; as this is probably due to a decrease in the moment of inertia the values will require a correction when the moment of inertia is redetermined this field season.

The values of 'm' in the table were derived from the vibration observations with the chronograph.

*Mean values of the constants of magnet No. 17 in 1918.*

MONTHS.	DECLINATION CONSTANTS.		H. F. CONSTANTS.				
	Mean magnetic collimation.	$P_{1,2}$	$P_{2,3}$	DISTRIBUTION FACTORS.		MEAN VALUES OF <i>m</i> .	
				Accepted values.		Monthly means.	Accepted <i>m</i> .
$p$	$q$						
January ...	— 7 18	5.68	7.00	7.80	— 32.2	807.37	806.80
February ...	— 7 25	5.69	7.15			807.24	
March ..	— 7 20	5.72	6.93			807.07	
April ...	— 7 17	6.07	6.98				
May ...	— 7 13	5.89	6.93			807.29	
June ...	— 6 59	5.89	7.21			807.01	
July ...	— 7 3	5.81	7.07			807.05	
August ...	— 7 5	5.88	7.26			807.04	
September ..	— 7 6	5.96	6.89			807.02	
October ...	— 7 2	5.86	7.06			807.04	
November ...	— 7 7	5.88	7.18			807.13	
December ...	— 6 57	6.02	7.06			807.19	

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 1918. The H.F. base line values have been derived from H as determined with the moment of inertia and distribution coefficient used in the computations for 1915.

*Base line values of magnetographs in 1918.*

MONTHS.	DECLINATION.			HORIZONTAL FORCE.		
	Mean value of Base line.	Base line accepted.	REMARKS.	Mean value of Base line.	Base line accepted.	REMARKS.
January ...	1 31·3	1 31·8		C. G. S. 32691	C. G. S. (a) 32695 (b) 32688	} To 14th } From 15th
February ...	1 32·2	1 31·8		32690	32690	
March ...	1 30·5	1 31·8		32691	32691	
April ...	1 30·8	1 31·9		32688	32688	
May ...	1 30·7*	} 1 31·9	* Obsd. by K.K.D.	32695	(a) 32693 (b) 32697	} To 19th } From 20th
" ...	1 31·9†		† " " S.D.			
June ...	1 31·8	1 31·8		32697	32697	
July ...	1 31·7	1 31·7		32697	32697	
August ...	1 32·0	1 32·0		32696	32696	
September ...	1 31·9	1 31·9		32696	32696	
October ...	1 32·1	1 32·1		32691	32691	
November ...	1 32·0	1 32·0		32686	32686	
December ...	1 31·5	1 31·5		32681	32681	

4. *Mean scale values and temperature range.*—The mean scale values for 1918 for an ordinate of 1/25 inch are:—

Horizontal Force 4·42 gammas.

Declination 1·03 minutes.

Vertical Force 5·72 to 8·76 gammas.

The mean temperature for the year was 26°·5 C.; with maximum and minimum monthly values of 26°·0 C. and 27°·0 C. The temperature of reduction is 27°·0 C.

5. *Mean monthly values and annual changes*—The following table shows the monthly mean values of the magnetic elements for 1917 and 1918 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 distribution factor used in the computations for 1915.

*Annual changes at Dehra Dūn in 1917-18.*

MONTHS.	HORIZONTAL FORCE			DECLINATION			DIP			VERTICAL FORCE		
	32000 C. G. S. +			E. 1° +			N. 44° +			32000 C. G. S. +		
	1917.	1918.	Annual change.	1917.	1918.	Annual change.	1917.	1918.	Annual change.	1917.	1918.	Annual change.
January ...	γ 1011	γ 994	γ -17	68·3	63·6	-4·7	42·5	46·2	+3·7	γ 677	γ 729	γ +52
February ...	1021	989	-32	67·7	63·3	-4·4	42·1	47·2	+5·1	679	744	+65
March ...	1025	988	-37	68·0	63·0	-5·0	42·1	48·1	+6·0	681	760	+79
April ...	1024	982	-42	67·5	62·5	-5·0	42·3	48·4	+6·1	685	761	+76
May ...	1022	992	-30	66·9	62·0	-4·9	42·8	47·8	+5·0	692	767	+65
June ...	1024	994	-30	66·5	61·3	-5·2	43·0	48·8	+5·8	699	780	+81
July ...	1020	992	-28	66·4	61·0	-5·4	44·0	49·5	+5·5	713	790	+77
August ...	987	981	-6	66·7	60·8	-5·9	46·2	50·6	+4·4	724	800	+76
September ...	999	971	-28	65·7	60·4	-5·3	45·6	51·6	+6·0	723	811	+88
October ...	993	963	-30	65·8	60·3	-5·5	45·8	51·9	+6·1	722	808	+86
November ...	995	968	-27	61·7	59·8	-4·9	45·8	52·3	+6·5	722	820	+98
December ...	994	951	-43	64·1	59·2	-4·9	46·4	53·2	+6·8	733	820	+87
Means ...	1010	980	-30	66·5	61·4	-5·1	44·1	49·6	+5·5	704	782	+78

## Toungoo Observatory.

1. The magnetographs worked satisfactorily throughout the year. During the inspection of the observatory in February the lenses of all the magnetographs were cleaned and the lines on the magnetograms were very much improved.

The V. F. magnet was adjusted on the 26th February on account of the magnet line on the magnetogram shifting to the edge of the paper owing to secular change and loss of magnetism.

Earth Inductor No. 46, which was temporarily in use at the observatory for part of the month of September last year, was replaced by the original instrument, No. 44, which was put into working order. The cause of the trouble in the latter instrument was due to the wire connection between the commutator and one of the binding screws touching the horizontal plate of the instrument from wear of the casing of the wire.

The moment of the observatory magnet, No. 19 A, fell by 5 units on the 20th December 1918. The observer was unable to give any reason for the change; it was probably due to carelessness on his part in accidentally giving the magnet a knock or in causing it to come in contact with some magnetic substance.

2. *Mean values of the Declination and H. F. constants.*—The table below gives the monthly mean 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.

*Mean values of the constants of magnet No. 19A in 1918.*

MONTHS.	DECLINATION CONSTANTS.		H. F. CONSTANTS.					REMARKS.		
	Mean magnetic collimation.		DISTRIBUTION FACTORS.			MEAN VALUES OF m.				
			P <sub>1-2</sub>	P <sub>2-3</sub>	Accepted values.		Monthly means.		Accepted m.	
				p	q					
January ...	-11 18		8·21	9·24	10·19	-546	872·66	Up to 7th May.		
February ...	-11 16		8·14	9·00			·58			
March ...	-11 3		8·14	9·09			·37			
April ...	-10 57		8·30	9·24			·29			
May ...	-11 26 } -11 5 }		8·22	9·18			...			
June ...	-11 28		8·31	9·28			·66			
July ...	-11 31		8·28	9·31			...			
August ...	-11 40		8·25	9·18			·53		872·53	
September ...	-11 43		8·28	9·04			...			
October ...	-11 32		8·22	9·14			·48		872·48	
November ...	-11 29		8·20	9·18			·36		872·36	to 7th December.
December ...	-11 34		8·21	9·06			·18		872·18	to 19th ..
					867·16	867·16	From 21st ..			

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 1918.

The H. F. base line values have been derived from H as determined with the moment of inertia and distribution coefficient used in the computations for 1915.

*Base line values of magnetographs in 1918.*

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 ...	0 52.2	0 52.2		.38557	.38557	
February ...	0 52.4	0 52.4		.38561	.38561	
March ...	{ 0 52.3 1 17.1	{ 0 52.3 1 17.1	Up to 10h. 52m. on 28th } From 12h. 48m. on 28th )	.38569	.38569	To 9h. on 29th.
April ...	1 16.9	1 16.9		.38710	.38710	From 10h. on 29th.
May ...	{ 1 16.7 1 16.7 1 16.5	1 16.6		.38704	.38704	
June ...	1 16.6	1 16.6		.38700	.38700	
July ...	1 16.8	1 16.8		.38694	.38694	
August ...	1 16.6	1 16.6		.38695	.38695	
September ...	1 16.3	1 16.3		.38697	.38697	
October ...	1 15.9	1 15.9		.38700	.38700	
November ...	1 16.1	1 16.1		.38697	.38697	
December ...	1 16.2	1 16.2		.38696	.38696	

4. *Mean scale values and temperature range.*—The mean scale values for 1918 for an ordinate of 1/25 inch are:—

Horizontal Force	{ 5.41 gammas to 9 hours on 29th March.
	{ 5.35 „, from 10 „, „, „ „ „
Declination	1.04 minutes.
Vertical Force	5.61 gammas.

The mean temperature for the year was 89°.2 Fahr. which remained uniform throughout. The temperature of reduction is 89°.0 Fahr.

5. *Mean monthly values and annual changes.*—The table below gives the mean monthly values of the magnetic elements for 1917 and 1918 and the annual changes for that period: the values of annual change are deduced from the values of H corrected for changes in the moment of inertia and the distribution factor used in the computations for 1915.

*Annual changes at Toungoo in 1917-18.*

MONTHS.	HORIZONTAL FORCE ·39000 C. G. S. +			DECLINATION W. ° +			DIP N. 23° +			VERTICAL FORCE ·16000 C. G. S. +		
	1917.	1918.	Annual change.	1917.	1918.	Annual change.	1917.	1918.	Annual change.	1917.	1918.	Annual change.
	γ	γ	γ	'	'	'	'	'	'	γ	γ	γ
January ...	26	53	+27	11.1	14.7	+3.6	9.0	8.1	-0.9	687	686	-1
February ...	38	55	+17	11.3	15.3	+4.0	8.6	8.4	-0.2	686	690	+4
March ...	48	64	+16	11.6	15.4	+3.8	8.3	8.7	+0.4	686	697	+11
April ...	38	67	+29	12.1	16.0	+3.9	8.4	8.5	+0.1	683	698	+15
May ...	39	70	+31	12.6	16.0	+3.4	9.2	8.6	-0.6	695	700	+5
June ...	44	73	+29	12.7	16.5	+3.8	8.1	8.3	+0.2	682	696	+14
July ...	38	73	+35	13.0	16.8	+3.8	8.0	8.2	+0.2	678	695	+17
August ...	18	70	+52	13.0	16.9	+3.9	8.9	8.4	-0.5	681	697	+16
September ...	37	66	+29	13.5	17.3	+3.8	8.2	8.5	+0.3	681	696	+15
October ...	36	71	+35	13.7	17.4	+3.7	8.3	8.5	+0.2	681	699	+18
November ...	43	79	+36	13.9	17.8	+3.9	8.2	8.2	0.0	683	698	+15
December ...	44	68	+24	14.4	18.4	+4.0	8.4	8.7	+0.3	686	701	+15
Means ...	37	67	+30	12.7	16.5	+3.8	8.5	8.4	-0.1	684	696	+12

## Kodaikanal Observatory.

1. This observatory is under the control of the Meteorological Department, but the absolute observations and the records of the self-registering instruments are forwarded periodically by the Director of the observatory for computation and for record in the party.

The results of the H. F. and V. F. magnetographs have been satisfactory except for an occasional break in the magnet lines on the magnetograms from the failure of the lights and stoppage of the clocks of these instruments.

From the 21st to the 26th March 1919 the declination magnetograph is reported to have been opened, cleaned and adjusted. A new suspension ribbon of phosphor-bronze was introduced and a new mirror fixed on the magnet system. While this was being done one of the magnets of the system broke, the broken magnet was fixed in position by a light aluminium holder and a similar piece of metal was attached to the opposite end of the magnet as a counterpoise. When it was found that this device was unsuitable the Director applied for a spare magnet, which was supplied to him.

From April to September 1919 no satisfactory adjustment of the magnet system was effected and consequently for a period of 6 months no reliable base line values can be obtained to compute the hourly mean values of declination or the diurnal inequality.

