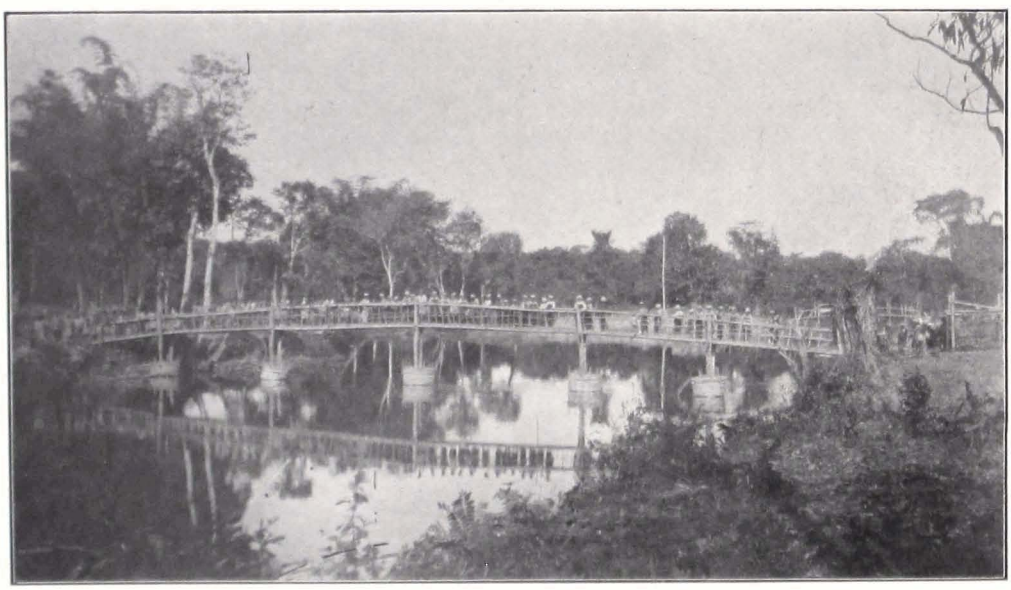
From a photograph by Mr. P. A. T. Kenny.

Survey Indian officers planetabling along Tochi River with Tochi column, Wazir Force, North Waziristan.



From a photograph by Mr. M. C. Petters.

HuKawng Valley. A strong bamboo bridge spanning the Inoning HKa at the Village of Tsingam Ga.

RECORDS

OF THE

SURVEY OF INDIA

Volume XV

(Supplementary to General Report 1919-20).

ANNUAL REPORTS OF

PARTIES AND OFFICES

1919-20.

PREPARED UNDER THE DIRECTION OF

Colonel C. H. D. RYDER, C. I. E., D. S. O., R. E.

Surveyor General of India.

DEHRA DÛN
PRINTED AT THE OFFICE OF THE TRIGONOMETRICAL SURVEY
1921

Price Four Rupees or Eight Shillings.

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PART I.—TOPOGRAPHICAL SURVEY.

NORTHERN CIRCLE.

Summary.—This circle was under the superintendence of Lieut.-Colonel R. T. Crichton, C. I. E., I. A., up to 7th March 1920 and of Lieut.-Colonel H. L. Crosthwait, R. E., from 8th March 1920 to the close of the survey year. It comprised Nos. 1, 2 and 3 Topo. Parties, No. 3 Drawing Office, 3 special parties and a detachment.

During the year Nos. 1, 2 and 3 Parties completed 9145 square miles of detail survey on the ½-inch, 1-inch, 2-inch and 3½-inch scales, and 47 square miles on larger scales. In connection with the survey on the smaller scales an area of 1250 square miles was triangulated and 1499 square miles traversed.

The detail survey consisted of:—

252	square	miles	of	½-inch revision survey.
264	,,	,,	,,	½-inch original survey.
4928	,,	,,	,,	1-inch revision survey.
418	,,	,,	,,	1-inch original survey.
1516	,,	,,	,,	1-inch re-survey.
265	,,	,,	,,	2-inch re-survey.
1237	,,	,,	,,	2-inch original survey.
265	,,	,,	,,	3½-inch experimental Aeroplane survey.

No. 22 (Riverain) Party and Sind-Sāgar Party continued special work in the Punjab for the Local Government. The former carried out the usual riverain survey in the Punjab and the latter rectangulation work in the Sind-Sāgar Doāb.

The Bīrjand Survey Detachment formed in June 1919 continued work in East Persia and returned to India on completion of its programme in September when it was disbanded.

A survey party designated "the Waziristan Survey Party" was formed under an Imperial officer and worked in the North-Western Frontier up to May and was disbanded in June.

No. 4 Party was practically in abeyance throughout the year.

No. 1 PARTY (PUNJAB AND UNITED PROVINCES).

By Major H. T. Morshead, D. S. O., R. E.

The field head-quarters of the party opened at Dehra Dūn on 1st November 1919 and reopened at Mussoorie on 1st May 1920.

The area surveyed consisted of high wooded hills and snowy ranges with low cultivated valleys.

The health of the party was adversely affected by the epidemic of influenza which raged throughout the Simla Hills during the spring of 1920. One surveyor and 3 khalasis died in the field; two other surveyors had to be sent on long leave, their health having broken down from repeated attacks of the disease.

Topography.—No. 1 Camp, under Mr. A. M. Talati, with 10 surveyors, from November 1919 to July 1920, worked on 1-inch revision survey of sheets 53 A/5.8.9.10.12.13.14 and 53 E/3.7.11.15(part) and ½-inch revision survey of sheets 53 E/10.14.

No. 2 Camp, under Mr. R. C. Hanson with 8 surveyors, was employed from November until the middle of January on the large-scale survey of the cities and environs of Lahore and Ferozepore, using blue prints of aerial mosaics.

On completion of this work, the camp moved into the Simla Hills and Sirmūr State, and worked until the end of June on 1-inch revision

Personnel.

Class I Officers.

Bt.-Lt.-Col. A. A. McHarg, D. S. O., R. E., in charge 11th November 1919.

Cap ain H. E. Roome, M. C., R. E, in charge from 20th November 1919 to 16th February 1920.

Bt.-Major K. Mason, M. C., R. E., in charge from 4th March to 10th May 1920.

Major H. T. Morshead, D. S O., R. E., in charge from 10th May to 6th August 1920.

Class II Officers.

Mr. G. J. S. Rae in charge from 11th to 20th November 1919 and from 16th February to 4th March 1920.

Mr. P. A. T. Kenny from 1st May 1920 and in charge from 6th August 1920.

Mr. A M. Talati.

,, R. C. Hanson.

,, F. J. Grice, from 1st June to 29th September 1920.

,, J. A. Calvert from 1st May 1920.

Upper Subordinate Service.

Mr. Muhammad Husain Khan from 23rd April 1920.

,, Jagdeesh Prasad Vastav to 21st March 1920.

,, Muhammad Khan.

Lower Subordinate Service.

40 Surveyors, etc.

survey of sheets 53 E/8 and 53 F/5.6.9.10.13.14, also ½-inch revision survey of sheets 53 E/12.15(part). 16.

The total area surveyed during the season amounted to 5,180 square miles; this includes 87 square miles of original 1-inch survey, and 252 square miles of ½-inch revision survey. The sheets surveyed were 53 A/5.8.9.10.12.13.14, 53 E/3.7.8.11.12.15.16, 53 F/5.6.9.10.13.14.

One surveyor was sent on special duty to Dera Ghāzi Khān from 8th April to 22nd May 1920 in order to survey the area of the new city under the supervision of the Settlement officer. The necessary corrections were inserted on the old fair sheet 39 J/12.

The 24-inch original survey of Mussoorie, undertaken at the expense, and by the request, of the Mussoorie City Board, was placed under the executive supervision of No. 1 Party from 1st May 1920. The work is estimated to cost Rs. 10,816 including the expense of fair-mapping in three sheets.

Mr. J. A. Calvert was in charge of the field work, with a varying number of traversers, levellers and surveyors. Photographic reductions of this survey on the 8-inch scale will also be used as the nucleus of a new contoured edition of the Mussoorie and Landour guide map, which has long been called for, and which it is hoped to produce in time for the 1921 Mussoorie season.

The framework of the survey involved 5·2 square miles of triangulation, 45 linear miles of traverse and 36 linear miles of levelling; beyond this, no triangulation or traversing was undertaken by the party during the year.

Recess duties.—A drawing section under Mr. G. J. S. Rae with an average strength of 8 draftsmen remained at head-quarters throughout the year and completed the large-scale fair-mapping of Lahore and Ferozepore, as well as the arrears of 1½-inch fair-mapping of the previous season, *viz.* sheets 43 O/8, 43 P/10.14.15 and 53 A/1.2.3.4.6.7. The above are the only new sheets submitted for publication during the year.

On the return of Nos. 1 and 2 Camps from the field in June and July, a second drawing section under Mr. R. C. Hanson with 10 draftsmen and pupils was formed to deal with the current season's fair-mapping. Thirteen 1½-inch and two ¾-inch fair sheets are in hand and will be completed during the winter.

A third drawing section under Mr. P. A. T. Kenny with an average of 8 draftsmen was employed, from 1st May 1920, on the fair-mapping on ¾-inch and 1½-inch scales of the area surveyed by the Wazīristān Survey Party during 1919-20. This included the drawing of five new 1½-inch sheets and the insertion of additional work on four old 1¹-inch and four old ¾-inch fair sheets. This work is still in hand.

A section under Mr. A. M. Talati, assisted by Mr. F. J. Grice, with 6 pupils was busily occupied for 3 months in preparing data and planetables in readiness for next field season. This work proved extremely laborious and required much trouble and care on the part of those concerned; the reasons for this are set out at length in the report of this party for last year.

The Surveyor General inspected the party in recess on 7th September 1920 and the Superintendent Northern Circle on several occasions.

No. 2 Party (PUNJAB, RĀJPUTĀNA AND UNITED PROVINCES)

By Bt.-Lt.-Col. S.W.S. Hamilton, D.S.O., R.E.

1. The detail survey for the Town Guide and Environs maps of Agra, Allahābād, Benares, Cawnpore and Lucknow having been completed in the previous season, the party was able to return to its normal topographical programme.

PERSONNEL.

Class I Officer.

Bt.-Lt.-Col. S. W. S. Hamilton, D.S.O., R.E., in charge from 6th December 1919.

Class II Officers.

Mr. H. P. D. Morton in charge to 5th December 1919.

„ Dunī Chand Puri.

Upper Subordinate Service.

Mr. Muhammad Husain.

„ Lakshmi Dutt Joshi.

„ Ghulam Hasan.

„ Daulat Ram Vohra.

„ Lalta Khan, I.D.S.M.

Lower Subordinate Service.

77 Surveyors, etc., and pupils.

This programme was as follows:—

(*a*) Original survey on the ½-inch scale in sheet 54 A/7.

(*b*) Original survey on the 1-inch scale in parts of sheets 54 E/1. 2. 5. 6.

(*c*) Re-survey on the 1-inch scale in parts of sheets 54 E/1. 2. 5. 6 and in sheets 54 E/9. 13. 14.

(*d*) Re-survey on the 2-inch scale in sheet 54 E/16.

(*e*) Continuation of the original survey of Mount Abu and leased area on the scale of 24 inches = 1 mile.

(*f*) Traversing for (*b*) above and also in sheets 54 E/3. 4. 7. 8 for original survey on the ½-inch scale.

(*g*) Classification of the aeroplane survey for Lucknow city guide map carried out in 1918-19.

(*h*) Experimental aeroplane survey of sheets 54 E/12. 16 in combination with No. 13 Party.

The country in 54 A/7 was mountainous and difficult of access, being mostly covered with heavy low jungle and thick grass, while the remainder was cultivated plains, open and easy, except in a few places where trees were numerous and close, and on the borders of the Jumna river where there was a good deal of broken ground and occasionally high grass. The Mount Abu area is situated on a plateau about 4000 feet above mean sea level, the highest point Adhar Devī being 4623 feet, and comprises some cultivated and grass lands but is mostly rocky and intricate ground covered with scrub jungle and trees.

The head-quarters opened in the field at Agra on the 29th October 1919 and re-opened in recess at Mussoorie on the 13th May 1920. The health of the party was excellent, except for those employed on the Mount Abu survey among whom there was some fever, as also amongst those employed in traversing in the earlier part of the season. One soldier surveyor died.

2. *Plane-tabling.*—Before the commencement of the field season the Superintendent of the circle decided to attach all the soldier surveyors and pupil surveyors in the circle numbering 7 and 39 respectively, to No. 2 Party for training in field survey, such men having had a previous training during the recess season in No. 3 Drawing Office and in other parties.

As stated above the country, except in sheet 54 A/7 and for two short isolated low rocky ranges of hills in sheets 54 E/1. 2, was cultivated plain open and easy with just a sufficient variation of close and intricate areas, here and there, to make it an ideal training ground, though it was not possible to give any real training in contouring and the depiction of hill features. This omission, however, is being made good by distributing those under training in their second year among other parties in the circle working in hilly areas. This method is to be followed again in the ensuing year, *i. e* pupils receive one season's training in the plains and one in the hills. The party was divided into five camps as given in the table below :—

No. of camps.	Name of camp officer.	Camp head-qnarters.	No. of surveyor instructors.	No. of soldier surveyors and pupils.	Numbers of sheets.	Scale of survey.	REMARKS.
1	Mr. D. C. Puri	Iglās	2	12	54 E/9.13 14	1-inch	Re-survey
2	Mr. L. D. Joshi	Hodal	2	10	54 E/1.5	1-inch	Original survey and Re-survey
3	Mr. Ghulam Hasan	Kāman	2	11	54 E/2.6	1-inch	do.
4	Mr. Ialtan Khan, I. D. S. M.	Agra	3	10	54 E/16	2-inch	Re-survey
5	Mr. D. R. Vohra	Mount Abu	8	...	Mount Abu and leased area	24-inch	Original survey
		Total	17	43	...	...	...

The surveyor instructors, who were ordinary trained surveyors not specially selected, were distributed among the camp officers to assist them in training owing to the large number of pupils that had to be allotted to each camp and to there being insufficient officers available for the purpose. At first all were concentrated for general and individual instruc-

tion at their respective camp head-quarters, being gradually allowed more and more latitude until each could be entrusted with a separate board of his own. This system was continued up to the end of January 1920, and the reports and expenditure thereon have been classed as "under training". After that, however, the majority of the soldier surveyors and pupils were capable of turning out work, though still under careful training and observation, of a standard sufficiently good to be accepted for fair-mapping. Their work, however, was necessarily slow and cost-rates have been affected accordingly. After January only one surveyor instructor was left with each camp officer, the remainder of those previously employed to assist in training being distributed among camps in order to complete to margin those sheets of which the survey had been commenced. The majority of the surveyors employed as instructors were not a success, only three out of nine men so employed being of any real use for this purpose.

The Mount Abu survey on a scale of 24 inches=1 mile was completed early in February. The total area surveyed was 4492 acres at a cost-rate of Rs. 1·5 per acre. Including last season's outturn, the Mount Abu and leased area totals 5076 acres. The scheduled boundary of the area, which was very considerably in error, was also corrected. Two of the surveyors were brought to Agra and employed on the ordinary programme of the party while Mr. D. R. Vohra and the remainder were ordered to Mussoorie to commence the fair-mapping of their work under the Officer in charge of No. 3 Drawing Office as explained under the head of recess duties. The ½-inch survey of sheet 54 A/7 which had, throughout the season, been directly under the Officer in charge of the party was also completed in February and the surveyor afterwards assisted in sheets 54 E/2. 6 in Camp No. 3. The work in sheets 54 E/1. 2. 5. 6. 9. 13. 14. 16 was based on old Revenue traverse data and in sheets 54 E/1. 2. 5. 6 on additional traverse data undertaken and completed during the season, including computations done in the field, while the survey in sheet 54 A/7 and the Mount Abu survey were based on triangulation carried out for the purpose in previous seasons.

As regards the aeroplane survey of Lucknow city, completed during the field season 1918-19, there was considerable delay in the supply of the prints required for classification due to the Royal Air Force Squadron being transferred to other duties, and it was not until December 1919 that the 219 negatives were sent to the Superintendent of the Trigonometrical Survey and the necessary prints were supplied by him; 18 negatives were broken in transit from the Royal Air Force. The resulting mosaic left much to be desired, and on examination in the field in March 1920 it was decided that it would be uneconomical to proceed further with either the classification or the fair-drawing of a guide map based on the aeroplane photographs, and that it would be more advantageous to draw the guide map, from reductions on the 16-inch scale of the Municipal survey of the city, on the 64-inch scale, then nearing completion. These reductions are still awaited.

The experimental aeroplane survey of sheets 54 E/ 12. 16 carried out in combination with No. 13 Party was practically confined in the field, to the provision of personnel for purposes of classification, etc. The area so surveyed has been included in the outturn and the fair-drawing of both sheets has been done by No. 2 Party. Owing to a late start, due to the aeroplanes and photographic apparatus not being obtainable earlier, and to no heights being then available, the few small hills in 54 E/12 were depicted by form lines only. This will be remedied by running a few triangulated heights during the ensuing field season and the sheet will then be rigorously contoured. Out-turn and cost-rates are given below.

Scale.	Class of survey.	Area in square miles.	Cost-rate per square mile— Rupees.
½-inch	Original	264	3·5
1-inch	Original	418	19·0
1-inch	Re-survey	1,426	16·0
2-inch	Re-survey	265	21·0

3. No *Triangulation* was carried out by the party during the year.

4. *Traversing.*—The country traversed consisted of cultivated plains, open and easy, with occasional isolated low rocky hills. The traversing carried out in sheets 54 E/ 1. 2. 5. 6

for original survey on the 1-inch scale, and that in sheets 54 E/ 3. 4. 7. 8 for original survey on the ½-inch scale, was supplementary to main circuit traverses already existing. The former was computed in the field to enable the surveyors to complete these sheets during the season.

The traverse camp was under Mr. Muhammad Husain with head-quarters at Bharatpur; establishment 4 traversers and 3 computers. All new traversing was completed in February after which the men were employed in computing and plotting their own work, and in the preparation of traverse plot sheets from old Revenue traverse data required for the work of the field season 1920-21. Fever amongst the traversers in the earlier part of the season, and the fact that the chainmen were untrained, have affected the cost-rates which are as under :—

Scale of Plane-tabling.	Area in square miles.	Linear miles chaining.	Cost-rate per linear mile— Rupees.
1-inch	441	215	19·2
½-inch	1,058	209	12·4

5. *Recess duties.*—(*a*) for purposes of fair-drawing the party was divided into four sections as given in the table below :—

Number of Section.	Name of Section Officer.	Number of draftsmen, etc.	Sheets on ½-inch scale.	Sheets on 1-inch scale.	Other Government Departments.
1	Mr. D. C. Puri	4	54 A/ NE. SW.	54 E/ 9. 13. 14.	
2	Mr. L.D. Joshi	4	...	54 E/ 1. 5. 12. 16	
3	Mr. Ghulam Hasan	14*	...	54 E/ 2. 6	Town Guide and Environs maps.
4	Mr. D.R. Vohra	3	53 D/ NW. NE. 54 A/ NW.	...	Miscellaneous duties.

Half-inch sheet 54 A/ NE. was submitted in August and sheets 54 A/ NW. SW. will be submitted in October, part of the typing and the examination of the latter sheet only remaining to be completed; sheets 53 D/ NW NE. will not be ready for submission till later. These last two are sheets taken over to assist No. 3 Drawing Office. One-inch sheets 54 E/1. 2. 5. 6. 9. 13 were submitted for publication in September 1920, and sheets 54 E/12 (outline only). 14. 16 will be completed and submitted for publication in October 1920, so that the party will then have no arrears of fair-mapping.

The fair-drawing of sheet 54 E/12 which was surveyed by photography from aeroplane only, classification being carried out afterwards with the photos on the ground, has been very laborious and slow. A set of the original aeroplane photographs was reduced, and a mosaic constructed on the 2-inch scale, in two half-sheets. The outline was then inked up on these in black, by the aid of the photos used for classification in the field on the original scale of photography (approximately 3½ inches to one mile) and on completion were sent to the reproducing office for fair-drawing blue prints on the 1½-inch scale. The original photographs were very poor, but there must always be many dark shadows in work of this nature, which reproduce on the fair-drawing blue prints, and make it most difficult to follow the outline as originally drawn on the mosaic. The rigorous contouring of this sheet has yet to be completed in the field and it is hoped to finish and submit this for the fair-drawing of the hill sheet by No. 3 Drawing Office early in 1921.

As sheet 54 E/16 had been surveyed by the ordinary method in addition to the experimental aeroplane survey, a different method was followed. Bank-post reproductions on the 2-inch scale were corrected, where necessary, from the photographs, errors being painted out in Chinese white and corrections added in red, the result being sent to the reproducing office for fair-drawing blue prints on the 1½-inch scale in the ordinary manner.

* Includes soldier surveyors under training.

The fair-drawing carried out on Town Guide and Environs maps has consisted of certain corrections to those pertaining to Agra and Allahābād, and of the fair-drawing of the four-inch map of Lucknow and Environs. The fair-drawing of the 12-inch Town Guide map of Lucknow city will be transferred to No. 3 Drawing Office. The fair-drawing of the sheets of the Mount Abu survey was completed by Mr. Vohra and the drawing section sent with him from the field in February, under the supervision of the Officer in charge No. 3 Drawing Office, before the party returned to recess. The cost-rates of fair-drawing are given below :—

Scale of fair-mapping.	Area in square miles.	Cost-rate per square mile. Rupees.
1½-inch	2,374	5·0
¾-inch	2,292	2·3
24-inch	5,076 (*acres*)	0·4 (*per acre*)

(*b*) A section composed of 6 traversers and computers under Mr. Muhammad Husain has been employed throughout the recess in computation and preparation of traverse plot charts from old Revenue data required for next season's survey on the 1-inch scale, in getting old traverse volumes completed and in order, and in preparing for record the triangulation volumes for sheet 54 A. Much other miscellaneous work has been done in bringing the party records, etc., up to date in transferring such as were no longer required for record in other offices to whose operations they might appertain, and to the circle Records section.

6. *Miscellaneous.*—There were no marked physiographical changes since the last survey in the areas included in the programme during the year.

7. *Inspections.*—The party was inspected twice by the Surveyor General, once in the field and once in recess, and on numerous occasions by the Superintendent, Northern Circle.

No. 3 PARTY (UNITED PROVINCES).

By Bt.-Major C. G. Lewis, R. E.

At the beginning of November the party arrived at its field head-quarters at Bareilly, whence the several camps proceeded to their respective areas, after the projection and plotting of plane-tables had been carried out. Field work was completed by the middle of May. A small section under Mr. Berrill remained in Mussoorie to carry on arrears of mapping.

The area under survey lay entirely in the Kumaun hills, and consisted, for the most part, of densely wooded hills and cultivated valleys.

The health of the party was good; the average amount of sickness among surveyors being one day in two months.

Surveyor Raj Ali died in Bareilly at the beginning of the field season. There were no deaths among menials.

Mr. Strong was in charge of the Simla Survey Detachment, directly under the Superintendent, Northern Circle (*vide* page 10), until his transfer to the Mesopotamian Survey Party in February.

Personnel.

Class I Officers.

Mr. H. H. B. Hanby, in charge to 14th June.
Bt.-Major C. G. Lewis, R. E., in charge from 15th June.

Class II Officers.

Mr. B. M. Berrill, to 23rd January.
„ J. H. Johnson.
„ W. H. Strong, M. B. E., to 1st February.
„ G. E. R. Cooper.
„ Moqimuddin.

Upper Subordinate Service.

Mr. Paras Ram to 28th August.
„ A. A. S. Matlub Ahmad to 19th September.

Lower Subordinate Service.

33 Surveyors, etc.

Plane-tabling.—The programme comprised the survey of sheets 53 O/5. 6. 9. 10. 11(part). 13. The greater part of the area consisted of reserved forests, of which survey on the 2-inch scale was required. The forests were irregularly distributed throughout the whole area and

the survey of the intervening non-forest lands on the 1-inch scale would have entailed numerous uneconomical changes of scale, consequently the whole area was surveyed on the larger scale, with the exception of some 90 square miles which contained no forests.

The work was distributed in three camps as follows :—

Mr. Johnson 53 O/9 (south). 10. 11 (part).

„ Moqimuddin 53 O/5. 6 (part).

„ Paras Ram 53 O/9 (north). 13.

The chief feature of the work was the necessity for surveying the intricate net-work of forest boundaries, both exterior and interior, down to sub-compartment boundaries; each individual pillar had to be shown and its position compared with the gazetted boundary notification. Where serious discrepancies occurred the notified descriptions were amended and sent to the Forest Department for acceptance and renotification.

The total out-turn for the party was 1327 square miles, of which 1237 square miles were on the 2-inch scale, and 90 square miles on the 1-inch scale.

The cost-rate of plane-tabling on the 2-inch scale was Rs. 44·8 per square mile, that for 1-inch is indeterminate owing to the small area surveyed on this scale.

Seven soldier surveyors completed their first period of training at the close of the field season and six returned to their units, one being retained for further training.

Triangulation.—The programme of triangulation comprised sheets 53 N/4. 8. 12. 16, 62 B/4 (south), 62 C/1 for 2-inch survey. The majority of the work was executed by Mr. Cooper, who, after giving instruction to Mr. Matlub Ahmad in sheet 62 C/1, carried out reconnaissance in the remaining sheets and had observed in 62 N/4. 8 when orders were received late in the season to take up the triangulation of sheets 53 J/12. 16, the survey of which was urgently required in connection with hydro-electric schemes. Mr. Cooper was able to complete these two sheets but the observation of the remainder of the programme will have to be completed next season. Mr. Matlub Ahmad completed the greater part of sheet 62 C/1. In the higher hills, the work was considerably impeded by snow from January onwards. Arrangements should be made to complete work at altitudes above 10,000 feet, by the end of December. The out-turns of the two triangulators were 1000 square miles and 250 square miles respectively. The cost-rate, excluding the area triangulated by the officer under training, was Rs. 11·3 per square mile including computations.

Traversing.—No traversing was carried out during the year under report.

Recess duties.—(*a*) The fair-mapping was distributed in four sections:

No. 1, under Captain Glennie (who was attached to the party during the recess season), sheets 53 O/13 N & S.

No. 2, under Mr. Johnson, sheets 53 O/9 S; and 53 O/10 N & S.

No. 3, under Mr. Moqimuddin, sheets 53 O/5 N & S and 53 O/6 N & S.

The mapping of one sheet, 53 O/9 N was carried out under Mr. Cooper, in charge of the computing section.

The whole of the mapping was done on the 2-inch-scale for publication on the same scale in two editions, public and forest. Owing to the scattered nature of the reserves, the Forest Department require all sheets completed to margin, so as to include intervening non-forest areas.

In addition to current mapping, a large number of arrears sheets remained over from last season. Of these 53 K/5 N & S, 53 K/9 N & S, 53 K/13 N & S, 53K/ 14 N & S, surveyed in 1915-16, had been completed and only required final examination; this was carried out by Mr. Hanby while on privilege leave. The remaining four sheets of arrears from 1917-18, 53 O/1 N & S, 53 O/2 N & S, in various stages of completion, were distributed one to each section, and will be submitted for publication before the end of recess.

The delay in submission of these fair sheets is due to a change of policy last year as regards the style of drawing. Previously the sheets had been drawn for reproduction, but in 1919 the Surveyor General gave orders for them to be drawn so as to be suitable for reduction to the 1-inch scale should the necessity arise. This entailed extensive corrections throughout the sheets.

Of the current mapping it is anticipated that all the sheets will be completed by the end of recess, with the exception of 53 O/9 N and 53 O/11 N & S. The latter two sheets

have not been commenced; these contained large areas of 4-inch survey of 1918-19, special prints of which had to be prepared for reduction to the 2-inch scale.

In order to cope with the mapping, considerable use was made of overtime work. 10 surveyors were placed on the overtime list, and it is estimated that four fair sheets were completely drawn during the extra time. Two sheets, both outline and hills, were given out as contract work, this method proved advantageous as the sheets were always available for the *pari passu* examination by the section officer during office hours.

The out-turn of fair-mapping including arrears was 1290 square miles and the cost-rate Rs. 22·9 per square mile.

(*b*). The computations of triangulation were completed in recess under Mr. Cooper, except those in sheet 62 C/1, where the field work had not been completed.

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

SIMLA SURVEY DETACHMENT (PUNJAB).

By W. H. Strong, M. B. E.

The detachment took the field on the 1st October for the completion of the large-scale survey in connection with the Simla extension scheme. The field work was completed by the 10th December and the detachment was then broken up.

Personnel.

Class II Officer.

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

Lower Subordinate Service.

10 Surveyors, etc.

Topography.—The total area surveyed was 1270 acres on the scale of 220 feet to 1 inch, the cost-rate being Rs. 6·6 per acre. No triangulation or traversing was carried out during the year under report.

Fair-mapping.—Three draftsmen were employed in Mussoorie on completing the 8 sheets of arrears mapping remaining over from the previous year. The current survey comprised 10 sheets the mapping of which was undertaken by No. 3 Drawing office.

No. 4 PARTY.

By Captain L. H. Jackson, I. A.

The topographical work of the party remained in abeyance, the officer in charge being employed alternately in Nos. 2 and 3 Parties.

Six pupil surveyors, transferred from No. 2 Party and two pupil draftsmen transferred from Sind-Sāgar Party, were employed from 1st June 1920 under the officer in charge No. 3 Drawing Office.

Mr. Nabidad Khan and one surveyor were employed on preparing blue prints of the sheets included in the programme, when it was decided that the party should not take the field next season. The necessary prints of sheets are, however, ready and stored so that they can be used at some future date.

Personnel.

Class I Officers.

Lt.-Col. E. A. Tandy, R. E., in charge to 3rd November 1919.

Lt.-Col. R. T. Crichton, C. I. E., I. A., from 4th to 30th November 1919.

Lt.-Col. S. W. S. Hamilton, D. S. O., R. E., in charge from 1st to 20th December 1919.

Major L. G. Crosthwait, I. A., in charge from 21st December 1919 to 8th January 1920.

Major H. T. Morshead, D. S. O., R. E., in charge from 9th January to 16th February 1920.

Lt.-Col. H. L. Crosthwait, R. E., in chargefrom 17th February to 14th April 1920.

Captain L. H. Jackson, I. A., from 15th April 1920.

Class II Officer.

Mr. Abdul Karim B. A. from 1st May 1920.

Upper Subordinate Service.

Mr. Nabidad Khan from 1st May 1920.

Lower Subordinate Service.

1 Clerk.

SIND-SĀGAR PARTY (PUNJAB).

By Dhani Ram Verma.

The programme of the party, undertaken in continuation of that of the last field season in connection with the Punjab Government's Sind-Sāgar Canal and Colonization project, consisted in the subdemarcation of 4000-acre rectangles into 100-acre rectangles in the area comprised in sheets 39 I/15. 16, 39 J/13. 14. 15, 39 M/2. 3. 4. 7. 8. 11. 12. 15. 16, 39 N/1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 13, and 44 A/3. 4, by the patwāri establishment under professional supervision.

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

Personnel.

Class II Officers.

Mr. Dhani Ram Verma, in charge.
„ J. C. Lears.
„ Abdul Karim to 30th April 1920.

Upper Subordinate Service.

Mr. Chuni Lal Kapur.
„ Nabidad Khan to 30th April 1920.

Lower Subordinate Service.

28 Surveyors, etc.

Revenue Establishment.

105 Nāib-tahsīldārs, Kānungos and Patwāris.

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

The field head-quarters opened at Muzaffargarh on the 15th October 1919, and the recess office was opened at Mussoorie on the 18th May 1920.

The health of the party was good throughout the field season. Two khalāsis died of pneumonia in the earlier part of the season.

At the commencement of the field season the party was divided into 4 camps, and from the beginning of January 1920, into 5 camps as follows :—

No. I Camp.—Under Mr. Chuni Lal Kapur with 9 to 3 traversers laid out 2867, 100-acre corners on the long sides of 4000-acre rectangles, embracing an area of 1733·1 square miles, in sheets 39 J/14. 15; 39 M/12. 16 and 39 N/2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 13. Two traversers were transferred from No. II Camp at the end of January 1920 to this camp, one of them was discharged for inefficiency on 21st March 1920.

No. II Camp.—Under Mr. Nabidad Khan with 14 to 2 traversers laid out 2420, 100-acre corners on the long sides of 4000-acre rectangles, embracing an area of 2010·6 square miles, in sheets 39 I/15. 16; 39 J/13; 39 M/3. 4. 7. 8. 11. 12. 15. 16.

Nos. III, IV and V Camps.—According to arrangements made prior to taking the field it was expected that the revenue staff would join punctually on 1st November 1919 but very few men did so. The camp officers having waited for a week proceeded to their respective areas with as many men as were then present. The revenue staff was divided into two camps, *viz.*, No. III Camp under Mr. J. C. Lears and No. IV Camp under Mr. Abdul Karim, the latter camp having two divisions in anticipation of the formation of No. V Camp on the arrival of more patwāris. No. V Camp was placed under the charge of Mr. Chuni Lal Kapur from the beginning of January 1920, in addition to his own, owing to the paucity of officers in the party. After the executive officer's personal representation to the Director of Land Records at Lahore on 23rd December 1919 the revenue staff began to arrive at Muzaffargarh from the middle of January 1920 and continued joining the party till the end of the month. As the men had joined on different dates, and the majority were absolutely untrained, considerable time was lost in training them individually during the course of operations. The number of revenue men deputed to the party varied from 42 in November 1919 to 84 in April 1920. These figures do not include 14 patwāris who had rejoined from departmental leave.

The camp under Mr. J. C. Lears, assisted by 1 nāib-tahsīldār and 8 kānungos, with 21 patwāris laid out 6372,100-acre corners inside the 4000-acre rectangles, embracing an area of 1263·5 square miles, in sheets 39 I/15.16; 39 M/2.3.4.7.8.11.12. 1 traverser was transferred from No. I Camp in the beginning of March 1920 and 4 from No. II Camp at the end of the month to this camp to assist the camp officer in *partalling* the work of the patwāris. On the completion of his camp's work, Mr. Nabidad Khan with 2 traversers was attached to this camp after 20th April 1920 for the same purpose.

The camp under Mr. Abdul Karim, assisted by 1 nāib-tahsīldār and 9 kānungos, with 17 patwāris laid out 5484 100-acre corners inside the 4000-acre rectangles, embracing an area of 1100·9 square miles, in sheets 39 J/14. 15; 39 N/1.2.34; and 39 M/12.16. Two traversers were transferred from No. I Camp in the beginning of March 1920 and 3 from No. II Camp at the end of the month to this camp to assist the camp officer in *partalling* the work of the patwāris.

The camp under Mr. Chuni Lal Kapur, assisted by 1 nāib-tahsīldār and 6 kānungos, with 20 patwāris laid out 5544 100-acre corners inside the 4000-acre rectangles, embracing an area of 1184·7 square miles, in sheets 39 M/12 16; 39 N/5.6.7 8.9.10.11.13. 4 traversers were transferred from No. I Camp from the middle of March 1920 to this camp to assist the camp officer in *partalling* the work of the patwāris.

In the earlier part of the field season draftsmen Hari Singh and Hari Datta were employed in recruiting khalāsis in the U. P. and Garhwāl. Very few local men were available for enlistment.

Nature of the country.—The country rectangulated is locally known as the "Thal" (sandy desert). The entire tract is sandy, studded with hillocks called "*tibbas*" assuming generally a north-east and south-west direction and alternating with narrow strips of hard land called "*lūks*" or "*pattis*". The eastern portion of the "Thal" which is designated as the "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 central portion of the "Thal" is open and the rest is wooded. The country along the western edge of the "Thal" in Muzaffargarh district is covered by a dense jungle of tall trees and high grass, interspersed with extensive pieces of cultivated lands. In the interior the "Thal" is sparsely inhabited, the population is mostly pastoral. There are scattered patches of cultivation irrigated from wells in the "pattis". The people in the "Thal" of Muzaffargarh district are generally troublesome, and on two occasions they attacked the staff. The water is brackish and bitter. The main transport is by camels.

Triangulation (supplementary).—This was carried out to relay nine 4000-acre corners in the area traversed in the previous season in sheet 39 N/4, the main corner stones and the traverse stations having been lost. As the area covered was accounted for in the report for 1917-18, its cost has now been included in that of the rectangular survey.

Subdemarcation.—The programme of the season consisted of two successive operations:—(1) location on the ground of 100-acre corners on the long sides of 4000-acre rectangles; (2) breaking down of the 4000-acre rectangles into 100-acre rectangles.

The 100-acre corners, situated on the long sides of the 4000-acre rectangles, were laid out by the traversers by subdividing 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 with 10 inches, the roughly dressed portion, exposed. 5287 such pillars were embedded on the 100-acre corners situated on the long sides.

With the 100-acre corners thus marked on the ground on the long sides, the patwāri 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 17400 flat-topped monolith pillars on the 100-acre corners situated within the 4000-acre rectangles.

The bulk of the revenue staff joined the party very late, as in the previous year, and consisted of untrained and new men. More dense jungle and higher sand hills were encountered and violent sand storms set in earlier, and were more frequent, than in the preceding year. The field work was carried on to the end of April when the heat had become very intense. The party was able to complete 3549·1 square miles out of the programme laid down for the season, leaving about 750 square miles in sheets 39 M/11.15.16 and 44 A/3.4 for subdemarcation next field season.

A maximum error of 1 in 1000 was allowed. The average out-turn per man per diem was 3·2 corners.

Nearly 80 per cent of the interior work was tested by 9667·8 linear miles of *partal* by the superior revenue staff, and nearly 20 per cent by the survey staff with 3482 linear miles of *partal* with theodolite and double chaining (short and long chains). Nearly the whole of the subdivisions of the long sides was tested with 1505 linear miles of *partal* by the camp officers and surveyors, with theodolite and double chaining (short and long chains). The total out-turn of rectangulation is shown in the annexed table.

Nature of work.	Number of corners located.	Number of 100-acre rectangles laid out.	Area covered by subdemarcation in square miles.
(1) Location of 100-acre corners on the long sides of 4000-acre rectangles.	5,287*	...	...
(2) Subdemarcation of 4000-acre rectangles into 100-acre rectangles.	17,400	22,714	3,549·1
Total ...	22,687	22,714	3,549·1

The average cost-rate of rectangulation executed, including computations, works out to Rs. 11·1 per corner and Rs. 71·2 per square mile or Re. 0-1-9 per acre. The total expenditure of the party from 1st October 1919 to 30th September 1920 was Rs. 2, 52,731.

Recess duties.—In recess the party worked with reduced strength. Mr. Abdul Karim and Mr. Nabidad Khan were transferred to No. 4 Party from 1st May 1920 and the services of three men were lent to the records section of the Northern Circle office from the 7th June 1920. Two of them were returned to the party after a month. 1 soldier surveyor and 8 pupils were temporarily attached te the party for instruction in drawing.

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

No. 1 Section.—Under Mr. J. C. Lears with 7 computers and draftsmen was employed on the final completion of the rough triangulation charts for Degree Sheets 38 P, 39 I, 39 M, 39 N, 43 D and 44 A which were in hand since 1918 and on the preparation of the manuscript lists of data for them. The first two and the last two of them with their manuscript lists of data have been submitted to the Superintendent of the Trigonometrical Survey. The remaining two are nearing completion and will be submitted before the party takes the field. No rough triangulation chart for Degree Sheet 39 J has yet been prepared. As it does not require much compilation it is intended to prepare it in the ensuing field season and submit it from the field.

No. 2 Section.—Mr. Chuni Lal Kapur was in charge of 9 men, all of whom except two were temporary hands entertained towards the close of the recess 1919 in place of the trained topographical surveyors who were transferred to No. 3 Drawing Office and topographical parties of the circle. They were brought to recess head-quarters for training in drawing, typing and computations and for completion of the Sind-Sāgar records. Mr. Chuni Lal Kapur trained them in traversing with a view to their employment on traversing in the field. The men were occasionally employed on miscellaneous work in connection with the completion of the Sind-Sāgar records and the preparations for the proposed extension of rectangulation in the Lower Bāri Doāb. The section prepared four progress indexes and two stone-depôt indexes on the scale of 4 miles to 1 inch for the Irrigation and Revenue Departments. At the request of the Executive Engineer, Thal Survey Division, Miānwāli, 4000-acre rectangles were plotted and ruled up on 49 published one-inch sheets of the Sind-Sāgar Doāb and 4000 and 100-acre rectangles on the one-inch sheets of the same above latitude 32°.

Miscellaneous.—Special arrangements for the supply of rations to the establishment employed in the field were made through the Deputy Commissioner of Muzaffargarh. In the interior of the desert ration-depôts were opened at Mundā, Ladhāna, Fatehpur, Chaubāra and Nawākot by the village "panchayets" for the supply of rations on cash payment. The camp officers and nāib-tahsīldārs and kānungos were supplied with extra camels for transporting rations from the depôts to their head-quarters and from there to their establishments scattered over the desert. They were provided with country scales and weights for weighment of rations. In the Bhakkar "Thal", the country being more populous than the Muzaffargarh "Thal", rations were generally available from the villages, and special arrangements were not needed. The resources of the adjoining "Kachhi" (riverain) tracts where there were several large villages were also utilised.

Inspection.—The Superintendent, Northern Circle, inspected the party in the field on 27th November 1919 and on four occasions in recess. The Surveyor General accompanied by the Superintendent, Northern Circle, inspected the party in recess on 8th September 1920.

* Includes 444 100-acre corners on certain long sides in the area left over for next field season.

No. 22 (RIVERAIN) PARTY (PUNJAB).

By Maya Das Puri, Rai Sahib.

The Punjab Riverain Survey Party was designated No. 22 (Riverain) Party from the 1st January 1920.

The field operations were commenced early in October 1919, and were brought to a close at the end of April 1920. The office of the party remained at Lahore throughout the year.

PERSONNEL.

Class II Officer.

Mr. Maya Das Puri, Rai Sahib, in charge.

Upper Subordinate Service.

Mr. Ram Narayan Hastir.
„ Vidya Dhar Chopra.

Lower Subordinate Service.

69 Surveyors, Traversers, etc.
1 Nāib Tahsīldār
(Settlement establishment).

2. In the field the party was divided into 3 camps, a computing section, and a compiling and plotting section. In recess 5 sections were formed *i. e.*, 3 for completing the arrears computations, one for the current computations, and one for compiling and enlarging riverain boundaries. For the first four months or so, the two Upper Subordinates and one surveyor were each employed in charge of a camp on detail traversing. They were then transferred to office to assist in plotting and compilation. After about two months the two Upper Subordinates were again sent out to supervise the main circuit along the Sutlej, and the Gujrānwāla town traversing. During recess they assisted in completing the computation records.

Lala Mūl Rāj, *Nāib Tahsīldār* remained in charge of the base-line camp from 22nd January to 19th May 1920 and finished the work along the Sutlej and the Chenāb in *tahsīls* Lodhrān, Shujābād and Multān. For the remaining period during the year he carried out miscellaneous duties.

3. The party continued the work of traversing and laying down base-lines. 371 linear and 429 square miles of main circuits and 2,650 linear and 491 square miles of minor traverses were executed; 458 theodolite stations of the former and 11,590 of the latter in 143 villages were fixed and 798 corners of 266 squares were demarcated in 883 square miles with permanent mark-stones on both banks of the Sutlej and the Chenāb rivers in districts Muzaffargarh, Multān and Montgomery and Bahāwalpur State, to serve as bases for the future survey and demarcation of boundaries and fields in the beds of the rivers. 1,554 plotted and 474 boundary *masāvis* (settlement mapping sheets) on the scale of 1/2,640, and 34 four-inch sheets, and 2 one-inch indexes were traced and supplied to the Settlement Officer, Multān. 15,181 pages of field books and 3,314 pages of set-up forming 102 volumes were almost completed. Some arrears of computations still remain to be finished as reported separately in detail. Besides these, 395 boundary *masāvis* were partly compiled on the scale 220 feet to an inch for the next season's work; and 222 miscellaneous traces were prepared including 16 traces (scale 4 inches = 1 mile) supplied to the Executive Engineer, Upper Sutlej Division, showing the riverain traverse data along the Sutlej and Chenāb, and all the traverse stations marked during the year were plotted on 36 four-inch sheets.

There was a general scarcity of transport in the Multān district and Bahāwalpur State; and a good deal of time was wasted on account of stones for base-lines not having been supplied in time by the Settlement authorities. Much jungle cutting had to be done along the Sutlej.

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

I. Field work.

Locality and Scale	Main-circuits				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.	
Sutlej River. District Multān, and Bahāwalpur State, Scale 1/2,640.	...	...	...	...	69	231	1,312	6,136*	64	383	121	415	* Out of these 6 stations were marked with dressed stones for future demarcation instead of Base-lines.
District Montgomery, and Bahāwalpur State.	68	429	371	458	...	...	...	...	...	...	...	...	
Chenāb River. Districts Multān and Muzaffargarh, Scale 1/2,640.	...	...	...	...	64	260	1,338	5,455	79	435	145	468	
Total	68	429	371	458	133	491	2,650	11,590	143	798	266	883	

II. Office work done for the cadastral surveys of riverain estates, in field and recess.

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 officer on scale 4 inches to a mile.	Number of 1″ index traces showing the arrangement of *masāvis* supplied to the Settlement officer.	Number of 4 inches sheets on which new work was plotted.
Sutlej ...	Multān ...	1/2,640	714	241	17	1	16
Chenāb ...	Multān ...	1/2,640	840	233	17	1	20
	Total	...	1,554	474	34	2	36

Besides these 222 miscellaneous including 16 traces (scale 4 inches=1 mile) supplied to the Executive Engineer, Upper Sutlej division, showing the riverain traverse data along the Sutlej and the Chenāb, were prepared; and 395 boundary *masāvis* were partly compiled for the next season's work.

III. Recess work.

Completion of Computation Record Volumes.

(i) Riverain.

Name of rivers and districts.	Main circuit, including Azimuths.				Minor Traversing.				Remarks.
	Field books.		Set-up.		Field books.		Set-up.		
	Number of volumes.	Pages.	Number of volumes.	Pages.	Number of volumes.	Pages.	Number of volumes.	Pages.	
River Jumna.									
District Ambāla ...	1	30	1	24	2	566	1	142	
River Sutlej.									
District Ambāla ...	...	...	...	...	2	442	1	94	
District Multān, and Bahāwalpur State.	5	460	4	212	10	2,955	7	558	
River Rāvi.									
Districts Multān and Muzaffargarh.	2	330	2	126	3	914	1	167	* Ten per cent final examination remains to be done in 9 volumes.
River Chenāb.									
Districts Multān and Muzaffargarh ...	1	88	2	41	6	1,828	4	405	† Ten per cent final examination remains to be done in 19 volumes.
District Gujrāt ...	...	...	...	...	3	733	1	139	
River Indus.									
Districts Dera Ghazi Khān and Muzaffargarh ...	3	446	2	73	12	3,660	6	823	
River Beās.									
District Kāngra ...	...	...	...	..	5	1,031	1	222	
Total ...	12	1,354	11*	476	43	12,129	22†	2,550	

III. RECESS WORK.

Completion of Computation Record Volumes.

(ii) Miscellaneous.

Name of district or town.	Nature of work.	Field books		Set-up		REMARKS.
		Number of volumes.	Pages.	No. of volumes.	Pages.	
Multān suburbs ...	Detail traversing.	1	298	1	73	
Gujrānwāla town.	Main circuits.	1	59	1	27	
	Detail traversing.	1	135	1	33	
District Kāngra ...	Road survey.	3	830	1	59	
District Gujrāt ...	Rectangle survey.	1	309	1	84	
Jhelum city ...	Detail survey.	1	67	1	12	
Total ...		8	1,698	6*	288	* Ten per cent final examination remains to be done in 3 volumes.

5. *The Multān suburbs traversing* was undertaken at the request of the Settlement officer, Multān during October 1919, and was finished in February 1920. It was based on the riverain main circuit run along the Chenāb connecting it with Multān Fort, and Multān City *Dome*. The stations were marked with two bricks vertically placed one above the other. 18 corners of 6 squares were fixed to serve as bases for the future survey. 33 dressed stones were embedded on 15 traverse stations, and on 18 corners of the base lines. 1,114 stations were laid out and 189 linear miles executed in 5 villages covering 20 square miles. 95 plotted *masāvis* on the scale 55 feet to an inch, 184 on the scale 110 feet to an inch, and one trace on the scale 4 inches = 1 mile were supplied to the Settlement Officer, Multān.

6. *The Gujrānwāla town traversing* was started at the request of the President, Municipal Committee, Gujrānwāla, during February 1920, and was finished during April 1920 for the detail survey of the municipal area on the scale 200 feet to an inch. It was connected with Shāhjamāl T.S. XXXVIII, Shāhdra Minaret and the Chenāb riverain main circuit. The stations outside the congested area were marked with bricks, and inside with 8-inch long iron pegs with round flat tops of 1½-inch radius. In all 617 stations were laid out, *i.e.*, 507 stations for the town survey, and 110 for making the three connections. On the connections the stations were marked with ordinary pegs. 145 linear and 3 square miles of traversing were done. A trace on the scales 8 inches and 16 inches = 1 mile showing the stations and copy of the traverse data were supplied to the President, Municipal Committee, Gujrānwāla.

7. The riverain area was, as usual, broken, full of swamps, shrubs, high grass and sand. The Sutlej was densely wooded. Portions of villages above the high banks were flat and generally well cultivated.

8. In the beginning of the season some men suffered from malaria but on the whole the health of the party was satisfactory. One computer and one old khalasi died of fever.

9. The main circuits on the Sutlej were connected with Chūrawāla T.S. III, Jhūlān T.S. IV, Akbar-da-Būnga T.S. VII, Moni-Dhai T.S. VIII, Kot-Baksha T.S. VI, Pāk-Patan T.S. IX, Pīr-Ghani T.S. X, Bangar T.S. XXXII, Fatehgarh T.S. XXXIV, and Khāi Mosque Flag.

10. The average errors were as follows:—

(*a*) Base lines

0·37 foot per corner of a base line as compared with its theoretical value.

	Angular error per station in seconds.	Linear error in links per ten chains.
(*b*) Main circuits		
Sutlej	3·01	0·24
Gujrānwāla town	2·55	0·12
(*c*) Minor traverses		
Sutlej	6·91	0·69
Chenāb	7·01	0·73
Multān suburbs	6·03	0·82
Gujrānwāla town	4·53	0·61

11. The total expenditure of the party was Rs. 1,05,509 as detailed below:—

Riverain	Rs. 99,165
Multān suburbs	,, 3,389
Gujrānwāla town	,, 2,955
	Total Rs. 1,05,509

12. The party was inspected by the Superintendent, Northern Circle, on the 25th November 1919.

SOUTHERN CIRCLE.

Summary.—This circle was under the superintendence of Lieut.-Colonel W.M. Coldstream, R.E. up to the 19th October 1919, under Major L. C. Thuillier, I.A. from the 20th October to the 10th November, under Lieut.-Colonel E. A. Tandy, R.E. from 11th November to 20th January 1920 and under Bt.-Lieut.-Colonel C. P. Gunter, O.B.E., R.E. from 21st January 1920; it comprised Nos. 5, 6, 7, 8 and 20 Parties, the Training Section and No. 4 Drawing Office.

During the year Nos. 5, 6 and 8 Parties completed 11,891 square miles of detail survey, 60 square miles were triangulated by No. 6 Party only. No theodolite traversing was done in the circle for topographical surveys.

The detail survey consisted of :—

3383	square miles	of	½-inch original survey.
108	„	„	„ ½-inch supplementary survey.
3112	„	„	„ 1-inch original survey.
360	„	„	„ 1-inch revision survey.
4523	„	„	„ 1-inch supplementary survey.
266	„	„	„ 1½-inch original survey.
16	„	„	„ 1½-inch resurvey.
3	„	„	„ 2-inch original survey.
70	„	„	„ 3-inch original survey (military).
50	„	„	„ 3-inch supplementary survey (military).

No. 20 Party surveyed an area of 14,449 acres in cantonments and military stations.

Owing to the shortage of supervising officers and establishment on account of the war the programme of the circle was considerably curtailed. No. 7 Party did not take the field but was employed on the drawing of ½-inch sheets and in the training of probationers for the Upper Subordinate Service in recess quarters at Bangalore.

The Training Section carried out detail surveys on the 1½-inch scale in sheet 57 G/9 in which there was no previous 1-inch survey. 20 pupil surveyors received instruction in plane-tabling during the field season of which 2 were unable to complete their training through sickness and were discharged. During recess 20 pupil surveyors and 2 pupil draftsmen were under instruction and 8 probationers for the Upper Subordinate Service were transferred to the section in the month of May to complete their training. Of these eight probationers, only three were found suitable for retention at the end of the survey year, the remaining five having been permitted to resign.

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

Reproductions	...	...	160
Enlargements	...	...	126
Reductions	...	...	344
Number of sheets vandyked		...	187
Number of prints pulled		...	9023

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

By Major L. C. Thuillier, I. A.

This party took the field in full strength and completed the detail survey on the 1-inch scale of sheets 55 N/2. 3. 4. 6. 7. 8. 10. 11. 12. 15. 16.

Personnel.

Class I Officer.

Major L. C. Thuillier, in charge to 19th October 1919 and from 11th November 1919.

Class II Officers.

Mr. V. W. Morton to 14th October 1919.
„ S. F. Norman, in charge from 20th October to 10th November 1919.
„ Haji Abdul Rahim, K. B. to 31st October 1919.
„ H. B. Simons from 1st November 1919 to 4th April 1920.
„ F. C. Pilcher.
„ F. W. Smith from 5th November 1919.

Upper Subordinate Service.

Mr. P. S. Vengusvami.
„ Damodar Khadilkar to 1st July 1920.
„ Pulin Behari Roy to 31st August 1920.

Lower Subordinate Service.

36 Surveyors, etc.

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

The field season opened at Jubbulpore on 3rd November 1919 and closed on 17th April 1920. The head-quarters of the party was transferred from Jubbulpore to Chhindwāra on 21st November and remained there throughout the field season.

The health of the party in the field was on the whole very good. A few cases of fever and influenza occurred.

Plane-tabling.—The nature of the country surveyed varied. To the north it consisted of intricate jungle-covered hills lying in the eastern end of the

Sātpurā range, and ending in the Lakhnādon plateau, a well wooded rolling country of alternate ridges and hollows. Along the southern side the country consisted of highly cultivated plains interspersed with jungle-covered hills.

The survey was carried out by three camps under Messrs. H. B. Simons, F. C. Pilcher and F. W. Smith. Mr. Damodar Khadilkar, Upper Subordinate officer, assisted Mr. Simons in instructing the pupil surveyors in his camp.

The 1-inch survey presented no great difficulties and the 1-inch revision survey was carried out by transferring the photographic reductions of previous 4-inch forest surveys to the plane-table section by means of the plotted traverse points run round each forest block.

A programme amounting to 3,027 square miles was completed. The total out-turn of 1-inch original survey and of 1-inch revision survey was 2,667 and 360 square miles, the average monthly out-turn per man was 23·4 and 23·8 square miles and the cost-rate per square mile was 20·5 and 25·0 respectively.

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

Recess duties.—The fair-mapping of the party was divided into three sections as under:—

No. 1 Section.—Under Mr. F. C. Pilcher, sheets 55 N/3. 4. 7. 8.

No. 2 Section.—Under Mr. F. W. Smith, sheets 55 N/2. 6. 10.

No. 3 Section.—Under Mr. P. S. Vengusvami, sheets 55 N/11. 12. 15. 16.

Sheets 55 N/2. 3. 4. 7. 8. 11. 15 were sent for publication during the year and the remaining fair sheets will be sent for publication before the end of the recess.

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

A total area of 3,027 square miles was mapped by the party for the 1-inch scale, the cost-rate per square mile being Rs. 11·28.

Owing to the dearth of officers and computers no work was done on the preparation of data for Triangulation Charts and Pamphlets during the year under report.

The arrears of Triangulation Charts and Pamphlets consist of the completion of Degree sheets 46 O and 54 L (southern half). The other charts mentioned in last year's report have been made over to the Triangulation Chart Section for completion. Sheet 55 N will now be taken up by this party, the complete sheet having been surveyed.

The party was inspected during recess by the Surveyor General and several times by the Superintendent, Southern Circle.

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

By J. O'B. Donaghey.

The party completed the detail survey on the ½-inch scale of sheets 56 D/11. 12. 15. 16, 57 A/1. 2. 5. 6. 9. 10 and of parts of 56 D/7. 8. 10. 14 and 57 A/13, on the 1-inch scale of sheets 57 A/14 and part of 57 A/13, on the 1½-inch scale of scattered areas of Hyderābād State reserved forests in sheets 56 G/16, 56 H/13. 14 and 56 L/1. 2. 3. 5. 7. 8. 9. 10. 11. 12. 14. 15, and on the 3-inch scale of parts of sheets 56 K/6. 7. 10. 11. The State Forest areas* surveyed in sheet 56 G/16 and the area† surveyed on the 3-inch scale in sheets 56 K/6. 7. 10. 11 had been previously surveyed by the party. The party also undertook the triangulation for 3-inch survey of parts of sheets 56 K/6. 7. 10. 11. The reserved forest areas consist of wooded hills, the remainder of the country is mostly undulating and highly cultivated.

Personnel.

Class I Officer.

Mr. J. O'B. Donaghey, in charge.

Class II Officers.

Mr. E. A. Meyer.
" Munshi Lal, B. A.
" N. S. Harihara Iyer.

Upper Subordinate Service.

Mr. K. G. Mandanna.
" Masud Khan.
" E. N. Natesan, B. A.

Lower Subordinate Service.

82 Surveyors, etc.

The field season opened on the 6th November 1919 and closed on the 28th April 1920 except for the 3-inch work which was completed by the 15th July 1920. The field head-quarters was at Secunderābād.

The health of the party was on the whole good, but there was some fever among the men working in the forest areas. Towards the close of the field season there were some cases of influenza in No 1 Camp. A surveyor died from the after effects of an attack of influenza and there were two deaths among the menials.

* 16·0 square miles. † 119·6 square miles.

Plane-tabling.—The nature of most of the country surveyed is open, undulating and cultivated with portions of hilly and somewhat intricate ground covered with low scrub and stones. The reserved forest areas consist of hills more or less densely wooded. No special difficulties were experienced in the plane-tabling of the area surveyed.

The supplementary survey portion of the area surveyed on the 3-inch scale was carried out from 3-inch reductions of No. 20 Party's 16-inch plane-table sections and of the large-scale Hyderābād Municipal Survey map, and the portion previously surveyed on the 3-inch scale was incorporated in the plane-table sections. The remaining areas which had been previously surveyed by the party on the 1-inch and ½-inch scales were surveyed "*de novo*" on the 3-inch scale.

The work was divided as follows:—

No. 1 Camp, under Mr. Meyer with one Upper Subordinate officer for a short period and 15 surveyors completed, on the ½-inch scale, the original survey of 56 D/11. 12. 15. 16, 57 A/6. 9. 10 and parts of sheets 56 D/7. 8. 10. 14 and 57 A/1. 2. 5. 13 and the supplementary survey of parts of sheets 57 A/1. 2. 5 and, on the 1-inch scale, the original survey of sheet 57 A/14 and part of sheet 57 A/13.

No. 2 Camp, under Mr. Harihara Iyer up to the 10th January 1920 and then under Mr. Munshi Lal, B. A., with two Upper Subordinate officers, Messrs. Mandanna and Natesan, B.A., and 10 surveyors was employed on the special survey of scattered reserved forests of Hyderābād in sheets 56 G/16, 56 H/13. 14 and 56 L/1. 2. 3. 5. 7. 8. 9. 10. 11. 12. 14. 15.

Head-Quarters camp.—Under Mr. Donaghey, assisted for a short period by Mr. Harihara Iyer and then by Mr. Masud Khan carried out the original and supplementary survey on the 3-inch scale of parts of sheets 56 K/6. 7. 10. 11.

A total area of 4,191 square miles was completed. The out-turn of the ½-inch original, ½-inch supplementary, 1-inch original, 1½-inch original, 3-inch original and 3-inch supplementary survey was 3, 383, 108, 298, 282, 70 and 50 square miles respectively, the average monthly out-turn per man was 61·6, 55·0, 57·7, 5·4, 4·9 and 14·0 square miles respectively and the cost-rate per square mile was Rs. 7·9, Rs. 10·0, Rs. 7·5, Rs. 96·1, Rs. 87·1 and Rs. 87·1 respectively. Of the total area surveyed 111 square miles are in the Bijāpur and Dhārwār districts of the Bombay Presidency, 170 square miles are in the Bellary district of the Madras Presidency and 3,910 square miles are in Hyderābād State.

Areas included in the total area surveyed and which have been previously reported as surveyed are as follows:—16 square miles previously surveyed on the ½-inch scale in sheet 56 G/16, 44 square miles previously surveyed on the ½-inch scale in sheets 56 K/NW. NE. SW. SE., 56 square miles previously surveyed on the 1-inch scale in sheets 56 K/NE. SW. SE. and 19 square miles previously surveyed on the ½-inch and 3-inch scales in sheets 56 K/NE. SE.

Triangulation.—The country is undulating with scattered rocky knolls, boulders and open patches of grass and includes the Secunderābād Cantonment and a portion of Hyderābād city areas. Mr. Mandanna completed an area of 60 square miles of supplementary triangulation in parts of sheets 56 K/NW. NE. SW. SE. for survey on the 3-inch scale.

The cost-rate per square mile was Rs. 36·4. The whole area is in the Hyderābād State.

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

No. 1 Section, under Mr. Meyer ½-inch sheets 56 D/SW. SE. and 57 A/NW. NE, 1-inch sheets 57 A/13. 14 and the Secunderābād 3-inch sheet which is comprised of parts of sheets 56 K/NW. NE. SW. SE.

No. 2 Section, under Mr. Natesan, B. A., for a short period and then under Mr. Munshi Lal, B. A., was employed on the 2-inch special forest sheets and undertook the completion of 15 sheets surveyed during the year under report and 21 sheets surveyed in previous years.

The 1-inch sheets 57 A/13. 14 have been submitted for publication, ½-inch sheets 57 A/NW. NE. will shortly be submitted for publication and, as the party is not taking the field for the year 1920-21, ½-inch sheets 56 D/SW. SE. and all the 2-inch special forest sheets will be submitted for publication by the end of December 1920. The fair-mapping of the Secunderābād 3-inch sheet has just been commenced and this sheet should be ready for publication in January 1921.

The computations of the supplementary triangulation were completed in the field. The arrears of computations consist of sheets 56 P/1. 5. 9. 13 and parts of sheets 56 P/2. 3. 4. 6. 10. 14 which are in hand and sheets 56 O/1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 15. 16 which have not yet been taken up.

No triangulation charts were undertaken. Charts 56.D, H, L, O and P will be undertaken by the party and charts 47.N and 57.A will be completed as regards areas surveyed by the party; chart 47.N will then be handed over to No. 8 Party and chart 57.A to No. 7 Party for completion when the survey remaining in these sheets has been carried out.

No. 7 PARTY (MADRAS).

By Major J. D. Campbell, D. S. O., R. E.

This party did not take the field during 1919-20.

Personnel.

Class I Officer.

Major J. D. Campbell, D. S. O., R. E., in charge from 3rd October 1919. to 5th May and from 2nd August 1920.

Class II Officers.

Mr. H.B. Simons, in charge to 2nd October 1919.
" S. F. Norman, in charge from 6th May to 1st August 1920.
" J. H. S. Wilson.
" C. E. C. French.
" Haji Abdul Rahim, K. B.
" F. H. Grant.

Upper Subordinate Service.

Mr. Eknath Battu to 1st April 1920.
" K. Narayanasvami Chetti.
" Damodar Khadilkar.
8 Probationers.

Lower Subordinate Service.

16 Surveyors, etc.

Recess Duties.—The previous season's fair-mapping was all completed by the end of October 1919, sheets 57 M/10. 12. 13. 14. 16 having been sent for publication since the last annual report. Subsequently the party has been engaged on the arrears of ½-inch mapping and triangulation charts of the circle.

The following ½-inch sheets have been partly or wholly drawn in this party:—55 C/SE., 55 H/NW. NE. SW. SE., 55 G/NW. NE. SW., 55 K/NW. NE., 55 L/NW. SW. SE., 56 C/SW., 56 D/NW., 56 G/NW., 57 M/NE., 57 N/NW. NE. SW. SE., 57 O/NW. NE. SW. SE., 58 G/SW., 58 H/NW. SW. SE., 58 L/SW., 64 B/NW., 66 A/SW., 66 B/NW., 66 C/SW.

Of these 34 sheets, 28 have been sent for publication.

The following triangulation charts have been taken up:— 48.K, 49.M, 55.D and G, 56.M, 57.H, N and O, 58.A and B, 66.B and C, of which, 49.M, 56.M, 58.A and B, and 66.B and C have been sent for publication. The party computations have been brought up to date.

During the field season 8 Upper Subordinate Probationers were attached to the party for training. They were given a course of triangulation plane-tabling, etc., and were handed over to the Survey Instructor for completion of course in April 1920.

No. 8 PARTY (MADRAS).

By C. E. C. French.

This party completed the detail survey of sheets 58 G/11.12.15.16; 58 H/9 10.13.14; 58 K/3.4.7.8.11.12.15.16; 58 L/1.2.5; and 58 O/1.2.3.4.7.8 on the 1-inch scale and the reserved forests of Mūlavittān and Valliyūr on the 2-inch scale.

Personnel.

Class I Officer.

Mr. W. M. Gorman, in charge to 6th May 1920.

Class II Officers.

Mr. C. E. C. French, in charge from 7th May 1920.
" S. F. Norman, to 5th May 1920.
" M. Mahadeva Mudaliar, M. A.
" B. T. Wyatt.
" M. S. Ganesa Aiyar from 1st November 1919.
" J. C. St. C. Pollett, from 10th December 1919.

Upper Subordinate Service.

Mr. H. Narasimhamurti Rao.
" Shaikh Muhammad Salik.

Lower Subordinate Service.

42 Surveyors, etc.

The area surveyed comprised fertile undulating plains devoid of forest with numerous tanks, small villages and isolated huts distributed over the country.

The party took the field on the 15th November 1919 at Tinnevelly and arrived at recess quarters Bangalore on the 25th April 1920.

The health of the party generally was good. During the early part of the season menials suffered from hunger owing to prevailing high prices, many being reduced to a state of emaciation. Cholera appeared in epidemic form in the area under survey towards the end of the field season, but owing to the arrangements made the party lost only one man.

Plane-tabling.—The country surveyed consisted of cultivated plains sloping gradually eastward to the sea and watered by the Vaippār, Vaigai and Tāmpraparni rivers. The rice

lands are well irrigated by canals and the tiled villages and temples in cocoanut palm groves stand out like islands and are very nearly on the same level as the surrounding cultivation. Palmyra palms are very numerous and are a characteristic feature of the country. Near the sea the rain-fall is excessive and the country consists of sand dunes and brackish swamps covered with low scrub jungle and palms. The communications are fairly good except in the large blocks of cultivation. Rāmnād district contains the well known Hindu temple of Rāmeswaram which is a specimen of Dravidian architecture at its best and is much resorted to by pilgrims from all parts of India, access to it having been rendered easy by the railway to the western extremity of Adam's Bridge. The eastern half of the country is thickly covered with palmyra palms which necessitated much detail survey with plane-table and chain. The principal towns in the area under survey are Pālamcottah and Rāmnād, both district head-quarters, Tinnevelly, Sermādevi, Tuticorin, a seaport and terminus of the South-Indian Railway, and Kalugumalai, which contains a celebrated rock-cut temple ornamented with Jain sculptures and inscriptions and which is also noted for a large cattle fair.

It is interesting to note that Marco Polo visited Southern India in the thirteenth century and calls it "the greater India and the finest and noblest province in the world".

The party's work was divided into 4 camps as follows :—

No. 1 Camp, under Mr. Mahadeva Mudaliar, assisted by Mr. K. Narayanasvami Chetti (to 28th November 1919) and later by Mr. B. T. Wyatt (from 16th January 1920) with 13 surveyors completed an area of 3·0 square miles of 2-inch original survey of reserved forests and 1553 square miles of 1-inch supplementary survey in sheets 58 H/9.10.13.14 and 58 L/1.2.5.

No. 2 Camp was taken into the field by Mr. Shaikh Muhammad Salik from whom it was taken over by Mr. Pollett on 16th January 1920, the former remaining as assistant as well as doing some plane-tabling himself. This camp with 9 surveyors completed an area of 1, 173 square miles of 1-inch supplementary survey in sheets 58 G/11.12.15.16.

No. 3 Camp, under Mr. M. S. Ganesa Aiyar, with 10 surveyors completed an area of 1086 square miles of 1-inch supplementary survey in sheets 58 K/3.4.7.8.

No. 4 Camp, under Mr. S. F. Norman, with 8 surveyors completed an area of 147 square miles of 1-inch original survey and 711 square miles of 1-inch supplementary survey in sheets 58 K/11.12.15.16 and 58 O/1.2.3.4.7.8.

A total area of 4673 square miles was completed. The out-turns of 2-inch original, 1-inch original and 1-inch supplementary survey were 3,147 and 4,523 square miles respectively, the average monthly out-turns per man per month were 7·1, 17·5 and 27·6 square miles respectively and cost-rates Rs. 53·8, 10·8 and 17·5 respectively.

No triangulation or traversing was undertaken by the party during the year under report.

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

No. 1 Section, under Mr. M. Mahadeva Mudaliar, M.A., sheets 58 H/9.10.13.14 58 L/1.2.5.

No. 2 Section, under Mr. J.C. St. C. Pollett, sheets 58 G/11.12.15.16.

No. 3 Section, under Mr. M.S. Ganesa Aiyar, sheets 58 K/3.4.7.8.

No. 4 Section, under Mr. B.T. Wyatt, sheets 58 K/11.12.15.16; 58 O/1.2.3.4.7.8.

All fair maps will be submitted for publication before the party leaves for the field.

The total area fair-mapped is 4671 square miles at a cost of Rs. 7·9 per square mile.

The fair-mapping of the 2-inch reserved forests will be undertaken by the Forest Map Office, Dehra Dūn, as soon as possible after the submission of the current season's fair-mapping in which these 2-inch areas are incorporated.

Mr. H. Narasimhamurti Rao with one computer brought all arrears of computation up to date for the coming season's requirements. The following triangulation charts, 58 G and 58 H, 58 K, 58 L, and 58 O, form part of the party's programme for the season; of these the last two are nearing completion. 58 H is under preparation and 58 G and 58 K cannot be undertaken until these areas are completely surveyed.

No. 20 PARTY (CANTONMENT).

By B. R. Hughes.

During the year the party continued survey operations in the Southern Circle.

PERSONNEL.

Class I Officer.

Mr. B. R. Hughes, in charge from 24th November 1919.

Class II Officers.

Mr. C. E. C. French, in charge to 23rd November 1919.
„ J. H. S. Wilson, from 1st May 1920.
„ O. D. Jackson.

Upper Subordinate Service.

Mr. Dharmu.
„ J. M. Mukerjee.

Lower Subordinate Service.

26 Surveyors, etc.

The field season continued throughout the year. The head-quarters of the party was at Secunderābād until the end of March 1920, and at Bangalore for the remainder of the year.

The health of the party was indifferent. Several of the draftsmen and khalāsis suffered from influenza at Secunderābād.

Plane-tabling.—The survey and contouring on the 16-inch scale of the cantonments and the military lands in the 9th Division of Secunderābād and Bolārum, St. Thomas's Mount, Pallāvaram, Fort St. George, Cannanore, Poonamallee, and Velichi military land, and the revision of 57 plans of the Secunderābād and Bolārum bāzārs on the 50-foot to an inch scale executed in 1908-09 was completed, and Wellington and Bangalore on the 16-inch scale and the bāzārs of St. Thomas's Mount, Pallāvaram, Cannanore, Poonamallee on the 64-inch scale are in progress.

The survey of certain bāzārs for the Bangalore Municipal Commission on the scale of 50-foot to an inch is also in hand; a separate note on this work is attached.

The accuracy of the survey was tested by 113·8 linear miles of *partal* and 62 *in situ* fixings. The testing in linear mile to a square mile of ground surveyed was 3·6 and 13·4 for the 16 and 64-inch respectively and 10 linear miles to a square mile for the 50-foot revision.

The total areas of original plane-tabling on the 16-inch and 64-inch scales were 14,449 and 441 acres respectively. The average monthly out-turn of 24 working days per man was 268·2 and 24·8 acres respectively, and the cost-rate per acre was Rs. 1·7 and 19·6 respectively. The work was retarded in Wellington and Cannanore owing to heavy rain.

The total area revised of 57 plans on the 50-foot to an inch scale of surveys executed in 1908-09 was 943 acres, and the cost was Rs. 7,492 at a cost-rate of Rs. 7·9 per acre with an average monthly out-turn of 55·6 acres.

Triangulation.—Sufficient number of stations and intersected points were fixed from the nearest Great Trigonometrical Series, for the connection of the theodolite traversing. Mr. Dharmu, Gokul Chand and Niaz Ahmad Khan were employed on the triangulation.

The total area triangulated was 95 square miles and the cost-rate was Rs. 20·9 per square mile, the daily out-turn being 2·4 square miles.

An area of 24 square miles was triangulated partly in connection with the surveys of bāzārs on the scale of 50-foot to an inch for the Bangalore Municipal Commission.

Traversing.—The traversing of Fort St. George and military lands, Pallāvaram, Velichi military district land, Poonamallee, Cannanore and Bangalore Civil and Military Station and bāzārs comprising a total of 157·9 linear miles at a cost of Rs. 10,681 and a cost-rate of Rs. 67·7 per linear mile, was completed. The average daily out-turn being 9 stations and 61 linear chains, at an average of 13 stations to a linear mile of traverse. Traversing of the bāzārs for the Municipal Commission for a scale of survey on the 50-foot to an inch was also completed. The average daily out-turn being 15 stations and 38·64 linear chains, at an average of 31 stations to a linear mile of traverse.

Levelling.—Levelling was undertaken by Mr. Jackson in Wellington and in other cantonments by Niaz Ahmad Khan and 78 bench-marks based on the Great Trigonometrical precise levelling were fixed and on which the traverse heights were based at a total cost of Rs. 2,917 for about 57·5 linear miles.

Recess Duties.—49 fair sheets of Aurangābād, Hosūr, Ahmadnagar, Jhānsi, Bellary and Manora were submitted to Dehra Dūn for publication and 3 sheets of Secunderābād cantonment and 77 sheets of Secunderābād and Bolārum bāzārs have been completed, but not yet sent for publication.

The total area fair-mapped on the 16-inch and 64-inch scales were 12,988 and 164 acres respectively: plans of 1226 acres on the scale of 50-foot to an inch have been brought up to date, at a cost of Rs. 12,630 and a cost-rate of Re. 0·87 per acre.

Inspections.—The party was inspected in the field in March and in recess in June and July by the Superintendent, Southern Circle, and in recess by the Officiating Surveyor General in August.

Note on the special survey of Bangalore bāzārs for the Municipality of the Civil and Military station on the scale of 50 feet to one inch.

The survey on the scale of 50 feet to an inch of 4 bāzār areas within the limits of the Civil and Military station of Bangalore, which is an enclave in the Mysore State, was assigned to No. 20 Party.

This class of work is not ordinarily within the scope of the usual cantonment work of the party.

It was decided to put in hand at the same time the revision of the 16-inch to a mile survey of the Bangalore Civil and Military station area, executed in 1906-07, so that economy would be effected, and so that the new survey would be available for inclusion within the area of the revised 16-inch cantonment map.

From past experience it was anticipated that many old traverse stations would not be available for the traversing that was to be the basis of the new survey, and before the work was undertaken a count was taken of the old traverse stations now in existence. The number reported was, however, so small that it was decided that traversing of the bāzār areas should be undertaken "*de novo*".

Traversing began in May, and it was found that only 85 old stations could be picked up out of a total number of 825 stations previously fixed throughout the area.

This deplorable loss of stations is a factor that presents itself as soon as resurvey is taken up, but it is considered that this loss might have been avoided, if Municipal and Garrison Engineers kept the retention of stations in view at the time of road repairs and other engineering undertakings.

To meet the complaint that the traverse stations are not shown sufficiently clearly on our maps, a new symbol has been introduced (a small triangle) to define the location of selected traverse stations.

During the course of traversing, as the bāzār areas were much scattered, it was decided that the best method of combining them to the origin of survey as well as to reduce the linear error was to fix points by triangulation to which the traverses shonld be tied up; this triangulation was carried out, and 24 points were fixed over an area of 24 square miles.

This method was found to be of great help both in the field work as well as in the computations and further assistance from their positions being defined on the field sheets will be derived by the detail surveyors.

The points fixed by triangulation were computed out by "Ray-trace"; this system is resorted to when triangulation is required between two points that may not be intervisible. A series of triangles is run between the two points, the intermediate stations being generally located where traverse stations with heights are required and intersected points are picked up in the usual way. For the computation the value of one side is assumed, and, by computing the triangles, a value is obtained for the distances between the known points; the ratio of this value to the true distance between the points is applied to every side to obtain its true length. The coordinates of the points can now be computed in the usual way.

To improve the contouring, the pupils of the Training Section were employed on levelling along roads thereby serving the work with numerous heights derived from the Great Trigonometrical bench-marks.

Traversing of 28·22 linear miles supplied 825 stations for this work, the angular error being 4·6 seconds per station and the linear error 1 part in 9, 376.

The area of survey being 524 acres, the traversing provided 1·6 stations to the acre, the average distance between stations being 180 feet.

The number of holdings is likely to work out at 45 per acre.

With a view to giving Provincial and Upper Subordinate officers the benefit of refresher courses in traversing and the astronomical observations connected therewith, six officers of the former and five of the latter were employed during the month of September 1920 on this work with satisfactory results; the area allotted in three bāzārs was 192 acres, the distance traversed 9·38 linear miles with 231 stations of observation.

TRAINING SECTION.

By S. S. McA'F. Fielding.

The field season of the Training Section for 1919-20, started early in November, the section leaving for the field from Bangalore on the 12th for Penukonda.

PERSONNEL.

Class II Officers.

Mr. S. F. Norman, in charge till 19th October 1919.
" S. S. McA'F. Fielding, in charge from 20th October 1919.

Lower Subordinate Service.

3 Surveyors (Assistant Instructors) and 20 pupil surveyors.

The area allotted for survey was in sheet 57 G/9, the scale of survey, 1½ inches to a mile, and no previous one-inch survey of the area existed. Penukonda was selected as the field head-quarters of the section but, being found unsuitable as it was too far from the work and rather inaccessible, a move was made early in December to Hindupur, the head-quarters of the taluk of that name, of Anantapur district, Madras Presidency. Most of the area surveyed lay in that taluk, a very small portion of the Mysore State falling in the southernmost limit of the sheet, and a small portion of Penukonda taluk (Anantapur district) in the northern limits of the work.

The ground selected was not the most suitable for instructional purposes for several reasons, the chief being the want of numerous and good triangulation points. Such points as there were fell chiefly in the eastern portion of the sheet, and consequently on the 1½-inch scale were rather too distant for the pupils working in the west. Clinometric heights taken from these points were often erratic and incorrect and frequent checking with the help of the telescopic clinometer was necessary. The nature of the ground itself was not suitable for instruction in contouring. The hills which exist in the east, being mostly shapeless masses of rock and boulders without prominent features or drainage, gave no opportunity for sketching whatever. The western half of the sheet is low undulating ground, again rather difficult for a beginner to contour accurately. The reserved forests on the hills in the east were open and easy to survey.