The Magnetic Observer reported that the observatory Earth Inductor (No. 45) worked unsatisfactorily and that it was taken to pieces, cleaned and adjusted on the 18th and 19th December. It gave trouble again and the cause was reported to be due to wear of the commutator which was turned true by the Director in December 1918. On the 1st February 1919 it was readjusted and from the 12th to 16th April 1919 both the Earth Inductor and galvanometer were reported to be working unsatisfactorily. From the 23rd April to the 6th May 1919 these instruments were again reported to be out of order. No observations were taken from the 27th June to the 3rd July.

The Director of the observatory applied to the officer in charge of the party for a spare Earth Inductor and galvanometer. Earth Inductor No. 46, with its galvanometer, was sent to him early in June 1919 and the instruments were taken into use on the 4th July 1919. This galvanometer was reported to be out of order from the 19th to the 23rd August 1919.

The dip observations at this observatory continued to be unsatisfactory and the records received up to the end of September 1919 show no improvement in the observations.

The magnetograms of all the three magnetographs, from the 7th to the 9th November 1918, were reported to be missing and have not been found.

In the statement of the weekly returns of the observatory of the 21st December 1918 the magnetic observer makes the following remarks, in accounting for the fall in the magnetic moment of the observatory magnet:—"The moment of the magnet has dropped since the 16th while experimenting with a small piece of metal which the Director gave as *aluminium* but which was subsequently found to be *steel*. The experiment was with a view to finding out what effect a small additional weight has on the value of 'm'. The piece of metal came in contact with the magnet and this has probably caused the drop in the moment."

On the 25th September 1919 it was reported that when the magnet of the observatory magnetometer was raised the suspension ribbon frequently slipped through the chuck attached to the lower end of the ribbon and that the chuck was therefore slightly repaired, and it was remarked that "the moment of inertia of the magnet may require to be redetermined".

It is very unfortunate that it was not thought necessary to determine the moment of inertia of the magnet before the chuck was repaired as an after determination alone will not throw any light on the actual change in the moment of inertia that has occurred between the last determination in 1915 and up to the time of repairing the chuck.

It is regrettable that the several mishaps mentioned above should have occurred as it means that there is little hope of obtaining reliable values of the magnetic elements at this observatory during the year under report.

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 distribution factor and moment of inertia used for the computations in 1915. The values of "m" in the table are all derived from vibration observations as determined with the chronograph.



Mean values of the constants of magnet No. 16 in 1918.

MONTHS.	DECLINATION CONSTANTS.		H. F. CONSTANTS.					
	Mean magnetic collimation.		DISTRIBUTION FACTORS.			MEAN VALUES OF H.		
			P <sub>1-2</sub>	P <sub>2-3</sub>	Accepted values		Monthly means	Accepted m.
				p	q			
January ...	' "	3 33	6.27	8.40	11.39	- 1621	883.66	882.77 (up to 14th Dec.)
February ...	' "	3 30	6.32	8.39			883.69	
March ...	' "	3 32	6.29	8.45			883.34	
April ...	' "	3 28	6.27	8.37			883.15	
May ...	' "	3 30	6.11	8.54			883.19	
June ...	' "	3 28	6.13	8.63			883.35	
July ...	' "	3 28	6.27	8.44			883.33	
August ...	' "	3 28	6.20	8.66			882.88	
September ...	' "	3 29	6.26	8.70			883.20	
October ...	' "	3 32	6.26	8.54			882.90	
November ...	' "	3 29	6.24	8.45			883.10	
December ...	' "	3 27	6.16	8.52			883.15 881.33	

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 1918.

The H. F. base line values have been derived from H as determined with the moment of inertia and distribution coefficient used in the computations for 1915.

Base line values of magnetographs in 1918.

MONTHS.	DECLINATION.		HORIZONTAL FORCE.	
	Mean value of Base line	Base line accepted	Mean value of Base line	Base line accepted
January ...	2 33.2	2 33.2	C. G. S. .37335	C. G. S. .37335
February ...	2 32.9	2 32.9	.37332	.37332
March ...	2 32.9	2 32.9	.37339	.37339
April ...	2 33.3	2 33.3	.37343	.37343
May ...	2 33.1	2 33.1	.37344	.37344
June ...	2 33.1	2 33.1	.37343	.37343
July ...	2 33.0	2 33.0	.37338	.37338
August ...	2 32.8	2 32.8	.37338	.37338
September ...	2 32.9	2 32.9	.37340	.37340
October ...	2 32.8	2 32.8	.37345	.37345
November ...	2 33.3	2 33.3	.37342	.37342
December ...	2 33.1	2 33.1	.37343	.37343

4. *Mean scale values and temperature range.*—The mean scale values for 1918 for an ordinate of 1/25 inch are:—

Horizontal Force	5.90 gammas.
Declination	1.03 minutes.
Vertical Force	6.08 to 7.40 gammas.

The mean temperature for the year was 17°·4 C., with maximum and minimum monthly values of 16°·5 C. and 18°·1 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 1917 and 1918 and the annual changes for that period: the annual change values are deduced from the values of H corrected for changes in the moment of inertia and distribution factor used in the computations for 1915.

*Annual changes at Kodaikānal in 1918.*

MONTHS.	HORIZONTAL FORCE ·37000 C. G. S. +			DECLINATION W. 1° +			DIP N. 4° +			VERTICAL FORCE ·02000 C. G. S. +		
	1917.	1918.	Annual change.	1917.	1918.	Annual change.	1917.	1918.	Annual change.	1917.	1918.	Annual change.
January ...	630	682	+ 52	31.4	36.8	+ 5.4	25.2	28.9	+ 3.7	906	953	+ 47
February ...	648	677	29	31.8	37.0	5.2	25.4	29.5	4.1	913	959	46
March ...	658	684	26	32.2	37.4	5.2	25.7	29.6	3.9	916	961	45
April ...	657	687	30	32.6	38.3	5.7	26.3	29.6	3.3	922	961	39
May ...	662	694	32	33.0	38.4	5.4	26.9	30.2	3.3	930	969	39
June ...	665	697	32	33.4	39.1	5.7	27.6	30.6	3.0	938	973	35
July ...	665	699	34	33.8	39.3	5.5	27.2	30.5	3.3	933	972	39
August ...	653	698	45	34.6	39.8	5.2	27.6	31.0	3.4	937	977	40
September ...	673	698	25	35.1	40.3	5.2	28.0	30.5	2.5	943	973	30
October ...	671	701	30	35.4	40.9	5.5	28.0	30.4	2.4	942	971	29
November ...	673	706	33	36.0	41.5	5.5	28.4	31.2	2.8	947	980	33
December ...	671	701	30	36.0	41.4	5.4	28.6	31.5	2.9	950	984	34
Means ...	661	694	+ 33	33.8	39.2	+ 5.4	27.1	30.3	+ 3.2	931	969	+ 38

III.—TABLES OF RESULTS.

*Mean values of the magnetic elements at observatories in 1918.*

Observatory.	Latitude and Longitude.	Dip.	Declination.	H. F.	V. F.
Dehra Dūn ...	{ 30 19 19 N. } { 78 3 19 E. }	N. 44 49.6	E. 2 1.4	·32980	·32782
Toungoo ...	{ 18 55 45 N. } { 96 27 3 E. }	N. 23 8.4	W. 0 16.5	·39067	·16696
Kodaikānal ...	{ 10 13 50 N. } { 77 27 46 E. }	N. 4 30.3	W. 1 39.2	·37694	·02969



*Hourly Means of the Declination at Dehra Dun in 1918, determined from all available days. Declination = E. 1° + tabular quantity.*

Hour	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.	68.9	61.0	63.8	63.6	63.4	63.0	62.8	62.5	62.7	63.9	65.2	65.1	64.3	62.9	63.1	63.3	63.3	63.5	63.5	63.7	63.8	63.9	63.8	63.8	63.6
	Feb.	63.4	63.5	63.2	63.0	62.9	62.8	62.8	64.0	64.7	64.6	64.6	63.9	63.0	62.7	63.0	63.2	63.2	63.2	63.0	63.0	63.2	63.3	63.3	63.4	63.3
	Mar.	63.3	63.2	63.1	63.0	62.9	62.8	62.8	64.3	65.6	65.9	64.8	62.8	62.7	62.6	62.7	62.9	62.9	62.9	62.6	62.7	62.9	63.0	63.0	63.1	63.0
Summer.	Oct.	60.7	60.7	60.7	60.5	60.4	60.3	61.4	62.5	61.4	61.6	61.6	58.1	57.6	58.5	59.4	59.9	59.9	59.7	59.9	60.2	60.4	60.4	60.4	60.5	60.8
	Nov.	60.0	60.1	59.9	59.8	59.8	59.7	59.6	60.5	60.7	60.2	59.1	58.5	58.8	59.6	59.9	60.0	59.7	58.7	59.8	59.9	59.9	59.9	59.9	60.0	60.8
	Dec.	59.3	59.4	59.2	59.3	59.0	58.9	58.9	59.1	59.7	60.0	59.6	58.2	58.2	59.0	59.9	59.9	59.6	59.2	59.3	59.2	59.4	59.5	59.5	59.3	59.2
Means	61.8	61.8	61.7	61.6	61.4	61.3	61.3	61.6	62.5	63.0	62.7	61.6	60.6	60.8	61.2	61.2	61.4	61.3	61.2	61.3	61.5	61.5	61.7	61.7	61.7	61.5
Summer.	April	63.0	63.1	63.0	62.9	62.9	62.9	63.6	65.0	66.2	64.1	61.8	60.2	59.4	59.7	60.6	61.6	61.6	62.0	62.1	61.8	61.9	62.2	62.4	62.6	62.5
	May	62.2	62.4	62.5	62.5	62.5	62.8	64.1	65.4	65.7	64.7	62.5	60.3	58.8	58.9	59.8	60.9	61.6	61.6	61.1	61.8	61.8	61.9	61.9	62.1	62.0
	June	61.6	61.8	62.0	61.9	62.0	62.3	63.6	64.7	64.7	64.0	62.3	60.2	58.8	58.0	58.1	58.8	59.7	60.5	61.3	61.1	60.7	60.9	61.1	61.8	61.8
Winter.	July	60.9	61.2	61.5	61.5	61.6	61.9	63.4	64.5	64.7	63.8	62.2	60.1	58.8	57.0	58.4	59.2	60.0	60.8	60.6	60.6	60.5	60.2	60.4	60.7	60.8
	Aug.	60.8	61.2	61.3	61.3	61.5	61.7	63.0	64.3	64.7	63.7	61.6	59.4	58.0	57.3	58.3	59.3	60.1	60.9	60.5	60.2	60.3	60.6	60.7	60.8	
	Sep.	60.6	60.8	60.9	61.0	61.0	61.1	61.6	63.0	63.8	62.9	60.9	58.7	57.2	56.6	57.6	58.0	60.2	60.9	60.3	60.0	60.1	60.6	60.7	60.8	
Means	61.5	61.8	61.9	61.9	61.9	62.1	63.2	64.5	65.0	64.2	62.3	60.1	58.6	58.0	58.3	59.2	60.1	60.7	61.3	61.0	60.9	61.0	61.1	61.3	61.5	61.3

*Diurnal Inequality of the Declination at Dehra Dun in 1918, deduced from the above Table.*