Communications inside the area were confined to two main roads. One a district board road running from Hindupur eastwards to meet the more important one from Bangalore to Bellary *via* Penukonda. Village cart tracks were numerous but rough and difficult. A portion of the Madras and Southern Mahratta Railway, Guntakal Section, passed through the western portion of the sheet. The area was generally well populated. There were no very important rivers in the sheet and no great variety of detail.

The section consisted of 20 pupils who were divided into 3 batches each under a 1st class surveyor as assistant instructor. Of these twenty pupils, two had been entertained in November 1918 and had received a full course of instruction in drawing in No. 4 Drawing Office, and the remainder at intervals between June and October 1919; three were entertained in Dehra Dūn where they had had some training in drawing before joining in Bangalore in October, five pupils including the three men from Dehra Dūn had no preliminary out-door instruction in plane-tabling in Bangalore before taking the field. The average time spent by the remainder in preliminary plane-tabling was one month to six weeks, the rest of their time being spent in drawing in office.

The preliminary training was found to be insufficient and the men required a good deal more attention and instruction in the field than in previous seasons. Three months preliminary training in Bangalore is not too much and gives the pupils a certain amount of self reliance and confidence in the field.

The area surveyed by the section was approximately 170 square miles, or an average of 9 square miles per man. This average is low, owing chiefly to the reason above mentioned. But accuracy in every detail was aimed at rather than rapid work. It has been found from experience that the best pupils should be able to do 10 to 15 square miles of extremely accurate work in a season, on the 2-inch or 1½-inch scale in not too intricate country. The majority of the pupils were also somewhat handicapped from want of sufficient training in drawing.

Early in December one of the pupils from Dehra Dūn was discharged owing to ill-health, and the number was again reduced by one being discharged for the same reason in March of this year. Barring these two the health of the pupils on the whole was good. There was a good deal of sickness among the menials at the commencement of the hot weather, but all were successfully treated in the local hospital at Hindupur.

The climate was on the whole good, it being a particularly dry season after the end of November.

The season closed at the end of April when the section returned to recess quarters in Bangalore.

Early in May the pupil surveyors were drafted out of the section as follows :—

Class A.—6 pupils ready to be transferred to parties for fair-mapping without further training.

Class B.—7 pupils, efficient as regards plane-tabling but requiring further training in drawing.

Class C.—5 pupils, not efficient plane-tablers but likely to become so after further training in field work.

On the 1st May 1920 those of class A were transferred to parties and those of class B to the Drawing office for further training in drawing and typing. Class B pupils were drafted to parties on the 1st August 1920.

One pupil of class C was discharged after return to recess. The remainder of that class have undergone further preliminary training in plane-tabling at Bangalore and will do another season's training in plane-tabling with the section in camp.

Eight Upper Subordinate Probationers were transferred to the section in May to complete their training.

During recess the class consisted of :—

8 Upper Subordinate Service Probationers.
20 Pupil surveyors.
2 Pupil draftsmen.

Three Upper Subordinate Service Probationers were found unsuitable for the service and allowed to resign in June 1920.

The training of the remainder was carried on in field astronomy, traversing and its computations, fair drawing, computation of field triangulation, subtense work, elementary levelling and typing.

In August two more of these Probationers were allowed to resign as they were found unsuitable.

The 22 pupils completed a preliminary course in plane-tabling at Bangalore, the 2 pupil draftsmen will probably return to No. 4 Drawing Office and the remainder have all been found suitable to undergo regular training in plane-tabling and will form next season's training camp in the field (these include 4 who have already done one season's training in camp).

The three Upper Subordinate Service Probationers will be drafted to parties at the end of this recess season, after they have completed further training in plane-tabling during October with a view to being instructed in "sketching in" ground. They will form a small camp in the vicinity of Kolār where the country is suitable for "sketching".

EASTERN CIRCLE.

Summary.—This circle was under the superintendence of Lieut.-Colonel C. L. Robertson, C.M.G., R.E., up to 24th October 1919, of Lieut.-Colonel W.M. Coldstream, R.E., from 25th October 1919 to 19th April 1920 and of Major E. T. Ritch, C. I. E., R. E., after that date and comprised Nos. 9, 10, 11, 12 and 21 Parties and No. 5 Drawing Office.

During the year Nos. 9, 10, 11, 12 and 21 Parties completed 9,428 square miles of detail survey, 8,137 square miles of triangulation and 1,597 linear miles of theodolite traversing.

The detail survey consisted of :—

3,615	square	miles	of ½-inch original survey.
5,231	,,	,,	,, 1-inch original survey.
20	,,	,,	,, 1-inch resurvey.
45	,,	,,	,, 1½-inch revision survey.
378	,,	,,	,, 2-inch original survey.
103	,,	,,	,, 3-inch original survey.
36	,,	,,	,, 4-inch original survey.

No. 9 Party (BENGAL).

BY BT.-LT.-COLONEL R. H. PHILLIMORE, D.S.O., R.E.

The party surveyed the following sheets on the one-inch scale; sheets 79 A/12. 15. 16; 79 B/2. 6. 9. 13. 14. Survey of sheet 79 B/10 was commenced but could not be completed.

PERSONNEL.

Class I Officer.

Bt.-Lt.-Colonel R. H. Phillimore, D S. O., R. E., in charge from 1st November 1919.

Class II Officers.

Mr. E. J. Biggie, in charge to 31st October 1919.
,, A. K. Mitra.

Upper Subordinate Service.

Mr. A. C. Ghosh.
,, G. L. Mitra.

Lower Subordinate Service.

23 Surveyors, etc.

The field head-quarters opened at Barrackpore on November 1st 1919 and closed on May 16th 1920.

The country surveyed was absolutely flat and covered with marshes and *bils*. These are generally the ancient beds of rivers which have silted up and changed courses. Towards the south survey reached the Sundarbans area, which is a maze of tidal rivers and creeks. Sheet 79 B/6 contains the city of Calcutta and is densely populated.

The whole area is well provided with railways, but there are very few metalled roads.

Villages were large and mostly comprised a number of huts scattered amongst an area densely wooded with bamboos, palms, and gardens. The country is covered with small excavated tanks.

The whole survey is based on theodolite traverse connected with tower stations of the Great Trigonometrical Survey. In the more open areas planetablers could get interpolations from prominent trees and points fixed by traversers; but inside the villages and in the more congested areas all detailed survey depended on plane-table traversing.

For the Calcutta area, use was made of the 12-inch Calcutta-Howrah town guide map which has recently been compiled from larger scale surveys. This map was reduced to the one-and-a-half-inch scale and revised on the ground.

The output of new survey was not as large as it might have been, because four of the best surveyors were kept at field head-quarters to complete the fair-mapping of the 12-inch town guide maps surveyed in season 1918-19.

The work was divided into two camps as follows :—

No. 1 Camp, under Mr. E. J. Biggie with 4 surveyors surveyed sheets 79 B/2. 6. Mr. Biggie also supervised the fair-mapping at field head-quarters.

No. 2 Camp, under Mr. A. K. Mitra with 14 surveyors surveyed sheets 79 A/12.15.16; 79 B/9. 13. 14 and part of 79 B/10.

The total area surveyed on the one-inch scale was 2,299 square miles; the area of Calcutta revised on 1½-inch scale was 45 square miles.

For the one-inch survey the average area for each trained man worked out at 29·5 square miles a month and the cost-rate for the whole detailed survey comes to Rs. 19·9 a square mile.

Traversing.—The area traversed by theodolite covered sheets 79 B/3. 4. 7. 8. 11. 12. 15. 16 and parts of 79 C/1. 5. 6. 9.

Mr. A. C. Ghosh and two surveyors completed 1,083 linear miles of traverse covering 2,440 square miles. Traverse was based on several tower stations of the Great Trigonometrical Survey and was connected to last season's traversing with satisfactory results.

The area runs well into the Sundarbans and reaches the sea front at Fraserganj. This part of Sundarbans has mostly been reclaimed during the last fifty years, and had not been included in the survey of the forest area carried out by No. 6 Party from 1906-08.

It is intersected by tidal rivers and creeks which are gradually silting up and changing their courses. These changes are brought about by the effect on the tides of the bunds built for reclamation. The tides have lost their natural spill area; their rise and fall is greatly increased and their range extends much higher up the rivers than formerly. On the other hand silt which was deposited over wide areas during flood tide twice a day, is now deposited in the river beds.

The area reclaimed in the Sundarbans is open and contains very little detail for survey beyond the rivers and creeks and the open village sites. Once the original jungle is cleared, it takes a long time for the land to become sweet, and other trees are very slow in growing up.

The obstacles to survey are the muddy creeks which are impossible to cross without boats; the water-logged nature of the soil which only dries up from January to May (paddy is not cut till January), and the brackish and unpalatable character of the drinking water.

Several of the surveyors had their camps looted during the field season and lost valuable private property. These robberies in a congested area are difficult to prevent, and inflict great hardship on the surveyors. The health of the party was not particularly good, one Upper Subordinate officer was on sick leave for 2 months, one surveyor and one pupil surveyor died early in the season.

Recess work.—None of the sheets surveyed in 1918-19 were completed before the party took the field, owing to the number of half-inch sheets which the party was drawing during the recess of 1919. Most of these sheets were completed during the field season, but sheets 79 B/1, 5 were completed during recess 1920 and submitted for publication before the end of July.

The 8 sheets completely surveyed during 1919-20, were drawn under supervision of—

Mr. E. J. Biggie, sheets 79 B/2.6.

Mr. A. K. Mitra, sheets 79 A/12.15.16 and 79 B/9.13.14.

None of these sheets had been completed by October 1st 1920.

Mr. Biggie also supervised the training of 20 pupils recruited for Nos. 9,12 and 21 Parties, who were trained in four-inch survey in the neighbourhood of Shillong as well as in drawing and typing.

Traverse computations were supervised by Mr. A. C. Ghosh.

No. 10 PARTY (UPPER BURMA).

By W. G. Jarbo.

PERSONNEL.

Class I Officer.

Mr. M. C. Petters, in charge to 19th June 1920.

Class II Officers.

Mr. W. G. Jarbo, in charge from 20th June 1920.
" H. H. Creed.
" D. N. Banerji, L. C. E.

Upper Subordinate Service.

Mr. Hayat Muhammad, K. S.
" Dhirendra Nath Saha.
" Ram Prasad, R. S.
Maung Pe. A. T. M.

Lower Subordinate Service.

17 Surveyors, etc.

The party continued the detail survey in the Myitkyinā, Putao and Upper Chindwin districts and also surveyed a portion of the Hukawng valley which is unadministered, the total area dealt with extending over sheets 92 C/2. 5 and parts of sheets 92 C/13, 92 G/1 and 92 E/NW. SE.

The country under survey ranges in altitude from 700 feet in the valley of the Uyu river to 12,000 feet on the watershed between the Mali Hka and Nmai Hka, being for the most part covered with dense forest which often necessitated heavy clearing before the plane-table could be set up.

The field season opened on the 3rd November 1919 and closed about the 8th June 1920, but

a small camp of three surveyors under an Upper Subordinate officer remained in Putao district during the rainy season. The health of the party was fair, most of the surveyors having suffered from malaria occasionally.

Plane-tabling.—The total area surveyed on all scales was 3,239 square miles of which 2,179 square miles have been dealt with in another report.

No. 1 Camp, under Mr. M. C. Petters, with three surveyors completed an area of 171 square miles on the one-inch scale in sheets 92 C/13 and 92 G/1, the survey of which was finished by the 15th of March 1920.

No. 2 Camp, under Mr. D. N. Banerji, with four surveyors completed an area of 337 square miles on the half-inch scale in sheets 92 E/NW. SE., comprising a portion of the drainage of the Mali Hka, ranging in altitude from 12,000 feet on the Mali Hka—Nmai Hka watershed to 1,000 feet at the bed of the Mali Hka. There are numerous villages along the banks of the Mali Hka and Nam Tisang but very few in the hills. The Mali Hka in this area is noted for its excellent mahser fishing.

No. 3 Camp, under Mr. D. N. Saha to 4th May and then under Mr. H. H. Creed, with 6 surveyors completed an area of 552 square miles on the one-inch scale in sheets 92 C/2.5 embracing portions of the Myitkyinā and Upper Chindwin districts and the unadministered territory known as the Hukawng valley. The country ranges in height from 700 feet in the valley of the Uyu river to 11,000 feet on the Kumon Bum range. It is for the most part covered with impenetrable forest and sparsely populated.

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

1-inch original survey 723 square miles at Rs. 50·1 per square mile.

½-inch „ „ 337 „ „ at „ 27·2 „ „

The cost-rates for both classes of survey are higher than those of last year which were Rs. 37·6 and Rs. 23·6 per square mile respectively. The increased cost-rate is due in some measure to the great distance from Myitkyinā to the areas of survey, much time being spent in marching, and also to the increased rate of mule hire.

Triangulation.—Triangulation in advance for detail survey on the half-inch scale was carried out in sheets 92 B/NW. NE. SW. SE. and 92 F/NW. SW.

Mr. H. H. Creed triangulated an area of 2,200 square miles for detail survey on the half-inch scale in sheets 92 B/NW. SW. and Mr. Ram Prasad, 2,400 square miles in sheets 92 B/NE. SE. and 92 F/NW. SW. The 2,400 square miles triangulated by Mr. Ram Prasad includes an area of 1,200 square miles in sheets 92 B/NE. SE. which had been previously triangulated but which required to be supplemented by many more points, and the cost-rates per square mile given in Table III apply only to 3,400 square miles of new triangulation.

The area triangulated embraced practically the whole of the Hukawng valley which for the most part is a fertile gently sloping plain surrounded by high mountainous ranges, intersected by numerous waterways, tributaries of the Tanai Hka, which stream, after breaking through a series of defiles and rapids, enters the plains as the Chindwin river.

The valley is peopled by Kachins and Shans in the low lands and by Chin Nāgās in the mountains on the north-west, their control being under numerous independent petty chiefs. Amber mines have been worked in the valley. Smoking and eating opium are much indulged in and the people are very indolent.

The cost-rate of new triangulation is Rs. 6·4 per square mile which is Rs. 2·2 per square mile less than last year. The cost of the 1,200 square miles of supplementary triangulation is Rs. 3,753.

Recess duties.—Mr. H. H. Creed was in charge of the fair-mapping which included sheets which had been commenced last year but were not completed.

Owing to Mr. Banerji and the surveyors who had been in his camp proceeding on privilege leave after a field season of 19 months and also to Mr. Saha with 3 surveyors remaining on in the Putao district during the recess to continue detail survey, it was not possible to complete the programme of fair-mapping, in spite of the loan of five draftsmen from the Maymyo Drawing Office.

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

1-inch fair-mapping, 605 square miles at Rs. 5·7 per square mile.

½-inch „ 973 „ „ at „ 5·4 „ „

The computations of the season's triangulation were carried out by Messrs. Hayat Muhammad, K. S., and Ram Prasad, R. S., and will be completed before the party takes the field.

The Superintendent, Eastern Circle, inspected the party during recess.

No. 11 PARTY (LOWER BURMA).

By J. O. Greiff.

The party was employed as follows :—

(*a*) Continuation of the topographical programme on the one-inch scale in the district of Mergui, Lower Burma.

(*b*) Survey on the three-inch scale, for military requirements, of about 100 square miles on the left bank of the Rangoon river, in the Hanthawaddy district.

(*c*) The deputation of a surveyor to point out and re-survey a portion of the Burma-China boundary in the Kokang district, Northern Shan States.

(*d*) The completion of the triangulation in the Mergui district.

Personnel.

Class I Officer.

Mr. J. O. Greiff, in charge.

Class II Officers.

Mr. O. J. H. Hart.
„ E. M. Kenny, to 12th June 1920.
„ H. T. Hughes, from 18th November 1919 to 31st August 1920.
„ F. C. Saint, from 13th August 1920.

Upper Subordinate Service.

Mr. Dalbir Rai, from 20th January 1920 to 31st May 1920.
„ P. C. Sen Gupta, B. Sc.

Lower Subordinate Service.

26 Surveyors, etc.

The nature of the country surveyed in the Mergui district has already been alluded to in previous reports, and the same dense forests, steep rugged hills, mangrove swamps, and absence of roads were met with. The greater portion of the area comprised the upper reaches of the Ngawun stream, and the lower basin of the Lenya river.

A main range of hills, running from south to north, separates the basins of the Ngawun and Lenya, and formed an inconvenient barrier to easy communication with the surveyors employed in the Ngawun valley. The ascent from both sides is steep, rugged in parts, and the forest dense. The eastern basin of the Ngawun is bounded by the main watershed, rising in one point to 4,000 feet in elevation, which forms the international boundary between Burma and Siam. From this watershed descend numerous streams, some of considerable size, through narrow winding valleys shrouded in impenetrable forest growth, which make it almost impossible to trace or follow the course of the streams from cleared hill tops. This difficulty was added to by the irregularities of the hill features. The spurs descend in a series of knolls, the saddles lying from 200 feet to 500 feet below them, and owing to there being no marked difference in elevation, it was impossible, without numerous fixings, and much plane-table traversing, to fix the direction of the spurs and drainage.

From the banks of the Ngawun, for a depth of about two to three miles on each side, stretches low undulating ground, densely wooded. Within this area, work could only be done by plane-table traversing. Hardly a point was visible and the only safe guide was the compass.

A peculiar and interesting feature along the right bank of the Ngawun is the existence of a broken ridge of lime and sandstone, rising sheer from its base to an elevation ranging from 300 to 1,400 feet. The serrated peaks of this ridge stand out like conspicuous battlements and spires in the midst of the forest growth, and form a striking feature. Except in a few cases, these outcrops are inaccessible. At the base of most of them are large dwelling caves, much used during the rains by the denizens of the forest, as well as by human beings.

The upper basin of the Ngawun constitutes the Ngawun Forest Reserve. The reserve though constituted in 1887 has never had its boundary demarcated or its growth examined, owing to its great inaccessibility. It contains a plentiful supply of valuable timber, the principal being the Pyinma, (*Lagerstraemia Reginae*), the girth of some of the trees being over 18 feet. The whole of this tract of country, extending from the Lenya watershed to the Siamese border is *terra incognita*, it has not been mapped before or visited by a European.

Bad as the island tracts are, those along the sea coast may fairly be said to be worse. They are inaccessible owing to the thick fringe of mangrove swamp along the bank, and to these physical difficulties are added swarms of mosquitos and sandflies which make life and work unbearable. It was necessary to supply surveyors employed along the coast with mosquito nets to sleep and work under, when in camp.

In the Archipelago, Kisseraing island and the eastern slopes of Domel island were surveyed. The former has been leased for a large sum to a tin mining company, but so far

the prospects of a big find have not been very hopeful. Except for the central ridge the whole island is chiefly mangrove swamp. Between Kisseraing and Domel islands are the Marble Isles but such marble as there is, is of an inferior quality. The Isles are of limestone formation, and rise sheer from the sea some hundreds of feet. At the bottom are lakes accessible only at low tide through tunnels in the rock. Within the islands are large caves with high roofs, the home of the edible swift.

The strip of country surveyed in the Hanthawaddy district, on the three-inch scale, for military requirements, lies on the left bank of the Rangoon river, between the towns of Syriam and Kyauktan. The whole of this tract is well inhabited and cultivated, and the town of Syriam acquires much importance from the presence of the large refineries belonging to the Burma Oil Companies. The factories cover a large area, employ a very large staff of Europeans and Indians, and constitute a busy self-contained town.

Through the centre of this strip of country runs the Kondan ridge, a low laterite spur, of the Pegu Yoma, which loses itself in the rocks in the Hmawwun stream. The general elevation of this ridge is about 150 feet. It commands the Rangoon river and consequently the approaches to the town of Rangoon. Along the ridge runs the main metalled road connecting Syriam and Kyauktan. The slopes are inhabited and large areas laid out in fruit and vegetable gardens. To the west they descend in undulating tracts of scrub jungle, cultivation, mango topes and orchards, to the river bank. The area is drained by a few large tidal streams, the mouths and banks of which are fringed with mangrove, cane, and thick scrub jungle. To the west from the base of the ridge, stretch open cultivated rice fields.

To judge from the numerous pagodas that adorn the crest of the ridge it must at one time have been regarded with some veneration. A few of the pagodas are still maintained in a splendid state of preservation, and the Kyaikkauk pagoda four miles south of the town of Syriam is a land mark for miles round, and is held in great sanctity. Outside the old town of Syriam are the ruins of the walls of the earliest European settlement in Burma, and of the church built in 1750 by the first Vicar Apostolic of Burma.

Distribution.—The field work was divided up into three camps :—

No. 1 Camp.—Mr. Hart in charge, with seven surveyors, formed the main camp, and surveyed an area of 910 square miles in sheets 96 I/13 (part), 14, 96 M/2. 6, 10. Until Mr. Dalbir Rai joined the party in January 1920, this officer was in charge of all the detail work. Throughout the season the main supply depôt for rations and for mules, and the hospital were under the direction and control of this camp.

No. 2 Camp.—Mr. Dalbir Rai in charge, with six surveyors, surveyed an area of 721 square miles in sheets 96 I/5 (part). 6. 7 (part). 9 (part). 10. 14. Two surveyors from this camp employed in Kisseraing island, were under the immediate control of the executive officer, their field work only being checked by the camp officer.

No. 3 Camp.—Mr. P. C. Sen Gupta in charge, with one surveyor, one computer, one draftsman and six pupil surveyors, triangulated and surveyed, on the three-inch scale, 103 square miles of country in the Hanthawaddy district, in parts of sheets 94 D/1. 2. 5. 6.

In this area it was originally decided to utilise the traverse data of the cadastral survey done between 1878-80, and from surrounding trigonometrical stations, to fix heights to the permanently maintained traverse stations. The data were obtained from the Deputy Commissioner, Hanthawaddy, and plotted on to the field charts. When tested, the plotted positions were found not to agree with the positions on the ground, the difference being from four to five chains. Evidently the Land Records Department when renewing the permanent marks, were not careful to replace them in their old positions. It was also found, that except for one station, Mianjinaong No. 1, of the Secondary G. T. triangulation, done in 1875-76, none of the other stations could be utilised, the stations having been destroyed and pagodas built on the sites. The executive officer was obliged to proceed to Syriam at the beginning of the season to start and lay out the triangulation. Mianjinaong No. 1 station was used as one end of a base on which to start work, the other end being fixed on a watch tower, belonging to the Burma Oil Company at Thilawa, by the three-point problem, from observations made to distant secondary G. T. points, Sule pagoda in Rangoon being one of the points used. The work proved well, and was completed by the 23rd December 1919. In addition 27·5 miles of simple traversing, with heights, was run through the work for plane-tabling. With the exception of one intermediate class surveyor Mowni Ram, the men employed on the work were all beginners.

Triangulation.—Triangulation was executed in the south of the Mergui district by Mr. H. T. Hughes, in sheets 96 J/1. 2. 5. 6; 96 J/9. 10. 11. 13. 14. 15. The area covered by triangulation is 1,629 square miles, of which 680 square miles is sea. For the length of field season and work to be done, the out-turn cannot be regarded as satisfactory. Much of the work done will also have to be supplemented with points. It was hoped that the triangulation in the Mergui district would have been completed last field season, but an area to the south remains to be done, as well as connections with the Siamese triangulation along the border.

The country triangulated is similar to that already described for plane-tabling. Below latitude 12° the district begins to assume the form of a peninsula, narrowing to only a few miles in width at Victoria Point. Through the centre runs a main range of hills, the slopes on each side breaking up into a mass of low irregular hills terminating in the sea coast on one side, and in the Pakchan river on the other. The southern portion of the district has, comparatively speaking, a fair amount of habitation, and a fairly good bridle road from Victoria Point to Bokpyin in the north. It is also said to be rich in tin and a large area of the peninsula is covered by tin mining leases. The forest growth is very dense and along the sea coast there are large stretches of marsh and mangrove swamp. Round Karathuri the country is low lying and evidently very unhealthy. No cattle can exist in this locality, the germs of disease being either in the water or the grass. Twenty-five mules contracted anthrax here in March, and died before the close of the field season.

Besides the above, a drawing office was maintained throughout the field season at Maymyo, under the charge of Mr. E. M. Kenny, to complete arrears of one-inch mapping, and to continue the mapping of half-inch and quarter-inch sheets.

At the request of the Government of Burma, a surveyor was deputed to accompany the Assistant Superintendent, North Hsenwi State, to point out and relay from the existing one-inch maps, and the report of the Burma-China Boundary Commission of 1898-1900, the position of the boundary line between certain pillars along the south-east limits of the Kokang district, disputed by the Chinese. The disputed boundary as well as an area of 19·60 square miles in sheet 93 I/14 was re-surveyed on the one-inch scale. The re-survey brought to light certain discrepancies in topographical detail in the old Boundary Commission maps. A trace of the re-survey was supplied to the political officer showing the correct position of the boundary, to enable him to discuss and settle the dispute with the Chinese at the Chief Political Meetings to be held on the frontier in 1920. The cost-rate for this work is Rs. 143·10 per square mile.

Field season.—The field head-quarters opened at Mergui on 11th November 1919 and closed on the 31st May 1920. The health of the party was good. A menial was killed by accident while felling a tree.

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

Original one-inch survey.....Rs. 70·4 per square mile.
Original three-inch survey.....Rs. 170·1 „ „ „
Triangulation.....Rs. 22·6 „ „ „

The cost-rate for one-inch detail survey is higher than that for the previous year, though the average out-turn per man is higher, being 24·5 square miles against 20·7 square miles. This is due to the rise in the pay and allowances of the establishment, the big increase in the rates paid for mules and equipment, and to the fact that three first class surveyors did not rejoin the party, and were replaced by second class men who did smaller areas of survey. Mules were paid for at Rs. 40 each per mensem, and were obtainable at Bhamo only.

For the three-inch detail survey the high cost-rate was to be expected, due to the fact that beginners were employed on the work; for the first three months their progress was very slow.

The rate for triangulation is abnormally high and is attributable to the heavy expenditure incurred on account of clearing and boat transport.

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

No. 1 Section, under the charge of Mr. Hart comprised the drawing office and current one-inch fair-mapping During the year under report 1,698·92 square miles of one-inch mapping was done in sheets 95 J/1. 5; 95 P/1. 8. 12; 96 I/6. 10. 13. 14; 96 M/1. 2. 5. 6. 9. 10. Of these sheets, seven have been submitted for publication, and it is hoped that three more will be submitted before the end of October. It is expected that all the fair-mapping of the country surveyed last season will be completed before the party takes the field.

4,678·22 square miles of half-inch mapping has also been completed, comprised in ten half-inch sheets, 93 O/SW., P/NW. SW. SE., 95 J/SW., 102 D/NW. NE. SW., G/NW. SW., which are in various stages of completion.

Five draftsmen from the drawing section have been employed during the recess season on the arrears mapping in No. 10 Party.

No. 2 Section, in charge of Mr. H. T. Hughes carried out the computations of the current season's triangulation, and continued the preparation of degree triangulation charts 95 E, I, L, 96 I, J, M. Two of these have been completed, and wait only final examination, the others have been brought up to date, and will be completed as plane-tabling progresses.

No. 3 Section, in charge of Mr. Gupta constituted a training section for pupils, and was employed on miscellaneous duties, *viz* the completion of field sections, adjustment of margins, preparation of traces and forest boundary plots of the Heinze and Kaleinaung Forest Reserve. Ten such plots on the two-inch scale have been completed, and will be despatched before the party takes the field.

The cost-rates for fair-mapping are Rs. 8·69 and Rs. 1·03 for one-inch and half-inch respectively.

Miscellaneous.—The most difficult problem in connection with the field work was the regular supply of provisions to the several camps scattered over a large area conspicuous for the absence of roads. All supplies had to be sent from Mergui by boats. Not even paddy for mules was available in the district and this had to be sent out from Mergui. The organization and arrangements need much forethought and management, as boats are not procurable at a moment's notice, and delays on account of stormy weather in the Archipelago were numerous. Along the coast and on the islands the supply of fresh water was another source of anxiety, water having frequently to be obtained from miles away. There are fishing villages along the coast, some of them with a scanty supply of fresh water, enough to meet village requirements, others without and obliged to procure their supply from miles away. The most inconvenient drawback to work along the coast is the want of camping ground The foreshore is mangrove swamp and mud, the fishing villages are built up on platforms raised forty to fifty feet above the ground, surrounded by wet and mud, and reeking with the odour of decaying fish. To pull up at these villages, meant either confining one's surroundings to a small country boat, or accepting the hospitality offered in a corner of a bamboo hut, devoid of cleanliness and privacy, and exposed to the gaze and curiosity of the entire village.

In sheet 96 I/14 the Khe Chaung valley bids fair to become a reputable tin mining centre. The greater part of the valley is covered by tin mining leases, and the extraction of tin is already in progress.

The drawing office at Maymyo, and the three-inch work at Syriam were inspected by the Superintendent, Eastern Circle, between the 26th February and 3rd March 1920 and the work of the party again in recess at Maymyo on the 16th and 20th August.

No. 12 PARTY (ASSAM).

By Major F. B. Scott, I. A.

The party carried out detail survey on the two-inch, one-inch and half-inch scales and triangulation and traversing in the districts of Lakhimpur, Bālipāra Frontier Tract, Khāsi and Jaintiā Hills, Sylhet, Cāchār, Nowgong and Nāgā Hills. The country consisted partly of plains and partly of low hills, both either densely wooded or very open.

The field season extended over a period of about six months from the 1st of November 1919 to the 15th of May 1920.

The health of the party was not good. Nearly all the surveyors whose work lay in the foothills and the adjoining plains suffered from malarial fever, and large numbers of menials were also affected.

Personnel.

Class I Officer.

Major F. B. Scott, I. A., in charge.

Class II Officers.

Mr. E. G. Hardinge, to 29th April 1920.
„ E. M. Kenny, from 21st June 1920.
„ Prafulla Chandra Mitra, B. A.

Upper Subordinate Service.

Mr. Girija Sonker Bagchi.

Lower Subordinate Service.

30 Surveyors, etc.

Plane-tabling.—The country surveyed in the Lakhimpur district was a flat plain, covered partly by a dense jungle of trees, cane, and grass, and partly cleared for cultivation and tea gardens. A densely wooded belt of low hills runs along the northern boundary of the district. The plains area is largely under water in the rainy season. The portion of the Sylhet district lying in the programme was similar to the Lakhimpur district. The Khāsi and Jaintiā Hills and Cāchār districts consist of an undulating grassy plateau of an average elevation of about 4,000 feet. The southern slope of the plateau, where it drops to the level of the plains of Sylhet and Cāchār, is steep and densely wooded. The plateau is intersected by deep and precipitous gorges, increasing in depth to the south. Coolies are the only means of transport, the villages are small, and supplies difficult to obtain.

The party was divided into three camps :—

No. I Camp, under Mr. E. G. Hardinge till the 8th February 1920 and then under surveyor Allah Ditta, with eight surveyors surveyed 605 square miles of original survey on the half-inch scale, 45 square miles on the one-inch scale and 193 square miles of reserved forests on the two-inch scale in sheets 83 C/SW. SE.

No. II Camp, under Mr. G. S. Bagchi with four surveyors and four pupils surveyed 494 square miles on the half-inch scale, 200 square miles on the one-inch scale and 26 square miles of reserved forests on the two-inch scale in sheets 83 C/SW. and 83 C/4. 8.

No. III Camp, under surveyor Amrit Ram with five surveyors surveyed 162 square miles on the one-inch scale and 37 square miles of reserved forests on the two-inch scale in sheets 83 I/3.4. The total area surveyed was 1,099 square miles on the half-inch scale, 407 square miles on the one-inch scale and 256 square miles on the two-inch scale, the cost-rates being Rs. 18·5, Rs. 44·5 and Rs. 96·7 respectively.

A special survey of 8·0 square miles of the Barpāni reserved forest was carried out for the Forest Department at a cost-rate of Rs. 43·7 per square mile.

Triangulation.—Triangulation was carried out by Mr. P. C. Mitra in sheets 83 C/NW. NE. and 83 G/NW. The country was mostly densely wooded hills rising to about 4,000 feet. A large amount of jungle clearing was necessary, and labour and supplies were unobtainable over part of the area. Coolies were the only means of transport. Smoke haze in February and rain in March interfered with the observations and Mr. Mitra was also delayed by a change of programme. An area of 1,801 square miles was triangulated at a cost-rate of Rs. 7·7 per square mile.

Traversing.—Traversing was carried out along the boundaries of reserved forests in sheets 83 I/3 , 83 C/4. 8 and 83 C/NE. SE. The boundaries ran for the most part along the foothills in most unhealthy country, the steep sided gorges and dense jungle making the work both slow and laborious. All the traversers suffered from malaria and enlarged spleens. The out-turn is consequently small and the cost-rate very high. 232 linear miles were traversed, covering an area of 173 square miles. Five traversers were employed. The cost-rate was Rs. 97·0 per linear mile for topographical surveys, Rs. 74·5 for forest boundary surveys and Rs. 25·3 for the special forest survey of the Barpāni Reserved Forests.

Recess duties.—The fair-mapping was divided into three sections :—

No. I Section, under Mr. P. C. Mitra, till the 20th June, then under Mr. E. M. Kenny, with ten surveyors and one draftsman carried out the fair-mapping of parts of sheets 83 C/4 , I/4 on the one-inch scale and sheets 83 C/SW. SE. (part) on the half-inch scale from original surveys, and half-inch sheets 83 F/SE. and 94 I/NW. compiled from one-inch sheets. Of these sheets No. 83 I/4 has been submitted for publication.

No. II Section, under Mr. G. S. Bagchi, with seven surveyors and one draftsman carried out the fair-mapping of parts of sheets 83 C/8 , I/3 on the one-inch scale from original surveys and sheets 93 O/SE. and 95 J/SE. (part) compiled from one-inch sheets.

No. III Section, under surveyor Amrit Ram, with four surveyors carried out the typing of fair-sheets and plane-table sections. An area of 481 square miles for publication on the one-inch scale from original surveys and of 2,892 square miles for publication on the half-inch scale from original surveys and compiled from one-inch published sheets was fair-mapped at a cost-rate of Rs. 14·8 and Rs. 2·5 per square mile respectively.

Mr. P. C. Mitra with four computers and traversers completed the computations of the triangulation and traversing done during the field season, and the four-inch boundary plots of artificial boundaries of reserved forests, and also prepared the triangulation charts and pamphlets of sheets 83 B and 83 F.

Miscellaneous.—All field work was stopped for about a fortnight in March by heavy and continuous rain. Malaria as mentioned above, was responsible for the loss of a large number of working days. One *khalāsi* was accidentally killed by an arrow shot from a game trap set by Daflās near Dulāhāt tea garden in sheet 83 E/16. A large number of similar traps were discovered and confiscated under the orders of the Political officer, Bālipāra Frontier Tract. Another *khalāsi* was mauled by a bear in the Saipung Reserved Forest in sheet 83 C/SE. but made a complete recovery. A large area north of the Narpuh Reserved Forest in sheets 83 C/SW. SE. was deserted by the villagers on account of the number of men killed by a man-eating tiger, and the surveyors working in this area were hampered by being unable to obtain coolies or supplies.

No. 21 (BURMA FOREST) PARTY.

By H. W. Biggie.

This party continued forest survey operations in Upper Burma and the Southern Shan States.

PERSONNEL.

Class I Officer.

Mr. H.W. Biggie.

Class II Officers.

Mr. W. G. Jarbo, up to 19th June 1920.
,, C. O. Picard, from 25th October 1919.
,, C. B. Sexton, up to 27th June 1920.

Upper Subordinate Service.

Mr. Bhamba Ram.

Lower Subordinate Service.

9 Surveyors, etc.

The country over which operations were carried out consists of well-wooded hills.

The field season closed on the 8th June 1920.

During the field season most of the members of the party suffered from periodical attacks of malaria from which there were two deaths among menials. A single case of cholera, a Kachin coolie, at the head-quarters camp at Banmauk in the Kathā district ended fatally.

Plane-tabling (*a*). (*Southern Forest Circle*).—This was carried out in sheets 93 D/5.6.7 in wooded hills ranging in altitude from 1,000 to 5,000 feet on either side of the district boundary between Meiktila and the Southern Shan States.

The work was under Mr. Jarbo with four unclassified surveyors and one pupil who was discharged as unsatisfactory. The out-turn was 87·6 square miles of detail survey on the 2-inch scale, of which 82·4 square miles lie in the Myittha, Pyinyaung, and Yebokson (east and west blocks) reserves in the Meiktila Forest Division and the Magwe reserve in the Southern Shan States Forest Division, and 5·2 square miles in adjoining non-reserved land.

The cost-rate per square mile is Rs. 258·9.

(*b*). *(Northern Forest Circle*).—This was carried out in sheets 83 P/9.10.14 in 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. The scenery is attractive and interesting, and the area is well provided with forest rest-houses which are a great convenience. The people are mostly Shans who are pleasing and agreeable, and ready to give assistance.

The work was under Mr. Sexton with Mr. Bhamba Ram and three surveyors. The out-turn was 35·50 square miles of detail survey on the 4-inch scale, and the whole area, excepting ·79 of a square mile in adjoining non-reserved land, lies in the Nansiaung, Chaunggyibya and Mode reserves in the Mansi Forest Division.

The cost-rate per square mile is Rs. 685·8.

Triangulation.—Subsidiary triangulation was carried out by Mr. Picard in the Chaunggyibya, Nansiaung, Hwelit, and Modo reserves in the Mansi Forest Division and the Mezabya reserve of the Kathā Forest Division. 37 points were fixed and cleared, as the triangulation previously completed in this locality by No. 10 Party was not found to give sufficient points for detail survey on the scale of 4 inches to one mile. No area can be given and, as the points were treated by the three-point problem and were provided to enable the closing of chain and compass traverses, details cannot be given under the main heading

"Triangulation" in Table II. The cost of the subsidiary triangulation is merged with the cost of traversing done in the same area.

Traversing (a). (Southern Forest Circle).—The area traversed lies in sheets 93 D/1.5.6.10 and comprises the country described under "Plane-tabling" in this circle, and the pine-clad plateau in and around the station of Kalaw in the Southern Shan States.

The work was under Mr. Jarbo with two traversers and one pupil surveyor. 178·3 linear miles of traversing, including 14·7 linear miles of revision was carried out, covering an area of 116 square miles in the Yupadaung reserve of the Meiktila Forest Division and the Magwe, Wetpyuye and Kalaw reserves of the Southern Shan States Forest Division.

The cost-rate per linear mile is Rs. 69·7.

(*b*). (*Northern Forest Circle*).—The area traversed is the same as that described under "Plane-tabling" in this circle. 44·4 linear miles of traversing was carried out, covering an area of 44·5 square miles in the Hwelit, Mode, and Mezabya reserves. The total cost, which includes the cost of the subsidiary triangulation done by Mr. Picard is Rs. 12,164.

The combined cost-rate per linear mile is Rs. 110·4 for traversing done for detail survey on the 2-inch and 4-inch scales in the Southern and Northern Circles respectively.

Recess duties.—(*a*). The fair-drawing of the party for which credit has been taken consists of 10·6 square miles on the 4-inch scale of the Nansiaung reserve in sheets 83 P/10.14 and 59 square miles on the 2-inch scale of the Myittha, Pyinyaung, and Yebokson (east and west blocks) reserves in sheets 93 D/5.6. All outline and contour drawing was done by transfer from hand traces made from the field sections. Contours were transferred to blue prints of the outline sheets.

The work was under Mr. Bhamba Ram with five surveyors of whom only three could be entrusted with fair-drawing.

The combined cost-rate per square mile is Rs. 62·3 for both scales of fair-drawing.

The total area of fair-drawing in hand is 174·2 square miles and this will be completed by the middle of November next.

(*b*). Other recess duties included the computations under Mr. Picard with two surveyors and five pupils. The work comprised the computations of the subsidiary triangulation and of 159 linear miles of traverses in the Southern and Northern Forest Circles.

The cost-rate per linear mile is Rs. 25·7. The combined cost-rate per linear mile for traversing and computations is Rs. 136·1.

Miscellaneous.—The cost-rates for all classes of work are abnormal and cannot be accepted as standards for the cost of special forest surveys. The year under report is the first complete year since the formation of the party and is burdened with the heavy initial expense of supplying it fully with tents, tarpaulins, furniture and various other items of equipment too numerous to mention. Freight, shipping and other dues on a large supply of instruments, tarpaulins and other items were payable from Calcutta to Maymyo or Indaw Railway Station in the Kathā district, and on 94 packages of tents occupying the full space of an 11-ton goods wagon, from Cawnpore to Indaw, whence they were transported by cart to Banmauk over a distance of 29 miles.

The party was working with a poorly qualified staff of Lower Subordinates. Four purely temporary Indians engaged when the nucleus of the party was formed in December 1918, turned out to be unsatisfactory, and all have now been discharged. The party was weaker throughout the year under report than when it existed as a detachment.

In the annual volume of the Records 1918-19, it was stated that "a scheme for training Burmans as surveyors is at present under consideration." This scheme is now in operation and a survey school under a Burmese instructor, lent by the Government of Burma, was started in Maymyo on the 1st July 1920 and now comprises 12 Burman and 4 Indian pupils.

The new office building for the party is now ready and will be occupied before the recess closes.

I am greatly indebted to the Chief Conservator and the officers of the Forest Department for the ready assistance which they have always accorded to further the work of the party.

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

TABLE I.

OUT-TURNS OF PLANE-TABLING 1919-20.

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.
½-inch	Original Survey	N	No. 2	Rājputāna ...	264	59·8	4·9	
		S	No. 6	Bombay	3	61·6	...	...
		S	No. 6	Hyderābād (Deccan)	3,380			
		E	No. 10	Upper Burma	2,516	73·1	0·4	0·9
		E	No. 12	Assam	1,099	59·3	1·7	0·3
½-inch	Revision Survey	N	No. 1	United Provinces	252	121·0	0·4	1·7
½-inch	Supplementary Survey	S	No. 6	Bombay	108	55·0	...	...
1-inch	Original Survey	N	No. 2	Rājputāna	115	31·4 (*a*)	14·0 (*a*)	0·6 (*a*)
					303	16·8 (*b*)	19·9 (*b*)	2·5 (*b*)
		S	No. 5	Central Provinces	2,667	23·4	10·9	4·4
		S	No. 6	Madras	170	57·7	...	...
		S	No. 6	Hyderābād (Deccan)	128			
		S	No. 8	Madras	147	17·5	2·0	25·1
		E	No. 9	Bengal	2,299	29·5	8·2	13·0
		E	No. 10	Upper Burma	723	17·3	1·1	6·4
		E	No. 11	Lower Burma	1,631	24·5	1 2	5·5
		E	No. 12	Assam	578	16·7	1·6	18·9
1-inch	Re-survey	N	No. 2	Punjab & United Provinces	395	28·8 (*a*)	12·8 (*a*)	4·2 (*a*)
					1,031	17·7 (*b*)	13·0 (*b*)	9·6 (*b*)
		N	No. 3	United Provinces	90	35·5	5·4	...
		E	No. 11	Northern Shan States ...	20	31·5	4·1	...
1-inch	Revision Survey	N	No. 1	United Provinces	4,928	58·6	2·4	1·8
		S	No. 5	Central Provinces	360	23·8	7·3	13·9
1-inch	Supplementary Survey	S	No. 8	Madras	4,523	27·6	6·7	7·5
1½-inch	Original Survey	S	No. 6	Hyderābād (Deccan)	266	5·4	...	...
1½-inch	Re-survey	S	No. 6	Hyderābād (Deccan)	16			
1½-inch	Revision Survey	E	No. 9	Bengal	45	2·3	15	18
2-inch	Original Survey	N	No. 3	United Provinces	1,237	11·1	16·5	1·5
		S	No. 8	Madras	3	7·1	...	...
		E	No. 12	Assam	290	8·7	2·6	24·4
		E	No. 21	Upper Burma	88	2·8	9·5	83·2
2-inch	Re-survey	N	No. 2	United Provinces	265	9·4	18·1	7·6
3-inch	Original Survey	E	No. 11	Lower Burma	103	3·4	13·9	118·3

(*a*) By trained surveyors. (*b*) By pupils.

TABLE I.—*Concluded.*

OUT-TURNS OF PLANE-TABLING 1919-20.—*Concluded.*

Scale.	Class of survey.	Circle.	Party.	Locality.	Out-turn, square miles.		Average number of fixings per square mile.	
					Total.	Average per man per month of 24 working days.	*In situ* (by resection).	Plane-table traverse.
3-inch	Original Survey (Mily.)	S	No. 6	Hyderābād (Deccan)	70	4·9	...	...
3-inch	Supplementary Survey (Mily.)	S	No. 6	Hyderābād (Deccan)	50	14·0	...	...
3½-inch	Experimental Aero. Survey	N	No. 2	Rājputāna and United Provinces	265	..	...	...
4-inch	Original Survey	E	No. 21	Upper Burma	36	1·1	0·3	372·4
6-inch	City Survey	N	No. 1	Punjab	35	Detailed figs. not available		
12-inch	City Survey	N	No. 1	Punjab				
16-inch	City Survey	N	No. 1	Punjab				
16-inch	Original Survey	S	No. 20	Secunderābād and Bolārum	acres 2,970	acres	per acre	per acre
				St. Thomas's Mount	1,943			
				Pallāvaram	1,685			
				Fort St. George and Mily. district lands	1,682			
				Poonamallee	459	268·2	0·2	3·4
				Velichi Military District lands	2,583			
				Cannanore	1,862			
				Wellington and Military lands	1,265			
16-inch	Revision Survey	S	No. 20	Bangalore Civil and Military Station	1,925	660·0	...	0·8
24-inch	Original Survey	N	No. 1	United Provinces	sq. miles 3	Detailed figs. not available		
					acres	acres	per acre	per acre
		N	No. 2	Rājputāna	4,492	148·2	2·5	
		N	No. 3	Punjab (Simla Extension)	1,270	91·5	4·1	...
64-inch	Original Survey	S	No. 20	St. Thomas's Mount Bāzārs	213			
				Pallāvaram	10			
				Cannanore	109	24·8	...	17·8
				Poonamallee	104			
				Ahmadnagar	5			
50 feet to 1-inch	Revision Survey	S	No. 20	Secunderābād Sadar bāzār	943	55·6	...	5·9
				Bolārum bāzār				

TABLE II.

DETAILS OF TRIANGULATION AND TRAVERSING 1919-20.

Scale.	Class of survey.	Circle.	Party.	Locality.	TRIANGULATION.									TRAVERSING.				
					Diameter of theodolite in inches.	Area in square miles.	Number of square miles to each point trigonometrically fixed.	Number of square miles to each height.	Stations.			Intersected Points.		Area in square miles.	Linear miles chaining.	Number of stations at which theodolite was set up.	Angular error per station in seconds.	Linear error per 1,000.
									Number of stations fixed.	Triangular error in seconds.	Linear error per mile in feet.	Number of intersected points fixed.	Linear error per mile in feet.					
1-inch .	Traversing .	N	No. 2	Rājputāna .	...	...	...	...	...	...	...	...	...	441	215	509	7·3	1·0
½-inch .	Ditto .	N	No. 2	Do. .	...	...	...	...	...	..	...	...	...	1058	209	476	7·3	1·0
2-inch .	Triangulation .	N	No. 3	United Provinces .	5	1,000	1·2	1·2	35 (a)	4·8	0·09	757	0·28	...	...	...	...	...
2-inch .	Ditto .	N	No. 3	Do. .	6	250	0·8	0·8	13 (a)	13·9	0·48	300	(b)	...	...	...	...	...
3-inch .	Military Original Survey	S	No. 6	Hyderābād .	6	60	0·2	0·2	16	7·0	0·20	276	0·36	...	...	...	...	...
16-inch .	Ditto .	S	No. 20	Cannanore Cantonment .	6	49	8·2	5·4	4	22·8	0·07	2	0·68	...	38·66	640	1·7	0·1
16-inch .	Ditto .	S	No. 20	Ahmadnagar .	6	...	...	...	...	...	...	...	...	...	1·26	23	10·4	0·9
16-inch .	Ditto .	S	No. 20	Secunderābād .	6	...	...	...	...	...	...	...	...	...	3·66	48	0·0	1·2
16-inch .	Ditto .	S	No. 20	Madras .	6	18	9·0	4·5	2		0·66	...	...	...	62·84	616	5·0	0·4
16-inch .	Ditto .	S	No. 20	Wellington .	6	4	4·0	1·0	1	11·7	...	...	...	...	13·37	302	5·8	1·3
16-inch .	Revision Survey .	S	No. 20	Bangalore Civil and Military Station	6	12	0·8	4·8	4	12	0·70	26	0·38		19·22	128	1·4	0·2
30 feet to 1-inch	Original Survey .	S	No. 20	Ditto Bāzārs .	6	12									18·84	594	0·0	0·1

(a) Excluding 3 G.T.H.S. and 28 G.T. secondary stations observed at.
(b) Not computed.

TABLE II.—*Concluded.*

DETAILS OF TRIANGULATION AND TRAVERSING 1919-20.—*Concluded.*

Scale.	Class of survey.	Circle.	Party.	Locality.	TRIANGULATION.									TRAVERSING.				
					Diameter of theodolite in inches.	Area in square miles.	Number of square miles to each point trigonometrically fixed.	Number of square miles to each height.	STATIONS. Number of stations fixed.	STATIONS. Triangular error in seconds.	STATIONS. Linear error per mile in feet.	INTERSECTED POINTS. Number of intersected points fixed.	INTERSECTED POINTS. Linear error per mile in feet.	Area in square miles.	Linear miles chaining.	Number of stations at which theodolite was set up.	Angular error per station in seconds.	Linear error per 1,000.
1-inch	Original Survey	E	No. 9	Bengal	...	...	...	...	...	...	...	...	...	2440	1,083	2,615	5·5	0·9
½-inch	Ditto	E	No. 10	Upper Burma	6	(*b*) 4,600	(*a*) 22·3	(*a*) 22·8	22	6·4	0·15	184	0·47	...	...	...	...	...
1-inch	Ditto	E	No. 11	Lower Burma	6	1,629	(*a*) 9·2	(*a*) 9·5	6	10·3	0·23	94	0·47	...	...	...	...	...
3-inch	Ditto	E	No. 11	Do.	6	107.	(*a*) 1·5	(*a*) 1·5	7	12·4	0·29	66	0·50	...	27·5	238	2·0	1·1
½-inch and 2-inch	Triangulation	E	No. 12	Assam	6	(*c*) 1,801	9·7	9·7	13	7·3	0·09	196	0·62	...	...	...	...	...
½-inch and 2-inch	Traversing	E	No. 12	Do.	...	...	...	...	...	...	...	...	...	173	264·1	4,129	3·6	2·2
2-inch	Original Survey	E	No. 21	Upper Burma	...	...	...	...	...	...	...	...	...	116	178·3	3,285	7·2	2·7
4-inch	Ditto	E	No. 21	Do.	...	...	...	...	37	...	...	...	...	45	44·4	1,077	7·2	3·1

(*a*) Additional points previously fixed will also be used in this area.
(*b*) This area includes 1,200 square miles of supplementary triangulation.
(*c*) Excludes about 300 square miles of overlap triangulation.

TABLE III.

COST-RATES OF SURVEY 1919-20.

Locality.	COST-RATES, RUPEES, PLANE-TABLING, PER SQUARE MILE.																					COST-RATES, RUPEES.				Total plane-tabling out-turns on all scales, square miles.	Total cost of party. Rs.	Remarks.
	¼-inch.		1-inch.				1¼-inch.		2-inch.			3-inch.		4-inch.	12&16 inch.	16-inch.		24-inch.	64-inch.	50 feet to 1-inch.		Traversing per linear mile.						
	Original survey.	Supplementary survey.	Original survey.	Re-survey.	Revision survey.	Supplementary survey.	Original survey.	Revision survey.	Original survey.	Re-survey.	Special Forest survey.	Original survey.	Supplementary survey.	Original survey.	Original survey from aeroplane mosaics.	Original survey.	Revision survey.	Original survey.	Original survey.	Correction of plans.	Triangulation per square mile.	Topographical.	Forest boundary.	Fair-mapping, per square mile.			
Punjab and United Provinces ...	...	...	...	...	13·2	...	...	...	...	...	..	...	...	...	...	...	...	...	...	...	...	...	...	13·9		...	
Punjab ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	226·4	...	...	...	...	...	...	...	...	...	5,218	1,31,704	
United Provinces ...	...	...	...	...	...	...	...	..	...	...	..	...	...	...	...	...	...	3385	...	...	...	...	...	...			
Punjab, Rājputāna and United Provinces ...	3·5	...	19·0	16·0	...	...	...	...	..	21·0	...	...	...	...	...	...	...	(e) 1·5	...	...	...	(b)19·2 (a)12·4	...	(b)5·0 (a) 2·3 (e)(d)0·4	2,638	1,33,034	Includes Rs. 8,645 debitable to the Secretary P. W. D., Rājputāna.
United Provinces ...	...	...	...	Indeterminate	...	...	...	...	44·8	...	...	...	...	...	...	...	...	...	...	...	•11·3	...	...	22·9	1,327	† 1,14,186	* Excluding area triangulated by an U. S. officer under training and including cost of arrears computations.
Punjab (Simla extension) ...	...	...	...		...	...	...	...	...	...	...	..	...	...	...	...	...	(e) 6·6	...	...	..	...	...	...	Indeterminate	...	† Includes Rs. 8,855 cost of Simla survey.
Central Provinces ...	...	...	20·5	...	25·0	...	...	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	11·2	3,027·1	99,715	
Bombay, Madras and Hyderābād ...	7·9	10·0	7·5	...	...	...	96·1	...	...	...	...	87·1	87·1	..	...	...	...	...	...	...	(f) 36·4	...	...	(a) 3·6 (b) 5·4 (c) 6·0	4,191·0	94,386	

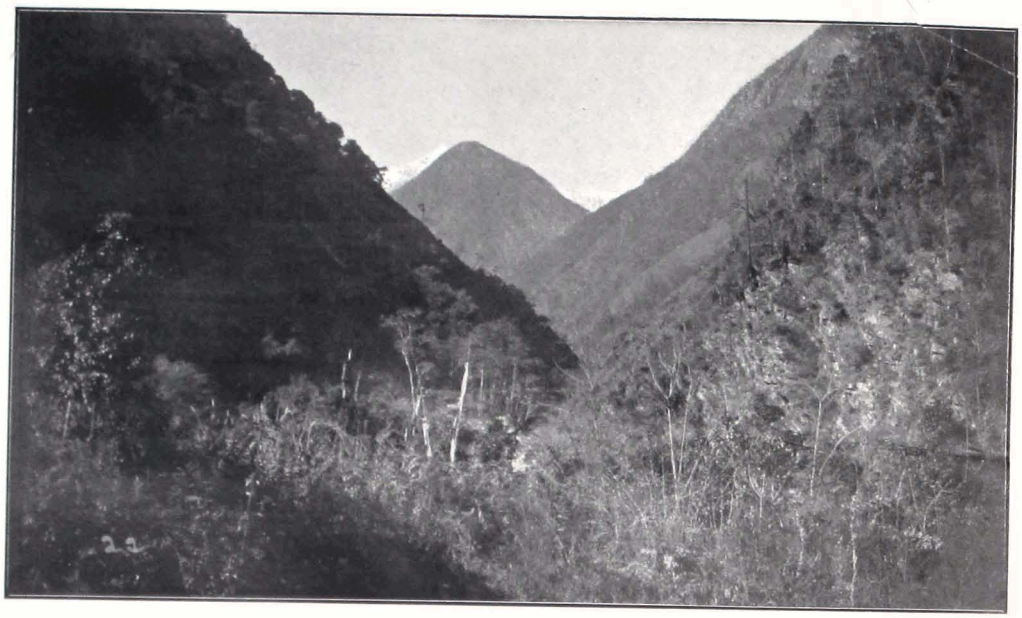
For ¼-inch. (b) For 1-inch. (c) For 2-inch. (d) For 24-inch. (e) Per acre. (f) Additional point previously fixed, will also be used in this area.

TABLE III.—*Concluded.*

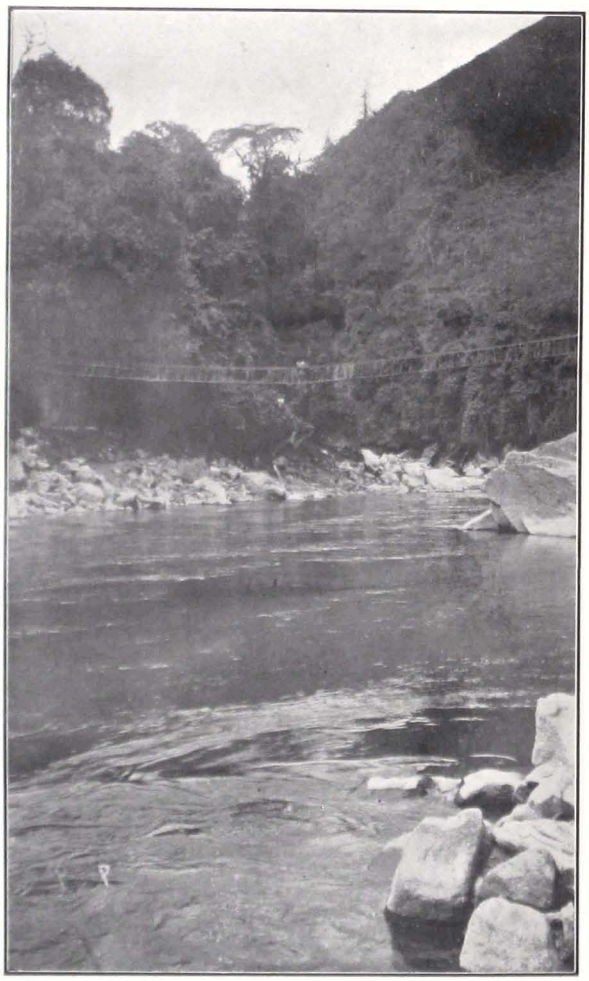
COST-RATES OF SURVEY 1919-20.—*Concluded.*

Party.	Locality.	COST-RATES, RUPEES, PLANE-TABLING, PER SQUARE MILE.																				COST-RATES, RUPEES.				Total plane-tabling out-turns on all scales, square miles.	Total cost of party.	Remarks.
		½-inch.		1-inch.				1¼-inch.		2-inch.			3-inch.		4-inch.	12&16 inch.	16-inch.		24-inch.	64-inch.	50 feet to 1-inch.	Triangulation per square mile.	Traversing per linear mile.		Fair-mapping, per square mile.		Rs.	
		Original survey.	Supplementary survey.	Original survey.	Re-survey.	Revision survey.	Supplementary survey.	Original survey.	Revision survey.	Original survey.	Re-survey.	Special Forest survey.	Original survey.	Supplementary survey.	Original survey.	Original survey from mosaics.	Original survey.	Revision survey.	Original survey.	Original survey.	Correction of plans.		Topographical.	Forest boundary.				
No. 8	Madras ...	...	...	10·8	...	...	17·5	...	...	53·8	...	...	...	...	...	...	...	..	...	...	...	...	..	...	7·9	4,673·4	1,21,487	
No. 20	Secunderābād and Bolāram, Ahmadnagar, St Thomas's Mount. Fort St. George and military district lands. Pallāvaram, Poonamallee, Velichi military district land, Cannanore, Wellington and military lands.	...	...	...	...	...	...	..	...	...	...	...	...	...	...	...	1·7	0·9	...	19·6	7·9	20·9	67·7	...	0·8	acres 17,763·4	70,933	Cost-rates are per acre.
No. 9	Bengal ...	...	...	19·9	...	...	...	...	14·5	...	...	...	...	...	...	...	...	...	...	...	...	...	13·2	...	8·5	2,344	96,797	
No. 10	Upper Burma ...	27·2	...	50·1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6·4	...	...	5·5	3,239·1	1,46.797	
No. 11	Lower Burma ...	...	...	70·4	...	...	...	...	...	...	...	...	170·1	...	...	...	...	...	...	...	...	22·6	...	...	3·1	1,754	2,00,681	Includes cost of Maymyo Drawing office.
No. 11	Northern Shan States	...	...	...	143·1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
No. 12	Assam ...	18·5	...	44·5	...	...	...	...	...	96·7	...	43·7	...	...	...	...	...	...	...	...	...	7·7	(c) 97·0 25·3	74·5	(b) 14·8 (a) 2·5	1,967	1,24,251	Includes Rs. 629 expenditure on special Forest survey debitable to Forest Dept.
No. 21	Upper Burma ...	...	...	...	...	..	...	...	...	258·9	...	...	...	...	685·8	...	...	...	...	...	...	...	...	110·4	62·3	124	94,877	

(*a*) For ½-inch. (*b*) For 1-inch. (*c*) Special Forest survey.



ACROSS THE FRONTIER. VIEW OF ADUNG WANG VALLEY NEAR THE SOURCE OF THE IRRAWADDY RIVER.



From photographs by Mr. M. C. Petters.

PUTAO DIST. A LIGHT CANE SUSPENSION BRIDGE WITH 12 INCH FOOTWAY ACROSS THE NAM TAMAI RIVER AT THE HEAD WATERS OF THE IRRAWADDY RIVER.

PART II.—GEODETIC AND SCIENTIFIC OPERATIONS.

TRIGONOMETRICAL SURVEY.

ASTRONOMICAL LATITUDES.

No latitude operations were carried out during the year under report. The personnel of this party was employed at the Head Quarters office of the Trigonometrical Survey for the greater part of the year but during February and March 1920 was employed on Air Photo Mapping at Agra and surrounding area. This work was carried out under the superintendence of Bt.-Major Lewis assisted by Bt.-Major E. O. Wheeler, M. C., R. E., and Captains E. A. Glennie, D. S. O., R. E., and H. G. Salmond (late R. A. F.). These three officers were lent by the Trigonometrical Survey office.

PERSONNEL OF NO. 13 PARTY.

Class I Officers.

Bt.-Major C. G. Lewis, R. E., in charge up to 14th June 1920.
Dr. J. de Graaff Hunter, M. A., Sc. D., F. Inst. P., in charge from 15th to 30th June 1920.
Captain G. Lennox, I. A., in charge from 1st July 1920.

Lower Subordinate Service.

1 Computer, etc.

Reports on this work by Bt.-Major Lewis and Captain Salmond have been published as a Professional Paper.

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.

Class I Officers.

Major C. M. Thompson, I. A., in charge up to 30th November 1919, from 21st January 1920 to 30th January 1920 and from 4th February 1920 to 20th February 1920.
Bt.-Lt.-Colonel C. P. Gunter, O. B. E., R. E., in charge from 1st December 1919 to 20th January 1920.
Lt.-Colonel G. A. Beazeley, D. S. O., R. E., in charge from 31st January 1920 to 3rd February 1920.
Major R. H. Thomas, D. S. O., R. E., in charge from 21st February 1920 to 4th April 1920.
Major E. T. Rich, C. I. E., R. E. in charge from 5th April 1920 to 19th April 1920.
Captain E. A. Glennie, D. S. O., R. E., in charge from 20th April 1920.

Lower Subordinate Service.

1 Clerk, etc.

TRIANGULATION.

The party did not take the field during field season 1919-20.

PERSONNEL OF NO. 15 PARTY.

Class I Officers.

Major R. H. Thomas, D. S. O., R. E., in charge up to 15th May 1920.
Captain O. Slater, M. C., R. E., in charge from 16th May 1920 to 30th September 1920.

Class II Officer.

Lieut. C. S. Mc Innes, from 1st October 1919 to 16th July 1920.

Lower Subordinate Service.

5 Computers, etc.

TIDAL OPERATIONS.

By O. C. Ollenbach.

Personnel of No. 16 Party.

Class I Officer.

Mr. O. C. Ollenbach in charge up to 9th December 1919. and from 10th June 1920.

Class II Officers.

Khan Sahib Syed Zille Hasnain in charge from 10th December 1919 up to 20th May 1920.

Mr. D. H. Luxa in charge from 21st May 1920 up to 9th June 1920.

Lower Subordinate Service.

20 Computers, &c.

During the year under report, the registrations of the tidal curves by means of self-registering tide-gauges were continued at the following ports :— 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 observatories being entrusted to the local officers of the ports concerned.

In addition to the above work, the predictions of the heights and times of high and low water for the year 1919 at the following ports :—Bhaunagar, Chittagong and Akyab, were compared against the actual observations of the heights and times of high and low water as supplied by the Port officers of the above ports. 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 many years ago, still maintained the required degree of accuracy.

TIDAL OBSERVATIONS AT BASRAH.

Hourly readings on an ordinary wooden tide-pole were carried out at Basrah by the military authorities; these readings were taken during day and night, and copies of these were supplied weekly throughout the year to this department by the Director, Inland Water Transport, Mesopotamia. The readings for the year commencing 1st January 1919, were reduced by the method of harmonic analysis, and the constants thus deduced, were used in the computations of data for the Basrah tide-tables 1921. These data were forwarded on the 18th December 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 for 1921 have not as 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 after a few years 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	41	
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 1904	1875 1906	1 1 } 2	
10	Porbandar ...	Personal	1893	1894	2	
10A	Porbandar ...	Automatic	1898	1902	2	Years 1898, 1899 & 1902 are excluded.
11	Port Albert Victor (Kāthiāwār).	Personal	1881	1882	1	
11A	Port Albert Victor (Kāthiāwār).	Automatic	1900	1903	4	
12	Bhaunagar ...	,,	1889	1894	5	
13	*Bombay (Apollo Bandar)*	,,	1878	Still Working	42	
14	*Bombay (Prince's Dock)*	,,	1888	,,	32	
15	Marmagao (Goa)	,,	1884	1889	5	
16	Kārwār	,,	1878	1883	5	
17	Beypore	,,	1878	1884	6	
18	Cochin	,,	1886	1892	6	
19	Tuticorin	,,	1888	1893	5	
20	Minicoy	,,	1891	1896	5	
21	Galle	,,	1884	1890	6	
22	Colombo	,,	1884	1890	6	
23	Trincomalee ...	,,	1890	1896	6	
24	Pāmban Pass ...	,,	1878	1882	4	
25	Negapatam ...	,,	1881	1888	5	Years 1883 to 1885 are excluded.
26	*Madras*	,,	1880 Restarted 1895	1890 Still Working	10 25 } 35	
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	39	
33	Chittagong ...	,,	1886	1891	5	
34	Akyab	,,	1887	1892	5	
35	Diamond Island	,,	1895	1899	5	
36	Bassein (Burma)	,,	1902	1903	2	
37	Elephant Point	,,	1880 Restarted 1884	1881 1888	5	Year 1880-81 is excluded.
38	*Rangoon*	,,	1880	Still Working	40	
39	Amherst	,,	1880	1886	6	
40	*Moulmein* ...	,,	1880 Restarted 1909	1886 Still Working	6 11 } 17	
41	Mergui	,,	1889	1894	5	
42	*Port Blair* ...	,,	1880	Still Working	40	
43	Basrah	Personal	1916	,,	4	Observations taken on a tide-pole.

WORKING OF THE OBSERVATORIES.

The tidal observatories at Rangoon and Moulmein were inspected jointly by Messrs. O. C. Ollenbach and D. H. Luxa.

Mr. O. C. Ollenbach visited Tavoy and inspected the proposed site for a tidal observatory there, but this site was found to be unsuitable and as no other suitable site was located in its neighbourhood, the Burma Government decided to hold this matter in abeyance for the present.

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

Mr. D. H. Luxa inspected the tidal observatories at Port Blair and Kidderpore.

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

(*a*) Checking the working zero of the tide-gauge, and comparing 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*) The cleaning and overhauling of all instruments thoroughly and getting 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 hole, 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.

Remarks regarding the working of each observatory inspected :—

Aden.—The inspection of this observatory was carried out in January 1920, it was previously inspected in December 1917 and was then found to be in a most unsatisfactory condition, but at the present inspection a vast improvement all round was noticed. The tide-gauge has worked very well during the past 2 years, and the tidal registrations have been continuous without a single break. The periodical reports, returns and tidal diagrams, were posted regularly from the observatory to the office of the Tidal operations.

Karāchi.—During the past year the interruptions in the tidal registrations at this observatory, due to the temporary blocking of the inlet hole, have been quite as frequent as in the preceding year. The duration of these interruptions has however been considerably decreased, due to the services of a diver having been placed at the disposal of the tidal observatory clerk, who as soon as he noticed any interruption in the tidal registration, was able to have the inlet hole examined and cleaned up by the diver. Most of these interruptions were found to have occurred during the winter months, and to be less frequent between March and September; in order to be able to overcome these interruptions, the tidal observatory clerk has been advised to use a brass plug containing a one-inch hole from October to February, and one with a $\frac{3}{4}$-inch hole from March to September. Both these brass plugs are kept in the observatory for this purpose. Except for these temporary breaks in the registrations of the tidal curves, the tide-gauge has worked satisfactorily.

Bombay (Apollo Bandar).—The tidal registrations at this observatory have been continuous and satisfactory since its last inspection in December 1918. Since when the well has been cleaned twice, viz. in May and November 1919.

Bombay (Prince's Dock).—The tide-gauge at this observatory has worked without a break during the past year. This is an exceptional record in the history of this observatory, as there used to be frequent interruptions in the tidal registrations for various reasons. The well of this observatory was cleaned in May and November 1919.

Madras.—The registrations of the tidal curves at this observatory have continued to be thoroughly satisfactory, not a single break in the registrations having occurred. This is chiefly due to the care and attention bestowed by the observatory clerk on his work.

Kidderpore.—There was only one break in the registration of the tidal curves at this observatory, and this was occasioned by the stoppage of the clock at 10.36 p. m. on the 4th March 1919. Except for this single interruption, the tide-gauge has worked very well during the past year.

Rangoon.—The tide-gauge at this observatory has worked without a single break throughout the past year.

Moulmein.—Since the last inspection of this observatory, only one break in the registrations was found to have occurred. The tide-gauge has worked well during the past year.

Port Blair.—The tidal registrations at this observatory have continued to be very satisfactorily carried out. There was not a single interruption in the registrations of the tidal curves during the past year. The tide-gauge and the auxiliary instruments were all found to be working well and in good order.

Computations and Reduction of Observations.

All the computations of the past year's work have been completed and there is nothing in arrears. The tidal observations at the nine working stations for the year 1919 have been reduced by harmonic analysis. In addition, the observations taken at Basrah on a tide-pole erected by the Military authorities, and supplied weekly to this department by the Director, Inland Water Transport, Mesopotamia, for the year 1919, have been similarly treated. The tidal constants, deduced from the above reductions, are shown in the attached tables.

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

Tide Symbol	ADEN $A_0=5\cdot841$				KARĀCHI $A_0=7\cdot247$				BOMBAY (Apollo Bandar) $A_0=10\cdot145$			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period		°		°		°		°		°		°
S_1	0·097	170·00	0·097	170·00	0·089	179·68	0·089	179·68	0·074	186·75	0·074	186·75
S_2	0·681	246·60	0·681	246·60	0·981	323·47	0·981	323·47	1·571	5·72	1·571	5·72
S_4	0·005	291·60	0·005	291·60	0·008	24·19	0 008	24·19	0·016	237·42	0·016	237·42
S_6	0·007	221·11	0·007	221·11	0·010	307·72	0·010	307·72	0·004	155·43	0·004	155·43
S_8	0·004	15·38	0·004	15·38	0·003	33·69	0·003	33·69	0·003	67·38	0·003	67·38
M_1	0·103	85·70	0·083	44·02	0·103	103·07	0·084	62·12	0·114	104·10	0·092	63·35
M_2	1·593	212·37	1·566	228·21	2·650	276·12	2·604	293·46	4·049	314·10	3·978	331·83
M_3	0·019	196·94	0·018	220·71	0·034	315·85	0·033	341·85	0·077	354·85	0·075	21·44
M_4	0·009	324·90	0·009	356·59	0·007	349·48	0·007	24·15	0·113	266·44	0·109	301·90
M_6	0·005	309·04	0·005	356·57	0·048	142·49	0·045	194·49	0·020	338·68	0·019	31·87
M_8	0·001	195·26	0·001	258·63	0 005	158·20	0·004	227·54	0·011	248·32	0·010	319·24
O_1	0·620	226·19	0·666	39·58	0·628	223.01	0·674	47·96	0·608	234·94	0·653	50·30
K_1	1·255	197·10	1·310	35·45	1·268	207·74	1·324	46·03	1·321	207·73	1·380	46·00
K_2	0·171	20·15	0·193	236·34	0 255	96·87	0·289	312·94	0·388	137·40	0·439	353·44
P_1	0·420	221·42	0·420	31·45	0·418	231·22	0·418	41·32	0·409	231·01	0·409	41·12
J_1	0·127	302·53	0·134	30·51	0·112	315·44	0·119	42·55	0·120	320·44	0·127	47·33
Q_1	0·148	115·89	0·159	43·76	0·151	123·38	0·162	53·60	0·146	129·61	0·157	60·45
L_2	0 052	162·31	0·046	233·98	0·079	236·68	0·071	309·04	0·072	277·56	0·065	350·11
N_2	0·434	93·18	0·426	223·50	0·626	146·50	0·615	279·11	0·982	184·17	0·965	317·39
ν_2	0 099	272·23	0·097	187·56	0·148	323·18	0·145	240·69	0·228	350·33	0·224	268·42
μ_2	0·064	151·49	0·062	183·18	0·050	233·71	0·048	268·38	0·176	273·42	0·170	308·88
T_2	0·069	233·03	0·069	234·62	0·117	307·68	0·117	309·32	0·180	350·70	0·180	352·36
$(MS)_4$	0·013	128·52	0·013	141·36	0.023	267·65	0·023	284·98	0 078	10·11	0·076	27·84
$(2SM)_2$	0·018	151·97	0·017	136·12	0·024	124·36	0·024	107·03	0·040	127·02	0·039	109·29
$2N_2$	0·088	318·39	0·087	203·19	0·080	5·21	0·079	253·09	0·104	63·56	0·102	312·26
$(M2N)_4$	0·013	118·18	0·013	264·34	0·024	192·50	0·023	342·44	0·028	102·37	0·027	253·31
$(M_2K_1)_3$	0·018	60·42	0·019	274·60	0·040	135·73	0·041	351·35	0·024	97·82	0·025	313·82
$(2M_3K_1)_3$	0·008	128·89	0·008	322·23	0·027	161·29	0·027	357·67	0·075	221·13	0·076	58·33
Long Period		°		°		°		°		°		°
Mm	0·039	175·82	0·037	61·35	0·051	31·82	0·048	276·55	0·043	345·70	0·041	230·22
Mf	0·031	177·70	0·036	26·75	0·044	23·17	0·052	230·61	0·039	27·37	0·046	234·39
MSf	0·015	172·03	0·015	156·19	0·029	157·99	0·029	140·66	0·046	81·27	0·045	63·54
Sa	1·349	74·32	0·349	354·29	0·142	196·36	0·142	116·27	0·111	23·33	0·111	303·22
Ssa	0·135	286·01	0·135	125·94	0·172	327·81	0·172	167·62	0·193	351·68	0·193	191·46

1919

Tide Symbol	BOMBAY (Prince's Dock) $A_0=8\cdot357$				MADRAS $A_0=2\cdot310$				KIDDERPORE $A_0=10\cdot382$			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period		°		°		°		°		°		°
S_1	0·087	183·81	0·087	183·81	0·028	79·18	0·028	79·18	0·091	198·50	0·091	198·50
S_2	1·628	4·41	1·628	4·41	0·458	268·44	0·458	268·44	1·515	98·62	1·515	98·62
S_4	0·015	216·40	0·015	216·40	0·002	184·97	0·002	184·97	0·084	108·37	0·084	108·37
S_6	0·002	157·17	0·002	157·17	0·002	148·00	0·002	148·00	0·004	26·57	0·004	26·57
S_8	0·003	356·31	0·003	356·31	0·002	190·62	0·002	190·62	0·005	255·96	0·005	255·96
M_1	0·119	102·16	0·096	61·41	0·008	5·86	0·006	325·36	0·032	246·26	0·026	206·03
M_2	4·169	312·83	4·096	330·57	1·113	221·48	1·094	239·71	3·845	36·82	3·778	55·60
M_3	0·076	357·38	0·074	23·97	0·001	335·23	0·001	2·58	0·033	320·01	0·032	348·18
M_4	0·114	295·11	0·110	330·57	0·007	156·57	0·007	193·04	0·760	353·96	0·733	31·52
M_6	0·010	110·48	0·009	163·68	0·006	29·75	0·006	84·45	0·171	252·13	0·162	308·46
M_8	0·003	293·75	0·003	4·68	0·001	75·96	0·001	148·90	0·081	178·46	0·076	253·58
O_1	0·615	234·01	0·661	49·36	0·086	146·13	0·093	322·01	0·200	205·02	0·215	21·47
K_1	1·341	206·73	1·400	45·00	0·280	137·91	0·293	336·16	0·387	214·36	0·404	52·58
K_2	0·369	135·73	0·418	351·77	0·108	49·27	0·122	265·27	0·401	235·01	0·454	90·96
P_1	0·407	231·27	0·407	41·38	0·096	165·67	0·096	335·80	0·159	237·59	0·159	47·75
J_1	0·123	319·90	0·130	46·79	0·021	225·20	0·022	311·79	0·033	302·83	0·035	29·11
Q_1	0·151	127·53	0·162	58·38	0·011	70·62	0·012	2·25	0·041	74·63	0·044	7·13
L_2	0·068	272·73	0·061	345·27	0·059	193·52	0·053	266·29	0·200	346·78	0·178	59·81
N_2	1·008	183·14	0·991	316·36	0·238	99·76	0·233	233·75	0·686	272·16	0·674	46·98
ν_2	0·227	355·58	0·223	273·68	0·059	272·08	0·058	190·91	0·318	83·36	0·313	2·98
μ_2	0·181	277·79	0·175	313·26	0·031	139·28	0·030	175·74	0·299	137·47	0·289	175·02
T_2	0·196	353·59	0·196	355·25	0·051	250·09	0·051	251·77	0·146	102·48	0·146	104·18
$(MS)_4$	0·119	24·92	0·117	42·65	0·003	157·83	0·003	176·07	0·663	54·48	0·652	73·25
$(2SM)_2$	0·049	126·85	0·048	109·11	0·018	222·95	0·018	204·71	0·094	19·77	0·092	0·99
$2N_2$	0·092	72·76	0·091	321·47	0·050	338·80	0·050	228·55	0·096	100·34	0·094	351·22
$(M_2N)_4$	0·013	172·19	0·013	323·15	0·003	96·12	0·003	248·34	0·289	234·93	0·279	28·54
$(M_2K_1)_3$	0·005	166·91	0·005	22·91	0·012	56·71	0·012	273·20	0·134	181·10	0·137	38·10
$(2M_2K_1)_3$	0·081	230·37	0·082	67·57	0·004	150·07	0·004	348·29	0·031	113·00	0·031	312·33
Long Period		°		°		°		°		°		°
Mm	0·048	351·64	0·045	236·15	0·057	211·04	0·054	95·28	0·310	145·18	0·292	29·13
Mf	0·039	35·25	0·046	242·26	0·052	154·66	0·061	1·13	0·270	207·23	0·317	53·11
MSf	0·049	76·17	0·048	58·44	0·024	226·68	0·024	208·44	0·884	59·80	0·869	41·02
Sa	0·114	119·97	0·114	39·86	0·405	291·59	0·405	211·46	2·429	232·03	2·429	151·87
Ssa	0·159	304·64	0·159	144·41	0·480	293·23	0·480	132·97	0·613	115·54	0·613	315·24

1919

Tide Symbol	RANGOON $A_0=10\cdot315$				MOULMEIN $A_0=8\cdot702$				PORT BLAIR. $A_0=4\cdot855$			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period		°		°		°		°		°		°
S_1	0·126	136·32	0·126	136·32	0·101	145·47	0·101	145·47	0·024	77·86	0·024	77·86
S_2	2·116	167·67	2·116	167·67	1·434	143·86	1·434	143·86	0·967	315·61	0·967	315·61
S_4	0·089	268·51	0·089	268·51	0·068	215·09	0·068	215·09	0·003	147·27	0·003	147·27
S_6	0·011	57·49	0·011	57·49	0·013	198·15	0·013	198·15	0·001	246·04	0·001	246·04
S_8	0·008	150·35	0·008	150·35	0·002	215·54	0·002	215·54	0·001	267·14	0·001	267·14
M_1	0·028	120·64	0·022	80·68	0·014	140·14	0·012	100·23	0·017	355·52	0·014	315·44
M_2	5·901	109·60	5·799	128·91	4·100	90·62	4·029	110·02	2·043	261·18	2·007	280·26
M_3	0·022	89·20	0·022	118·17	0·018	98·97	0·017	128·08	0·005	336·37	0·005	4·99
M_4	0·517	127·51	0·499	166·13	0·979	122·43	0·945	161·24	0·008	42·75	0·007	80·91
M_6	0·249	22·11	0·236	80·04	0·094	122·31	0·090	180·53	0·003	10·13	0·003	67·36
M_8	0·090	15·59	0·084	92·83	0·053	27·03	0·049	104·67	0·003	334·54	0·003	50·85
O_1	0·281	205·77	0·302	22·77	0·255	227·26	0·274	44·37	0·141	124·63	0·152	301·38
K_1	0·665	197·13	0·694	35·33	0·438	200·85	0·457	39·05	0·387	128·52	0·404	326·73
K_2	0·536	302·05	0·607	157·96	0·339	284·84	0·384	140·75	0·221	89·95	0·251	305·88
P_1	0·146	243·61	0·146	53·79	0·124	242·71	0·124	52·89	0·135	149·81	0·135	319·97
J_1	0·041	330·26	0·044	56·23	0·026	322·64	0·027	48·56	0·030	221·70	0·031	307·81
Q_1	0·038	107·29	0·041	40·63	0·048	122·79	0·051	56·28	0·016	355·27	0·017	288·24
L_2	0·471	63·72	0·420	136·99	0·335	36·88	0·299	110·19	0·083	211·02	0·074	284·19
N_2	1·039	342·88	1·020	118·52	0·713	320·83	0·700	96·63	0·390	143·11	0·383	278·40
ν_2	0·389	168·82	0·382	89·23	0·322	154·27	0·316	74·81	0·105	307·53	0·103	227·59
μ_2	0·561	245·81	0·542	284·43	0·385	230·76	0·371	269·58	0·071	261·52	0·068	299·68
T_2	0·302	141·51	0·302	143·24	0·237	123·61	0·237	125·34	0·120	290·26	0·120	291·98
$(MS)_4$	0·455	194·34	0·447	213·65	0·766	182·29	0·753	201·70	0·011	105·50	0·011	124·57
$(2SM)_2$	0·128	65·93	0·126	46·62	0·125	52·32	0·123	32·92	0·030	174·13	0·029	155·06
$2N_2$	0·233	172·22	0·229	64·19	0·092	122·17	0·090	14·35	0·045	50·82	0·044	302·32
$(M_2N)_4$	0·209	6·98	0·201	161·93	0·356	357·34	0·344	152·54	0·009	191·06	0·009	345·12
$(M_2K_1)_3$	0·161	235·90	0·165	93·42	0·201	230·66	0·206	88·26	0·024	82·49	0·025	299·78
$(2M_2K_1)_3$	0·112	207·56	0·112	47·97	0·100	221·98	0·101	62·59	0·003	323·13	0·003	163·07
Long Period		°		°		°		°		°		°
Mm	0·147	163·52	0·139	47·19	0·342	121·93	0·323	5·54	0·045	131·36	0·042	15·15
Mf	0·207	178·93	0·243	24·24	0·349	197·06	0·410	42·27	0·031	161·98	0·036	7·54
MSf	0·448	63·12	0·440	43·81	1·210	64·17	1·189	44·76	0·021	78·85	0·021	59·77
Sa	1·221	228·53	1·221	148·35	2·425	223·80	2·425	113·62	0·196	255·65	0·196	175·49
Ssa	0·091	307·94	0·091	147·59	0·699	72·77	0·699	272·41	0·188	339·71	0·188	179·38

1919

Tide Symbol	BASRAH $A_0 = 7 \cdot 230$				$A_0 =$				$A_0 =$			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short Period												
S_1	0·198	211°·34	0·198	211°·34								
S_2												
S_4												
S_6												
S_8												
M_1												
M_2	1·142	88·44	1·122	104·48								
M_3												
M_4												
M_6												
M_8												
O_1	0·345	183·75	0·371	357·34								
K_1	0·652	191·70	0·680	30·04								
K_2												
P_1	0·186	188·20	0·186	358·24								
J_1	0·032	232·92	0·034	320·78								
Q_1	0·080	71·95	0·086	0·13								
L_2												
N_2												
ν_2												
μ_2												
T_2												
$(MS)_4$												
$(2SM)_2$												
$2N_2$												
$(M_2N)_4$												
$(M_2K_1)_3$	0·198	189·51	0·203	43·88								
$(2M_2K_1)_3$	0·172	176·82	0·173	10·55								
Long Period												
Mm												
Mf												
MSf												
Sa												
Ssa												

Data forwarded to England.