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter.	Jan.	+0.3	+0.4	+0.2	0.0	-0.2	-0.6	-0.9	+0.8	+1.6	+1.5	+0.7	+0.4	+0.3	-0.3	-0.7	-0.5	-0.3	-0.1	+0.1	+0.1	+0.2	+0.2	+0.2	
	Feb.	+0.1	+0.2	-0.1	-0.3	-0.4	-0.4	-0.5	+1.4	+1.3	+0.6	-0.2	-0.7	-0.6	-0.6	-0.3	-0.1	-0.1	-0.4	-0.3	-0.3	-0.1	0.0	0.0	+0.1
	Mar.	+0.3	+0.2	+0.2	0.0	-0.2	+0.2	+1.3	+2.6	+2.9	+1.8	-0.2	-2.5	-2.2	-2.2	-1.2	-0.3	-0.1	-0.4	-0.5	-0.3	-0.1	0.0	+0.1	+0.1
Summer.	Oct.	+0.4	+0.4	+0.4	+0.2	0.0	0.0	+1.1	+2.2	+2.2	+1.3	-0.4	-2.2	-1.8	-0.9	-0.4	-0.4	-0.6	-0.4	-0.1	+0.1	+0.1	+0.1	+0.3	+0.3
	Nov.	+0.2	+0.3	+0.1	0.0	-0.1	-0.2	-0.1	+0.7	+0.9	+0.4	-0.7	-1.3	-1.0	-0.2	+0.1	+0.2	-0.1	-0.1	0.0	+0.1	0.0	+0.1	+0.1	+0.2
	Dec.	+0.1	+0.2	0.0	-0.2	-0.3	-0.3	-0.1	+0.5	+0.8	+0.4	-0.6	-1.0	-0.8	-0.2	+0.4	+0.4	-0.0	0.0	+0.1	+0.2	+0.3	+0.3	+0.1	-0.1
Means	+0.3	+0.3	+0.2	+0.1	-0.1	-0.2	+0.1	+1.0	+1.5	+1.2	+0.1	-0.9	-1.2	-0.7	-0.3	-0.1	-0.2	-0.3	-0.2	0.0	+0.1	+0.2	+0.2	+0.2	
Summer.	April	+0.5	+0.6	+0.6	+0.5	+0.4	+1.1	+2.5	+3.7	+3.5	+1.6	-0.7	-2.3	-2.8	-1.9	-0.9	-0.9	-0.5	-0.4	-0.7	-0.6	-0.8	-0.1	+0.1	+0.4
	May	+0.2	+0.4	+0.6	+0.5	+0.8	+2.1	+3.4	+3.7	+2.7	+0.5	-1.7	-3.2	-3.6	-3.1	-2.2	-1.1	-0.4	+0.1	-0.2	-0.2	-0.2	-0.1	+0.1	+0.2
	June	+0.3	+0.5	+0.7	+0.6	+1.0	+2.3	+3.4	+3.4	+2.7	+1.0	-1.1	-2.5	-3.3	-3.2	-2.5	-1.6	-0.8	0.0	-0.2	-0.6	-0.4	-0.2	0.0	+0.2
Winter.	July	-0.1	+0.2	+0.5	+0.5	+0.6	+2.4	+3.5	+3.7	+2.8	+1.2	-0.9	-2.2	-3.1	-2.6	-1.8	-1.0	-0.2	0.4	-0.5	-0.8	-0.6	-0.3	-0.2	-0.2
	Aug.	0.0	+0.4	+0.5	+0.7	+0.9	+2.2	+3.5	+3.9	+2.9	+0.8	-1.4	-2.6	-3.4	-3.5	-1.5	-0.7	-0.3	-0.3	-0.6	-0.5	-0.2	-0.1	0.0	0.0
	Sep.	+0.2	+0.4	+0.5	+0.6	+0.7	+1.2	+2.6	+3.4	+2.5	+0.5	-1.7	-3.2	-3.6	-2.8	-1.4	-0.5	-0.2	-0.1	-0.4	-0.3	+0.2	0.0	+0.1	+0.1
Means	+0.2	+0.5	+0.6	+0.6	+0.8	+1.9	+3.2	+3.7	+2.9	+1.0	-1.2	-2.7	-3.3	-3.0	-2.1	-1.2	-0.6	0.0	-0.3	-0.4	-0.3	-0.2	0.0	+0.2	+0.3

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

Hourly Means of Horizontal Force in C. G. S. units (corrected for temperature) at Dehra Dun in 1918, from all available days. Horizontal 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		
Winter	Jan.	987	988	988	988	988	989	989	999	1006	1014	1017	1015	1012	1007	999	992	990	986	985	984	982	981	982	986	987	994	
	Feb.	981	979	986	984	985	989	989	993	994	999	996	999	1003	1002	997	993	986	984	982	983	982	981	981	981	984	989	
	Mar.	979	983	984	984	984	985	984	983	982	988	993	1002	1003	1009	1007	999	990	986	984	984	980	978	981	981	983	988	
	Oct.	961	962	960	963	963	962	963	961	958	958	960	971	980	980	973	967	962	967	958	958	957	955	959	961	964	963	
	Nov.	963	961	964	963	963	963	965	968	971	974	979	984	987	985	979	972	967	961	961	959	959	959	960	964	965	968	
	Dec.	948	948	952	949	940	950	951	952	953	951	949	951	958	960	960	959	953	949	949	949	948	947	946	948	955	951	
	Means	970	970	972	972	972	974	974	976	977	981	982	987	991	991	986	980	975	971	970	969	968	967	968	971	973	976	
	Summer	April	976	976	977	976	977	976	977	976	973	976	985	994	1001	1005	999	992	984	977	977	977	979	978	990	983	994	982
		May	987	987	987	989	989	989	989	984	986	989	996	1004	1011	1014	1010	1003	995	987	982	983	983	983	986	987	988	992
		June	991	991	990	991	992	992	993	991	988	989	991	999	1007	1012	1012	1007	997	989	988	987	989	990	993	994	993	994
July		988	989	988	989	989	991	992	991	991	991	991	994	999	1005	1008	1005	998	990	986	983	987	989	989	989	989	992	
Aug.		980	980	979	982	981	980	982	979	971	969	974	983	988	994	993	991	987	980	976	974	977	980	978	978	980	981	
Sep.		973	975	977	977	975	976	974	966	960	957	959	966	976	981	981	978	973	967	968	968	967	966	969	972	976	971	
Means		983	983	983	984	984	984	985	981	978	979	983	990	997	1002	1001	996	989	982	980	979	980	981	983	984	985	985	

Diurnal Inequality of the Horizontal Force at Dehra Dun in 1918, deduced from the above Table.

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

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 1918, 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		
Winter.	Jan.	732	731	731	731	730	730	730	730	732	733	727	723	723	722	722	725	729	730	730	731	732	732	733	733	733	729	
	Feb.	747	748	749	747	747	747	747	748	749	749	740	746	733	734	736	739	742	743	744	746	747	748	749	749	749	744	
	Mar.	766	766	766	765	765	765	765	768	767	761	753	744	743	746	752	757	760	761	760	761	763	765	765	765	765	760	
	Oct.	813	813	812	813	812	812	812	814	814	809	805	796	793	796	801	805	807	808	808	810	811	811	813	813	813	808	
	Nov.	824	823	824	823	823	823	823	823	824	822	818	814	813	815	816	817	818	819	820	820	820	822	822	823	822	820	
	Dec.	823	823	823	821	821	821	822	822	822	820	816	812	813	815	818	820	820	820	820	821	821	821	821	821	822	822	
	Means	794	794	794	793	793	793	793	794	795	792	778	772	770	772	774	777	779	780	780	781	783	783	784	784	784	784	
	Summer.	April	766	766	766	765	765	765	770	767	759	749	743	743	744	749	753	758	760	762	763	763	765	766	767	767	767	761
		May	763	762	762	762	762	763	766	766	759	751	743	738	740	744	749	754	757	760	761	761	762	763	764	764	764	757
		June	784	785	785	786	785	786	789	788	783	777	771	766	765	766	770	774	778	781	783	783	783	785	785	786	786	780
		July	795	795	796	796	796	797	800	799	796	791	784	775	775	776	779	763	787	790	792	792	793	794	795	795	795	790
		Aug.	803	804	804	804	804	805	807	807	804	799	793	785	785	787	790	795	798	801	802	802	803	804	804	806	805	800
Sep.		814	815	815	815	815	815	816	817	816	810	804	796	796	799	804	808	809	810	811	812	813	815	815	816	815	811	
Means		788	788	788	788	788	789	791	791	788	781	774	767	768	770	774	779	782	784	785	786	787	788	788	789	789	783	

Diurnal Inequality of the Vertical Force at Dehra Dun in 1918, 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.	+3	+2	+2	+2	+1	+1	+1	+1	+3	+5	+4	-2	-6	-7	-7	-4	0	+1	+1	+2	+3	+3	+3	+4	+4	
	Feb.	+3	+4	+4	+3	+3	+3	+3	+4	+5	+2	-4	-8	-11	-10	-8	-5	-2	-1	0	+2	+3	+4	+5	+5	+5	
	Mar.	+5	+6	+6	+5	+5	+5	+5	+8	+7	+1	-7	-16	-17	-14	-8	-3	0	+1	0	+1	+3	+5	+5	+5	+5	
	Oct.	+5	+5	+4	+5	+4	+4	+4	+6	+6	+1	-3	-12	-15	-12	-7	-3	-1	0	0	+2	+3	+3	+5	+5	+5	
	Nov.	+4	+3	+4	+3	+3	+3	+3	+3	+4	+2	-2	-6	-7	-5	-4	-3	-2	-1	0	0	+2	+2	+2	+2	+3	
	Dec.	+3	+3	+3	+1	+1	+1	+2	+2	+2	0	-4	-8	-7	-5	-2	0	0	0	0	+1	+1	+1	+1	+1	+2	
	Means	+4	+4	+4	+3	+3	+3	+3	+4	+5	+2	-2	-8	-10	-8	-6	-3	-1	0	0	+1	+3	+3	+4	+4	+4	
	Summer.	April	+5	+5	+5	+4	+4	+4	+7	+9	+6	-2	-12	-18	-17	-12	-8	-3	-1	+1	+1	+2	+4	+5	+6	+6	+6
		May	+6	+5	+5	+5	+5	+6	+9	+8	+2	-6	-14	-19	-17	-13	-8	-3	0	+3	+4	+4	+5	+6	+7	+7	+7
		June	+4	+5	+5	+5	+5	+6	+9	+8	+3	-3	-9	-14	-15	-14	-10	-6	-2	+1	+3	+3	+3	+5	+5	+6	+6
		July	+5	+5	+6	+6	+6	+7	+10	+9	+6	+1	-6	-15	-15	-14	-11	-7	-3	0	+2	+2	+3	+4	+5	+5	+5
		Aug.	+3	+4	+4	+4	+4	+5	+7	+7	+4	-1	-7	-15	-15	-13	-10	-5	-2	+1	+2	+2	+3	+4	+4	+6	+5
Sep.		+3	+4	+4	+4	+4	+4	+5	+6	+5	-1	-7	-15	-15	-12	-7	-3	-2	-1	0	+1	+2	+4	+4	+5	+4	
Means		+5	+5	+5	+5	+5	+6	+8	+8	+5	-2	-9	-16	-15	-13	-9	-4	-1	+1	+2	+3	+4	+5	+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 Dehra Dun in 1918. 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.	46.7	46.6	46.6	46.5	46.3	46.2	46.0	45.7	45.4	45.2	45.0	44.9	45.1	45.6	45.9	46.2	46.6	46.7	46.7	46.7	46.9	47.0	46.9	46.8	46.7	46.2
	Feb.	47.8	47.6	47.6	47.5	47.4	47.3	47.2	47.2	46.8	46.8	46.6	46.5	46.0	46.4	46.7	46.7	47.3	47.4	47.5	47.6	47.7	47.8	47.9	47.7	47.7	47.2
	Mar.	48.8	48.6	48.6	48.6	48.5	48.6	48.8	48.8	48.1	48.1	47.5	46.5	46.2	46.3	46.7	47.3	48.0	48.3	48.3	48.6	48.8	48.7	48.7	48.6	48.6	48.1
Summer.	Oct.	52.3	52.3	52.3	52.2	52.1	52.1	52.3	52.5	52.2	52.2	51.9	50.9	50.2	50.4	51.0	51.5	51.9	52.2	52.2	52.3	52.4	52.5	52.4	52.3	52.1	51.9
	Nov.	52.7	52.8	52.7	52.7	52.7	52.6	52.4	52.3	52.1	51.6	51.6	50.9	50.9	51.1	51.5	51.9	52.2	52.6	52.6	52.8	52.9	52.9	52.8	53.6	53.6	52.3
	Dec.	53.5	53.5	53.3	53.3	53.2	53.3	53.2	53.2	53.2	53.2	53.1	52.7	52.4	52.4	52.6	52.8	53.0	53.3	53.3	53.3	53.4	53.4	53.5	53.4	53.1	53.2
Means	50.3	50.3	50.2	50.2	50.1	50.1	50.0	50.0	50.0	49.6	49.3	48.8	48.4	48.6	49.0	49.4	49.8	50.1	50.1	50.2	50.4	50.4	50.4	50.2	50.1	49.8	
Winter.	April	49.0	49.0	49.0	49.0	48.9	49.0	49.1	49.2	48.6	47.7	46.9	46.6	46.6	47.1	47.8	48.3	48.3	48.8	48.8	48.8	48.8	48.9	48.9	48.7	48.7	48.4
	May	48.3	48.3	48.3	48.1	48.1	48.2	48.3	48.6	48.1	47.5	46.8	46.1	45.8	45.9	46.4	47.0	47.5	48.1	48.5	48.4	48.5	48.5	48.4	48.4	48.3	47.8
	June	49.2	49.2	49.2	49.2	49.2	49.4	49.4	49.4	49.3	48.9	48.5	47.8	47.3	47.1	47.4	47.8	48.6	49.1	49.3	49.4	49.2	49.3	49.2	49.1	49.2	48.8
Summer.	July	49.9	49.9	49.9	49.9	49.8	49.8	49.8	49.8	49.5	49.2	48.5	48.3	48.1	48.1	48.1	48.4	49.0	49.6	49.9	50.0	49.9	49.9	49.9	49.9	49.9	49.5
	Aug.	50.7	50.8	50.9	50.7	50.8	50.9	51.0	51.3	51.1	50.5	49.7	49.4	49.2	49.4	49.8	50.2	50.7	50.9	50.9	51.0	50.9	50.8	50.9	51.0	50.9	50.6
	Sep.	51.7	51.7	51.6	51.5	51.7	51.6	51.8	52.2	52.5	52.3	51.9	51.1	50.6	50.5	50.8	51.1	51.4	51.8	51.8	51.9	52.0	52.1	51.9	51.9	51.6	51.6
Means	49.8	49.8	49.8	49.7	49.8	49.8	49.9	50.1	50.0	49.7	49.1	48.4	48.0	47.9	48.2	48.7	49.2	49.7	49.9	49.9	49.9	49.9	49.9	49.8	49.8	49.5	