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

(*a*) Values of the tidal constants for 40 ports for the tide-tables for 1923, ready for use for the tide-predicting machine.

(*b*) Values of the tidal constants for the tide-tables for Basrah for the year 1921.

(*c*) Actual heights and times of high and low water during 1918 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 the times and heights of high and low water-readings were taken during day-light on watches and tide-poles respectively.

(*d*) Comparisons of the above against predicted values for 1918, 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 1919, 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 the three other stations where tidal registrations by self-registering tide-gauges were stopped, but at which the times and the heights of high and low water were noted by a watch and read on a tide-pole respectively, during day-light. The errors of the predictions thus determined, are tabulated in the 6 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 1919.

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.	697	32	52	5	7	4
Karāchi ...	,,	696	31	37	15	11	6
Bhaunagar ...	T. P.	365	69	31	0	0	0
Bombay (Apollo Bandar)	Auto.	705	37	47	9	5	2
Bombay (Prince's Dock)	,,	700	38	44	9	7	2
Madras ...	,,	705	25	41	12	13	9
Kidderpore ...	,,	706	28	39	13	14	6
Chittagong ...	T. P.	365	12	45	10	17	16
Akyab ...	,,	365	90	9	0	0	1
Rangoon ...	Auto.	706	38	44	10	6	2
Moulmein ...	,,	705	30	42	9	13	6
Port Blair ...	,,	705	39	44	9	6	2

No. 2.

Percentages and amounts of the errors in the predicted times of low water at the various tidal stations for the year 1919.

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.	696	35	51	5	6	3
Karachi ...	,,	706	31	39	11	12	7
Bhaunagar ...	T.P.	365	68	32	0	0	0
Bombay (Apollo Bandar)	Auto.	705	36	46	8	6	4
Bombay (Prince's Dock)	,,	704	29	40	11	14	6
Madras ...	,,	706	24	35	13	18	10
Kidderpore ...	,,	705	29	43	12	11	5
Chittagong ...	T.P.	365	12	43	12	19	14
Akyab ...	,,	365	91	9	0	0	0
Rangoon ...	Auto.	705	30	40	14	12	4
Moulmein ...	,,	705	19	34	12	19	16
Port Blair ...	,,	706	40	46	9	4	1

No. 3.

Percentages and amounts of the errors in the predicted heights of high water at the various tidal stations for the year 1919.

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.	697	6·7	97	3	0	0
Karachi ...	,,	696	9·3	71	24	5	0
Bhaunagar ...	T.P.	365	31·4	64	34	2	0
Bombay (Apollo Bandar)	Auto.	705	13·9	79	17	4	0
Bombay (Prince's Dock)	,,	700	13·9	53	32	13	2
Madras ...	,,	705	3·5	83	15	2	0
Kidderpore ...	,,	706	11·7	35	27	20	18
Chittagong ...	T.P.	365	13·8	41	25	14	20
Akyab ...	,,	365	8·3	73	20	7	0
Rangoon ...	Auto.	706	16·4	54	30	13	3
Moulmein ...	,,	705	12·7	36	27	19	18
Port Blair ...	,,	705	6·6	91	9	0	0

No. 4.

Percentages and amounts of the errors in the predicted heights of low water at the various tidal stations for the year 1919.

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.	696	6·7	98	2	0	0
Karāchi ...	,,	706	9·3	76	22	2	0
Bhaunagar ...	T.P.	365	31·4	59	38	3	0
Bombay (Apollo Bandar)	Auto.	705	13·9	76	21	3	0
Bombay (Prince's Dock)	,,	704	13·9	63	27	7	3
Madras ...	,,	706	3·5	87	12	1	0
Kidderpore ...	,,	705	11·7	46	29	12	13
Chittagong ...	T.P.	365	13·3	28	27	20	25
Akyab ...	,,	365	8·3	65	31	4	0
Rangoon ...	Auto.	705	16·4	36	27	17	20
Moulmein ...	,,	705	12·7	44	25	13	18
Port Blair ...	,,	706	6·6	97	3		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 1919.

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.	
Open Coast.			H. W.	L. W.	H. W.	L. W.	H. W.	L. W.
Aden	Auto.	6·7	10	9	0·025	0·025	2	2
Karāchi	,,	9·3	12	12	0·027	0·027	3	3
Bhaunagar	T.P.	31·4	4	5	0·011	0·011	4	4
Bombay (Apollo Bandar)	Auto.	13·9	9	10	0·018	0·018	3	3
Bombay (Prince's Dock)	,,	13·9	10	12	0·030	0·024	5	4
Madras	,,	3·5	14	15	0·071	0·048	3	2
Akyab	T.P.	8·3	3	3	0·030	0·040	3	4
Port Blair	Auto.	6·6	9	9	0·025	0·025	2	2
General Mean	...	...	9	9	0·030	0·027	3	3
Riverain.								
Kidderpore	Auto.	11·7	13	12	0·057	0·043	8	6
Chittagong	T.P.	13·3	17	17	0·044	0·056	7	9
Rangoon	Auto.	16·4	9	12	0·025	0·041	5	8
Moulmein	,,	12·7	12	18	0·046	0·046	7	7
General Mean	...	...	13	15	0·043	0·047	7	8

No. 6.

Summary for 1919.

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	78	75	96	97	97	98
2 ,,	Tide-pole	100	100	96	97	99	100
3 Riverain	S. R. Tide-gauge	74	65	70	69	93	92
1 ,,	Tide-pole	57	55	66	55	91	86

Comparisons of the Predictions for the year 1919 with those for the previous year.

On comparing the tidal predictions at the nine working stations for the year 1919 against those for the year 1918, it was seen that the predictions of times for 1919 at Aden had improved, while those for Madras had deteriorated in accuracy since the previous year. The predictions of times at the other stations, and of the heights at all the stations, except at (Apollo Bandar) Bombay were practically of the same standard of accuracy as those for the year 1918.

The greatest difference between the actual and predicted heights of low water for 1919 at the riverain ports was as follows :—

Kidderpore ... 2 feet 2 inches on 10th August 1919, actuals being lower.
Rangoon ... 2 feet 11 inches on 28th September 1919, actuals being lower.
Moulmein ... 2 feet 10 inches on 14th August 1919, actuals being higher.

Tide-Tables.

The tide-tables for the year 1920 for the Indian Ports as also for Basrah were received from England on the 6th and 12th January 1920 respectively, and were immediately distributed to the various Port authorities and other officials.

The tide-tables for the year 1921 have not as yet been received from England, they will be despatched to the various authorities as soon as they are received. The printing of the tide-tables for Basrah for 1920 was discontinued at the office of the Trigonometrical Survey, Dehra Dūn; these tables were printed by Messrs. Neill and Co., Ltd., Edinburgh, the printers of tide-tables for the Indian Ports.

The amount realised on the sale of tide-tables during the year ending 30th September 1920, was Rs. 3599/3/9 inclusive of Rs. 600 which was outstanding from the previous year for the sale of the 1919 tide-tables.

Health of Party.

One computer died during the year under report.

Programme for season 1920-21.

Tidal observations during the coming field season will be continued at the 9 observatories still working.

LEVELLING

By Brevet-Major K. Mason, M.C., R.E.

PERSONNEL OF No. 17 PARTY.

Class I Officer.

Bt.-Major K. Mason, M. C., R. E. in charge from 11th May 1920.

Class II Officers.

Mr. H. G. Shaw, retired: in temporary employ in charge up to 10th May 1920.
" O. N. Pushong.
" K. S. Gopalachari, B. A.
" N. N. Chuckerbutty, L. C. E.

Upper Subordinate Service.

Mr. K. K. Das, B. A.
" S. C. Mukerjee.

Lower Subordinate Service.

10 Computers.
1 Recorder.
1 Clerk.

I. The party comprised two field detachments and a small head-quarters. It closed its office at Mussoorie on the 16th October 1919 and opened at Dehra Dūn on the 20th October 1919.

Detachments left for the field between the 6th and 9th November 1919 and returned to recess quarters at Mussoorie between the 19th and 28th May 1920.

II. Field Detachments. The two double detachments that took the field were composed as follows:—

No. 1 Detachment. Mr. Chuckerbutty (in charge); second leveller, Mr. Mukerjee. During the "fore and back" work, the former had charge of detachment 1 (A), the latter 1 (B).

No. 2 Detachment. Mr. Pushong (in charge); second leveller, Mr. Gopalachari.

III. Programme. The programme was allotted to these two detachments as follows:—

No. 1 Detachment.

(*a*) *In the Punjab.* Revision of the line from Ferozepore *via* Moga and Jagraon to Ludhiāna along the Ludhiāna-Ferozepore road. (Part of line 61).

(*b*) *In the Punjab.* New line from Amritsar *via* Jullundur and Phillaur to Ludhiāna along the Grand Trunk road. (New line 56 F). This is part of line 137 of the New Level Net.

(*c*) *and* (*d*) *In the Sind-Sāgar Doāb.* New line from Shāhpur T. S. *via* Leiah and Khairāwāla to Shorkot Road railway station. New line from Khairāwāla *via* Jandānwāla to near Wānbhachrān railway station.

No. 2 Detachment.

(*e*) *and* (*f*) *In Assam and Bengal.* Revision of the line from Silchar *via* Karīmganj to Comilla. (Line 77 H and part of 77 F).

(*g*) *In the U.P.* Revision of the section Bareilly to Lucknow. (Part of line 64).

IV. Systems of Levelling. Lines (*a*) and (*b*) were levelled on the "fore and back" system; (*c*), (*d*), (*e*) and (*f*) by the simultaneous double levelling method; while (*g*) was levelled on a modified form of the "fore and back" system.

V. Instruments. The instruments used were in all cases Binocular Precise Levels; staves were of the Survey Committee pattern. Weekly comparisons were made in the field against 10-foot standard tapes in order, as nearly as possible, to determine the variation of the length of the staves due to humidity changes at the time of observation.

VI. Out-turn. The out-turn consisted of:—

(*a*) and (*b*), 182 miles of levelling of high precision in the Punjab; the heights of 4 primary and 155 secondary bench-marks were determined.

(*c*) and (*d*), 228 miles of new secondary levelling of precision in the Sind-Sāgar Doāb, for the Punjab Irrigation Department; the heights of 80 secondary bench-marks were determined during this levelling.

(*e*) and (*f*), 196 miles of revision levelling of precision in Assam, to investigate the effects of seismic disturbance due to the Srimangal earthquake of 8th July 1918. 5 primary and 122 secondary bench-marks were connected by this line.

(*g*), 176 miles of revision levelling of high precision in the U.P., undertaken owing to the loss of old bench-marks. The heights of 7 primary and 177 secondary bench-marks were determined during this levelling.

The total out-turn is therefore 358 miles of primary levelling of high precision and 424 miles of secondary levelling of precision; the details of this will be found in table I.

VII. River Crossings. In line 56 F, Amritsar to Ludhiāna, the Beās and the Sutlej were crossed by the main bridges on the Grand Trunk road.

In line 55 F, between Shorkot and Jandānwāla, the Chenāb was crossed by a long 'shot' of 7 chains.

VIII. Probable accidental and systematic errors.

(i) The probable and mean accidental and systematic errors for the 'fore and back' lines according to the formulæ*

$$\eta_r^2 = \frac{1}{9}\left[\frac{\Sigma\Delta^2}{\Sigma L} - \frac{\Sigma r^2}{(\Sigma L)^2}.\Sigma\frac{S^2}{L}\right].$$

$$\sigma_r^2 = \frac{1}{9\Sigma L}.\Sigma\frac{S^2}{L}.$$

are as tabulated below:

The maximum errors in each class permitted by the International Geodetic Association in order to admit the classification of the work as "Levelling of high precision" are also shown.

Line	Probable accidental error. Ft. per mile	Maximum permissible	Mean accidental error. Ft. per mile	Maximum permissible	Probable systematic error. Ft. per mile	Maximum permissible	Mean systematic error. Ft. per mile	Maximum permissible
(*a*) Amritsar to Ludhiāna	±0·00287	±0·00416	±0·00431	±0·00624	±0·00032	±0·00106	±0·00048	±0 00159
(*b*) Ferozepore to Ludhiāna	±0·00245	±0·00416	±0·00368	±0·00624	±0·00059	±0·00106	±0·00089	±0·00159
(*g*) Bareilly to Lucknow	±0·00207	±0·00416	±0·00311	±0 00624	±0 00040	±0·00106	±0·00060	±0·00159

It will be seen from the above table that lines (*a*),(*b*) and (*g*) fulfil the conditions required for classification as "Primary levelling of high precision".

(ii) The probable error of the mean result per mile of simultaneous double levelling for the whole of India according to the formula†

$$\text{P. E.} = \pm 0{\cdot}6745\sqrt{\frac{\Sigma d^2}{4M}} \text{ is } \pm\ 0{\cdot}0042 \text{ ft.}$$

The probable errors of lines (*c*) Shorkot Road railway station to Jandānwāla, (*d*) Khairāwāla to Shāhpur T.S., (*e*) Karīmganj to Silchar and (*f*) Karīmganj to Comilla are ±0·00242 ft., ±0·00252 ft., ±0·00264 ft. and ±0·00215 ft. respectively.

IX. Health. The health of both the detachments remained good on the whole throughout the season.

X. Discussion of Results.

A. *The lines Ferozepore to Ludhiāna and Amritsar to Ludhiāna.*

(*1*) *History.* The line Ferozepore-Ludhiāna-Ambāla, a section of line 61 (Ferozepore-Meerut), was originally levelled in the years 1860-61-62. In the season 1905-06 the standard bench-mark at Ludhiāna was connected to this old line from the bench-mark at Dorāha. The values published to date are those derived from these two levellings which were employed in the adjustment of the old level net of India.

In 1913-14, the line Ambāla-Ludhiāna was relevelled.

Accepting the latest adjusted value at Ambāla, this revision showed a *rise* of 0·301 ft. at Dorāha compared with the 1860-62 work, while the section Dorāha-Ludhiāna showed but little discrepancy from that done in 1905-06.

This discrepancy of nearly four inches in 57 miles could not be explained by faults in levelling, and it was decided to hold the publication of the results of this line in abeyance, pending the revision of the line Ferozepore-Ludhiāna and the levelling of the new line Amritsar-Ludhiāna.

The levelling of these two lines was completed during last field season, and shows that the section Ferozepore-Jagraon is on the whole unaltered since the early levelling of 1860-62.

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* Departmental Paper No. 6, page 18. Formula 1st and 2nd (a).

† Pages 375 and 377 of G.T.S. Volume XIX.

(2) *Adjustment of discrepancies.* The three lines from Ludhiāna to Ambāla, to Ferozepore, and to Amritsar have now been readjusted from the results of 1913-14 and 1919-20 as follows:—

The standards at Amritsar, Ferozepore and Ambāla are accepted from their most recently adjusted and published values as the basis of adjustment.

The section Ferozepore-Jagraon is accepted from the old levelling, with the exception of one embedded bench-mark at Ferozepore which appears to have suffered local subsidence, and for which a new value has been assigned. The heights of new bench-marks on this section have been made accordant with the preceding and succeeding old bench-marks.

Three values are now obtained for the bench-mark at Dorāha, *viz.*—

from Ambāla, 843·552 feet.
from Jagraon, 843·331 feet.
from Amritsar, 843·313 feet.

A new value for this bench-mark, B.M.1/53 B, now designated $110_{(1)}$/53B has been adopted from the mean of these three values (843·399 ft.).

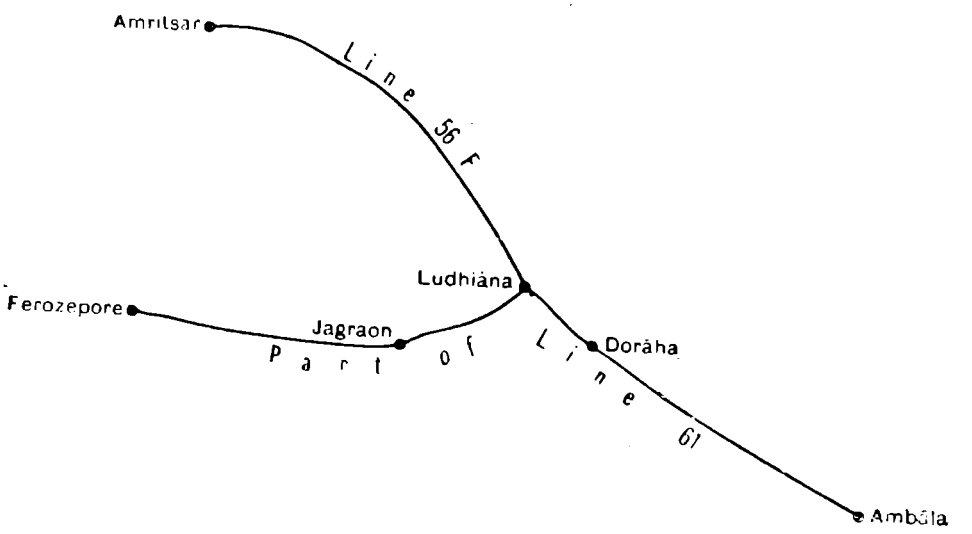
Accepting this new value at Dorāha and the published standard at Ambāla, the error in the Dorāha-Ambāla section has been distributed in direct proportion to the distances between the bench-marks. The discrepancy between the new and old heights of B.M. 19/53 B and B.M. 35/53 B is inappreciable and their old heights are retained; B.M.15/53 B is assigned a new value and designation (B.M.$113_{(15)}$/53 B).

Between BM.4/44N (Jagraon) and BM.1/53B (Dorāha), (now designated B.M. $110_{(1)}$/53B), adjustment has been made to conform with the published height of Jagraon and the new height of Dorāha, obtained from the mean of the three values specified above. All the old bench-marks at Ludhiāna and between this place and Dorāha have thus obtained new height values.

The new bench-marks between Amritsar and Ludhiāna are adjusted to conform with the published standard at Amritsar and the new value at Ludhiāna, obtained from the section Jagraon-Ludhiāna-Dorāha.

(3) *Remarks.* The above has seemed the most suitable method of provisionally distributing the discrepancies at this Ludhiāna link. It seems fairly certain that the bench-marks in the Ambāla district have settled, since the last adjustment to the net. This supposition can however only be proved by check-levelling a series of radiating lines from Ambāla, to more stable Standards. At present there is no prospect of this being done and it has been considered advisable to distribute the errors over these lines as described above, with a view to bringing the results into general accordance, and to avoid further delay in publication.

Sketch showing Amritsar-Ferozepore-Ambāla level link.
(Not drawn to scale).



B. *Levelling in the Sind-Sāgar Doāb.*

The two new lines mentioned in III, (*c*) and (*d*) have been set up as follows:—

(1) Line 55 F. Shorkot Road railway station *via* Khairāwāla to Jandānwāla; the portion from near Jandānwāla to near Wānbhachrān railway station is treated as a branch-line.

(2) Line 55 G. Khairāwāla *via* Leiah to Shāhpur T.S.

As regards line 55F, the discrepancy between the old and new heights at the terminal bench-marks, 19/44B (Shorkot) and 15/38P (Jandānwāla) was −0·419 ft. in 132 miles.

The old heights of the terminals are accepted and the heights of the intermediate bench-marks burdened with this discrepancy distributed proportionately to distances.

In considering the line 55G, the height of Khairāwāla, BM.162/39N, was adopted from the line 55F, *adjusted*, and the heights of all bench-marks to Shāhpur T.S. taken direct from the new levelling. The accepted height of Shāhpur T.S. disagrees with that now obtained by −0·176 ft. It was considered advisable to give Shāhpur T.S. a new value, not only on account of this discrepancy, but because check-levelling executed between the three tower stations, Shāhpur T.S., Farowāla T.S., and Sukhīwāla T.S. gave discordant results. All these three have therefore been given new height values accordant with the new levelling; these values disagree with the old by +0·176 ft., −0·153 ft. and +0·290 ft. respectively and indicate irregular disturbance.

C. *Silchar to Comilla (Srimangal earthquake area).*

Work was commenced at Silchar on 25th November 1919 and closed at Comilla on the 16th February 1920.

The line was originally levelled in 1911-12. Revision was undertaken in the winter of 1919-20 to investigate whether any disturbance had taken place during the earthquake of 8th July 1918, the epicentre of which was reported in the Records of the Geological Survey of India, Volume XLIX, Part III, 1918* to be in the Bālisirā Hills near Kālī Ghāt 3½ miles south of Srimangal railway station. It is to be regretted that the mark-stone of Churāmani H.S. which was connected by spirit levelling in 1911-12, and the location of which cannot have been a quarter of a mile from the epicentre, was destroyed by the earthquake and the pillar razed to the ground. Thus no comparison of this point was possible. The knoll on which the H.S. stood and the spurs immediately south of it bore deep fissures zig-zagging down the hillsides.

The G.T.S. bench-marks north of and within a quarter of a mile of Srimangal railway station which was practically destroyed by the earthquake show no subsidence, nor is there any evidence of regular disturbance west of Srimangal until the low range of hills 6 miles west of it and lying between Sātgaon and Rasidpur is crossed. Three quarters of a mile north of Rasidpur railway station, a tree bench-mark at Kamaichara shows practically no alteration; a mile and a half west of this the settlement of all bench-marks begins. The settlement varies from 1½ inches to 9 inches according to the nature of the soil and type of bench-mark and continues uninterruptedly past Mīrpur dāk bungalow, Shāistaganj and Shahaji Bāzār up to a railway bridge 30 miles from Srimangal near telegraph post No. 149/14 which shows practically no alteration in height (see table next page). Thereafter settlement is occasional but very small to Kamalasāgar beyond which no appreciable disturbance has taken place. The bench-marks that have settled include two of the embedded type, but unfortunately none on rock which is situated some distance beneath the alluvial soil.

Comparing results with plate II of the Report in the Geological Survey of India Records, Volume XLIX, Part III, 1918, as far as can be ascertained by precise levelling no settlement took place in the epicentral area N.E. of the epicentral axis, but in the area between the epicentral area and Isoseist No. 2, west-south-west of the former, settlement up to 9 inches occurred. Those bench-marks situated on masonry above ground have generally been disturbed more than those embedded in the soil; the latter however show distinct settlement.

The following table shows the bench-marks disturbed in the area between Kamaichara and the railway bridge near telegraph post No. 149/14 mentioned above.

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* The Report of this earthquake contained in this Volume of the Geological Survey Records, should be studied for a full appreciation of the value of the levelling evidence. See also the Memoirs of the Geological Survey of India, Vol. XLVI, Part I, dealing with Srimangal earthquake published in 1920.

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

Bench-marks of the original Levelling that were connected during the revisionary operations.			Distance between bench-marks.	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 1919-20 than when originally levelled.	Remarks.
Number	Degree Sheet	Description.		From published Leights. Original levelling.	Date of Original levelling.	From revision 1919-20 (Unadjusted).		
35	83 D	Embedded bench-mark at Karimganj	0·0	0 000	1911-12	0·000		* In 77·6 miles, *i.e.* practically unaltered. Difference in level from tree B.M. in Kamaichara village (origin of subsidence).
50	78 P	Tree in Kamaichara village	77·6	+ 4·390	,,	+ 4·336	− 0·054*	0·000
51	,,	On wing-wall of road bridge	1·4	−15·008	,,	−15·103	− 0·095	− 0·041
52	,,	On kerb of well of Mirpur I.B.	1·2	−13·131	,,	−13·263	− 0·132	− 0·078
53	,,	Embedded bench-mark at Mirpur I.B.	0·0	−17·523	,,	−17·705	− 0·182	− 0·128
54	,,	On wing-wall of road bridge	2·4	−14·304	,,	−15·065	− 0·761	− 0·707
55	,,	On wing-wall of road bridge	1·8	−16·824	,,	−17·360	− 0·536	− 0·482
56	,,	On verandah flooring of Shāistaganj I.B.	0·7	−20·170	,,	−20·469	− 0·299	− 0·245
57	,,	On wing-wall of road bridge	1·7	−24·698	,,	−24·845	− 0·147	− 0·093
58	,,	On railway boundary stone	2·9	− 3·693	,,	− 3·806	− 0·113	− 0·059
60	,,	Embedded bench-mark at Shahaji Bāzār I. B. ...	0·9	− 4·799	,,	− 4·991	− 0·192	− 0·138
61	,,	Tree opposite telegraph post No. 152/7	2·5	− 6·067	,,	− 6·270	− 0·203	− 0·149
62	,,	On wing-wall of railway bridge	2·8	−12·835	,,	−12·863	− 0·028	+ 0·026 in 18 miles

The levelling results are interesting from the point of view of the cause of the earthquake. The Geological Survey had already pointed out the probable existence of a fault in the neighbourhood of and parallel to the major epicentral axis. The levelling appears to confirm this and to point to the cause of the earthquake as being a crustal slip on the fault-plane. A large portion of the crust west-south-west of this fault-plane appears to have subsided to an extent varying from two to nine inches, while that portion lying on the other side (E.N.E.) of the fault remained stationary*.

D. *Bareilly to Lucknow.*

Work commenced at Lucknow on 6th March and closed at Bareilly on 6th May 1920. The country was practically level but the approach of the hot weather made levelling operations difficult.

The line was originally levelled in the seasons 1867-68-69 and was relevelled mainly owing to the loss of old bench-marks. Revision, which was a modified form of the 'fore and back' system, disclosed no changes of interest or worthy of discussion. Mile-stones, bridges, etc., are all either new or repaired so that with the exception of the bench-marks at Bareilly, Shāhjahānpur, Sītāpur and Lucknow, no comparison with old values is fair. A few old bench-marks which were identified with certainty and which showed small but decided alterations, and those which were considered doubtful have been assigned new values. It is to be regretted that in a few cases the officials who were entrusted with the construction of bench-marks did not adhere to the plans and designs supplied by this department.

XI. General notes; future programme and research.

(*a*) *Systems of levelling.* In 1913-14, the new system of "fore and back double levelling of high precision" on the lines laid down by the 17th General Conference of the International Geodetic Association on the 25th September 1912 was first adopted by this department.

* *Vide* Memoirs of the Geological Survey of India. Vol. XLVI, Part I, Calcutta, 1920.

This method is unnecessarily refined for much of the levelling required in India and it has been decided that in future our work shall consist of:—

(i) Levelling of high precision on the "fore and back" system.

(ii) Levelling of precision on the simultaneous system.

The first mentioned system will be employed for all levelling for the new geodetic level net of India, a programme for which has been drawn up. It is intended that this net shall be levelled with the utmost precision having in view the elimination of all possible sources of error and that it shall be worked independently of, and superimposed on, the old level net, which will eventually be readjusted to the new net. According to the present programme, which may undergo modification in course of time, the new net consisting of about 13,300 miles of levelling should be complete in 1938. As far as practicable the new net will be levelled mesh by mesh beginning at the north-west of India and ending in the extreme south.

The following table shows the programme for the new level net:—

Table showing programme for New Level Net.

Season	Line	From	To	Miles	Completed	Remaining	Season's or double season's total	Remarks
...	140	Muttra	Bareilly	130	130	...	...	
...	120	Aurangābād	Calcutta	310	310	...	...	
1920-21	*Part* 101	Kotri	Jacobābād	314	...	314	644	
,,	107	Muttra	Mārwār Pāli	330	...	330		
1921-23	*Part* 101	Karāchi	Kotri	258	...	258	1248	
,,	101	Jacobābād	Khānpur					
,,	105	Khānpur	Jhang	245	55	190		
,,	113	Surat	Dhūlia	130	...	130		
,,	102	Khānpur	Mārwār Pāli	339	...	339		
,,	104	Viramgām	Tatta	331	...	331		
1923-25	103	Mārwār Pāli	Viramgām	214	...	214	1258	
,,	136	Jhang	Lāla Mūsa	170	...	170		
,,	137	Lāla Mūsa	Ludhiāna	200	90	110		
,,	138	Ludhiāna	Hissār	130	...	130		
,,	106	Jhang	Muttra	453	365	88		
,,	108	Muttra	Cawnpore	201	...	201		
,,	142	Cawnpore	Rāmnagar	80	45	35		
,,	139	Ludhiāna	Bareilly	310	...	310		
1925-27	141	Bareilly	Rāmnagar	160	...	160	1338	
,,	109	Cawnpore	Bhopāl	312	130	182		
,,	110	Bhopāl	Ajmer	305	...	305		
,,	111	Bhopāl	Dhūlia	260	...	260		
,,	112	Viramgām	Surat	235	...	235		
,,	115	Bhopāl	Nāgpur	196	...	196		
1927-29	114	Dhūlia	Nāgpur	321	...	321	1412	
,,	116	Nāgpur	Raipur	170	...	170		
,,	119	Cawnpore	Aurangābād	289	95	194		
,,	118	Raipur	Aurangābād	342	...	342		
,,	143	Rāmnagar	Samāstipur	385	...	385		

Skeleton Map showing lines of proposed new Level Net of INDIA

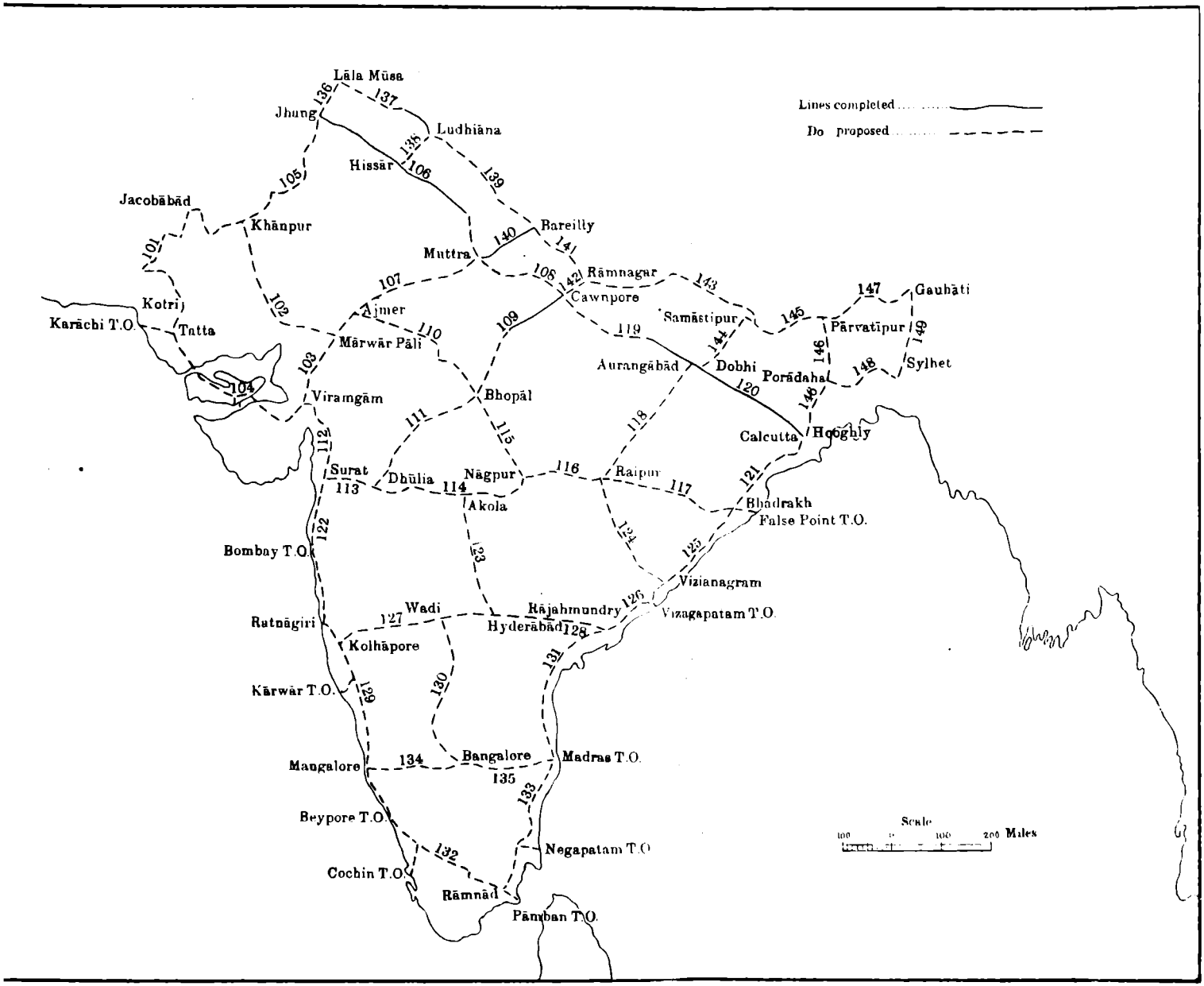

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Table showing programme for New Level Net.—(Concld.).

Season	Line	From	To	Miles	Completed	Remaining	Season's or double season's total	Remarks
1929-31	144	Sāmāstipur	Dobhi	116	...	116		
,,	145	Samāstipur	Pārvatīpur	235	...	235		
,,	146	Pārvatīpur	Hooghly	230	...	230		
,,	149	Sylhet	Gauhāti	110	..	110	1353	
,,	147	Pārvatīpur	Gauhāti	210	...	210		
,,	148	Porādaha	Sylhet	220	...	220		
,,	121	Calcutta	Bhadrakh	232	...	232		
1931-33	117	Raipur	Bhadrakh	336	...	336		* Includes branch-line to Bombay (ApolloBandar) T.O.
,,	122	Surat	Ratnāgiri	348	...	348*		
,,	123	Akola	Hyderābād	286	...	286	1385	† Includes branch-line to Vizagapatam T. O.
,,	128	Hyderābād	Rājahmundry	255	...	255		
,,	126	Vizianagram	Rājahmundry	160	...	160†		
1933-35	124	Raipur	Vizianagram	318	...	318‡		
,,	125	Bhadrakh	Vizianagram	360	...	360	1385	‡ Includes branch-line to False Point T. O.
,,	127	Ratnāgiri	Hyderābād	370	...	370		
,,	130	Wādi	Bangalore	337	...	337		
1935-37	129	Kolhāpur	Mangalore	454	...	454§		§ Includes 100 miles to Kārwār T. O.
,,	134	Mangalore	Bangalore	200	...	200	1374	
,,	131	Rājahmundry	Madras	340	...	340		‖ Includes lines to Negapatam T.O. and Pāmban T.O.
,,	133	Madras	Rāmnād	380	...	380‖		
1937-38	132	Mangalore	Rāmnād	490	...	490⊙	685	⊙ Includes lines to Cochin T. O. and Beypore T.O.
,,	135	Bangalore	Madras	195	...	195		
			Totals ...	13,302	1,220	12,082	12,082	

Length of level net 13,302 miles; 1,220 miles completed; 12,082 miles remain for 18 seasons; average 671 miles per season exclusive of branches to G. T. Stations.

All work not required for this new level net will be done on the old system of simultaneous double levelling. It is intended by this means to take up much more levelling for the departments of Irrigation and Public Works than has hitherto been possible, provided that funds are available for the work from these departments. This levelling will be of different degrees of refinement according to the requirements of each case and having in view the rise in cost due to the increase of precision. It will be adjusted at once to the present level net of India and published during the same year; and it will be readjusted to the new net on its completion in or about 1938.

(*b*) *Systematic errors.* A recent publication by the Survey of Egypt has called attention to the systematic error caused by the rapid change in refraction near the ground due to rapid change of temperature in the morning. This has given rise to an alteration in the practice in Egypt; observations are now taken as follows:— Station I, back staff, forward staff, forward staff, back staff. Station II, forward staff, back staff, back staff, forward staff. It is interesting to note that the same practice was introduced into Indian levelling some twenty years ago. Its adoption was due to two reasons; the systematic error due to (1) refraction effects** and (2) unequal lighting on the two staves where radiation effects are apparent earlier and to a greater extent on the illuminated staff than on the shaded one, and hence a systematic error might be introduced into the levelling on this account, particularly in the case of long "shots". It was partly also for this reason that the staff distance was reduced to 5 chains††.

** G. T. Survey of India, Vol. XIX, p. 76, (ii).

†† Records of the Survey of India, Vol. I, 1919-10, p. 45.

A point which does not seem to be mentioned by the Egyptian levellers is the danger of levelling in the very early morning or late evening immediately after the sun has risen or before it has set. In India new levellers have to be warned against this danger.

Owing to the irregular heating of the atmospheric layers near the ground when the sun is near the horizon, refraction causes the staff graduations to appear to "hang" steadily for some seconds in an abnormal position. To an inexperienced leveller the object appears steady and normal, and unless warned, a large accidental error may be generated.

In connection with the question of systematic errors, the question of refraction is an important one, particularly in the case of mountain levelling.

A curious discrepancy of +3 ft. between the very carefully triangulated height of Mussoorie from Dehra Dūn and the spirit levelled height of the same point has been known for some years to exist. Colonel Sir S.G. Burrard put forward the theory* that this discrepancy was due to the fact that the triangulation is based on the adopted spheroid while levelling follows the geoid; and that this discrepancy therefore was a measure of the separation of the two surfaces at Mussoorie. This point has been fully discussed by Dr. J. de G. Hunter, in a recent Professional Paper † on the basis of observed deflections of the plumb-line between Dehra Dūn and Mussoorie. Briefly summarised, his conclusions prove that approximately only 1·4 ft. of this 3 ft. discrepancy is explained by Col. Burrard's theory. There still remains 1·6 ft. to be accounted for and it appears that this must be an accumulated systematic error due to refraction during the levelling.

It is proposed to investigate this question as soon as levellers are available in the following way. Three levellers will level the section by different methods. The first will adopt the ordinary method of high precision levelling taking all modern precautions against the accumulation of errors. The second leveller will follow closely but will observe and correct for temperatures during the observation "shots". The third leveller will follow the second and will level with a theodolite to a staff mark at the same height throughout, equal to the trunnion height of the instrument, thereby ensuring that the rays are as near as possible parallel to the slope.

It may be recorded here that the spirit levelled height of Reban H.S. in the valley of Kashmīr shows a discrepancy of 5 ft. from the triangulated height of the same point, and though the level circuit is not yet closed, and the triangulation has not been so repeatedly checked, it seems possible that the same causes that are at work in the case of the Mussoorie discrepancy have been in action here, since in both cases the triangulated height exceeds the spirit level value. It must however be noted that no plumb-line deflections have yet been observed along this line into Kashmīr and therefore the separation between the geoidal and adopted spheroidal surfaces cannot yet be determined. It is hoped before long to complete this level circuit by a line over the Banihāl pass to Reban H.S., to connect bench-marks of this line to the Primary Series in its neighbourhood by theodolite observations, and to observe the plumb-line deflections at selected points.

(*c*) *Publications.* The following new editions of, and addenda to, pamphlets were published during the year:—

New editions of pamphlets 44, 53 and 57.

Addenda to pamphlets 56, 63, 72 and 73.

The following new publications are now in the press (September, 1920):—

Addenda slip to latest edition pamphlet 38. (Sind-Sāgar).

Addenda slip to addenda pamphlet 39. (Sind-Sāgar).

New addenda pamphlet 44 (Sind-Sāgar and Ludhiāna, Ferozepore and Amritsar districts).

Addenda slip to latest edition pamphlet 53 (Ambāla and Bareilly districts).

New edition of pamphlet 54 (Shāhjahānpur district).

Addenda slip to addenda pamphlet 63 (Lucknow district).

Correction slips to addenda pamphlets 72,73,78,79 and 83 (Silchar to Comilla; Srimangal earthquake effects).

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* G.T. Survey of India, Vol XIX, Appendix No. 8.

† Survey of India Professional Paper No. 14. *Atmospheric Refraction—Appendix.*

TABLE I.—*Tabular statement of out-turn of work, season 1919-20.*

Detachment Nos.	Lines.	Months.	Mean distance levelled in both directions. Main-Line.	Extras and branch-lines.	Total.	Relevelled.	Total number of feet (Mean of both directions) Rises.	Falls.	Mean number of stations at which the instruments were set up in both directions.	Number of bench-marks connected. Primary. Standard. Old	Standard. New	Primary stations of triangulation. Old	Primary stations of triangulation. New	Secondary. Embodied. Old	Embodied. New	Inscribed. Old	Inscribed. New	Stones at corner of 4000 acres rectangles. Old	Stones at corner of 4000 acres rectangles. New	Minor stations of triangulation. Old	Minor stations of triangulation. New	P. W. D. Old	P. W. D. New	Railway. Old	Railway. New	Jaderin traverse stations. Old	Jaderin traverse stations. New
			Mls.Chs.Lks.	Mls.Chs.Lks.	Mls.Chs.Lks.	Mls.Chs.Lks.	Rises.	Falls.		Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New
1 (A) and 1 (B)	Ferozepore to Ludhiāna "Fore and Back"	Nov. 1919	30 47 49	2 30 70	32 78 19	...	201·174	151·401	355	2	...	...	3	4	6	8	81	...	...	...	...	...	...	...	...	...	...
		Dec. 1919	47 39 41	13 34 66	60 74 07	6 30 54	401·300 43·806*	253·206 45·761*	597 62*																		
		Totals	78 06 90	15 65 36	93 72 26	6 30 54	646·280	450·368	1014	2	...	...	3	4	6	8	81	...	..	...	...	...	...	...	...	...	...
	Khairāwāla to Shāhpur T. S. "Simultaneous"	Jan. 1920	55 30 74	4 07 56	59 38 30	...	485·224	458·831	608 30*	...	...	3	...	...	2	...	4	...	24	...	3	...	...	...	...	...	...
		Feb. 1920	14 21 20	...	14 21 20	...	327·415	324·967	178 5*																		
		Totals	69 51 94	4 07 56	73 59 50	...	812·639	783·798	821	...	...	3	...	...	2	...	4	...	24	...	3	...	...	...	...	...	...
	Shorkot Road railway station to Jandānwāla "Simultaneous"	Feb. 1920	66 71 70	...	66 71 70	...	594·431	530·236	650 36*	...	...	...	...	3	5	3	2	1	35	...	3	...	...	...	...	1	2
		Mar. 1920	64 75 08	22 00 44	86 75 52	...	1000·777	878·842	758 43*																		
		Totals	131 66 78	22 00 44	153 67 22	...	1595·208	1409·078	1487	...	...	...	...	3	5	3	2	1	35	...	3	...	...	...	...	1	2
	Amritsar to Ludhiāna "Fore and Back"	Ap. 1920	60 73 04	...	60 73 04	...	407·440	368·311	564	1	...	...	1	1	8	4	60	...	..	...	...	...	...	...	...	...	...
		May 1920	27 08 13	...	27 08 13	4 09 56	154·099 14·142*	140·885 21·057*	232 31*																		
		Totals	88 01 17	...	88 01 17	4 09 56	575·681	530·853	827	1	...	...	1	1	8	4	60	...	...	...	...	...	...	...	...	...	...
		Grand Totals	367 46 79	41 73 36	409 40 15	10 40 10	3629·808	3174·097	4149	3	...	3	4	8	21	15	147	1	59	...	6	...	...	...	...	1	3

* In relevelments.

TABLE I.—*Tabular statement of out-turn of work, season 1919-20.*—(*Concluded*).

Detachment Nos.	Lines.	Months.	Mean distance levelled in both directions.				Total number of feet (Mean of both directions).		Mean number of stations at which the instruments were set up in both directions.	Number of bench-marks connected.																		
			Main-Line.	Extras and branch-lines.	Total.	Relevelled.				Primary.				Secondary.														
										Standard.		Primary stations of triangulation.		Embedded.		Inscribed.		Stones at corner of 400 acres rectangles.		Minor stations of triangulation.		P. W. D.		Railway.		Jaderia traverse stations.	
			Mls.Chs.Lks.	Mls.Chs.Lks.	Mls.Chs.Lks.	Mls.Chs.Lks.	Rises.	Falls.		Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New
2	Silchar to Karimganj "Simultaneous"	Nov. 1919	9 16 92	0 46 06	9 62 98	...	153·105	177·665	164																			
		Dec. 1919	24 15 16	1 26 08	25 41 24	...	266·085	275·964	376	1	...	1	...	3	...	23	1	...	...	...	..	...	...	1	...	...	...
		Totals	33 32 08	1 72 14	35 24 22	...	419·190	453·629	540	1	...	1	...	3	...	23	1	...	...	...	...	...	...	1	...	...	...
	Karimganj to Comilla "Simultaneous"	Dec. 1919	41 73 42	...	41 73 42	...	399·120	383·346	572																			
		Jan. 1920	72 20 92	5 39 94	77 60 86	...	891·104	925·539	1087	1	...	1	1	15	...	69	..	...	...	..	...	...	...	10	....	...	..
		Feb. 1920	38 67 18	3 17 30	42 04 48	...	302·945	308·765	558																			
		Totals	153 01 52	8 57 24	161 58 76	...	1593·169	1617·650	2217	1	...	1	1	15	...	69	...	...	...	...	...	...	...	10	...	...	...
	Lucknow to Bareilly "Fore and back"	Mar. 1920	72 74 97	9 10 55	82 05 52	2 67 71	509·202	447 087	806																			
		Ap. 1920	70 26 83	9 16 83	79 43 66	2 09 50	511·313	420·271	862	4	...	3	...	4	9	56	104	...	...	...	...	...	3	1	...	...	...
		May 1920	14 26 48	...	14 26 48	...	101·282	81·669	195																			
		Totals	157 48 28	18 27 38	175 75 66	4 77 21	1121·797	949·027	1863	4	..	3	...	4	9	56	104	...	...	...	...	...	3	1	...	...	...
		Grand Totals	344 01 88	28 76 76	372 78 64	4 77 21	3134·156	3020·306	4620	6	...	5	1	22	9	148	105	...	...	...	...	...	3	12	...	...	...

TABLE II.—Check-Levelling.

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

Bench-marks of the original levelling that were connected for check-levelling.			Distance from starting bench-mark.	Observed heights, above (+) or below (−) starting bench-mark as determined by			Difference (Check—Original). The sign + denotes that the height was greater and the sign − less in 1919-20 than when originally levelled.
Number.	Degree Sheet.	Description.		Original levelling.	Date.	Check-levelling 1919-20.	
			Miles.	Feet.		Feet.	Feet.
Check-Levelling at Amritsar.							
139	44 I	Embedded, Amritsar ...	0·0	0·000	1909-10	0·000	0·000
140	„	Station platform ...	0·1	+4·241	„	+4·241	0·000
142	„	Rāmbāgh gate ...	0·8	+4·699	„	+4·700	+0·001
Check-Levelling at Shorkot Road railway station.							
19	44 B	Embedded, Shorkot Road ...	0·0	0·000	1911-12	0·000	0·000
18	„	Station platform ...	0·4	+6·527	„	+6·547	+0·020
17	„	Station passage ...	0·4	+4·700	„	+4·719	+0·019
16	„	Jāderin Traverse station ...	1·1	+5·619	„	+5·644	+0·025
Check-Levelling at Jandānwāla.							
15	38 P	Embedded, Jandānwāla ...	0·0	0·000	1910-11	0·000	0·000
16	„	Verandah flooring ...	0·0	+5·691	„	+5·687	−0·004
17	„	Embedded, Shahīdkalān ...	6·1	+4·107	„	+4·065	−0·042
Check-Levelling at Shāhpur T. S.							
1	39 I	Shāhpur T. S.	0·0	0·000	1859-60	0·000	0·000
6	39 J	Sukhīwāla T. S.	9·6	−13·895	„	−13·786	+0·109
5	„	Farowāla T.S.	21·0	−33·041	„	−33·380	−0·339

TABLE III.—Revision Levelling.

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

Bench-marks of the original levelling that were connected during the revisionary operations			Distance from starting bench-mark	Difference between orthometric heights, above (+) or below (−) the starting bench-mark			Difference (Revision − Original). The sign + denotes that the height was greater and the sign − less in 1919-20 than when originally levelled
Number	Degree Sheet	Description		From published heights	Date of Original levelling	From revision 1919-20 (Unadjusted)	
			Miles	Feet		Feet	Feet
		Revision of Part of line No. 61 (Ferozepore-Meerut).					
5	44 J	Standard, Ferozepore ...	0·0	0·000	1906-07	0·000	0·000
1*	,,	Embedded, ,, ...	0·3	− 4·179	1860-61-62	− 4·208	−0·029
6	,,	Stone coping ...	0·2	+ 1·645	1906-07	+ 1·643	−0·002
7	,,	Stone step ...	0·2	− 1·391	,,	− 1·396	−0·005
157	,,	Stone Embedded, Kaliānwāla ...	15·8	+ 26·300	1860-61-62	+ 26·356	+0·056
1	44 N	,, ,, Dagru ...	28·0	+ 67·586	,,	+ 67·623	+0·037
4	,,	,, ,, Jagraon ...	53·4	+115·189	,,	+115·243	+0·054
76	,,	Platform of well ...	76·8	+155·255	1913-14	+155·440	+0·185
10	,,	Station platform ...	77·2	+160·904	1906-07	+161·091	+0·187
11	,,	Stone flooring ...	77·5	+159·389	,,	+159·557	+0·168
13	,,	Verandah flooring ...	77·8	+161·672	,,	+161·867	+0·195
12	,,	Stone step ...	77·9	+158·841	,,	+159·040	+0·199
14	,,	Stone step ...	78·1	+156·873	,,	+157·064	+0·191
15	,,	Standard, Ludhiāna ...	78·1	+157·756	,,	+157·930	+0·174
		Revision of branch-line No. 77H (Karīmganj-Silchar).					
107	83 D	Standard, Silchar ...	0·0	0·000	1911-12	0·000	0·000
108	,,	Cenotaph ...	0·2	− 7·616	,,	− 7·614	+0·002
109	,,	*Kachahri* verandah ...	0·5	− 6·092	,,	− 6·090	+0·002
110	,,	Pillar ...	0·6	− 7·531	,,	− 7·540	−0·009
106	,,	Circuit house verandah ...	0·02	+ 2·016	,,	+ 2·015	−0·001
105	,,	Station platform ...	0·64	− 10·820	,,	− 10·871	−0·051
104	,,	Pillar ...	0·99	− 17·281	,,	− 17·334	−0·053
102	,,	Bridge ...	3·0	− 21·399	,,	− 21·428	−0·029
101	,,	Pillar ...	4·0	− 5·236	,,	− 5·214	+0·022
100	,,	Bridge ...	5·1	− 19·820	,,	− 19·839	−0·019
95	,,	Embedded, Salchāpra ...	9·2	− 24·505	,,	− 24·568	−0·063
94	,,	Bungalow verandah ...	9·3	− 21·949	,,	− 21·996	−0·047
92	,,	Goods-shed platform ...	11·2	− 17·256	,,	− 17·447	−0·191
91	,,	Pillar ...	12·2	− 22·934	,,	− 22·981	−0·047
88	,,	Culvert ...	15·7	− 24·849	,,	− 24·892	−0·043
87	,,	Culvert ...	16·6	− 22·566	,,	− 22·628	−0·062
86	,,	Embedded, Badarpur ...	17·4	− 7·527	,,	− 7·562	−0·035
83	,,	Station platform ...	19·3	− 20·049	,,	− 20·185	−0·136
81	,,	Culvert ...	21·4	− 23·989	,,	− 24·033	−0·044
80	,,	Culvert ...	22·8	− 25·081	,,	− 25·114	−0·033
79	,,	Culvert ...	24·1	− 27·253	,,	− 27·299	−0·046
78	,,	Base of signal ...	24·4	− 23·812	,,	− 23·924	−0·112
77	,,	Bridge ...	25·1	− 25·460	,,	− 25·521	−0·061
75	,,	Bridge ...	28·2	− 19·527	,,	− 19·560	−0·033
73	,,	Bridge ...	30·2	− 35·771	,,	− 35·856	−0·085
72	,,	Dali Tila G.T. H.S. ...	33·2	+ 75·866	,,	+ 75·829	−0·037
71	,,	Station platform ...	31·9	− 25·794	,,	− 26·013	−0·219
70	,,	Pillar ...	32·9	− 30·386	,,	− 30·477	−0·091
35	,,	Embedded, Karīmganj ...	33·4	− 34·421	,,	− 34·458	−0·037
		Revision of Part of branch-line No. 77F (Gauhāti to Comilla and Chittagong).					
35	83 D	Embedded, Karīmganj ...	0·0	0·000	1911-12	0·000	0·000
37	,,	Bridge ...	4·6	+ 8·097	,,	+ 8·078	−0·019
39	,,	Culvert ...	6·6	+ 9·211	,,	+ 9·199	−0·012
40	,,	Root of tree ...	8·1	+ 1·360	,,	+ 1·249	−0·111
42	,,	Rail head in pillar ...	11·6	− 9·568	,,	− 9·617	−0·049
43	,,	Embedded, Latu R.S. ...	12·1	− 10·759	,,	− 10·810	−0·051
44	,,	Rail head in pillar ...	13·2	− 6·590	,,	− 6·634	−0·044
45	,,	,, ,, ,, ,, ...	14·2	− 12·015	,,	− 12·237	−0·222
46	,,	,, ,, ,, ,, ...	14·7	− 10·923	,,	− 10·962	−0·039
47	,,	Culvert ...	15·5	− 9·077	,,	− 9·158	−0·081
48	,,	Rail head in pillar ...	16·1	− 10·126	,,	− 10·166	−0·040

* Now 144(1).

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	Difference between orthometric heights, above (+) or below (−) the starting bench-mark			Difference (Revision − Original). The sign + denotes that the height was greater and the sign − less in 1919-20 than when originally levelled
Number	Degree Sheet	Description		From published heights	Date of Original levelling	From revision 1919-20 (Unadjusted)	
			Miles	Feet		Feet	Feet
Revision of Part of branch-line No. 77F (Gauhāti to Comilla and Chittagong).—Contd.							
49	83 D	Culvert ...	17·5	− 5·025	1911-12	− 5·054	−0·029
50	,,	Rail head in pillar ...	18·2	− 7·911	,,	− 7·935	−0·024
51	,,	Root of tree ...	18·6	− 6·129	,,	− 6·130	−0·001
52	,,	Embedded, Barlekha R.S. ...	19·8	− 3·660	,,	− 3·682	−0·022
53	,,	Root of tree ...	21·1	− 6·774	,,	− 6·799	−0·025
56	,,	Station verandah ...	24·7	− 5·184	,,	− 5·226	−0·042
57	,,	Root of tree ...	25·6	− 8·234	,,	− 8·267	−0·033
58	,,	Bridge ...	27·0	− 1·891	,,	− 1·917	−0·026
59	,,	Embedded, Jūri R.S. ...	29·4	− 16·266	,,	− 16·292	−0·026
60	,,	Bridge ...	29·6	− 12·831	,,	− 12·855	−0·024
62	,,	Root of tree ...	32·6	− 13·836	,,	− 13·900	−0·064
63	,,	Rail head in pillar ...	34·6	− 12·189	,,	− 12·229	−0·040
64	,,	Root of tree ...	36·1	− 13·073	,,	− 13·097	−0·024
65	,,	Embedded, Kulaurā ...	37·2	− 13·358	,,	− 13·379	−0·021
67	,,	Rail head in pillar ...	38·2	− 7·712	,,	− 7·742	−0·030
68	,,	Root of tree ...	39·6	− 1·187	,,	− 1·262	−0·075
25	78 P	Dispensary verandah ...	43·4	+ 9·528	,,	+ 9·501	−0·027
26	,,	Embedded, Tilāgaon R.S. ...	45·8	+ 1·683	,,	+ 1·649	−0·034
27	,,	Rail head in pillar ...	45·9	+ 7·201	,,	+ 7·188	−0·013
28	,,	Station verandah ...	45·9	+ 10·617	,,	+ 10·547	−0·070
29	,,	Root of tree ...	47·1	+ 5·978	,,	+ 5·834	−0·144
30	,,	Root of tree ...	48·4	− 0·344	,,	− 0·404	−0·060
31	,,	Root of tree ...	48·8	+ 3·069	,,	+ 3·051	−0·018
32	,,	Railway boundary stone ...	50·3	+ 6·432	,,	+ 6·269	−0·163
33	,,	Bungalow verandah ...	52·4	+ 13·615	,,	+ 13·573	−0·042
34	,,	Embedded, Shamshernagar I. B.	52·5	+ 9·816	,,	+ 9·801	−0·015
38	,,	Bridge ...	54·5	+ 12·405	,,	+ 12·274	−0·131
41	,,	Culvert ...	60·8	+ 74·553	,,	+ 74·516	−0·037
42	,,	Rail head in pillar ...	62·0	+ 84·026	,,	+ 83·961	−0·065
43	,,	Embedded, Srimangal ...	65·4	− 10·118	,,	− 10·153	−0·035
44	,,	Station verandah ...	65·8	+ 6·388	,,	+ 6·295	−0·093
48	,,	Root of tree ...	70·4	− 11·238	,,	− 11·259	−0·021
49	,,	Bungalow verandah ..	71·8	+ 81·965	,,	+ 81·940	−0·025
50	,,	Root of tree ...	77·6	+ 4·390	,,	+ 4·336	−0·054
51	,,	Bridge ...	79·0	− 15·008	,,	− 15·103	−0·095
52	,,	Well, Mīrpur I.B. ...	80·2	− 13·131	,,	− 13·263	−0·132
53	,,	Embedded, Mīrpur I.B. ...	80·2	− 17·523	,,	− 17·705	−0·182
54	,,	Bridge ...	82·6	− 14·304	,,	− 15·065	−0·761
55	,,	Bridge ...	84·4	− 16·824	,,	− 17·360	−0·536
56	,,	Bungalow verandah ...	85·1	− 20·170	,,	− 20·469	−0·299
57	,,	Bridge ...	86·8	− 24·698	,,	− 24·845	−0·147
58	,,	Railway boundary stone ...	89·7	− 3·693	,,	− 3·806	−0·113
60	,,	Embedded, Shahaji Bāzār ...	90·6	− 4·799	,,	− 4·991	−0·192
61	,,	Root of tree ...	93·1	− 6·067	,,	− 6·270	−0·203
62	,,	Bridge ...	95·9	− 12·835	,,	− 12·863	−0·028
63	,,	Bridge ...	98·3	− 21·472	,,	− 21·530	−0·058
64	,,	Bridge ...	101·6	− 23·180	,,	− 23·255	−0·075
65	,,	Bridge ...	103·2	− 14·578	,,	− 14·671	−0·093
66	,,	Embedded, Mantala ...	103·9	− 25·318	,,	− 25·396	−0·078
67	,,	Bridge ...	104·9	− 16·281	,,	− 16·332	−0·051
69	,,	Station verandah ...	108·2	− 18·530	,,	− 18·624	−0·094
70	,,	Bridge ...	108·7	− 18·627	,,	− 18·700	−0·073
1	79 M	Bridge ...	110·6	− 21·489	,,	− 21·593	−0·104
2	,,	Bridge ...	112·1	− 14·763	,,	− 14·959	−0·196
3	,,	Embedded, Mukundapur ...	112·9	− 11·717	,,	− 11·792	−0·075
4	,,	Railway signal base ...	112·9	− 15·348	,,	− 15·422	−0·074
8	,,	Embedded, Akhaurā R.S. ...	120·3	− 29·075	,,	− 29·201	−0·126
9	,,	Station verandah ...	120·6	− 20·176	,,	− 20·392	−0·216

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	Difference between orthometric heights, above (+) or below (−) the starting bench-mark			Difference (Revision—Original). The sign + denotes that the height was greater and the sign — less in 1919-20 than when originally levelled
Number	Degree Sheet	Description		From published heights	Date of Original levelling	From revision 1919-20 (Unadjusted)	
			Miles	Feet		Feet	Feet
Revision of Part of branch-line No. 77F (Gauhāti to Comilla and Chittagong).—Contd.							
10	79 M	Bridge ...	123·1	− 11·902	1911-12	− 11·938	−0·036
11	,,	Bridge ...	124·7	− 25·033	,,	− 25·170	−0·137
12	,,	Railway boundary stone ...	126·4	− 29·583	,,	− 29·723	−0·140
13	,,	Bridge ...	127·2	− 18·930	,,	− 19·004	−0·074
14	,,	Railway boundary stone ...	128·3	− 28·300	,,	− 28·344	−0·044
15	,,	Station verandah ...	130·1	− 17·718	,,	− 17·737	−0·019
16	,,	Embedded, Kamalasāgar ...	130·2	− 17·094	,,	− 17·113	−0·019
17	,,	Barjatua G.T. H.S. ...	133·4	+ 108·264	,,	+108·193	−0·071
18	,,	Bridge ...	131·4	− 23·961	,,	− 23·974	−0·013
19	,,	Culvert ...	132·6	− 19·336	,,	− 19·344	−0·008
20	,,	Bridge ...	134·5	− 23·073	,,	− 23·089	−0·016
21	,,	Bridge ...	136·1	− 24·925	,,	− 24·942	−0·017
22	,,	Railway signal base ..	137·5	− 22·554	,,	− 22·595	−0·041
23	,,	Embedded, Nayanpur ...	137·6	− 29·208	,,	− 29·242	−0·034
24	,,	Root of tree ...	139·0	− 26·987	,,	− 27·083	−0·096
26	,,	Bridge ...	141·9	− 24·161	,,	− 24·205	−0·044
27	,,	Road boundary pillar ...	144·3	− 25·935	,,	− 25·945	−0·010
28	,,	Bridge ...	146·9	− 19·087	,,	− 19·092	−0·005
30	,,	Bridge ...	148·3	− 20·522	,,	− 20·531	−0·009
31	,,	Comilla post office ...	151·1	− 15·966	,,	− 16·020	−0·054
32	,,	Comilla circuit house ...	151·1	− 14·561	,,	− 14·614	−0·053
33	,,	,, standard B.M. ...	151·2	− 16·682	,,	− 16·725	−0·043
34	,,	,, church ...	151·3	− 19·269	,,	− 19·311	−0·042
35	,,	,, collector's court ...	151·6	− 18·886	,,	− 18·915	−0·029
36	,,	,, District Board office ...	151·7	− 19·505	,,	− 19·570	−0·065
37	,,	,, jail ...	151·7	− 21·265	,,	− 21·339	−0·074
38	,,	,, station verandah ...	152·7	− 19·277	,,	− 19·318	−0·041
39	,,	,, dāk bungalow ...	153·0	− 24·464	,,	− 24·528	−0·064
Revision of Part of main-line No. 64 (Meerut-Lucknow).							
96	63 B	Standard, Lucknow ...	0·0	0·000	1909-10	0·000	0·000
8	,,	Embedded, Lucknow ...	0·1	− 9·870	1867-69	− 9·866	+0·004
97	,,	Railway bridge ...	0·2	+ 6·847	1905-06	+ 6·855	+0·008
7	,,	Christ's church ...	1·3	− 30·078	1867-69	− 30·079	−0·001
99	,,	M.S. No. 2 from iron arch bridge	1·5	− 27·310	1905-06	− 27·317	−0·007
6	,,	Judge's court (old museum) ...	2·8	− 28·690	1867-69	− 28·697	−0·007
43	63 A	Bridge No. 24 ...	22·9	+ 25·155	,,	+ 25·138	−0·017
41	,,	Embedded, Atāria ...	25·2	+ 24·531	,,	+ 24·553	+0·022
39	,,	Bridge No. 39 ...	34·6	+ 40·022	,,	+ 40·068	+0·046
36	,,	Bridge No. 51 ...	41·3	+ 42·592	,,	+ 42·623	+0·031
35	,,	Bridge No. 53 ...	43·7	+ 33·646	,,	+ 33·709	+0·063
34	,,	Bridge No. 55 ...	44·8	+ 42·111	,,	+ 42·206	+0·095
33	,,	Embedded, Jalālpur ...	44·9	+ 39·544	,,	+ 39·564	+0·020
32	,,	Bridge No. 59 ...	47·5	+ 49·419	,,	+ 49·494	+0·075
30	,,	Bridge No. 66 ...	50·2	+ 45·628	,,	+ 45·709	+0·081
29	,,	Bridge No. 70 ...	51·6	+ 53·929	,,	+ 54·024	+0·095
28	,,	Bridge No. 72 ...	...	+ 54·357	,,	+ 54·975	+0·618
27	,,	Stone prism ...	57·2	+ 52·911	1905-06	+ 53·031	+0·120
26	,,	Standard, Sītāpur ...	57·0	+ 54·215	,,	+ 54·338	+0·123
23	,,	Collector's *kachahri* ...	56·9	+ 53·293	1867-69	+ 53·417	+0·124
22	,,	Culvert No. 5 ...	56·4	+ 54·025	1905-06	+ 54·144	+0·119
21	,,	Cantonment church, Sītāpur ...	55·8	+ 54·353	1867-69	+ 54·485	+0·132
20	,,	Abbas Beg's well ...	57·3	+ 55·559	,,	+ 55·588	+0·029
				+ *55·467**			*+0·121*
19	,,	Sirwaia T.S. ...	63·7	+ 77·773	,,	+ 77·865	+0·092
17	,,	Embedded, Gaddi-ka-purwa ...	66·4	+ 68·054	,,	+ 68·147	+0·093
16	,,	Culvert, Gaddi-ka-purwa ...	66·5	+ 69·331	,,	+ 69·334	+0·003
14	,,	Darāwal T.S. ...	75·3	+ 79·572	,,	+ 79·572	+0·098

* Reconnected in 1905-06, value depending on Sītāpur church.

TABLE III.—Revision Levelling.—(*Concluded*).

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

Bench-marks of the original levelling that were connected during the revisionary operations			Distance from starting bench-mark	Difference between orthometric heights, above (+) or below (−) the starting bench-mark			Difference (Revision—Original). The sign + denotes that the height was greater and the sign— less in 1919-20 than when originally levelled
Number	Degree Sheet	Description		From published heights	Date of Original levelling	From revision 1919-20 (Unadjusted)	
			Miles	Feet		Feet	Feet
		Revision of Part of main-line No. 64 (Meerut-Lucknow).—Contd.					
13	63 A	Parser T.S. ...	80·1	+ 90·896	1867-69	+ 90·951	+0·055
11	,,	Dīn Dayāl's well ...	73·3	+ 76·209	,,	+ 76·242	+0·033
7	,,	Trijunction pillar ...	79·8	+ 81·195	,,	+ 80·959	−0·236
4	,,	Trijunction pillar ...	91·1	+ 93·048	,,	+ 93·188	+0·140
1	,,	Trijunction pillar ...	95·6	+ 96·485	,,	+ 96·568	+0·083
14	54 M	Bridge in *mauza* Bhitāra ...	104·2	+109·798	,,	+109·894	+0·096
12	,,	Trijunction pillar ...	108·4	+111·748	,,	+111·902	+0·154
7	,,	Bullan Shāh's tomb ...	109·1	+112·772	,,	+112·982	+0·210
11	,,	Standard, Shāhjahānpur ...	110·3	+115·568	1905-06	+115·750	+0·182
10	,,	Church, Shāhjahānpur ...	110·4	+113·205	1867-69	+113·396	+0·191
41	,,	General mile pillar, Shāhjahānpur	110·6	+113·755	1905-06	+113·928	+0·173
6	,,	Bridge No. 36 ...	111·1	+112·032	1867-69	+112·143	+0·111
3	,,	Well in *mauza* Banthara ...	117·7	+100·327	,,	+100·339	+0·012
2	,,	Bridge in *mauza* Gurgia-Fīrozpur	120·3	+106·213	,,	+106·361	+0·148
58	53 P	Commissioner's office, Bareilly ...	159·5	+172·543	1905-06	+172·711	+0·168
57	,,	Standard, Bareilly ...	159·0	+170·895	,,	+171·043	+0·148
56	,,	Well near Sorabjee's shop, Bareilly	158·8	+169·731	1867-69	+169·827	+0·096
54	,,	Ornamental well, Bareilly ...	157·9	+168·006	1905-06	+168·134	+0·128
53	,,	Cantonment church, Bareilly ...	157·5	+166·020	1867-69	+166·181	+0·161
284*	,,	Culvert No. 4 near Royal Artillery lines, Bareilly ...	158·3	+168·779	1914-15	+168·908	+0·129

* Appertains to Bareilly to Hāthras line.

TABLE IV.

List of Great Trigonometrical Survey stations connected by Spirit-levelling Season 1919-20.

Name of station	Height above mean-sea-level			Difference	Remarks
	New spirit-levelling	Old spirit-levelling	Triangulation	Δ^n—New	
	Feet	Feet	Feet	Feet	
Eastern Frontier Series-Section 23°-26°.					
Churāmani H. S. ...	280·139	...	282·000	+1·861	Ground floor mark-stone
Gurhāgarh Meridional Series.					
Sodhiwāla T. S. ...	692·044	...	693·000	+0·956	Ground floor mark-stone
Tamālwāla T. S. ...	703·668	...	703·000	−0·668	„ „ „ „
Daraoli T. S. ...	738·504	...	739·000	+0·496	„ „ „ „
Dhire Kot T. S. ...	786·901	...	789·000	+2·099	„ „ „ „
Great Indus Series.					
Shāhpur T. S. ...	504·244	504·068	...	−0·176	Ground floor mark-stone
Sukhīwāla T. S. ...	490·462	490·173	...	−0·289	„ „ „ „
Farowāla T. S. ...	470·874	471·027	...	+0·153	„ „ „ „
Minor stations of Sind-Sāgar Series of 1917-18.					
Sobhāwāla s. ...	494·617	...	...	...	Topmost mark
Sohāgānwāla s. ...	523·450	...	526·000	+2·550	„
Josāwāla s. ...	537·044	...	539·000	+1·956	„
Rangpur Baghur s. ...	643·684	...	645·000	+1·316	„
Shāhyānwāli s. ...	635·329	...	640·000	+4·671	„
Miru s. ...	658·066	...	665·000	+6·934	„

MAGNETIC SURVEY.

By E. C. J. Bond.

Personnel of No. 18 Party.

Class II Officers.

Mr. E. C. J. Bond, V. D., in charge.
" N. R. Mazumdar.
" R. B. Mathur, B. A., up to 19th September.

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 1919-20 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 1919.

I.—Work during the field and recess seasons.

1. *Work during the field season.*—The field season opened on the 7th October 1919 and closed on the 1st May 1920.

The field season's programme comprised observations at all the repeat stations in India, Burma and Ceylon; and the usual annual observations for the comparison of instruments at the Dehra Dūn and Toungoo observatories, as well as at the Alibāg and Kodaikānal observatories which are under the control of the Meteorological Department.

Since the magnetic elements undergo very appreciable changes from year to year and it is not possible to forecast with any degree of accuracy what the annual changes will be, even in a few years' time, it becomes necessary to observe at short intervals at repeat stations in order to obtain reliable values of the annual changes. Five years was decided upon as being a suitable interval and the 75 repeat stations which were last visited in 1914-15 were, therefore, again observed at during the field season of 1919-20. The 75 repeat stations were permanently marked in 1914-15, as experience had shown that it was very essential to observe at exactly the same site when observations are repeated, so as to ensure that correct values of the magnetic elements are obtained for an accurate determination of the annual changes. In addition to the 75 repeat stations referred to above 5 new stations were permanently marked and observed at this year, two of these being in Upper Burma, one in Bengal and one in Assam: these 5 extra stations were much needed for determining the true course of the lines of equal annual change in these particular localities.

Three detachments were employed in carrying out the field season's programme, one in Northern India, one in Southern India including Ceylon, and one in Assam, Burma and at Port Blair in the Andaman Islands.

Each of the 80 repeat stations was observed at on two consecutive days and double sets of declination, dip and horizontal force observations were taken on each day. The object of observing at each of the stations for two days was to obtain the best results and to make sure that extra observations would be available if any of the results happened to be unsatisfactory owing to any magnetic disturbance during an observation.

Since a hospital was built within a few feet of the pillar marking the site of the Manmād repeat station it was necessary to remove the pillar to a more suitable position: this was done during the field season and complete sets of observations were taken both at the old and the new sites.

2. *Work during the recess.*—The computations of the field observations taken during the year under report and the reduction and tabulation of the values of declination, dip and horizontal force for the three observatories (Dehra Dūn, Toungoo and Kodaikānal) for 1919, 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.

Publication of the results of the magnetic survey to epoch.—It is to be regretted that there will be further delay in publishing the results of the magnetic survey to epoch. Major R. H. Thomas, D. S. O., R. E., Offg. Superintendent of the Trigonometrical Survey, who was formerly in charge of the party and had adjusted the magnetic constants used in the computations of the horizontal force before he proceeded to Europe on military duty in 1914, has, on his return to the department, considered it advisable to revise the constants of all the instruments employed in the magnetic survey by utilizing the additional data which has accumulated since, and it has now been decided to recompute the observations with greater refinement and to extend and publish the values of all the elements up to 1920. The revised data for the final reduction of the observations of horizontal force are now available and the computations are being proceeded with.

Reduction of the detail survey.—The recomputations of the observations at the detail survey stations necessitated by the revision of the constants referred to above will next be taken in hand and the values of the magnetic components in the disturbed areas will then be studied to ascertain whether the results in these areas will disclose any prominent magnetic features. The observations in the disturbed areas, however, are very conflicting and do not seem to point to the existence of any definite sources of attraction but appear to indicate that the disturbances are of a purely local character and are probably due entirely to the unequally magnetized rocks or iron ore hidden close below the ground surface.

There is no doubt that in many instances the disturbances are produced by the presence of iron ore; but, there is no means of ascertaining in which of the areas the disturbances are chiefly due to this cause. Even where the iron ore is known to exist in certain areas, such for instance as the Tata Iron Fields in Central India, it is not possible to locate good and workable ore with the aid of the magnet, for it is only where the ore is of inferior quality and is of no economic value that it seems to influence the magnet most: this will be understood from the following statement received in 1910 from the Director of the Geological Survey of India:—"Only certain iron ores are magnetic. Thus magnetite (Fe_3O_4) is highly magnetic whilst hematite (Fe_2O_3), one of the commonest of iron ores (in India), is as a rule, not magnetic, although, at times, feebly so. Thus a large expanse of hematite hidden under alluvium might perfectly well escape detection through observations based on magnetic qualities only, whilst, on the other hand, certain igneous rocks, which contain more or less magnetite as one of their primary constituents, although not in sufficient quantity to be of any economic value whatsoever might have considerably more effect on the magnet than an extensive and valuable mass of hematite". This is practically borne out by some of the members of the staff employed at the Tata Iron Fields in Central India whose experience is that the compass needle is not affected in any of the localities producing rich iron ore but is much disturbed in places where the ore is of very inferior quality and is practically unworkable.