Diurnal Inequality of the Dip at Dehra Dun in 1918, 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.	+0.5	+0.4	+0.4	+0.4	+0.3	+0.1	0.0	-0.2	-0.5	-0.8	-1.0	-1.2	-1.3	-1.1	-0.7	-0.3	0.0	+0.4	+0.5	+0.7	+0.8	+0.7	+0.6	+0.6	+0.5
	Feb.	+0.6	+0.7	+0.3	+0.4	+0.3	+0.2	+0.1	0.0	-0.4	-0.6	-0.6	-0.9	-1.3	-1.2	-0.8	-0.5	+0.1	+0.2	+0.3	+0.4	+0.5	+0.6	+0.6	+0.5	+0.5
	Mar.	+0.7	+0.5	+0.5	+0.5	+0.5	+0.4	+0.5	+0.7	+0.7	0.0	-0.6	-1.6	-1.9	-1.8	-1.4	-0.8	-0.1	+0.2	+0.2	+0.5	+0.7	+0.6	+0.6	+0.5	+0.5
Summer.	Oct.	+0.4	+0.4	+0.4	+0.3	+0.2	+0.3	+0.2	+0.6	+0.3	0.0	0.0	-1.0	-1.7	-1.5	-0.9	-0.4	0.0	+0.3	+0.3	+0.4	+0.5	+0.6	+0.5	+0.4	+0.2
	Nov.	+0.4	+0.5	+0.4	+0.4	+0.4	+0.4	+0.3	+0.1	0.0	-0.2	-0.7	-1.2	-1.4	-1.2	-0.8	-0.4	-0.1	+0.3	+0.3	+0.5	+0.6	+0.5	+0.3	+0.3	+0.3
	Dec.	+0.3	+0.3	+0.1	+0.1	0.0	+0.1	0.0	0.0	0.0	0.0	-0.1	-0.5	-0.8	-0.8	-0.6	-0.4	-0.2	+0.1	+0.1	+0.1	+0.2	+0.3	+0.2	-0.1	-0.1
Means	+0.5	+0.5	+0.4	+0.4	+0.3	+0.3	+0.2	+0.2	+0.2	-0.2	-0.5	-1.0	-1.4	-1.2	-0.8	-0.4	0.0	+0.3	+0.3	+0.4	+0.6	+0.6	+0.4	+0.3	+0.3	
Summer.	April	+0.6	+0.6	+0.6	+0.6	+0.6	+0.7	+0.8	+0.8	+0.2	-0.7	-1.5	-1.8	-1.8	-1.3	-1.3	-0.6	-0.1	+0.4	+0.4	+0.4	+0.5	+0.5	+0.5	+0.3	+0.3
	May	+0.5	+0.5	+0.5	+0.3	+0.3	+0.4	+0.5	+0.8	+0.3	-0.3	-1.0	-1.7	-2.0	-1.9	-1.4	-0.8	-0.3	+0.3	+0.3	+0.7	+0.6	+0.7	+0.6	+0.6	+0.5
	June	+0.4	+0.4	+0.5	+0.4	+0.4	+0.6	+0.6	+0.6	+0.5	+0.1	-0.3	-1.0	-1.5	-1.7	-1.4	-1.0	-0.2	+0.3	+0.3	+0.5	+0.6	+0.4	+0.4	+0.3	+0.4
Summer.	July	+0.4	+0.4	+0.5	+0.4	+0.4	+0.5	+0.5	+0.5	+0.3	0.0	-0.3	-1.0	-1.2	-1.4	-1.1	-0.5	+0.1	+0.1	+0.4	+0.5	+0.6	+0.5	+0.4	+0.4	+0.4
	Aug.	+0.1	+0.2	+0.3	+0.3	+0.3	+0.3	+0.4	+0.7	+0.5	+0.0	-0.1	-0.9	-1.2	-1.4	-1.2	-0.8	-0.4	+0.1	+0.3	+0.3	+0.2	+0.3	+0.3	+0.4	+0.3
	Sep.	+0.1	+0.1	-0.1	+0.1	0.0	+0.2	+0.6	+0.9	+0.7	+0.7	+0.3	-0.5	-1.0	-1.1	-0.8	-0.5	-0.2	+0.2	+0.2	+0.3	+0.4	+0.5	+0.3	+0.3	0.0
Means	+0.8	+0.3	+0.3	+0.2	+0.3	+0.4	+0.6	+0.5	+0.2	+0.2	-0.4	-1.1	-1.5	-1.6	-1.3	-0.8	-0.3	+0.2	+0.2	+0.4	+0.4	+0.4	+0.4	+0.3	+0.3	

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

Hourly Means of the Declination at Toungoo in 1918, determined from all available days. Declination = W.  $\theta$  + tabular quantity.

Table with 24 columns (Hours 1-24) and 13 rows (Jan, Feb, Mar, Oct, Nov, Dec, Means, April, May, June, July, Aug, Sep, Means). Values represent declination in minutes.

Diurnal Inequality of the Declination at Toungoo in 1918, deduced from the above Table.

Table with 24 columns (Hours 1-24) and 13 rows (Jan, Feb, Mar, Oct, Nov, Dec, Means, April, May, June, July, Aug, Sep, Means). Values represent diurnal inequality in minutes.

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. S. units (corrected for temperature) at Tongoo in 1918, from all available days. Horizontal Force = 39000 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
Winter {Jan. Feb. Mar. Oct. Nov. Dec.	037	039	041	042	043	044	049	055	064	072	080	085	085	078	069	060	051	046	043	041	037	036	035	039	053	
	043	041	040	044	045	045	050	055	062	072	083	085	087	083	073	061	051	046	046	044	043	039	040	040	048	
	043	044	046	047	050	053	053	053	053	079	097	109	110	110	102	090	085	057	057	055	049	044	046	049	064	
	054	056	058	060	061	061	060	060	070	084	100	110	116	114	109	094	087	062	061	061	060	058	055	059	060	
	056	059	060	063	063	062	063	070	070	087	107	115	114	111	107	096	086	079	072	069	068	062	058	060	058	
Means	050	051	052	054	054	055	058	061	069	080	092	099	101	094	084	072	063	058	056	055	052	050	050	051	053	085
Summer {April May June July Aug. Sep.	048	050	050	051	053	055	053	054	069	089	105	115	113	105	092	075	063	057	055	054	053	053	052	054	057	
	054	056	057	058	059	059	061	065	074	089	102	110	109	103	090	076	064	056	055	055	055	053	053	054	057	
	059	060	061	060	060	062	063	068	076	085	098	103	107	106	096	083	072	063	061	061	062	061	062	062	063	
	058	059	060	061	061	061	061	061	069	077	100	104	106	100	093	084	074	064	059	059	058	060	060	060	059	
	059	059	059	059	059	059	062	062	063	070	081	092	100	103	091	081	071	064	061	061	059	056	059	060	058	
Means	055	057	058	059	060	061	061	063	071	085	098	104	106	101	091	079	068	061	059	058	056	057	057	058	070	

Diurnal Inequality of the Horizontal Force at Tongoo in 1918, deduced from the above Table.

Hours	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. Feb. Mar. Oct. Nov. Dec.	7	12	12	11	9	4	2	11	19	27	32	32	25	16	16	2	7	10	12	12	16	17	17	18	7
	16	14	15	11	9	5	0	7	17	28	30	32	28	18	16	4	9	9	11	11	16	16	15	15	7
	21	20	18	17	14	11	11	1	14	33	45	46	38	26	26	1	7	7	9	9	15	20	18	18	7
	15	15	13	11	10	11	11	1	13	29	39	45	38	23	23	4	9	9	10	10	11	13	16	12	11
	16	13	12	11	11	9	9	3	6	18	28	35	28	17	17	0	2	4	7	11	14	17	16	16	10
Means	14	13	11	11	10	7	4	4	15	27	34	36	29	19	7	2	7	9	10	13	15	15	14	12	7
Summer {April May June July Aug. Sep.	19	17	16	14	12	14	13	2	22	38	48	46	38	25	8	4	10	12	13	13	14	14	15	13	7
	16	14	13	12	11	9	5	4	19	32	40	39	33	20	6	6	14	14	15	15	15	15	16	15	7
	14	13	12	13	13	11	5	3	12	25	30	34	32	23	10	1	10	12	12	12	11	11	12	11	7
	15	14	13	12	12	9	4	4	16	27	31	33	30	20	11	1	9	9	14	14	15	13	13	13	7
	12	11	11	11	11	8	7	9	9	22	30	35	30	23	11	1	6	6	6	9	11	14	10	10	11
Means	13	12	11	11	10	9	7	4	15	28	34	36	31	21	9	2	9	12	12	12	14	13	13	13	7

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 1918, 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	
Winter.	Jan.	689	689	689	689	689	688	687	686	689	691	690	685	680	677	675	677	682	684	683	686	686	686	687	689	689	686
	Feb.	695	695	695	695	695	695	691	694	695	691	683	679	677	681	684	686	688	687	688	692	692	692	693	694	695	690
	Mar.	703	704	704	703	703	703	705	705	699	691	685	680	681	686	693	697	698	697	696	699	699	700	701	703	703	697
	Oct.	705	705	705	705	705	705	707	706	699	690	682	680	683	691	698	700	699	696	698	701	701	702	703	705	705	699
	Nov.	702	702	702	702	702	702	702	703	700	694	687	686	690	693	694	695	696	694	697	698	698	699	699	701	702	698
Dec.	705	705	705	705	705	705	706	705	702	695	687	686	690	695	699	702	701	699	701	703	703	703	704	705	705	701	
Means	700	700	700	700	700	700	700	700	697	692	686	683	684	687	691	693	694	693	694	697	697	697	698	700	700	695	
Summer.	April	704	705	704	704	704	703	707	704	696	688	691	678	682	689	694	698	700	699	698	699	700	701	702	703	704	698
	May	704	704	704	704	704	706	710	707	699	689	683	682	685	691	696	702	705	703	701	700	701	702	703	704	704	700
	June	701	701	701	701	701	702	705	702	696	688	683	681	684	685	693	697	699	698	698	697	698	699	700	701	701	696
	July	701	701	701	701	701	702	707	703	695	685	680	677	679	683	686	691	698	699	698	696	698	699	700	701	702	695
	Aug.	703	703	703	703	704	704	709	706	697	686	679	677	677	683	689	695	700	700	699	698	699	700	702	703	703	697
Sep.	703	703	703	703	703	703	708	705	693	681	675	674	678	686	694	698	699	697	697	699	699	701	701	702	703	696	
Means	703	703	703	703	703	703	708	705	696	686	682	678	681	686	692	697	700	699	699	698	699	700	701	702	703	697	

Diurnal Inequality of the Vertical Force at Toungoo in 1918, deduced from the above Table.