3. *Programme for 1920-21.*—During the ensuing field season observations will be taken for the comparison of instruments at the Dehra Dūn and Toungoo observatories. The Alibāg and Kodaikānal observatories, under the Meteorological Department, will also be visited for the same purpose. In addition it is proposed to take observations at six evenly distributed repeat stations (most of these are *en route* to the observatories) with the object of controlling and making a careful study of the actual changes which the magnetic elements undergo annually in different parts of India.

II.—THE OBSERVATORIES IN 1919-20.

Dehra Dun Observatory.

1. The magnetographs have worked satisfactorily during the year.

The mirror of the vertical force magnet had deteriorated from the effects of damp in the underground room and the lines on the magnetograms were in consequence very faint. A new mirror was therefore substituted for the old one, and this seems to have affected the sensitiveness of the balance which was adjusted ten days later on the 20th October 1919. The trace, however, had shifted up towards the edge of the photographic paper and the magnet was again adjusted on the 1st November 1919. Since then it continued to work satisfactorily until it became necessary to readjust it on the 26th June 1920, on account of a further shift of the magnet lines towards the edge of the paper.

New thermometers, Nos. 44 and 999, were introduced for the magnetometer No. 17 at this observatory as it was thought that some inconsistencies noticed in the horizontal force observations were due to incorrect registering of temperatures by the thermometers previously in use. There is, however, no evidence of any change by the introduction of these new thermometers.

The thatching and parts of the wooden framework over the roof of the observatory, which had rotted from age, were renewed this year before the monsoon set in.

The underground room of the observatory, which was free from inundation during last year's rains, was flooded this year in the middle of August, owing to continuous heavy rain. The pump that is connected to the passage in the observatory and was believed to be capable of pumping out the water quicker than it could accumulate in the passage failed this year to expel the water quick enough, as it was flowing into the passage more rapidly than it had ever done in previous years. It was necessary, therefore, besides working the pump, to employ coolies night and day to bail out the water. This process was continued for a week until the flow of the water into the passage subsided. No further difficulty was experienced after the cessation of the heavy rain which fortunately lasted only a week.

There is no doubt that the walls of the observatory are becoming weaker year after year and may be less able to resist the high pressure of the sub-soil water during heavy rain in the future, hence the need for a new site for the observatory is a matter which requires consideration and early attention.

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 $P_{1\cdot2}$ and $P_{2\cdot3}$ and the accepted values of p and q used in determining the values of the 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* in the table were derived from the vibration observations with the chronograph.

Mean values of the constants of magnet No. 17 in 1919.

Months.	Declination constants.	H. F. constants.					
		Distribution Factors.				Mean values of m.	
	Mean magnetic collimation.	$P_{1\cdot2}$	$P_{2\cdot3}$	Accepted values. p	Accepted values. q	Monthly means.	Accepted m.
	′ ″						
January ...	− 6 55	6·08	6·68			807·30	
February ...	− 6 57	6·13	6·78			807·16	
March ...	− 6 56	6·00	6·54			807·08	
April ...	− 6 53	6·10	6·63			807·22	
May ...	− 6 53	6·09	6·67			807·16	
June ...	− 6 53	6·09	6·83	7·30	−·382	806·99	806·80
July ...	− 6 48	6·18	6·78			806·93	
August ...	− 6 41	6·15	6·95			807·06	
September ...	− 6 54	6·18	6·96			807·06	
October ...	− 6 42	6·23	6·93			807·21 806 72	
November ...	− 6 43	6·19	6·79			806·49	
December ...	− 6 49	6·17	6·82			806·82	

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 1919. The H. F. base line values have been derived from H as determined with the moment of inertia and distribution factor used in the computations for 1915.

Base line values of magnetographs in 1919.

Months.	Declination.			Horizontal Force.		
	Mean value of Base line.	Base line accepted.	Remarks.	Mean value of Base line.	Base line accepted.	Remarks.
	° ′	° ′		C. G. S.	C. G. S.	
January ...	1 31·4	1 31·4		·32682	·32682	
February ...	1 31·6	1 31·6		·32682	·32682	
March ...	1 32·1	1 32·1	Up to 10h. 5m. on 1st April	·32685	·32685	
April ...	1 1·3	1 1·3	From 12h. on 1st April.	·32683	·32683	
May ...	1 1·5	1 1·5		·32684	·32684	
June ...	1 1·5	1 1·5		·32688	·32688	
July ...	1 1·5	1 1·5		·32688	·32688	
August ...	1 1·5	1 1·5		·32687	·32687	
September ...	1 1·9	1 1·9		·32685	·32685	
October ...	1 2·0	1 2·0		·32692	·32683 ·32700	To 16th From 17th
November ...	1 2·5	1 2·5		·32701	·32701	
December ...	1 2·8	1 2·8		·32695	·32695	

4. *Mean scale values and temperature range.*—The mean scale values for 1919 for an ordinate of 1/25 inch are :—

Horizontal Force	4·39 gammas.
Declination	1·03 minutes.
Vertical Force	3·89 to 9·53 gammas.

The mean temperature for the year was 25°·6 C., with maximum and minimum monthly values of 25°·1 C., and 26°·3 C. The temperature of reduction is 27°·0 C.

5. *Mean monthly values and annual changes.*—The following table shows the mean monthly values of the magnetic elements for 1918 and 1919 and the annual changes for that period : the annual changes for H. F. 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 Dün in 1918-19.

Months.	Horizontal Force ·32000 C. G. S. +			Declination East.			Dip N. 44° +			Vertical Force ·32000 C. G. S. +		
	1918.	1919.	Annual change.	1918.	1919.	Annual change.	1918.	1919.	Annual change.	1918.	1919.	Annual change.
	γ	γ	γ	° ′	° ′	′	′	′	′	γ	γ	γ
January ...	994	956	−38	2 3·6	1 58·5	−5·1	46·2	53·0	+6·8	729	822	+ 93
February ...	989	960	−29	2 3·3	1 58·4	−4·9	47·2	52·6	+5·4	744	818	+ 74
March ...	988	957	−31	2 3·0	1 58·1	−4 9	48·1	53·5	+5·4	760	831	+ 71
April ...	982	962	−20	2 2·5	1 57·2	−5·3	48·4	53·2	+4·8	761	832	+ 71
May ...	992	955	−37	2 2·0	1 56·7	−5·3	47·8	54·4	+6 6	757	848	+ 91
June ...	994	980	−14	2 1·3	1 56·0	−5·3	48·8	53·3	+4·5	780	851	+ 71
July ...	992	978	−14	2 1·0	1 55·5	−5·5	49·5	54·0	+4·5	790	862	+ 72
August ...	981	954	−27	2 0·8	1 55·2	−5·6	50·6	55·7	+5·1	800	872	+ 72
September ...	971	943	−28	2 0·4	1 55·1	−5·3	51·6	56·4	+4·8	811	874	+ 63
October ...	963	951	−12	2 0·3	1 54·3	−6·0	51·9	57·7	+5·8	808	908	+100
November ...	968	975	+ 7	1 59·8	1 54·1	−5·7	52·3	56·9	+4·6	820	917	+ 97
December ...	951	967	+16	1 59·2	1 54·1	−5·1	53·2	57·4	+4·2	820	916	+ 96
Means ...	980	962	−19	2 1·4	1 56·1	−5·3	49·6	54·8	+5·2	782	863	+81

Toungoo Observatory.

1. The magnetographs worked satisfactorily throughout the year. During the month of March 1920 the drum of the V. F. magnetograph stopped revolving on a few occasions ; this was due to its axis being out of the vertical. The axis was adjusted but went out of the vertical in June 1920, when it was again adjusted. The drum has since worked satisfactorily.

The burner of the V. F. instrument lamp had become worn and the lamp burned badly, causing some loss of trace. When the defect became known a new burner was indented for from the Mathematical Instrument Office, Calcutta. No further trouble was experienced with the new burner.

A chronograph, obtained on loan from No. 14 Party, was taken to Toungoo when the observatory was visited this field season. It was used in the vibration observations to obtain accurate values of the moment *m* of the observatory magnet and also to determine the moment of inertia with the Survey gilt bar. Similar observations at the observatory were last taken with the chronograph in 1915.

The chuck formerly in use with the magnets of the observatory magnetometer had lost its grip from wear and the opportunity was taken, while a chronograph was at the observatory, of substituting a spare chuck and determining the moment of inertia of the collimator magnet. A set of observations with the old chuck was completed on the 8th June 1920 and observations with the new chuck were commenced on the following day. There was no appreciable change in the moment of inertia between the two sets of observations.

The meteorological observatory which was formerly in the compound of the old hospital at Toungoo has now, with the approval of the Surveyor General of India, been removed to a site south of the Magnetic Observatory compound. At the request of the Director General of Indian observatories the meteorological instruments, which will shortly be installed, will be in charge of the Magnetic Observer and will be read daily by him or his Recorder who will submit the meteorological reports according to directions.

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 $P_{1\cdot2}$ and $P_{2\cdot3}$ and

the accepted values of p and q used in determining the values of the revised distribution factor and moment of inertia used for the computations for 1915.

There has been a rapid rate of decrease in the moment of this observatory magnet as compared with the magnets of the other observatories and it is, therefore, proposed to replace it, during the ensuing field season, by magnet No. 20 which was previously used at the Barrackpore observatory.

Mean values of the constants of magnet No. 19A in 1919.

Months.	Declination constants.	H. F. constants.					
		Distribution Factors.				Mean values of m.	
	Mean magnetic collimation.			Accepted values			
		$P_{1\cdot2}$	$P_{2\cdot3}$	p	q	Monthly means	Accepted m.
	′ ″						
January ...	− 11 36	8·26	9·23			867·05	867·03
February ...	− 11 41	8·32	9·32			866·89	866·97
March ...	− 11 43	8·24	9·54			866·57	866·50
April ...	− 11 44	8·23	9·73			866·44	866·44
May ...	− 11 39	8·15	9·81			866·37	866·38
June ...	− 11 9	8·25	9·55	10·19	−546	866·26	866·32
July ...	− 11 12	8·25	9·33				866·26
August ...	− 11 5	8·21	9·68			866·21	866·20
September ...	− 11 4	8·17	9·71			866·11	866·14
October ...	− 11 3	8·19	9·70			865·98	866·08
November ...	− 11 8	8·15	9·85				866·02
December ...	− 11 4	8·16	9·62			865·81	865·96

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 1919. The H. F. base line values have been derived from H as determined with the moment of inertia and distribution factor used in the computations for 1915.

Base line values of magnetographs in 1919.

Months.	Declination.				Horizontal Force.	
	Mean value of Base line		Base line accepted		Mean value of Base line	Base line accepted
	° ′		° ′		C. G. S.	C. G. S.
January	−1	16·3	−1	16·3	·38699	·38699
February	−1	15·8	−1	15·8	·38699	·38699
March	−1	15·7	−1	15·7	·38681	·38681
April	−1	15·8	−1	15·8	·38688	·38688
May	−1	15·7	−1	15·7	·38690	·38690
June	−1	15·3	−1	15·3	·38690	·38690
July	−1	15·3	−1	15·3	·38689	·38689
August	−1	15·4	−1	15·4	·38685	·38685
September	−1	15·4	−1	15·4	·38682	·38682
October	−1	15·2	−1	15·2	·38682	·38682
November	−1	15·1	−1	15·1	·38680	·38680
December	−1	15·1	−1	15·1	·38684	·38684

4. *Mean scale values and temperature range.*—The mean scale values for 1919 for an ordinate of 1/25 inch are:—

Horizontal Force	5·35 gammas.
Declination	1·04 minutes.
Vertical Force	5·69 gammas.

The mean temperature for the year was 89°·3 Fahr., with maximum and minimum monthly values of 89°·1 Fahr. and 90°·1 Fahr.

The temperature of reduction is 89°·0 Fahr.

5. *Mean monthly values and annual changes.*—The table below gives the mean monthly values of the magnetic elements for 1918 and 1919 and the annual changes for that period: the values of annual change 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 Toungoo in 1918-19.

Months.	Horizontal Force ·39000 C. G. S. +			Declination W. 0° +			Dip N. 23°+			Vertical Force ·16000 C. G. S. +		
	1918.	1919.	Annual change.	1918.	1919.	Annual change.	1918.	1919.	Annual change.	1918.	1919.	Annual change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January ...	53	81	+28	14·7	19·0	+4·3	8·1	8·5	+0·4	686	703	+17
February ...	55	90	+35	15·3	18·9	+3·6	8·4	8·1	−0·3	690	701	+11
March ...	64	71	+ 7	15·4	19·1	+3·7	8·7	8·3	−0·4	697	696	− 1
April ...	67	89	+22	16·0	19·6	+3·6	8 5	8·4	−0·1	698	705	+ 7
May ...	70	86	+16	16·0	19·9	+3 9	8·6	8·6	0·0	700	706	+ 6
June ...	73	116	+43	16·5	19·8	+3 3	8·3	7·5	−0·8	696	705	+ 9
July ...	73	118	+45	16·8	20·1	+3·3	8·2	7·8	−0·4	695	709	+14
August ...	70	94	+24	16·9	20·5	+3·6	8·4	8·9	+0·5	697	713	+'6
September ...	66	91	+25	17·3	21·1	+3·8	8·5	8·7	+0·2	693	709	+13
October ...	71	96	+25	17·4	21·3	+3·9	8·5	8·8	+0·3	699	714	+15
November ...	79	116	+37	17·8	21·5	+3·7	8·2	8·0	−0·2	698	711	+13
December ...	68	118	+50	18·4	22·0	+3·6	8·7	8·0	−0·7	701	712	+11
Means ...	67	97	+30	16·5	20·2	+3·7	8·4	8·3	−0·1	696	707	+11

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 V.F. magnetograph has worked satisfactorily. The clock which is common to both the Declination and H.F. magnetographs is reported to have stopped very often during the year and to have given much trouble.

In the returns from this observatory it is stated that the slit and lens of the H.F. magnetograph were cleaned on the 6th May; the focus adjusted on the 16th June and the mirror, lens and clock of the instrument cleaned and the hour flag adjusted on the 17th June.

The Declination magnetograph is reported as being unsettled and the frequent adjustments made throughout the year unsatisfactory. It has in consequence been difficult to decide upon the base lines for the periods between the frequent interruptions.

It is also stated that during the latter part of June 1920 all the instruments had to be readjusted.

When the observatory was visited in December 1919, for taking the usual annual observations for the comparison of instruments, observations were also taken with the Survey gilt bar for determining the moment of inertia of the observatory magnet.

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 1919.

Months.	Declination constants.	H.F. constants.					
		Distribution Factors.				Mean values of m.	
	Mean magnetic collimation.			Accepted values.		Monthly means.	Accepted m.
		$P_{1\cdot2}$	$P_{2\cdot3}$	p	q		
	′ ″						
January ...	− 3 25	6·13	8·56			881·47	
February ...	− 3 25	6·10	8·65			881·26	
March ..	− 3 21	6·13	8·47			881·88	
April ...	− 3 24	6·14	8·30			881·73	
May ...	− 3 23	6·07	8·40			881·66	
June ...	− 3 23	6·00	8·44	11·39	−·1621	881·83	881·74
July ...	− 3 23	6·06	8·50			881·68	
August ...	− 3 23	6·00	8·28			881·55	
September ..	− 3 22	6·10	8·49			881·73	
October ...	− 3 21	6·13	8·38			881·90	
November ...	− 3 22	6·13	8·29			881·88	
December ...	− 3 19	6·19	8·49			881·92	

3. Mean base line values.—The following table gives the mean monthly observed and accepted base line values of the Declination and H.F. magnetographs: the accepted values have been used to compute the values of these elements for 1919.

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 1919.

Months.	Declination.			Horizontal Force.
	Mean value of Base line.	Base line accepted	Remarks.	Monthly mean value of Base line.
	° ′	° ′		
January ...	2 32·9	2 32·9	...	·37362
February ...	2 33·5	2 33·5	from 1st to 10h on 18th	·37364
,, ...	2 32·4	2 32·4	from 11h on 18th to 27th	..
March ...	2 33·2	2 33·2	from 3rd to 21st	·37362
,, ...	2 48·8	2 48·8	from 29th to 31st	.
April ...	2 52·9	2 52·9	from 1st to 5th	·37362
,, ...	2 51·5	2 51·5	from 9th to 15th	...
,, ...	2 55·6	2 55·6	for 21st	...
,, ...	2 57·8	2 57·8	from 28th April to 8th May	...
May ...	3 2·3	3 2·3	for 23rd	·37364
,, ...	3 3·7	3 3·7	from 25th May to 10h on 22nd June	...
June ...	3 2·8	3 2·8	from 11h on 22nd to 30th June	·37362
July ...	3 3·6	3 3·6	from 1st to 10h on 7th	·373 8
,, ...	3 0·1	3 0·1	from 11h on 7th to 27th	...
August ...	3 9·1	3 9·1	from 2nd to 10th	·37358
,, ...	3 11·2	3 11·2	from 13th to 17th	...
,, ...	3 13·6	3 13·6	from 18th to 29th	...
September ...	3 8·2	3 8·2	from 4th to 18th	·37356
,, ..	3 9·4	3 9·4	from 21st to 29th	...
October ...	3 8·5	3 8·5	from 7th to 31st	·37355
November ...	3 8·9	3 8·9	...	·37352
December ...	3 9·0	3 9·0	...	·37354

4. *Mean scale values and temperature range.*—The mean scale values for 1919 for an ordinate of 1/25 inch are:—

Horizontal Force	5·90 gammas.
Declination	1·03 minutes.
Vertical Force	7·18 to 7·44 gammas.

The mean temperature for the year was 17°·3 C., with maximum and minimum monthly values of 16°·5 C. and 18°·0 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 1918 and 1919 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 1918-19.

Months.	Horizontal Force ·37000 C. G. S.+			Declination W. 1° +			Dip N. 4° +			Vertical Force ·02000 C. G. S.+		
	1918.	1919.	Annual change.	1918.	1919.	Annual change.	1918.	1919.	Annual change.	1918.	1919.	Annual change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January ...	682	732	+ 50	36·8	41·7	+ 4·9	28 9	31·5	+ 2·6	953	986	+ 33
February ...	677	739	62	37·0	42·2	5·2	29 5	31·8	2·3	959	989	30
March ...	684	735	51	37·4	42·8	5 4	29·6	32·1	2 5	961	993	32
April ...	687	749	62	38·3	43·5	5·2	29·6	32·7	3·1	961	1000	39
May ...	694	744	50	38·4	43·7	5 3	30·2	32·9	2 7	969	1002	33
June ...	697	766	69	39·1	44·3	5 2	30·6	33 5	2·9	973	1011	38
July ...	699	766	67	39·3	44·1	4 8	30 5	34·2	3·7	972	1018	46
August ...	698	749	51	39 8	44·8	5·0	31·0	35 5	4·5	977	1031	54
September ...	698	752	54	40·3	46 2	5 9	30·5	33 8	3·3	973	1013	40
October ...	701	759	58	40·9	46·4	5·5	30·4	34·4	4 0	971	1020	49
November ..	706	774	68	41·5	46·7	5·2	31·2	34·7	3·5	980	1025	45
December ...	701	772	71	41·4	47·4	6·0	31·5	35·1	3·6	984	1029	45
Means ...	694	753	+ 59	39·2	44·5	+ 5·3	30·3	33·5	+ 3·2	969	1010	+ 40

III.—Tables of Results.

Mean values of the magnetic elements at observatories in 1919.

Observatory.	Latitude and Longitude.	Dip.	Declination.	H. F.	V. F.
	° ′ ″	° ′	° ′	C. G. S.	C. G. S.
Dehra Dūn ...	30 19 19 N. 78 3 19 E.	N. 44 54·8	E. 1 56·1	·32962	·32863
Toungoo ...	18 55 45 N. 96 27 3 E.	N. 23 8·3	W. 0 20·2	·39097	·16707
Kodaikānal ...	10 13 50 N. 77 27 46 E.	N. 4 33·5	W. 1 44·5	·37753	·03010

D = Dehra Dūn ... { Lat. 30 19 19 N. / Long. 78 3 19 E.

T = Toungoo ... { Lat. 18 55 45 N. / Long. 96 27 3 E.

K = Kodaikānal ... { Lat. 10 13 50 N. / Long. 77 27 46 E.

Classification and dates of Magnetic disturbances in 1919.

1919	January.			February.			March.			April.			May.			June.			July.			August.			September.			October.			November.			December.		
Dates.	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K	D	T	K
1 ...	C	C	C	S	S	S	M	M	M	S	S	S	C	C	C	S	S	S	S	S	S	C	S	—	C	C	—	M	M	—	C	C	C	C	C	C
2 ...	C	C	C	S	S	S	M	M	S	C	C	C	G	G	M	S	S	S	S	S	S	C	S	S	C	C	—	G	G	G	C	C	S	C	C	C
3 ...	C	C	C	S	S	S	S	S	S	C	C	C	M	M	M	S	S	S	S	S	S	C	S	S	C	C	—	G	G	G	C	C	S	C	C	C
4 ...	G	G	M	S	S	S	S	S	S	C	C	C	S	S	S	S	S	S	S	S	S	C	S	C	S	C	S	S	S	G	M	C	S	C	C	C
5 ...	M	M	M	S	S	S	S	S	S	C	C	C	S	S	S	S	S	S	C	C	C	C	S	C	C	C	C	G	G	G	C	C	S	C	C	C
6 ...	M	M	M	S	S	S	S	S	S	C	C	C	S	S	S	C	C	C	C	C	C	C	S	C	C	C	C	G	G	S	C	C	S	C	C	C
7 ...	S	S	S	C	C	C	M	M	S	C	C	C	S	S	S	C	C	C	C	C	C	C	S	C	C	C	C	G	S	S	C	C	S	C	C	C
8 ...	S	S	S	C	C	C	M	M	S	C	C	C	S	S	S	C	C	C	C	C	C	S	S	C	C	C	C	S	S	M	C	C	S	C	C	C
9 ...	S	C	C	C	C	C	S	S	S	C	C	C	S	S	S	C	C	C	S	S	S	C	S	C	C	C	C	S	S	M	C	C	S	C	C	C
10 ...	C	C	C	C	C	C	S	S	S	C	C	C	S	S	S	C	C	C	S	S	S	C	S	C	C	C	C	S	S	S	C	C	S	C	C	C
11 ...	C	C	C	C	C	C	C	C	S	C	C	C	S	S	S	C	C	C	S	S	S	C	S	C	C	C	C	S	S	S	C	C	S	C	C	C
12 ..	C	C	C	C	C	C	C	C	S	C	C	C	S	S	S	C	C	C	S	S	S	C	S	C	C	C	C	S	S	S	C	C	S	C	C	C
13 ...	S	S	S	S	S	S	C	C	S	S	S	S	M	M	S	C	C	C	S	S	S	C	S	C	C	C	C	S	S	S	C	C	S	C	C	C
14 ...	M	M	M	M	M	M	S	S	S	—	—	—	S	S	S	C	C	C	S	S	S	C	S	C	C	C	C	S	S	S	C	C	S	C	C	C
15 ...	S	S	S	M	S	S	S	S	S	C	C	C	M	M	M	S	S	S	C	C	C	C	S	C	C	C	C	S	S	S	C	C	S	C	C	C
16 ...	S	S	S	M	S	S	S	S	S	C	C	C	M	M	M	S	S	S	C	C	C	C	S	C	C	C	C	S	S	S	C	C	S	C	C	C
17 ...	S	S	S	S	S	S	S	S	S	C	C	C	S	S	S	C	C	C	C	C	C	C	S	C	C	C	C	S	S	S	C	C	S	C	C	C
18 ...	S	S	S	S	C	S	C	C	S	C	C	C	S	S	S	C	C	C	C	C	C	C	S	C	C	C	C	S	S	S	C	C	S	C	C	C
19 ...	S	S	S	S	C	S	C	C	S	—	—	—	—	—	—	C	C	C	C	C	C	C	S	C	C	C	C	S	S	S	C	C	S	C	C	C
20 ...	S	S	S	S	C	S	M	M	S	—	—	—	G	G	S	C	C	C	C	C	C	C	S	C	C	C	C	S	S	M	C	C	S	C	C	C
21 ...	S	S	S	M	M	M	M	M	S	M	M	S	M	G	S	C	C	C	C	C	C	C	S	C	C	C	C	S	S	S	C	C	S	C	C	C
22 ...	S	S	S	M	M	M	M	M	S	M	M	S	G	G	M	C	C	C	C	C	C	C	S	C	C	C	C	S	S	S	C	C	S	C	C	C
23 ...	S	S	C	M	S	C	S	C	C	S	S	S	S	S	S	C	C	C	C	C	C	C	S	C	C	C	C	S	S	S	C	C	S	C	C	C
24 ...	C	C	C	S	C	C	C	C	C	S	S	S	S	S	C	C	C	C	C	C	C	C	S	C	C	C	C	S	S	M	C	C	S	C	C	C
25 ...	C	C	C	C	C	C	S	C	C	S	S	S	S	S	S	C	C	C	C	C	C	C	S	C	C	C	C	S	S	S	C	C	S	C	C	C
26 ...	C	C	C	C	C	C	C	M	S	C	C	C	S	S	S	C	C	C	C	C	C	C	S	C	C	C	C	S	S	S	C	C	S	C	C	C
27 ...	C	C	C	C	C	C	M	M	S	S	C	C	S	S	S	C	C	C	C	C	C	C	S	C	C	C	C	S	S	S	C	C	S	C	C	C
28 ...	C	C	C	G	G	G	M	M	S	C	S	S	C	C	C	S	S	S	C	C	C	C	S	C	C	C	C	S	S	S	C	C	S	C	C	C
29 ...	S	S	C	...	...	...	S	S	S	S	S	S	C	C	C	S	S	C	C	C	C	S	S	C	C	C	C	C	C	C	C	C	C	C	C	C
30 ...	C	C	C	...	...	...	S	S	S	...	...	...	C	C	C	C	C	C	S	S	S	C	C	C	C	C	C	S	C	C	C	C	C	C	C	C
31 ...	G	G	G	...	...	...	S	S	S	...	...	...	C	C	C	...	...	...	S	S	S	C	C	C	...	...	...	S	C	S	C	C	C	C	C	C
C ...	12	13	14	9	9	9	8	9	10	6	7	11	8	8	5	11	11	9	12	14	18	9	14	14	8	12	10	7	7	7	19	20	21	21	24	25
S ...	14	13	12	13	14	15	16	15	15	18	19	14	13	13	21	19	19	21	16	17	13	19	15	14	20	16	16	13	14	14	8	7	7	8	5	4
M ...	3	3	4	5	4	1	7	7	4	5	4	2	3	3	4	...	...	...	1	...	...	...	...	...	2	2	1	6	6	5	3	3	1	2	2	2
G ...	2	2	1	1	1	1	...	...	...	...	...	...	3	2	1	...	...	...	...	...	...	2	2	2	...	...	...	4	4	4	...	...	...	...	..	...
V.G. ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Trace lost ...	...	...	...	...	...	2	...	...	2	1	...	3	4	...	...	...	...	...	2	...	...	1	...	1	...	...	3	1	...	1	...	...	1	...	...	...

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

Hourly Means of the Declination at Dehra Dun in 1919, determined from all available days. Declination = E. 1° + tabular quantity.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter.	Jan.	58·8	58·8	58·8	58·6	58·4	58·2	58·0	58·3	59·0	59·5	59·3	58·0	57·3	57·4	57·8	58·3	58·7	58·5	58·5	58·8	58·7	58·8	59·0	58·9	58·9	58·5
	Feb.	58·6	58·7	58·6	58·6	58·5	58·3	58·2	58·5	59·5	59·8	59·1	57·9	56·9	57·0	57·7	58·3	58·9	58·8	58·5	58·3	58·2	58·3	58·5	58·5	58·6	58·4
	Mar.	58·4	58·5	58·4	58·1	58·0	57·8	57·7	58 5	59·8	60·4	60·1	58·7	56·9	56·0	55·9	56·9	57·7	57·9	57·6	57·6	57·8	58·1	58·2	58·3	58·4	58·1
	Oct.	54·7	54·6	54·4	54·5	54·4	54·2	54·2	55·0	56·1	56·0	55·1	53·9	52·8	52·5	53·1	54·0	51·3	54·1	53·9	54·1	54·1	54·2	54·4	54·6	54·7	54·3
	Nov.	54·4	54·4	54·2	54·1	53·9	53·8	53·7	54·0	54·6	55·0	54·5	53·8	53·2	53·4	53·9	54·1	54·1	54·3	54·2	54·2	54·3	54·3	54·4	54 6	54·5	54·1
	Dec.	54·3	54·4	54·2	54·0	53 6	53·4	53·2	53·1	53·6	54·4	54·9	54·5	53·8	53·8	53·9	54·1	54·1	54·2	54·2	54·4	54·4	54·5	54·4	54·4	54·3	54·1
	Means	56·5	56·6	56·4	56·3	56·1	56·0	55·8	56·2	57·1	57·5	57·2	56·1	55·2	55·0	55·4	56·0	56·3	56·3	56·2	56·2	56·3	56·4	56·5	56·6	56·6	56·3
Summer.	April	57·8	57·7	57·7	57·8	57·7	57·6	58·1	59·1	60·2	60·2	58·8	56·4	54·8	53·9	54·2	55·1	56·1	56·6	56·8	56·6	56·8	57·0	57·2	57·4	57·6	57·2
	May	57·0	57·4	57·3	57·4	57·3	57·4	58·6	59·6	60·2	59·5	57·6	55·2	53·8	53·2	53·8	54·5	55·4	56·1	56·8	56·6	56·4	56·4	56·5	56·6	56·8	56·7
	June	55·9	56·3	56·5	56·6	56·7	57·0	58·6	59·8	60·0	59·0	57·2	55·2	53·5	52·6	52·5	53·2	54·0	54·9	55·8	55·6	55·3	55·3	55·5	55·8	55·9	56·0
	July	55·7	56·0	56·1	56 2	56·3	56·6	57·9	58·9	59·0	58·4	56·9	55·0	53·5	52·5	52·1	52·5	53·4	54·4	55·2	55·0	54·9	55·0	55·1	55·5	55·7	55·5
	Aug.	55·4	55·7	55·9	56·1	56·0	56·3	57·5	58·5	58·7	57·6	55·8	53·9	52·7	52·1	52·2	53·0	53·9	54·7	55·3	54·9	54·7	54·7	54·9	55·1	55·4	55·2
	Sep.	55·7	55·9	55·9	55 9	55·9	55·8	56·3	57·5	58·1	57·4	55·5	53·5	52·3	51·7	52·2	53·4	54·5	54·9	54·8	54·6	54·7	55·0	55·1	55·4	55·6	55·1
	Means	56·3	56·5	56·6	56·7	56·7	56·8	57·8	58·9	59·4	58·7	57·0	54·9	53·4	52·7	52·8	53·6	54·6	55·3	55·8	55·6	55·5	55·6	55·7	56·0	56·2	56·0

Diurnal Inequality of the Declination at Dehra Dun in 1919, deduced from the above Table.

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

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

Hourly Means of Horizontal Force in C.G.S. units (corrected for temperature) at Dehra Dun in 1919, 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
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter	Jan.	953	954	953	955	953	957	960	961	958	957	953	958	961	960	**961**	961	958	955	954	954	**950**	950	953	954	954	956
	Feb.	957	956	955	956	956	956	959	959	957	957	959	966	976	**978**	973	968	960	952	**951**	952	955	957	961	958	956	960
	Mar.	953	956	953	957	955	957	958	956	957	960	967	**972**	971	970	965	955	949	**946**	948	951	951	951	952	951	952	957
	Oct.	946	951	955	952	953	953	953	954	951	952	960	961	**962**	961	956	950	944	941	**940**	943	946	945	952	949	**947**	951
	Nov.	968	969	970	970	971	972	975	979	985	988	990	989	**990**	984	979	974	973	972	971	968	968	969	**966**	969	968	975
	Dec.	963	963	963	963	965	967	970	974	978	**981**	980	979	976	973	970	966	964	962	962	959	**957**	959	959	963	964	967
	Means	957	958	958	959	959	960	963	964	964	966	968	971	**973**	971	967	962	958	955	**954**	955	955	955	957	957	957	961
Summer	April	955	957	961	957	958	959	960	958	955	956	964	972	977	981	**981**	977	966	958	956	954	**951**	955	956	957	957	962
	May	953	951	954	955	954	952	953	948	**942**	943	949	964	973	979	976	969	960	952	947	946	947	950	952	955	959	955
	June	976	976	975	975	976	976	977	978	975	978	984	990	994	998	997	991	985	978	972	**971**	972	974	974	974	976	980
	July	973	972	972	974	973	975	976	976	975	974	979	990	995	**1001**	1000	991	981	974	971	970	**969**	970	971	969	971	978
	Aug.	951	953	953	953	954	954	953	951	947	**946**	950	959	966	970	**972**	965	959	952	945	947	947	950	951	953	953	954
	Sep.	938	939	941	941	942	943	945	940	936	**933**	937	943	949	**957**	956	953	945	941	**943**	942	942	941	944	941	942	943
	Means	958	958	959	959	960	960	961	959	955	955	961	970	976	**981**	980	974	966	959	956	955	**955**	957	958	958	960	962

Diurnal Inequality of the Horizontal Force at Dehra Dun in 1919, deduced from the above Table.

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

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 1919, from all available days. Vertical Force = ·32000 C.G.S. + tabular quantity.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter	Jan.	824	824	823	824	823	824	824	824	825	824	819	813	813	814	818	821	822	822	823	823	823	824	824	823	823	822
	Feb.	820	820	820	820	820	819	820	821	821	816	810	808	808	811	814	817	818	818	818	819	821	821	821	820	820	818
	Mar.	836	836	835	836	835	835	835	837	838	834	828	820	816	817	822	825	828	830	831	833	835	835	836	836	837	831
	Oct.	912	913	914	916	915	916	917	919	917	909	906	885	884	891	898	903	903	905	909	910	911	910	912	909	908	908
	Nov.	918	919	919	919	919	919	919	920	921	918	913	905	906	909	911	914	916	917	919	919	920	921	921	921	921	917
	Dec.	919	918	918	918	917	917	919	919	920	919	916	905	904	907	911	914	917	917	920	920	918	919	919	920	921	916
	Means	872	872	872	872	872	872	872	873	874	870	865	856	855	858	862	866	867	868	870	871	871	872	872	872	872	869
Summer	April	837	837	837	835	835	835	837	839	838	833	825	817	815	819	825	829	830	831	832	833	835	836	837	837	837	832
	May	853	853	853	853	852	853	856	855	851	846	838	832	833	838	842	846	848	849	849	850	850	851	852	852	852	848
	June	856	857	857	857	856	857	861	859	854	848	841	833	833	835	838	843	848	852	854	854	854	855	855	855	856	851
	July	869	869	868	868	868	869	873	871	867	860	853	847	845	848	850	855	859	863	865	865	865	867	867	867	869	862
	Aug.	877	877	876	876	876	877	879	878	874	868	862	856	857	861	865	869	871	872	873	873	875	876	877	877	877	872
	Sep.	879	880	880	879	878	879	879	880	879	874	868	861	860	864	868	872	873	875	874	875	877	877	878	877	877	874
	Means	862	862	862	861	861	862	864	864	861	855	848	841	841	844	848	852	855	857	858	858	859	860	861	861	861	857

Diurnal Inequality of the Vertical Force at Dehra Dun in 1919, deduced from the above Table.

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

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 1919, 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.	53·2	53·2	53·2	53·2	53·2	53·0	52·9	52·8	53·0	53·0	53·0	52·4	**52·3**	52·4	52·5	52·7	52·9	53·1	53·2	53·2	53·4	**53·4**	53·2	53·2	53·2	53·0
	Feb.	52·8	52·9	53·0	52·9	52·9	52·9	52·8	52·8	52·9	52·6	52·3	51·7	**51·2**	51·3	51·7	52·1	52·6	53·0	53·0	**53·1**	53·0	52·9	52·7	52·8	52·9	52·6
	Mar.	53·9	53·8	53·8	53·7	53·8	53·6	53·6	53·8	53·8	53·4	52·7	52·1	**51·9**	52·0	52·6	53·2	53·7	54·0	53·9	53·8	54·0	54·0	54·0	**54·0**	54·0	53·5
	Oct.	58·2	58·0	57·9	58·1	58·0	58·1	58·1	58·2	58·2	57·8	57·2	56·1	**55·9**	56·4	57·0	57·6	57·9	58·1	**58·4**	58·3	58·2	58·2	57·9	57·9	58·0	57·7
	Nov.	57·4	57·4	57·4	57·4	57·3	57·2	57·1	56·9	56·6	56·3	56·0	**55·6**	55·7	56·1	56·4	56·9	57·0	57·1	57·3	57·5	57·5	57·5	**57·6**	57·5	57·6	56·9
	Dec.	57·7	57·6	57·6	57·6	57·5	57·4	57·4	57·2	57·0	56·8	56·7	**56·1**	56·2	56·6	56·9	57·3	57·6	57·7	57·8	**58·0**	58·0	58·0	58·0	57·8	57·8	57·4
	Means	55·5	55·5	55·5	55·5	55·5	55·4	55·3	55·3	55·3	55·0	54·7	54·0	**53·9**	54·1	54·5	55·0	55·3	55·5	55·6	55·7	**55·7**	55·7	55·6	55·5	55·6	55·2
Summer	April	53·8	53·7	53·5	53·6	53·6	53·6	53·6	53·8	53·9	53·6	52·7	51·9	**51·5**	51·6	51·9	52·3	52·9	53·4	53·6	53·7	**54·0**	53·8	53·8	53·7	53·7	53·2
	May	54·8	54·9	54·7	54·7	54·7	54·9	54·9	55·1	**55·3**	54·9	54·2	53·1	52·7	**52·6**	53·0	53·6	54·2	54·6	54·9	55·0	54·9	54·8	54·8	54·6	54·4	54·4
	June	53·7	53·8	53·9	53·9	53·7	53·8	**54·0**	53·8	53·7	53·2	52·6	51·8	51·6	**51·5**	51·7	52·3	52·8	53·4	53·8	53·9	53·8	53·8	53·8	**53·8**	53·7	53·3
	July	54·6	54·6	54·5	54·5	54·5	54·5	54·6	54·5	54·4	54·1	53·4	52·6	52·2	**52·0**	52·2	52·9	53·6	54·2	54·5	54·5	54·5	54·6	54·6	**54·7**	54·7	54·0
	Aug.	56·1	56·0	56·0	56·0	55·9	56·0	56·1	56·2	56·2	55·9	55·4	54·6	**54·3**	54·3	54·4	55·0	55·4	55·9	56·2	56·1	**56·2**	56·1	56·1	56·0	56·0	55·7
	Sep.	56·9	56·9	56·8	56·8	56·7	56·7	56·6	56·9	**57·0**	56·9	56·4	55·7	55·4	**55·1**	55·4	55·8	56·2	56·6	56·4	56·5	56·6	56·6	56·6	56·6	56·6	56·4
	Means	55·0	55·0	54·9	54·9	54·9	54·9	55·0	55·1	**55·1**	54·8	54·1	53·3	53·0	**52·9**	53·1	53·7	54·2	54·7	54·9	55·0	55·0	55·0	55·0	54·9	54·9	54·5

Diurnal Inequality of the Dip at Dehra Dun in 1919, deduced from the above Table.

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

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

Hourly Means of the Declination at Toungoo in 1919, determined from all available days. Declination = W. 0° + tabular quantity.

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

Diurnal Inequality of the Declination at Toungoo in 1919, deduced from the above Table.