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

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

Hourly Means of the Dip at Toungoo in 1918, determined from all available days. Dip =  $N. 23^\circ + \text{tabular quantity}$ .

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. Feb. Mar. } { Oct. Nov. Dec. }	8.9	8.8	8.7	8.7	8.7	8.6	8.3	8.0	8.0	7.9	7.6	7.0	6.7	6.7	6.8	7.2	7.9	8.2	8.2	8.5	8.6	8.7	8.7	8.9	8.8	8.1	8.4	
	9.1	9.2	9.2	9.1	9.1	9.0	8.8	8.7	8.5	7.7	6.9	6.6	6.4	6.8	7.3	7.9	8.3	8.4	8.5	8.9	8.9	9.0	9.1	9.1	9.1	9.1	9.1	
	9.7	9.8	9.7	9.6	9.6	9.5	9.6	9.6	8.8	7.7	6.7	5.9	5.9	5.9	6.6	7.4	8.2	8.6	8.7	9.0	9.2	9.2	9.5	9.6	9.6	9.5	8.7	
	9.5	9.5	9.4	9.3	9.3	9.3	9.5	9.4	8.6	7.4	6.3	5.9	5.0	6.7	7.7	8.4	8.7	8.6	8.8	9.0	9.0	9.2	9.3	9.4	9.3	9.3	8.5	
	9.0	8.9	8.9	8.9	8.9	8.9	8.8	8.7	8.2	7.3	6.5	6.2	6.5	6.9	7.4	7.8	8.0	8.0	8.1	8.5	8.5	8.6	8.8	8.9	8.9	8.9	8.2	
	9.5	9.4	9.3	9.2	9.2	9.3	9.3	9.2	9.2	8.8	8.0	7.2	6.9	7.2	7.7	8.2	8.7	8.8	8.7	9.0	9.2	9.2	9.2	9.3	9.3	9.4	9.4	8.7
	9.3	9.3	9.2	9.1	8.9	8.9	9.1	9.1	8.9	8.5	7.7	6.9	6.4	6.4	6.9	7.5	8.0	8.4	8.5	8.6	8.9	8.9	9.1	9.1	9.2	9.2	9.2	8.4
	9.6	9.7	9.6	9.5	9.4	9.3	9.3	9.7	9.4	8.4	7.1	6.8	5.6	5.9	6.7	7.5	8.3	8.9	9.0	8.9	9.1	9.2	9.3	9.4	9.3	9.3	8.5	
	9.4	9.4	9.3	9.3	9.3	9.4	9.4	9.7	9.3	8.4	7.2	6.3	6.0	6.3	6.9	7.7	8.6	9.2	9.3	9.2	9.1	9.2	9.3	9.4	9.4	9.4	8.5	
	9.1	9.0	9.0	9.0	9.0	9.0	9.1	9.2	8.9	8.1	7.2	6.5	6.2	6.3	6.4	7.3	8.0	8.5	8.7	8.8	8.7	8.7	8.8	8.9	9.0	8.9	8.3	
	9.1	9.1	9.0	9.0	9.0	9.1	9.1	9.3	8.9	8.0	6.9	6.2	5.8	5.9	6.3	6.8	7.5	8.3	8.7	8.8	8.7	8.9	8.9	9.0	9.0	9.1	8.2	
	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.6	9.3	8.4	7.2	6.4	6.0	6.8	6.4	7.1	7.9	8.6	8.8	8.9	8.8	9.0	9.0	9.1	9.2	9.2	8.4	
9.4	9.2	9.2	9.1	9.1	9.1	9.1	9.5	9.5	8.5	7.1	6.2	6.0	6.2	6.9	7.8	8.4	8.7	8.7	8.8	9.0	9.1	9.3	9.3	9.2	9.3	8.5		
9.3	9.3	9.2	9.2	9.2	9.2	9.2	9.5	9.2	8.3	7.1	6.4	5.9	6.1	6.6	7.4	8.1	8.7	8.9	8.9	8.9	9.0	9.1	9.2	9.2	9.2	8.4		
Means																												

Diurnal Inequality of the Dip at Toungoo in 1918, 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. Feb. Mar. } { Oct. Nov. Dec. }	+0.8	+0.7	+0.6	+0.6	+0.6	+0.5	+0.2	-0.1	-0.1	-0.2	-0.5	-1.1	-1.4	-1.4	-1.3	-0.9	-0.2	+0.1	+0.1	+0.4	+0.5	+0.6	+0.6	+0.8	+0.8	+0.7	
	+0.7	+0.8	+0.7	+0.7	+0.7	+0.6	+0.4	+0.3	+0.1	-0.7	-1.5	-1.8	-2.0	-2.0	-1.6	-1.1	-0.5	-0.1	0.0	+0.1	+0.5	+0.5	+0.6	+0.7	+0.7	+0.7	
	+1.0	+1.1	+1.0	+0.8	+0.9	+0.8	+0.9	+0.9	+0.1	-1.0	-2.0	-2.8	-2.8	-2.8	-2.1	-1.3	-0.5	-0.1	+0.1	0.0	+0.3	+0.5	+0.8	+0.8	+0.9	+0.8	+0.8
	+1.0	+1.0	+0.9	+0.8	+0.8	+0.8	+1.0	+0.9	+0.1	-1.1	-2.2	-2.6	-2.6	-2.6	-1.8	-0.9	-0.1	+0.2	+0.1	+0.3	+0.5	+0.5	+0.7	+0.8	+0.9	+0.8	+0.8
	+0.8	+0.7	+0.7	+0.7	+0.7	+0.7	+0.6	+0.5	0.0	-0.9	-1.7	-2.0	-1.7	-1.7	-1.3	-0.8	-0.4	+0.2	+0.3	+0.3	+0.5	+0.5	+0.6	+0.7	+0.7	+0.7	+0.7
	+0.8	+0.7	+0.6	+0.5	+0.5	+0.6	+0.6	+0.5	+0.1	-0.7	-1.5	-1.8	-1.5	-1.5	-1.0	-0.5	0.0	+0.1	+0.3	+0.3	+0.5	+0.5	+0.5	+0.6	+0.6	+0.7	+0.7
	+0.9	+0.8	+0.7	+0.7	+0.7	+0.7	+0.7	+0.7	+0.5	+0.1	-0.7	-1.5	-2.0	-2.0	-1.5	-0.9	-0.4	0.0	+0.1	+0.2	+0.5	+0.5	+0.7	+0.7	+0.8	+0.8	+0.8
	+1.1	+1.2	+1.1	+1.0	+1.0	+0.8	+1.2	+1.2	+0.9	-0.1	-1.4	-2.7	-2.9	-2.6	-1.8	-1.0	-0.2	+0.4	+0.5	+0.4	+0.5	+0.7	+0.8	+0.8	+0.8	+0.8	+0.8
	+0.8	+0.8	+0.7	+0.7	+0.7	+0.8	+1.1	+0.9	+0.7	-0.2	-1.4	-2.3	-2.6	-2.3	-1.7	-0.9	-0.3	+0.6	+0.7	+0.6	+0.5	+0.6	+0.7	+0.8	+0.8	+0.8	+0.8
	+0.8	+0.8	+0.7	+0.7	+0.7	+0.8	+0.8	+0.9	+0.6	-0.2	-1.1	-1.8	-2.1	-2.0	-1.9	-1.0	0.0	+0.2	+0.4	+0.5	+0.4	+0.5	+0.6	+0.6	+0.7	+0.7	+0.6
	+0.9	+0.9	+0.8	+0.8	+0.8	+0.9	+1.1	+1.1	+0.7	-0.2	-1.3	-2.0	-2.4	-2.3	-1.9	-1.4	-0.7	+0.1	+0.5	+0.6	+0.5	+0.7	+0.7	+0.8	+0.8	+0.8	+0.9
	+0.8	+0.8	+0.8	+0.8	+0.8	+0.8	+0.8	+1.2	+0.9	0.0	-1.2	-2.0	-2.4	-2.6	-2.0	-1.3	-0.5	+0.2	+0.4	+0.5	+0.4	+0.6	+0.6	+0.7	+0.8	+0.8	+0.8
+0.9	+0.9	+0.7	+0.6	+0.6	+0.6	+0.6	+1.0	+1.0	0.0	-1.4	-2.3	-2.5	-2.3	-1.6	-0.7	-0.1	+0.2	+0.2	+0.3	+0.5	+0.6	+0.6	+0.8	+0.8	+0.8	+0.8	
+0.9	+0.9	+0.8	+0.8	+0.8	+0.8	+0.8	+1.1	+0.8	-0.1	-1.3	-2.0	-2.5	-2.3	-1.8	-1.0	-0.3	+0.3	+0.5	+0.5	+0.5	+0.6	+0.7	+0.8	+0.8	+0.8	+0.8	
Means																											

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 1918, determined from all available days. Declination =  $W. I^{\circ}$  + 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. Feb. Mar.	36.6	36.7	36.7	36.8	37.0	37.3	37.7	38.3	38.2	37.4	36.6	36.2	36.2	36.0	35.8	36.0	36.4	36.6	36.9	36.6	36.5	36.5	36.6	36.7	36.7	36.8
	37.1	37.1	37.4	37.4	37.4	37.5	37.7	38.0	37.6	37.1	36.6	36.3	36.7	36.3	36.3	36.2	36.2	36.6	36.9	36.9	37.0	37.0	37.2	37.2	37.1	37.0
	37.4	37.4	37.4	37.4	37.5	37.6	37.5	36.9	36.8	36.8	36.8	37.1	37.7	38.2	37.8	37.2	36.9	36.9	37.3	37.3	37.5	37.5	37.5	37.5	37.4	37.4
	40.6	40.5	40.5	40.6	40.7	40.9	40.7	40.4	40.4	40.6	41.1	41.8	42.1	41.8	41.2	40.7	40.6	40.6	40.7	41.0	40.8	40.9	40.9	40.9	40.8	40.9
Summer { April May June	41.5	41.5	41.5	41.6	41.7	41.8	41.9	42.0	41.8	41.7	41.8	42.3	42.0	41.2	40.8	40.3	40.4	41.0	41.5	41.3	41.4	41.7	41.7	41.6	41.6	41.5
	39.1	39.1	39.2	39.2	39.3	39.5	39.6	39.6	39.4	39.2	39.2	39.4	39.5	39.2	38.8	38.5	38.5	38.9	39.1	39.0	39.1	39.2	39.2	39.2	39.2	39.2
	38.3	38.0	38.1	38.2	38.2	38.2	37.8	37.0	37.0	37.6	38.2	39.0	40.4	40.2	39.2	38.7	38.3	38.2	38.2	38.2	38.5	38.7	38.5	38.4	38.3	38.3
	39.9	39.6	39.5	39.5	39.5	39.4	38.5	37.5	37.4	38.3	39.7	40.9	41.7	41.7	41.4	40.7	40.0	39.5	39.4	39.5	39.8	39.8	39.7	39.5	39.4	39.3
Autumn { July Aug. Sept.	40.4	40.2	40.2	40.0	40.0	39.9	39.2	38.2	38.3	39.5	40.7	41.8	42.3	42.2	41.6	40.5	39.9	40.0	40.2	40.2	40.3	40.5	40.5	40.4	40.4	40.3
	39.0	39.0	38.9	38.9	38.9	38.8	38.2	37.3	37.3	38.2	39.3	40.3	41.0	40.9	40.4	39.7	39.2	39.0	39.0	39.3	39.6	39.5	39.5	39.4	39.3	
	38.3	38.0	38.1	38.2	38.2	38.2	37.8	37.0	37.0	37.6	38.2	39.0	40.4	40.2	39.2	38.7	38.3	38.2	38.2	38.2	38.5	38.7	38.6	38.5	38.4	38.4
	39.9	39.6	39.5	39.5	39.5	39.4	38.5	37.5	37.4	38.3	39.7	40.9	41.7	41.7	41.4	40.7	40.0	39.5	39.4	39.5	39.8	39.8	39.7	39.5	39.4	39.3
Means																										

Diurnal Inequality of the Declination at Kodaikanal in 1918, deduced from the above Table.

Hours	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. Feb. Mar.	+0.2	+0.1	+0.1	+0.0	-0.2	-0.4	-0.9	-1.5	-1.4	-0.6	+0.2	+0.6	+0.6	+0.8	+1.0	+0.8	+0.4	+0.2	-0.1	+0.2	+0.3	+0.2	+0.2	+0.1	+0.1
	-0.1	-0.1	-0.1	0.0	0.0	-0.1	-0.7	-1.0	-0.6	-0.1	+0.4	+0.7	+0.3	+0.7	+0.7	+0.8	+0.8	+0.4	+0.4	+0.1	+0.1	-0.2	-0.2	-0.1	-0.1
	0.0	0.0	0.0	0.0	-0.1	-0.2	-0.1	+0.5	+0.6	+0.6	+0.3	-0.3	-0.8	-0.9	-0.4	+0.2	+0.5	+0.3	+0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0
	+0.3	+0.4	+0.4	+0.3	0.0	0.0	+0.5	+0.5	+0.5	+0.3	-0.2	-0.9	-1.2	-0.9	-0.3	+0.2	+0.3	+0.2	-0.1	+0.1	0.0	0.0	0.0	+0.1	+0.2
Summer { April May June	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.2	+0.1	-0.3	-0.5	-0.6	0.0	+0.3	+0.0	+0.7	+0.3	+0.2	+0.3	+0.3	+0.2	+0.2	+0.1	+0.1
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	+0.3	+0.4	+0.4	+0.3	0.0	0.0	+0.5	+0.5	+0.5	+0.3	-0.2	-0.9	-1.2	-0.9	-0.3	+0.2	+0.3	+0.2	-0.1	+0.1	0.0	0.0	0.0	+0.1	+0.2
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Autumn { July Aug. Sept.	+0.1	+0.1	+0.1	+0.0	+0.0	+0.3	+0.4	+0.5	+0.5	+0.3	-0.2	-0.9	-1.2	-0.9	-0.3	+0.2	+0.3	+0.2	+0.3	+0.3	+0.2	+0.2	+0.2	+0.1	+0.1
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	+0.3	+0.4	+0.4	+0.3	0.0	0.0	+0.5	+0.5	+0.5	+0.3	-0.2	-0.9	-1.2	-0.9	-0.3	+0.2	+0.3	+0.2	+0.3	+0.3	+0.2	+0.2	+0.2	+0.1	+0.1
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Means																									

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 Kodaihanal in 1918, from all available days. Horizontal Force = 37000 C. G. S. + tabular quantity.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter { Jan. Feb. Mar.	662	663	664	665	665	667	670	678	698	699	706	716	722	724	717	707	694	682	673	667	664	662	661	662	663	662
	653	652	658	657	659	660	660	669	685	714	728	734	732	711	692	680	677	676	669	663	659	657	654	655	655	657
	651	654	657	659	661	660	659	671	698	713	736	765	764	724	701	686	679	680	676	661	659	656	656	657	655	664
Summer { Oct. Nov. Dec.	675	678	679	682	681	680	679	688	714	742	761	772	768	742	717	704	698	695	689	684	679	675	676	677	678	701
	684	684	686	685	685	685	688	699	717	740	758	760	764	738	722	713	707	701	694	688	687	685	685	686	687	716
	682	683	687	684	686	686	686	695	713	736	749	749	742	745	709	699	698	696	692	688	686	682	682	682	688	701
Means	669	660	672	673	673	673	674	683	703	727	743	749	744	727	709	698	692	688	682	676	672	670	670	670	671	692
Summer { April May June	658	660	662	661	664	661	663	678	707	738	759	761	745	720	695	683	678	678	676	667	667	665	664	665	665	687
	672	674	675	676	676	675	676	683	707	735	753	762	756	736	710	692	681	678	678	675	672	670	671	672	674	691
	679	680	681	682	681	681	681	689	701	724	737	747	747	736	720	704	690	683	683	682	680	680	681	682	682	687
Summer { July Aug. Sep.	676	678	679	680	679	680	684	690	705	726	745	752	751	739	727	712	697	684	683	680	680	679	676	674	678	699
	674	674	675	677	678	676	680	685	702	729	748	761	756	745	729	714	700	688	684	679	678	677	676	674	675	698
	674	676	679	681	681	681	681	691	715	744	761	761	748	727	709	700	695	689	684	677	674	670	671	674	677	698
Means	672	674	675	677	677	676	678	686	707	733	751	757	751	734	715	701	690	683	681	677	675	674	674	674	675	696

Diurnal Inequality of the Horizontal Force at Kodaihanal in 1918, deduced from the above Table.

Month	Day	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. Feb. Mar.	20	-	17	-	15	-	12	-	8	-	4	-	0	-	4	-	8	-	12	-	16	-	20	-	24	-
	24	-	19	-	17	-	14	-	10	-	6	-	2	-	0	-	4	-	8	-	12	-	16	-	20	-
	33	-	30	-	23	-	24	-	26	-	28	-	31	-	35	-	38	-	40	-	42	-	44	-	46	-
Summer { Oct. Nov. Dec.	26	-	23	-	21	-	18	-	15	-	12	-	9	-	6	-	3	-	0	-	3	-	6	-	9	-
	22	-	20	-	21	-	18	-	15	-	12	-	9	-	6	-	3	-	0	-	3	-	6	-	9	-
	19	-	18	-	15	-	12	-	9	-	6	-	3	-	0	-	3	-	6	-	9	-	12	-	15	-
Means	-	24	-	19	-	19	-	18	-	15	-	15	-	12	-	10	-	8	-	6	-	5	-	4	-	3
Summer { April May June	29	-	27	-	26	-	24	-	21	-	18	-	15	-	12	-	9	-	6	-	3	-	0	-	3	-
	22	-	20	-	19	-	18	-	16	-	14	-	12	-	10	-	8	-	6	-	4	-	3	-	2	-
	18	-	17	-	16	-	15	-	15	-	15	-	15	-	14	-	13	-	12	-	11	-	10	-	9	-
Summer { July Aug. Sep.	25	-	21	-	20	-	19	-	18	-	17	-	16	-	15	-	14	-	13	-	12	-	11	-	10	-
	24	-	24	-	20	-	22	-	18	-	17	-	16	-	15	-	14	-	13	-	12	-	11	-	10	-
	24	-	22	-	22	-	19	-	17	-	17	-	17	-	16	-	15	-	14	-	13	-	12	-	11	-
Means	-	24	-	22	-	21	-	19	-	19	-	19	-	18	-	17	-	16	-	15	-	14	-	13	-	12

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

Hourly Means of Vertical Force in C.G.S. units (corrected for temperature) at Kodalkanal in 1918, from all available days. Vertical Force = 0.0000 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
Winter { Jan. Feb. Mar.	958	958	958	958	957	958	957	955	956	957	961	962	959	949	949	937	939	943	949	952	953	954	955	957	958	958
	963	963	965	965	965	965	965	965	965	962	957	961	961	950	951	953	953	953	953	955	959	960	961	962	964	964
	970	971	970	970	970	970	970	970	965	965	950	941	941	945	949	955	955	955	957	959	961	962	965	966	968	969
Summer { Oct. Nov. Dec.	982	982	981	982	981	981	985	981	975	966	955	950	950	962	955	961	961	966	971	974	974	975	985	987	982	971
	988	986	987	986	987	987	985	980	981	977	973	971	972	971	972	973	974	978	978	981	981	982	985	987	987	980
	992	991	992	991	990	990	992	990	986	977	968	964	967	972	976	981	982	981	985	986	987	987	988	990	993	984
Means	976	975	976	975	975	975	977	975	971	966	961	957	957	957	957	960	961	962	965	969	970	971	973	974	976	968
Summer { April May June	969	970	970	969	969	969	975	973	965	966	947	941	939	943	950	957	959	959	961	963	965	966	966	967	969	961
	977	976	976	978	977	978	983	983	977	966	966	949	946	950	966	964	968	970	970	968	970	972	975	975	977	969
	979	979	978	978	979	980	982	978	978	970	962	955	959	962	965	969	971	972	973	972	973	975	977	978	979	978
Summer { July Aug. Sep.	978	978	979	979	980	984	983	983	978	969	962	959	955	957	961	963	966	966	969	971	971	973	975	976	977	978
	987	988	987	989	988	989	991	991	981	970	962	955	963	956	963	966	972	975	978	978	981	981	985	986	987	973
	987	988	987	988	988	988	992	985	970	954	944	939	943	952	961	967	969	971	974	976	978	979	982	985	986	973
Means	980	980	980	980	981	985	983	983	975	964	956	951	949	953	959	964	968	969	971	971	973	975	977	978	979	971

Diurnal Inequality of the Vertical Force at Kodalkanal in 1918, deduced from the above Table.

Month	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. Feb. Mar.	+5	+4	+10	+5	+7	+6	+6	+3	+3	+4	+8	+9	+6	-4	-14	-16	-14	-10	-5	-1	0	+1	+2	+3	+5	+7
	+4	+4	+10	+6	+6	+6	+6	+6	+3	-2	-8	-8	-8	-8	-8	-6	-6	-6	-4	0	+1	+2	+3	+5	+7	
	+9	+10	+9	+9	+9	+11	+9	+4	-2	-11	-20	-20	-20	-16	-12	-8	-6	-4	-2	0	+1	+4	+5	+7	+8	+8
Summer { Oct. Nov. Dec.	+11	+11	+11	+10	+10	+14	+10	+4	+4	-5	-16	-21	-19	-16	-10	-7	-5	0	+3	+3	+4	+8	+9	+11	+11	
	+8	+7	+8	+7	+7	+8	+6	+2	-3	-7	-9	-9	-9	-8	-3	-2	-3	+1	+1	+2	+3	+6	+7	+7	+7	
	+8	+7	+7	+6	+6	+8	+6	+2	-7	-16	-20	-17	-12	-8	-7	-2	-3	+1	+2	+3	+3	+4	+6	+9	+9	
Means	+8	+7	+8	+7	+7	+9	+7	+3	-2	-7	-11	-11	-11	-11	-8	-7	-6	-2	+1	+2	+3	+5	+6	+8	+8	
Summer { April May June	+8	+9	+7	+8	+8	+14	+12	+4	-6	-14	-20	-22	-18	-11	-4	-2	-2	0	+2	+4	+5	+6	+8	+8	+8	
	+8	+6	+5	+5	+9	+14	+14	+8	-3	-13	-20	-23	-19	-13	-5	-1	-1	0	-1	+1	+3	+4	+6	+6	+6	
	+6	+6	+5	+6	+7	+10	+9	+5	-3	-10	-12	-14	-11	-8	-4	-2	-2	0	-1	0	+2	+4	+5	+6	+6	
Summer { July Aug. Sep.	+6	+10	+15	+7	+8	+12	+11	+6	-3	-10	-13	-17	-15	-11	-9	-7	-5	-2	-1	+1	+1	+3	+4	+5	+6	
	+10	+11	+12	+11	+12	+17	+14	+4	-7	-15	-22	-24	-21	-17	-11	-5	-2	-1	+1	+4	+4	+8	+9	+10	+10	
	+14	+15	+15	+14	+15	+19	+12	-3	-19	-29	-34	-30	-21	-12	-6	-4	-2	+1	+3	+5	+6	+9	+12	+13	+13	
Means	+9	+9	+9	+9	+10	+11	+12	+4	-7	-15	-20	-22	-18	-12	-7	-3	-2	0	0	+2	+4	+6	+7	+8	+8	

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 1918, determined from all available days. Dip =  $N. 4^{\circ} + \text{tabular quantity}$ .

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	18	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter { Jan. Feb. Mar. }	29.5	29.5	29.4	29.4	29.3	29.4	29.3	29.1	29.1	29.1	29.4	29.4	29.1	28.2	27.3	27.2	27.5	28.0	28.5	28.9	29.0	29.0	29.1	29.2	29.4	29.5
	30.0	30.0	30.2	30.1	30.1	30.1	30.1	30.0	29.9	29.5	28.9	28.3	28.3	28.4	28.6	28.9	28.9	28.9	29.1	29.7	29.8	29.8	29.9	29.9	30.1	29.6
	30.6	30.7	30.7	30.6	30.6	30.6	30.6	30.5	29.8	29.0	28.1	27.2	27.3	27.8	28.4	28.8	29.1	29.2	29.5	29.7	29.8	30.1	30.2	30.4	30.5	29.6
	31.5	31.5	31.4	31.4	31.4	31.4	31.4	30.6	30.6	29.6	28.5	28.0	28.2	28.4	28.6	29.4	29.7	30.0	30.4	30.7	30.8	30.9	31.3	31.3	31.5	30.4
Summer { Apr. May June }	32.0	31.8	31.9	31.8	31.9	31.9	32.0	31.7	31.1	30.6	30.1	29.9	30.0	30.1	30.3	30.5	30.6	30.6	31.0	31.4	31.5	31.6	31.7	31.7	31.9	31.2
	32.4	32.3	32.4	32.2	32.2	32.2	32.4	32.1	31.6	30.7	29.7	29.4	29.7	30.3	30.8	31.3	31.4	31.3	31.7	31.8	31.9	32.0	32.0	32.2	32.4	31.5
	31.0	31.0	31.0	30.9	30.9	30.9	31.1	30.8	30.4	29.8	29.1	28.7	28.8	28.9	29.0	29.4	29.5	29.7	30.0	30.3	30.5	30.6	30.7	30.9	31.0	30.2
	30.5	30.6	30.6	30.5	30.4	30.5	31.0	30.7	29.8	29.6	27.3	27.2	27.1	27.7	28.5	29.2	29.4	29.4	29.6	29.9	30.1	30.2	30.3	30.4	30.4	29.6
Autumn { July Aug. Sep. }	31.2	31.2	31.2	31.2	31.2	31.3	31.7	31.5	31.3	30.0	29.2	28.9	28.6	28.8	29.3	29.8	29.9	30.3	30.5	30.7	30.9	31.0	31.0	31.1	31.2	30.6
	32.0	32.1	32.0	32.2	32.1	32.2	32.6	32.3	31.3	30.1	29.2	28.5	28.6	29.7	29.8	29.8	30.2	30.8	31.1	31.1	31.4	31.7	31.8	31.8	31.2	30.5
	32.0	32.1	32.1	32.0	32.0	32.0	32.4	31.7	30.1	28.5	27.5	27.0	27.5	28.5	29.4	30.0	30.2	30.4	30.7	31.0	31.2	31.3	31.6	31.8	31.9	30.6
	31.3	31.4	31.3	31.3	31.3	31.4	31.8	31.5	30.7	29.5	28.6	28.1	28.0	28.5	29.2	29.8	30.1	30.3	30.5	30.6	30.9	31.0	31.1	31.2	31.3	30.1

Diurnal Inequality of the Dip at Kodaikanal in 1918, deduced from the above Table.

Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	18	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter { Jan. Feb. Mar. }	+0.6	+0.6	+0.5	+0.4	+0.4	+0.5	+0.4	+0.2	+0.2	+0.2	+0.5	+0.5	+0.2	-0.7	-1.6	-1.7	-1.4	-0.9	0.0	0.0	+0.1	+0.2	+0.3	+0.3	+0.5	+0.6
	+0.5	+0.5	+0.7	+0.6	+0.6	+0.6	+0.6	+0.4	+0.4	0.0	-0.6	-1.2	-1.2	-1.1	-0.9	-0.6	-0.6	-0.6	-0.4	0.0	+0.2	+0.3	+0.4	+0.5	+0.6	+0.6
	+1.0	+1.1	+1.1	+1.0	+1.0	+1.0	+1.2	+0.9	+0.2	-0.6	-1.5	-2.4	-2.3	-1.8	-1.2	-0.3	-0.5	-0.4	-0.1	+0.1	+0.2	+0.5	+0.6	+0.6	+0.9	+0.9
	+1.1	+1.1	+1.0	+1.0	+1.0	+1.0	+1.4	+1.0	+0.2	-0.8	-1.9	-2.4	-2.2	-2.0	-1.6	-1.0	-0.7	-0.4	0.0	+0.3	+0.4	+0.5	+0.9	+0.9	+1.1	+1.1
Summer { Apr. May June }	+0.8	+0.8	+0.7	+0.7	+0.7	+0.7	+0.9	+0.6	+0.6	+0.6	+0.7	+0.7	+0.4	-1.3	-1.2	-0.8	-0.7	-0.5	-0.2	+0.1	+0.3	+0.4	+0.5	+0.7	+0.8	+0.8
	+0.9	+0.8	+0.8	+0.8	+0.9	+0.9	+1.0	+0.8	+0.7	-0.5	-1.6	-2.3	-2.5	-2.0	-1.3	-0.4	0.0	+0.2	+0.1	+0.3	+0.5	+0.6	+0.7	+0.8	+0.8	+0.8
	+0.6	+0.6	+0.5	+0.5	+0.6	+0.7	+1.0	+0.8	+0.4	-0.5	-1.2	-1.6	-1.7	-1.3	-0.9	-0.4	-0.2	0.0	+0.1	0.0	+0.1	+0.3	+0.4	+0.5	+0.6	+0.6
	+0.7	+0.7	+0.7	+0.7	+0.7	+0.8	+1.2	+1.0	+0.5	-0.5	-1.3	-1.6	-1.9	-1.7	-1.2	-0.9	-0.6	-0.2	0.0	+0.2	+0.4	+0.5	+0.6	+0.7	+0.7	+0.7
Autumn { July Aug. Sep. }	+1.0	+1.1	+1.0	+1.0	+1.1	+1.2	+1.6	+1.3	+0.3	-0.9	-2.5	-2.7	-3.0	-2.3	-1.8	-1.5	-1.1	-0.3	+0.1	+0.1	+0.4	+0.5	+0.5	+0.7	+0.8	+1.0
	+1.5	+1.6	+1.6	+1.5	+1.5	+1.5	+1.9	+1.2	+0.3	-2.0	-3.0	-3.5	-3.0	-2.0	-1.1	-0.5	-0.3	-0.1	+0.1	+0.5	+0.7	+0.8	+0.9	+1.1	+1.4	+1.4
	+0.9	+1.0	+0.9	+0.9	+0.9	+1.0	+1.4	+1.1	+0.3	-0.9	-1.8	-2.3	-2.4	-1.9	-1.2	-0.6	-0.3	-0.1	+0.1	+0.3	+0.4	+0.6	+0.7	+0.8	+0.9	+0.9
	+0.9	+1.0	+0.9	+0.8	+0.8	+0.9	+1.4	+1.1	+0.2	-1.0	-1.8	-2.4	-2.4	-1.9	-1.1	-0.4	-0.2	-0.2	0.0	+0.3	+0.5	+0.6	+0.7	+0.8	+0.8	+0.8

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





## BASE LINE.

## PERSONNEL OF No. 19 PARTY.

*Imperial Officers.*

Colonel Sir Gerald Lenox Conyngham, R.E.,  
F.R.S., in charge from 1st to 9th October 1918.

Bt.-Colonel A. A. McHarg, D.S.O., R.E., in  
charge from 10th October 1918 to 31st March  
1919.

Major H. McC. Cowie, R.E., in charge from  
1st April to 8th May 1919.

Major C. M. Thompson, I.A., in charge from  
9th May 1919.

*Lower Subordinate Services.*

1 Clerk, etc.

No work was undertaken by this party as a Party during the year under report. The officers and establishment from time to time posted to it for administrative purposes were employed on miscellaneous work.

## THE COMPUTING OFFICE.

BY MAJOR C. M. THOMPSON, I. A.

## PERSONNEL.

*Imperial Service.*

Major H. McC. Cowie, R.E. till 18th March 1919.

Major C. M. Thompson, I.A. from 19th March 1919.

*Provincial Service.*

Mr. Hanuman Prasad, E.A.S., in charge Workshops and Stores.

*Upper Subordinate Service.*

Mr. Sarat Kumar Mukerji, S.A.S., in charge Printing Office.

Rai Sahib Ishan Chandra Deva, B.A., Head Computer, 11 Senior Computers and 6 Junior Computers.

1 Proof Reader, 22 Compositors, 5 pressmen, and 8 book-binders.

1 Head Artificer and 22 fitters and carpenters.

Babu Ganga Prasad Mathur, 2nd Computer, retired from service on 19th October 1918. Babu Harendra Chandra Deva B.A. was appointed on 24th February 1919.

case of ocean areas the presence of the

*Isostasy.*—From the geodetic point of view the most interesting event of the year was the publication of Professional Paper No. 17 by Colonel Sir Sidney Burrard, K.C.S.I., R.E., F.R.S.

The title of this paper is *Investigations of Isostasy in Himalayan and Neighbouring Regions*, and it puts forward the proposition that the anomalies both in the values of  $g$  and in the attractions of the plumb-line, which remain after the effects of isostatic compensation on the Hayford hypothesis have been allowed for, may be due to imperfections in the application of the hypothesis rather than to departures from complete compensation.

Hitherto in computing the compensation all masses standing above the mean level of the sea have been assumed to have a density of 2.67 (mean density of the earth's crust); if, however, the rocks over any area are known to be for considerable depths of an appreciably different density, it is only reasonable to take account of this difference in deducing the density of the compensating mass, just as in the case of ocean areas the presence of the sea water is taken account of.

Sir Sidney Burrard's discussion is chiefly concerned with the Gangetic trough over which area of deep alluvial deposits the gravity anomalies are generally negative, whereas in the Himalayas to the north and along the margin of the trough to the south they tend to be positive. His argument is clearly given in the following passage.\*—

“If the Gangetic trough contains light deposits to a considerable depth, and if the light density of these deposits is isostatically compensated to a depth of 113 kilometers by equivalent heavy density in the crust, the gravity anomalies at stations over the trough will be negative, because the light deposits are nearer to the surface than the deep heavy rocks, which form the compensation: the light rocks thus having a more immediate effect on the pendulum than the heavy.”

“On the other hand the light deposits will have no appreciable effect at stations north and south of the trough, whilst the heavy compensation-rock will increase the intensity of gravity at these stations and will tend to make their anomalies positive. A pendulum is actuated by the vertical component of gravity: the vertical component due to surface rock deposits, situated in a horizontal direction to one side of the pendulum will be very small, but the vertical component of the compensation rocks situated at a great depth will be considerable.”

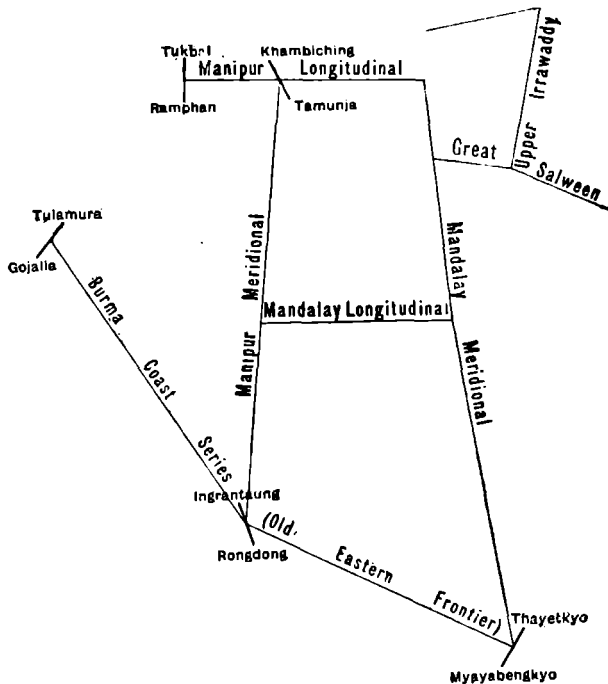
“It is in this way that the hypothesis of isostatic compensation, if applied to the Gangetic trough, may explain the presence of positive anomalies north and south of the trough.”

The reduction of these ideas to figures has presented formidable difficulties for neither the shape nor the depth of the Gangetic trough is known with any accuracy. A series of calculations have been made to obtain an approximation to the truth, and it has been found that if a V-shaped trough is assumed for the Indo-Gangetic belt with an average depth of 50,000 feet and 120 miles wide, filled with light materials of density 2.4 and isostatically compensated it offers a solution for the anomalies.

*Triangulation.*—(a) The adjustment of the pendent portion of the Burma Coast Series which extends to the south of latitude 18°, and of the Bangkok Series has been carried out. The stations and intersected points of the following series required for inclusion in the triangulation pamphlets have also been adjusted.—(1) Burma Coast Series (2) Mandalay Longitudinal and Meridional Series (3) Manipur Meridional Series (4) Thayetmyo Series extending to Cape Negrais *via* Prome, Myanaung and Bassein (5) Thayetmyo and Toungoo Series (6) Pegu, Rangoon and Coast Series. \*

(b) The initial heights for the triangulation in Burma are those of Ramphan and Tukbai of the Manipur Longitudinal Series, and those of Gojalia and Tulamura of the Shillong Meridional (Eastern Frontier) Series. All of these stations belong to the N.E. quadrilateral of the Indian triangulation. The Burma heights have been based on the heights of these stations and an adjustment has been effected on the following lines:—

Heights have been computed from Gojalia-Tulamura (*see diagram*) through the Eastern



Frontier Series, (now Burma Coast Series,) and from Ramphan-Tukbai through the Manipur Meridional Series to their junction at the stations Rongdong-Angrantaung (Ingrantaung). The small error met with at the junction stations Rongdong and Angrantaung (Ingrantaung) was distributed amongst the stations of the two series proportionately to their distances from the starting stations. With these adjusted values of heights of Rongdong and Angrantaung (Ingrantaung) the heights of the Burma Coast Series, up to Myayabengkya, those of the Man-

dalay Meridional Series and Manipur Longitudinal Series up to Tamunja and Khambiching have been revised and the error found at the closing stations similarly distributed, with additional adjustments wherever spirit-levelled heights were available. The heights of the Mandalay Longitudinal Series have also been adjusted between the final values of Manipur and Mandalay Meridional Series. The pendent series—Great Salween and Upper Irrawaddy have also been brought into terms of the final values of the Mandalay Meridional Series.

*Levelling.*—The following have been published:—

(a) 2nd edition of levelling pamphlet 57 incorporating the results of the revision of the Gooty-Bellary line (1914-15). In this edition the information relating to distances has been added and the descriptions of bench-marks have been materially revised and corrected.

(b) Addendum to Levelling Pamphlet 56 embodying the line Bāgalkot to Raichūr (1914). In addition to these, addendum slips have been issued for pamphlets 43 and 47.

(c) A reprint of the Levelling Pamphlet 53 having been called for on account of extensive revisions carried out in that sheet, a corrected 2nd edition has been prepared and is in course of printing. It will be ready for publication early next year.

*Computations and Investigations.*—

(1) In compliance with a request from the Chief of the General Staff, Simla, spherical co-ordinates were computed for over five hundred points to furnish data for the construction of an index map of the Peshāwar Division of the N. W. F. Provinces for the use of the Army Department.

(2) Deflections were computed for the stations of Burma triangulation required for inclusion in the triangulation pamphlets published during the year.

(3) For purposes of investigation the following were computed:—

(a) Bouguer corrections for the 20 gravity stations in Turkistān given on page 215 of Professional Paper No. 16. (b) Compensated deflections with modified values of Hayford factors for the 102 latitude and 18 longitude stations dealt with in Professional Paper No. 13.

In addition to above, computations were carried out in connection with the conversion of rectangular co-ordinates to spherical and *vice versa*. Some graticules were also computed for the Officer in Charge No. 11 Party.

The remodelling of professional forms to reduce them to foolscap size is being carried out in the Computing Office.

*Revision of the Hand Book of Topography.*—Chapter III (1914) of the Hand-Book of Topography is being re-written. The revised edition will be ready for publication in the course of the next year.

*Requisitions.*—158 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.

*Triangulation pamphlets.*—Sustained progress has been made in the compilation and publication of triangulation pamphlets. 61 pamphlets were published and issued during the year and press copies for 107 pamphlets including 14 for the Officer in charge, East Persia Survey Party, were compiled and made ready for the press.

#### PRINTING SECTION.

The following were printed in the course of the year:—

Volume XIII of the Records of the Survey of India, 1917-18, Triangulation pamphlets covering 220 degree sheets, Levelling pamphlets 57 (2nd Edition) and 56 (Addendum) including correction slips for pamphlets 43 and 47, Levelling pamphlet for Mesopotamia, Professional Paper No. 17, Extracts from Auxiliary Tables for the use of Explorers, Tables of reduced results of Magnetic Observations by 18 Party, a glossary of Tibetan names, and a large amount of miscellaneous work.

In the book-binding section the work dealt with comprised 350 copies of Professional Paper No. 17, 3050 triangulation pamphlets, 600 Levelling pamphlets, 200 copies of the Tide Tables for the Port of Basrah and over 3000 copies of miscellaneous publications including the distribution lists for Professional Papers 16 and 17. The binding of the Records Volume XI (350 copies) was completed.

#### WORKSHOPS.

The work of this section consisted principally in the construction of a number of racks for the new godown and one for Computing Office, and in carrying out alterations in the racks of the Forest Map Office. Photo carriers were made for the Photo-Zinco Office and the Thomason Civil Engineering College, Roorkee, and a number of almirahs were constructed for the Library of the Trigonometrical Survey Office. The departmental instruments were cleaned and repaired, and a large amount of other petty work was carried out.

#### OBSERVATORIES.

(1) *Seismography and Meteorology.*—The Omori Seismograph was in operation throughout the year and the usual daily meteorological observations were made.

(2) *Solar Photography.*—The Photohelio 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.

1. *Statement of earthquakes recorded during the year 1918-19.*

No.	Month and Date	Time of beginning (corrected)		Duration	Distance of Epicentre.		REMARKS Intensity &c.
		Dehra	Siml (from W.R.)		Dehra	Siml (from W.B.)	
		hrs. mts.	hrs. mts.	mts.	miles.	miles.	
1	1-10-18	6 49	6 50	24	235	200	slight
2	9-11-18	10 19	10 18	132	3,850	3,000	severe
3	19-11-18	0 22	0 22	92	3,780	3,000	"
4	1-12-18	8 7½	8 8	60	630	300	moderate
5	5-12-18	17 39½	17 39	138	6,720	6,500	"
6	11-12-18	14 49½	14 46	10	630	200	slight
7	1- 1-19	7 13	7 13	41	3,570	5,500	severe
8	1- 1-19	8 46½	8 47	60	2,520	4,500	"
9	1- 5-19	13 8	...	240	9,870	...	very great
10	3- 5-19	5 31½	...	120	3,850	...	moderate
11	7- 5-19	1 22	1 22	100	5,680	5,000	great
12	23- 5-19	11 43	...	25	470	...	moderate
13	24- 7-19	7 37	7 37	40	630	400	"
14	6- 9-19	13 23½	13 24	10	140	...	slight (local)
15	14- 9-19	18 10	18 9	5	420	200	slight

2. *Statement showing the number of days on which solar photographs were taken during the year 1918-19.*

Month.	No. of days.	8" Negts.		12" Negts.		No. of days on which sun was invisible.	Month.	No. of days.	8" Negts.		12" Negts.		No. of days on which sun was invisible.
		Good.	Bad.	Good.	Bad.				Good.	Bad.	Good.	Bad.	
October 1918	30	55	5	...	...	1	April 1919	29	51	4	3	1	1
November "	30	54	5	1	...	...	May "	30	52	2	2	1	1
December "	28	48	4	2	...	3	June "	28	46	4	...	...	2
January 1919	23	36	4	1	...	8	July "	23	34	4	...	...	8
February "	26	46	4	1	1	2	August "	24	37	4	3	1	7
March "	26	47	3	2	2	5	September "	27	47	3	2	1	3
Totals ...								324	553	46	17	7	41



## APPENDIX

### List of Survey of India Publications

(Corrected up to 30th September 1919)

.....	.....	.....	.....
.....	.....	.....	.....
.....	.....	.....	.....
.....	.....	.....	.....

**PUBLICATIONS**  
OF THE  
**SURVEY OF INDIA**

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**SYNOPSIS**

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**Eastern Ports—**

Galle (Ceylon)—Trincomalee (Ceylon)—Colombo (Ceylon)—Negapatam—Madras—Cocanāda—Vizagapatam—False Point—Dublat (Saugor Island)—Diamond Harbour—Kidderpore (Calcutta)—Chittagong—Akyab—Diamond Island (Burma)—Bassein—Elephant Point (Burma)—Rangoon—Amherst—Moulmein—Mergui—Port Blair.

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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  $\left\{ \begin{array}{l} 1\text{—Government of India Orders (called "Circular Orders" up to 1898.)} \\ 2\text{—Departmental Orders (Administrative).} \\ 3\text{—Departmental Orders (Professional).} \end{array} \right.$

In 1904 the various orders issued since 1878 were reclassified as follows:—

	<i>Number to date.</i>
1.—Government of India Orders.—	720
2.—Circular Orders (Administrative).—	384
3.—Circular Orders (Professional).—	196
4.—Departmental Orders. (appointments, promotions, transfers, etc.)	

These are numbered serially and had reached the above numbers by September 1919. *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).  
Ditto ditto 1909-1913.—Calcutta, 1915.

**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 Dün, 1903.—(Out of print).

**CATALOGUES AND LISTS.**

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2. **Catalogue of Maps** of the Bombay Presidency, Calcutta, 1913. *Price As. 4 or 6<sup>d</sup>.*
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6. Catalogue of Scientific Books and Subjects in the Library of the Trigonometrical Survey Office. Dehra Dün, 1908. *Price Re. 1 or 2<sup>s</sup>.*
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5. \*Photo-Litho Office, Notes on Organization, Methods and Processes. By *Major W. C. Hedley, R. E.* Revised and amplified by *Capt. S. W. S. Hamilton, R. E.* Calcutta, 1914.

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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.*
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