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

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

Hourly Means of Horizontal Force in C.G.S. units (corrected for temperature) at Toungoo in 1919, 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
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter	Jan.	072	070	071	071	072	073	077	080	087	092	099	107	**111**	106	095	086	079	075	073	072	069	068	**067**	072	074	081
	Feb.	079	079	077	077	077	078	079	085	094	103	115	123	**126**	118	108	096	088	081	079	078	**075**	075	078	082	081	090
	Mar.	**054**	056	059	057	059	061	061	065	074	088	103	113	**113**	102	089	075	063	059	058	057	057	057	056	057	055	071
	Oct.	093	083	088	090	091	091	092	093	101	111	121	130	**130**	119	106	097	089	086	085	**081**	081	084	085	089	088	096
	Nov.	103	103	103	105	106	107	110	116	126	136	146	**151**	147	137	127	118	112	108	108	104	**101**	101	104	101	104	116
	Dec.	106	110	110	110	110	113	117	122	128	135	141	**145**	144	136	127	121	114	110	109	107	105	**104**	107	106	107	118
	Means	083	084	085	085	086	087	089	094	102	111	121	128	**129**	120	109	099	091	087	085	083	**081**	082	083	085	085	095
Summer	April	**071**	072	074	075	075	076	077	079	089	107	121	129	**130**	124	114	103	092	082	078	077	075	071	073	075	075	089
	May	072	074	074	076	077	078	076	080	088	102	115	120	**120**	115	106	094	083	075	074	073	073	072	**072**	075	076	086
	June	101	103	103	104	104	105	106	111	121	134	147	154	**156**	150	139	126	111	102	**100**	101	102	101	101	101	101	116
	July	103	104	104	105	107	108	111	115	122	134	144	152	**155**	148	142	131	116	105	**100**	102	104	103	103	103	101	118
	Aug.	082	082	083	084	085	085	087	087	092	104	113	119	**124**	120	114	107	096	087	082	**081**	082	082	084	084	085	094
	Sep.	077	**077**	077	080	082	082	081	079	083	098	110	118	**124**	119	113	101	092	084	084	085	084	083	082	084	081	091
	Means	**084**	085	086	087	088	089	090	092	099	113	125	132	**135**	129	121	110	098	089	086	087	087	085	086	087	087	099

Diurnal Inequality of the Horizontal Force at Toungoo in 1919, deduced from the above Table.

		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
Winter	Jan.	− 9	−11	−10	−10	− 9	− 8	− 4	− 1	+ 6	+11	+18	+26	+30	+25	+14	+ 5	− 2	− 6	− 8	− 9	−12	−13	−14	− 9	− 7	
	Feb.	−11	−11	−13	−13	−13	−12	−11	− 5	+ 4	+13	+25	+33	+36	+28	+18	+ 6	− 2	− 9	−11	−12	−15	−15	−12	− 8	− 9	
	Mar.	−17	−15	−12	−14	−12	−10	−10	− 6	+ 3	+17	+32	+42	+42	+31	+18	+ 4	− 8	−12	−13	−14	−14	−14	−15	−14	−16	
	Oct.	−13	−13	− 8	− 6	− 5	− 5	− 4	− 3	+ 5	+15	+25	+34	+34	+23	+10	+ 1	− 7	−10	−11	−15	−15	−12	−11	− 7	− 8	
	Nov.	−13	−13	−13	−11	−10	− 9	− 6	0	+10	+20	+30	+35	+31	+21	+11	+ 2	− 4	− 8	− 8	−12	−15	−15	−12	−15	−12	
	Dec.	−12	− 8	− 8	− 8	− 8	− 5	− 1	+ 4	+10	+17	+23	+27	+26	+18	+ 9	+ 3	− 4	− 8	− 9	−11	−13	−14	−11	−12	−11	
	Means	−12	−11	−10	−10	− 9	− 8	− 6	− 1	+ 7	+16	+26	+33	+34	+25	+14	+ 4	− 4	− 8	−10	−12	−14	−13	−12	−10	−10	
Summer	April	−18	−17	−15	−14	−14	−13	−12	−10	0	+18	+32	+40	+41	+35	+25	+14	+ 3	− 7	−11	−12	−14	−18	−16	−14	−14	
	May	−14	−12	−12	−10	− 9	− 8	−10	− 6	+ 2	+16	+29	+34	+34	+29	+20	+ 8	− 3	−11	−12	−13	−13	−14	−14	−11	−10	
	June	−15	−13	−13	−12	−12	−11	−10	− 5	+ 5	+18	+31	+38	+40	+34	+23	+10	− 5	−14	−16	−15	−14	−15	−15	−15	−15	
	July	−15	−14	−14	−13	−11	−10	− 7	− 3	+ 4	+16	+26	+34	+37	+30	+24	+13	− 2	−13	−18	−16	−14	−15	−15	−15	−17	
	Aug.	−12	−12	−11	−10	− 9	− 9	− 7	− 7	− 2	+10	+19	+25	+30	+26	+20	+13	+ 2	− 7	−12	−13	−12	−12	−10	−10	− 9	
	Sep.	−14	−14	−14	−11	− 9	− 9	−10	−12	− 8	+ 7	+19	+27	+33	+28	+22	+10	+ 1	− 7	− 7	− 6	− 7	− 8	− 9	− 7	−10	
	Means	−15	−14	−13	−12	−11	−10	− 9	− 7	0	+14	+26	+33	+36	+30	+22	+11	− 1	−10	−13	−12	−12	−14	−13	−12	−12	

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 1919, from all available days. Vertical Force = ·16000 C.G.S. + tabular quantity.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter	Jan.	708	708	708	708	707	707	707	708	708	703	693	687	689	692	698	702	703	702	703	705	705	706	707	708	708	703
	Feb.	707	707	707	707	707	707	707	707	703	694	685	681	685	695	702	706	704	700	700	703	703	704	705	706	707	701
	Mar.	702	702	702	701	701	700	702	701	697	690	683	681	682	687	694	697	696	695	695	698	699	700	700	701	702	696
	Oct.	719	719	719	719	719	719	720	719	713	705	699	698	701	707	713	716	715	712	713	715	716	717	719	719	719	714
	Nov.	715	715	715	715	715	715	715	716	714	710	704	702	705	705	704	706	709	710	711	712	713	713	715	715	716	711
	Dec.	715	715	715	715	715	715	715	715	716	714	709	704	703	704	707	711	713	712	713	714	714	714	715	716	716	712
	Means	711	711	711	711	711	711	711	711	709	703	696	692	694	698	703	706	707	705	706	708	708	709	710	711	711	706
Summer	April	710	710	710	710	710	710	712	711	705	697	690	686	688	695	703	708	708	707	705	706	707	708	709	709	710	705
	May	711	712	712	711	711	712	715	713	706	694	686	685	689	698	703	707	711	711	708	707	708	709	710	711	711	706
	June	710	710	710	710	711	711	715	712	705	697	691	689	689	694	699	704	708	708	707	705	706	708	709	709	710	705
	July	712	713	713	712	713	713	717	716	710	702	696	693	695	699	704	708	712	711	711	708	710	711	712	713	713	709
	Aug.	719	719	719	719	719	720	723	720	711	702	697	696	698	703	708	714	716	716	714	714	715	716	717	718	719	713
	Sep.	715	715	715	715	715	715	719	717	708	696	690	688	691	699	708	714	715	712	710	712	712	713	714	715	716	709
	Means	713	713	713	713	713	714	717	715	707	698	692	690	692	698	704	709	712	711	709	709	710	711	712	713	713	708

Diurnal Inequality of the Vertical Force at Toungoo in 1919, deduced from the above Tabl.

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

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

Hourly Means of the Dip at Toungoo in 1919, determined from all available days. Dip = N. 23° + tabular quantity.

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

Diurnal Inequality of the Dip at Toungoo in 1919, deduced from the above Table.

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

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 1919, determined from all available days. Declination = W. 1° + tabular quantity.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter.	Jan.	41·7	41·6	41·7	41·8	41·9	42·0	42·2	42·2	41·9	41·5	41·8	42·3	**42·4**	42·1	41·8	41·4	**41·2**	41·4	41·5	41·4	41·4	41·5	41·5	41·5	41·6	41·7
	Feb.	42·2	42·1	42·2	42·1	42·2	42·3	42·6	42·7	42·4	42·2	42·6	**42·8**	42·7	42·3	41·8	41·5	**41·5**	41·9	42·3	42·2	42·2	42·3	42·3	42·3	42·2	42·2
	Mar.	42·9	42·7	42·7	42·8	42·9	43·0	43·1	43·0	42·8	42·5	**42·4**	42·7	43·1	**43·3**	43·2	42·8	42·6	42·7	42·9	42·8	42·8	42·8	42·8	42·8	42·8	42·8
	Oct.	46·3	46·2	46·3	46·4	46·5	46·6	46·5	46·4	46·2	46·2	46·5	46·9	**46·9**	46·8	46·4	46·1	**46·1**	46·3	46·5	46·3	46·4	46·4	46·5	**46·4**	**46·5**	46·4
	Nov.	46·8	46·7	46·8	46·9	47·1	47·2	47·4	**47·6**	47·3	47·1	47·0	46·9	46·7	46·2	**46·0**	46·1	46·2	46·3	46·5	46·4	46·4	46·6	46·7	**46·7**	**46·7**	46·7
	Dec.	47·3	47·3	47·4	47·6	47·8	48·2	48·3	**48·7**	48·4	47·8	47·3	47·0	46·9	**46·7**	46·8	46·9	46·8	46·9	47·1	47·0	47·0	47·1	47·2	**47·3**	**47·3**	47·4
	Means	44·5	44·4	44·5	44·6	44·7	44·9	45·0	**45·1**	44·8	44·6	44·6	44·8	44·8	44·6	44·3	44·1	**44·1**	44·3	44·5	44·4	44·4	44·5	44·5	44·5	44·5	44·5
Summer.	April	43·4	43·3	43·3	43·3	43·4	43·4	43·2	42·8	**42·8**	43·0	43·4	43·8	44·4	**44·6**	44·4	43·9	43·3	43·2	43·2	43·4	43·5	43·4	43·4	43·2	43·1	43·5
	May	43·8	43·5	43·5	43·5	43·4	43·4	42·8	**42·2**	42·3	43·0	44·1	44·8	**45·3**	45·2	44·6	44·2	43·9	43·6	43·3	43·8	43·9	43·9	43·8	43·7	43·6	43·7
	June	44·5	44·3	44·2	44·1	43·9	43·8	43·1	**42·3**	42·5	43·3	44·3	44·9	45·7	**45·8**	45·5	45·0	44·5	44·3	44·4	44·6	44·8	44·8	**44·7**	44·6	44·5	44·3
	July	44·2	44·0	44·0	44·0	44·0	43·9	43·6	43·2	**43·2**	43·5	43·9	44·0	44·4	**44·7**	44·7	44·5	44·2	44·1	44·0	44·2	44·3	44·4	44·3	44·3	44·2	44·1
	Aug.	45·0	44·8	44·7	44·6	44·6	44·4	43·9	**43·2**	43·3	44·1	45·0	45·5	**46·0**	46·0	45·7	45·3	44·8	44·5	44·6	45·0	45·1	45·2	45·1	45·0	44·9	44·8
	Sep.	46·1	45·9	45·9	45·9	45·9	45·9	45·4	**44·5**	44·6	45·6	46·5	47·3	48·1	**48·2**	47·6	46·9	46·3	46·0	46·0	46·2	46·3	46·3	46·2	46·2	46·1	46·2
	Means	44·5	44·3	44·3	44·2	44·2	44·1	43·7	**43·0**	43·1	43·8	44·5	45·1	45·7	**45·8**	45·4	45·0	44·5	44·3	44·3	44·5	44·7	44·7	44·6	44·5	44·4	44·4

Diurnal Inequality of the Declination at Kodaikanal in 1919, deduced from the above Table.

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

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

Hourly Means of Horizontal Force in C.G.S. units (corrected for temperature) at Kodaikanal in 1919, from all available days. Horizontal Force = ·37000 C.G.S. + tabular quantity.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter	Jan.	712	713	712	715	715	717	719	723	732	756	778	792	789	769	750	737	730	726	721	718	714	712	713	713	713	732
	Feb.	717	718	718	718	718	717	717	728	755	790	817	819	801	767	736	724	725	730	727	721	721	720	721	719	717	739
	Mar.	709	711	711	715	715	716	715	723	747	777	801	811	794	769	746	733	728	726	722	717	713	712	712	709	710	735
	Oct.	734	738	744	743	743	742	742	751	772	797	818	821	810	791	771	757	750	748	743	741	740	738	742	739	739	759
	Nov.	753	753	755	755	756	757	761	771	789	808	824	827	820	806	790	779	771	766	762	756	755	753	750	752	753	774
	Dec.	756	756	757	757	759	760	761	768	779	795	810	820	818	808	795	778	768	762	760	756	753	753	753	755	757	772
	Means	730	732	733	734	734	735	736	744	762	787	808	815	805	785	765	751	745	743	739	735	733	731	732	731	732	752
Summer	April	720	722	725	725	727	726	726	734	762	794	818	825	814	792	767	750	742	739	736	729	724	723	722	723	723	749
	May	720	722	725	725	725	723	725	733	757	787	803	808	800	784	763	744	734	732	727	724	720	720	721	723	725	744
	June	748	749	749	749	749	749	750	757	772	796	814	823	821	810	793	772	757	749	749	750	748	747	745	746	748	766
	July	745	745	746	749	749	749	753	757	773	795	814	823	817	809	793	774	759	747	748	749	746	745	745	742	744	766
	Aug.	727	729	730	731	731	732	734	739	756	777	792	802	798	787	776	761	750	740	735	733	729	729	729	731	731	749
	Sep.	722	722	723	727	730	730	732	738	764	796	821	829	819	797	772	752	742	741	739	734	730	728	728	726	727	752
	Means	730	732	733	734	735	735	737	743	764	791	810	818	812	797	777	759	747	741	739	737	733	732	732	732	733	754

Diurnal Inequality of the Horizontal Force at Kodaikanal in 1919, deduced from the above Table.

		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
Winter	Jan.	−20	−19	−20	−17	−17	−15	−13	− 9	0	+24	+46	+60	+57	+37	+18	+ 5	− 2	− 6	−11	−14	−18	−20	−19	−19	−19	
	Feb.	−22	−21	−21	−21	−21	−22	−22	−11	+16	+51	+78	+80	+62	+28	− 3	−15	−14	− 9	−12	−18	−18	−19	−18	−20	−22	
	Mar.	−26	−24	−24	−20	−20	−19	−20	−12	+12	+42	+66	+76	+59	+34	+11	− 2	− 7	− 9	−13	−18	−22	−23	−23	−26	−25	
	Oct.	−25	−21	−15	−16	−16	−17	−17	− 8	+13	+38	+59	+62	+51	+32	+12	− 2	− 9	−11	−16	−18	−19	−21	−17	−20	−20	
	Nov.	−21	−21	−19	−19	−18	−17	−13	− 3	+15	+34	+50	+53	+46	+32	+16	+ 5	− 3	− 8	−12	−18	−19	−21	−24	−22	−21	
	Dec.	−16	−16	−15	−15	−13	−12	−11	− 4	+ 7	+23	+38	+48	+46	+36	+23	+ 6	− 4	−10	−12	−16	−19	−19	−19	−17	−15	
	Means	−22	−20	−19	−18	−18	−17	−16	− 8	+10	+35	+56	+63	+53	+33	+13	− 1	− 7	− 9	−13	−17	−19	−21	−20	−21	−20	
Summer	April	−29	−27	−24	−24	−22	−23	−23	−15	+13	+45	+69	+76	+65	+43	+18	+ 1	− 7	−10	−13	−20	−25	−26	−27	−26	−26	
	May	−24	−22	−19	−19	−19	−21	−19	−11	+13	+43	+59	+64	+56	+40	+19	0	−10	−12	−17	−20	−24	−24	−23	−21	−19	
	June	−18	−17	−17	−17	−17	−17	−16	− 9	+ 6	+30	+48	+57	+55	+44	+27	+ 6	− 9	−17	−17	−16	−18	−19	−21	−20	−18	
	July	−21	−21	−20	−17	−17	−17	−13	− 9	+ 7	+29	+48	+57	+51	+43	+27	+ 8	− 7	−19	−18	−17	−20	−21	−21	−24	−22	
	Aug.	−22	−20	−19	−18	−18	−17	−15	−10	+ 7	+28	+43	+53	+49	+38	+27	+12	+ 1	− 9	−14	−16	−20	−20	−20	−18	−18	
	Sep.	−30	−30	−29	−25	−22	−22	−20	−14	+12	+44	+69	+77	+67	+45	+20	0	−10	−11	−13	−18	−22	−24	−24	−26	−25	
	Means	−24	−22	−21	−20	−19	−19	−17	−11	+10	+37	+56	+64	+58	+43	+23	+ 5	− 7	−13	−15	−17	−21	−22	−22	−22	−21	

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

Hourly Means of Vertical Force in C.G.S. units (corrected for temperature) at Kodaikanal in 1919, from all available days. Vertical Force = ·02000 C.G.S. + tabular quantity.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Winter	Jan.	993	994	993	994	994	995	997	997	994	986	976	968	966	967	971	977	981	982	986	989	989	990	991	992	993	986
	Feb.	998	998	997	998	998	997	999	998	994	984	971	961	966	973	985	989	990	987	989	993	994	995	997	997	997	989
	Mar.	1003	1004	1002	1003	1003	1003	1005	1003	998	992	980	970	969	974	978	982	985	988	993	997	997	998	1000	1000	1002	993
	Oct.	1028	1029	1030	1028	1029	1028	1031	1030	1025	1018	1009	1002	999	1002	1004	1010	1014	1015	1020	1022	1025	1025	1028	1027	1027	1020
	Nov.	1030	1030	1030	1030	1031	1031	1031	1031	1030	1027	1023	1018	1015	1012	1012	1015	1019	1020	1024	1024	1026	1027	1028	1029	1029	1025
	Dec.	1035	1035	1035	1034	1035	1034	1035	1034	1034	1032	1028	1024	1017	1014	1013	1017	1023	1027	1029	1031	1031	1032	1033	1036	1036	1029
	Means	1015	1015	1015	1015	1015	1015	1016	1016	1013	1007	998	991	989	990	994	998	1002	1003	1007	1009	1010	1011	1013	1014	1014	1007
Summer	April	1008	1009	1009	1008	1009	1009	1013	1012	1003	995	986	980	978	981	988	995	1000	1000	1000	1000	1002	1004	1007	1008	1009	1000
	May	1012	1013	1013	1012	1012	1013	1016	1014	1006	994	985	979	977	982	988	993	1000	1004	1004	1004	1005	1008	1010	1012	1013	1002
	June	1016	1017	1016	1016	1017	1018	1022	1022	1018	1010	1003	997	994	995	1000	1005	1008	1010	1011	1011	1012	1014	1015	1016	1017	1011
	July	1024	1025	1025	1025	1026	1027	1030	1028	1022	1014	1007	1002	1000	1003	1006	1011	1015	1018	1019	1018	1019	1021	1022	1023	1024	1018
	Aug.	1039	1040	1040	1040	1040	1041	1045	1041	1031	1021	1016	1015	1015	1020	1022	1026	1030	1029	1029	1031	1033	1035	1037	1038	1039	1031
	Sep.	1024	1025	1027	1026	1026	1027	1032	1025	1011	999	988	981	983	989	997	1007	1013	1015	1016	1018	1020	1022	1024	1024	1025	1013
	Means	1021	1022	1022	1021	1022	1023	1026	1024	1015	1006	998	992	991	995	1000	1006	1011	1013	1014	1014	1015	1017	1019	1020	1021	1013

Diurnal Inequality of the Vertical Force at Kodaikanal in 1919, deduced from the above Table.

		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
Winter	Jan.	+ 7	+ 8	+ 7	+ 8	+ 8	+ 9	+11	+11	+ 8	0	−10	−18	−20	−19	−15	− 9	− 5	− 4	0	+ 3	+ 3	+ 4	+ 5	+ 6	+ 7	
	Feb.	+ 9	+ 9	+ 8	+ 9	+ 9	+ 8	+10	+ 9	+ 5	− 5	−18	−28	−23	−16	− 4	0	+ 1	− 2	0	+ 4	+ 5	+ 6	+ 8	+ 8	+ 8	
	Mar.	+10	+11	+ 9	+10	+10	+10	+12	+10	+ 5	− 1	−13	−23	−24	−19	−15	−11	− 8	− 5	0	+ 4	+ 4	+ 5	+ 7	+ 7	+ 9	
	Oct.	+ 8	+ 9	+10	+ 8	+ 9	+ 8	+11	+10	+ 5	− 2	−11	−18	−21	−18	−16	−10	− 6	− 5	0	+ 2	+ 5	+ 5	+ 8	+ 7	+ 7	
	Nov.	+ 5	+ 5	+ 5	+ 5	+ 6	+ 6	+ 6	+ 6	+ 5	+ 2	− 2	− 7	−10	−13	−13	−10	− 6	− 5	− 1	− 1	+ 1	+ 2	+ 3	+ 4	+ 4	
	Dec.	+ 6	+ 6	+ 6	+ 5	+ 6	+ 5	+ 6	+ 5	+ 5	+ 3	− 1	− 5	−12	−15	−16	−12	− 6	− 2	0	+ 2	+ 2	+ 3	+ 4	+ 7	+ 7	
	Means	+ 8	+ 8	+ 8	+ 8	+ 8	+ 8	+ 9	+ 9	+ 6	0	− 9	−16	−18	−17	−13	− 9	− 5	− 4	0	+ 2	+ 3	+ 4	+ 6	+ 7	+ 7	
Summer	April	+ 8	+ 9	+ 9	+ 8	+ 9	+ 9	+13	+12	+ 3	− 5	−14	−20	−22	−19	−12	− 5	0	0	0	0	+ 2	+ 4	+ 7	+ 8	+ 9	
	May	+10	+11	+11	+10	+10	+11	+14	+12	+ 4	− 8	−17	−23	−25	−20	−14	− 9	− 2	+ 2	+ 2	+ 2	+ 3	+ 6	+ 8	+10	+11	
	June	+ 5	+ 6	+ 5	+ 5	+ 6	+ 7	+11	+11	+ 7	− 1	− 8	−14	−17	−16	−11	− 6	− 3	− 1	0	0	+ 1	+ 3	+ 4	+ 5	+ 6	
	July	+ 6	+ 7	+ 7	+ 7	+ 8	+ 9	+12	+10	+ 4	− 4	−11	−16	−18	−15	−12	− 7	− 3	0	+ 1	0	+ 1	+ 3	+ 4	+ 5	+ 6	
	Aug.	+ 8	+ 9	+ 9	+ 9	+ 9	+10	+14	+10	0	−10	−15	−16	−16	−11	− 9	− 5	− 1	− 2	− 2	0	+ 2	+ 4	+ 6	+ 7	+ 6	
	Sep.	+11	+12	+14	+13	+13	+14	+19	+12	− 2	−14	−25	−32	−30	−24	−16	− 6	0	+ 2	+ 5	+ 5	+ 7	+ 9	+11	+11	+12	
	Means	+ 8	+ 9	+ 9	+ 8	+ 9	+10	+13	+11	+ 2	− 7	−15	−21	−22	−18	−13	− 7	− 2	0	+ 1	+ 1	+ 2	+ 4	+ 6	+ 7	+ 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 1919, determined from all available days. Dip = N. 4° + tabular quantity.

	Hours	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means
Winter	Jan.	32·3	32·4	32·3	32·3	32·3	32·4	**32·6**	32·6	32·2	**31·3**	**30·3**	29·4	**29·3**	29·5	30·0	30·6	31·1	31·2	31·6	31·9	31·9	32·0	32·1	32·2	**32·3**	31·5
	Feb.	32·7	32·7	32·6	32·7	32·7	32·6	**32·8**	32·6	32·1	30·9	29·5	**28·6**	29·2	30·1	31·4	31·8	31·9	31·6	31·8	32·2	32·3	32·4	32·6	32·6	**32·6**	31·8
	Mar.	33·2	33·3	33·1	33·2	33·2	33·2	**33·3**	33·1	32·5	**31·7**	30·5	**29·5**	29·5	30·1	30·7	31·1	31·4	31·7	32·2	32·6	32·6	32·7	32·9	32·9	**33·1**	32·1
	Oct.	35·3	35·3	35·4	35·2	35·3	35·2	**35·5**	35·3	**34·7**	33·9	**33·0**	32·3	**32·1**	32·5	32·8	33·5	33·9	**34·0**	34·5	34·7	35·0	35·0	35·2	35·2	**35·2**	34·4
	Nov.	35·3	35·3	35·3	35·3	**35·4**	35·4	35·4	35·3	35·1	**34·7**	34·2	33·7	33·5	**33·3**	33·4	33·8	34·2	**34·3**	34·7	34·8	35·0	35·1	35·2	35·2	**35·2**	34·7
	Dec.	35·8	35·8	35·7	35·7	35·7	35·6	35·7	35·6	35·5	35·2	34·7	34·3	33·7	**33·5**	33·5	34·0	34·6	35·0	35·2	35·4	35·4	35·5	35·6	**35·9**	**35·8**	35·1
	Means	34·1	34·1	34·1	34·1	34·1	34·1	**34·2**	34·1	33·7	33·0	32·0	31·3	**31·2**	31·5	32·0	32·5	32·9	33·0	33·3	33·6	33·7	33·8	33·9	**34·0**	**34·0**	33·3
Summer	April	33·6	33·7	33·6	33·5	33·6	33·6	**34·0**	33·8	32·8	31·9	30·9	30·3	**30·2**	30·6	31·4	32·2	32·7	32·7	32·7	32·8	33·0	33·2	33·5	33·6	**33·6**	32·7
	May	33·9	34·0	34·0	33·9	33·9	34·0	**34·3**	34·0	33·1	31·8	30·9	30·3	**30·2**	30·8	31·5	32·0	32·7	33·1	33·2	33·2	33·3	33·6	33·8	33·9	**34·0**	32·9
	June	34·1	34·2	34·1	34·1	34·2	34·3	**34·6**	34·6	34·1	33·2	32·4	31·8	**31·6**	31·8	32·3	32·9	33·3	33·5	33·6	33·6	33·7	33·9	34·0	34·1	**34·2**	33·5
	July	34·8	34·9	34·9	34·9	35·0	35·1	**35·3**	35·1	34·5	33·6	32·8	32·3	**32·2**	32·5	32·9	33·5	33·9	34·3	34·4	34·3	34·4	34·6	**34·7**	34·8	**34·8**	34·2
	Aug.	36·3	36·4	36·4	36·4	36·4	36·5	**36·8**	36·4	35·4	34·3	33·8	33·6	33·6	34·2	34·4	34·9	35·3	35·3	35·4	35·6	35·8	36·0	**36·1**	36·2	**36·3**	35·5
	Sep.	35·0	35·1	35·3	35·2	35·1	35·2	**35·7**	35·0	33·5	32·2	31·0	30·4	30·6	31·3	32·2	33·3	33·9	34·1	34·3	34·4	34·6	34·8	**35·0**	35·0	**35·1**	33·8
	Means	34·6	34·7	34·7	34·7	34·7	34·8	**35·1**	34·8	33·9	32·8	32·0	31·5	**31·4**	31·9	32·5	33·1	33·6	33·8	33·9	34·0	34·1	34·4	**34·5**	34·6	**34·7**	33·8

Diurnal Inequality of the Dip at Kodaikanal in 1919, deduced from the above Table.

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

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

BASE LINE.

No comparator or base line work was undertaken by this party during the year under report. From March 3rd the Officer in charge was placed on special duty in Calcutta in charge of the Map Record and Issue Office.

PERSONNEL of No. 19 PARTY.

Class I Officers.

Major C. M. Thompson, I. A., in charge up to 11th December 1919, from 21st February to 2nd March 1920 and from 29th June to 30th September 1920.

Major H. J. Couchman, D. S. O., M. C., R. E., in charge from 12th December 1919 to 20th February 1920.

Major O. H. B. Trenchard, R. E., in charge from 3rd March to 28th June 1920.

Lower Subordinate Service.

1 Clerk, etc.

THE COMPUTING OFFICE

By J. de Graaff Hunter, M. A., Sc. D., F. Inst. P.

Personnel

Class I Officers.

Major C. M. Thompson, I. A., in charge till 20th February 1920.

Dr. J. de Graaff Hunter, M. A., Sc. D., F. Inst. P in charge from 30th April 1920.

Class II Officer.

Mr. Hanuman Prasad, in charge Workshops & Stores. In charge Computing Office from 21st February to 29th April 1920.

Upper Subordinate Service.

Mr. Sarat Kumar Mukerji, in charge Printing Section.

Computing Office.

Head computer.

Rai Sahib Ishan Chandra Deva, B. A.

Babu S. C. Guha, B.A., officiating from 28th June to 30th September 1920.

11 Senior & 5 Junior computers.

Printing Section.

1 Proof reader, 23 compositors, 6 distributers, 5 pressmen, 1 stereotyper and 8 book-binders.

Workshops.

1 Head Artificer, 23 fitters and carpenters.

Computations.—The following computations were carried out during the year :—

(*a*) Tables bearing on the subject of rectangular coordinates were computed.

(*b*) Altitudes of the sun at different hours from 8 A. M. to 4 P. M. on different dates from November 1919 to February 1920.

(*c*) Nunkun Peaks by combining Major Mason's observations of 1911 with the old observations of 1859-60.

(*d*) Graticules for No. 2 Drawing Office.

(*e*) Fundamental equations were solved for the simultaneous reduction of magnetic observations by No. 18 Party.

(*f*) For detecting errors in the traverse line Ganges Diāra No. 1 (Purnea) of 1905-06 and Rājshāhi-Mālda traverse of 1915-16, which was asked for by the Director of Bengal Surveys as their junction points disclosed an error of 7 chains.

(*g*) For Auxiliary Tables Part III (5th Edn.).

(*h*) Values of $\frac{r^n \cos n\theta}{\lfloor n}$ and $\frac{r^n \sin n\theta}{\lfloor n}$ for the adjustment of minor triangulation.

Adjustments.—

(*a*) Mawkmai Series and Mong Hsat Series in hand.

(*b*) Heights of North Baluchistān and Kalāt Series completed (in terms of Great Indus Series).

(*c*) Kashmīr Series and Russian triangulation taken up.

(*d*) Adjustment of trig. heights of all India is under contemplation.

(*e*) Corrections have been applied to some of Burma degree sheets.

Miscellaneous.—(*a*) Revised barometric and hypsometric heights near Turfan for Sir Aurel Stein.

(*b*) Compiled requisite information for the combined chart 42 (South) and 43 (North).

(*c*) Prepared and submitted a report on Sir Aurel Stein's work and examined Gilgit triangulation.

(*d*) Examined and checked Tide Tables for 16 Party and Traverse by 22 Party.

(*e*) Submitted report on the work of Rai Sahib Ram Singh and Rai Bahadur Lal Singh in Central Asia.

(*f*) Checked forms designed by Major Morshead.

(*g*) The remodelling of professional forms is in progress.

Triangulation Pamphlets.—46 pamphlets were printed and issued during the year, including 14 sheets for the East Persia Party, which were vandyked. About 40 sheets were compiled and compared of which 25 were supplied to the Superintendent Eastern Circle. Besides the above some compilations were made from explorations in Persia.

Levelling.—The following have been published :—

(*a*) Second edition of levelling pamphlets 44 and 53.

(*b*) Addenda to Levelling Pamphlets 63, 72 and 73.

(*c*) A reprint of the Levelling Pamphlet 54 having been called for on account of important revisions in that sheet, a corrected 3rd edition has been prepared and will be ready for publication early next year.

Revision.—

(*a*) The revision of the Auxiliary Tables of the Survey of India is in hand : Part III, 5th edition is in course of printing. This part will be mainly devoted to tables required for the computations of topographical survey.

(*b*) Chapter III (1914) of the Hand Book of Topography is under revision and will be ready for publication by the end of this year.

Requisitions.—165 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. All the requisitions from Eastern Circle, which were considerable, for triangulation data in Burma had to be copied and supplied.

Research Work.—The question of the adjustment of minor triangulation has been taken up. It will be seen that in this case it is essential that a much shorter process than that which may rightly be followed in the case of geodetic triangulation must be devised. Failing this, owing to the enormous mass of minor triangulation, the work of adjusting it would be impracticable. That the work should be adjusted in some cases is most desirable; otherwise there is apt to be great confusion when publication is undertaken. It is possible to suggest that the adjustments may be performed by applying corrections which change at a uniform rate between two points of closure. But in practice there are generally several more points of closure, so that this method cannot be applied at all easily. Moreover, it takes no account of the azimuth and side closures, which are inter-related with the changes in latitude and longitude. Such a process only renders the lack of adjustment less apparent: while it exists, probably in as localised a form as before, the so called adjustment has sometimes been made: and the results arrived at have not been mutually accordant.

Considerable progress has already been made in finding a short method, which leads to consistent results. It is possible thereby to satisfy any number of closing conditions. The solution is not the most probable adjustment, but does not differ greatly from it. It is a development of Chap. VI, Prof. Paper 16. The method has been applied to two degree sheets, and it appears that perhaps about a fortnight's work would suffice to adjust a sheet, after the method has become standardised.

The above work has so far been only in the hands of Dr. Hunter, but there is no reason to suppose that it will offer difficulty to the Computing office staff.

Dr. Hunter has also prepared a long note on the specifications of microscope theodolites, in view of certain developments in glass graticules and other details. This has been sent to the Director General of Stores, India Office, by whom it was called for.

Printing Section.

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

Volume XIV (1918-19) of the Records of the Survey of India; Triangulation Pamphlets of which some were final editions, complete with topo. data; Levelling Pamphlets 44, 53 and addenda to 63, 72 and 73; Auxiliary Tables, Part I (reprint); Hand Book of Levelling; Catalogue of library books; Topo: Hand Book Chapter III; Air-Photo Surveying; Wazīristān Report and English Indent.

A second Wharfedale Machine has been installed and was started in February 1920.

In the Book-binding Section the work dealt with comprised 2500 copies of triangulation pamphlets, 600 copies of Levelling pamphlets, and 3450 copies of miscellaneous publications including angle books and library books. The binding of the Records Volume XIV (350 copies) is in hand.

Workshops.

During the year 1919-20 the following work was done in the workshop:—

Fitting the new Wharfedale machine and installing motor for running the same; making alterations in Photo Zinco Office presses; frame for the large reflecting mirror; making woodwork verandah for Photo Zinco Office duffers; making almirahs and cabinets for the library; packing field presses, etc.; making tables and stools for Drawing Office and Printing Office; making parts of signals for Sind Sāgar Party and other miscellaneous work.

Observatories.

(1) *Seismography and Meteorology.*—The Omori Seismograph was in operation throughout the year and the usual daily meteorological observations were made. From 1st to 21st September in addition to the usual observations, readings were recorded of the barometer and hygrometer at 8, 10, 12, 14 and 16 hours for investigation purposes in connection with the expedition of Dr. Kellas and Major Morshead to Kamet. The Photo-helio observatory continued its work as in past years. The following statements show the earthquakes recorded and the number of days on which solar photographs were taken.

1. *Statement of earthquakes recorded during the year 1919-20.*

No.	Month and Date	Time of beginning (corrected)		Duration	Distance of Epicentre		REMARKS
		Dehra	Simla (from W.R.*)		Dehra	Simla (from W.R.*)	Intensity &c.
		h m	*h m*	*h m*	*miles*	*miles*	
1	30-10-19	20 10	20 9	...	...	...	A local shock of slight intensity.
2	21-12-19	1 19	1 18	0 30	4,410	1,500	Moderate
3	21-12-19	2 16	2 15	1 10	2,800	2,500	,,
4	3- 2-20	17 6½	...	2 15	4,970	...	,,
5	27- 2-20	9 28	9 29	0 30	875	500	Slight
6	3- 5-20	14 5	14 4	0 27	280	300	,,
7	3- 5-20	20 24	20 23	0 27	280	300	,,
8	8- 5-20	11 21½	11 20	0 52	1,950	2,000	,,
9	8- 5-20	3 25	3 25	1 4	1,950	2,000	,,
10	5- 6-20	9 57½	9 59	1 20½	1,700	2,000	Great
11	11- 7-20	21 30	21 33	0 18	350	200	Slight
12	21- 9-20	20 27¼	20 28	2 23	2,500	4,500	Great
13	21- 9-20	5 10	5 10	0 11	400	400	Slight

* W. R. means daily Weather Report published at Simla.

2. *Statement showing the number of days on which solar photographs were taken during the year 1919-20.*

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 1919	31	56	4	1	...	...	April 1920	29	52	6	...	...	1
November ,,	29	53	4	2	...	1	May ,,	29	50	13	...	...	2
December ,,	24	41	3	...	...	7	June ,,	23	39	12	...	...	7
January 1920	27	45	4	4	1	4	July ,,	22	32	8	...	...	9
February ,,	27	49	3	2	...	2	August ,,	25	41	6	1	1	6
March ,,	28	47	4	1	...	3	September ,,	30	51	6	2	1	...
							Total ...	324	556	73	13	3	42

APPENDIX I.

(Read at the R.A.S. Geophysical Meeting on Mar. 5, 1920.)

THE EARTH'S AXES AND FIGURE.

By J. de Graaff Hunter, M. A., Sc.D., F. Inst. P.

1. When the expression "The Earth's Axes" is used it is generally intended to refer to the axes of that ellipsoid which agrees most closely with the mean sea-level equipotential surface of the earth; and much more often than not this ellipsoid is considered to be one of revolution round the polar axis and is briefly named the "spheroid".

"The Figure of the Earth" implies the actual mean sea-level equipotential surface which is called the "geoid". This is the reality of nature. The spheroid has certain uses and may for some purposes be used instead of the geoid. I do not think it has ever been rigidly defined.

2. In the early part of the 19th century discrepancies between geoid and a selected spheroid were uniformly ascribed to either observation errors or to the selected spheroid being of incorrect dimensions or location; and the view seemed to prevail that if a spheroid were correctly selected it should coincide with the geoid.

3. Results which became available later made it quite clear that there cannot be coincidence between geoid and spheroid, and it seems necessary to consider whether any precise meaning is implied by the name "spheroid". For over 200 years various determinations of the spheroid have been made. Two methods have been employed by geodesists:—

(i) Measurements of arcs of triangulation, with terminal measurements of latitude and longitude or both,

(ii) Pendulum observations, which may be applied to Clairaut's equation to find the ellipticity.

In the first of these methods there is no reason why the work should not be satisfactory, if proper precautions are taken, even though the geoid is widely different from the spheroid. In the second method, since Clairaut's equation is deduced for a spheroid, it is only an approximation when applied to the geoid.

4. A solution by (i) making the residual deflections of the plumb-line a minimum over any area—even over the whole earth—will not lead to precisely the same spheroid as that whose ellipticity is determined by (ii). It appears then that there is no uniquely defined spheroid in the minds of present day geodesists.

5. There is a spheroid which would be a possible form of equilibrium for the earth if it behaved as a fluid; and no doubt the earth does in a great portion of its mass act practically as a fluid would. But the external portions do not act as a fluid, and so this hydrodynamical equilibrium spheroid has no special significance. In latter years Hayford brought in corrections, on account of isostasy, to his work to determine the axes and ellipticity of the spheroid. This results in a modified spheroid which I think amounts to much the same as the hydrodynamical spheroid just alluded to.

6. Now the determinations of Helmert and Hayford are:—

		a	b	$1/\epsilon$
Hayford	1906	$6378 \cdot 283 \pm \cdot 034$ km.	$6356 \cdot 868$ km	$297 \cdot 8 \pm 0 \cdot 9$
Helmert	1907	$6378 \cdot 200$	$6356 \cdot 818$	$298 \cdot 3$
Hayford	1909	$6378 \cdot 388 \pm \cdot 018$	$6356 \cdot 909$	$297 \cdot 0 \pm 0 \cdot 5$

which may be compared with the determinations of

Everest	1830	$6377 \cdot 276$	$6356 \cdot 075$	$300 \cdot 80$
Clarke	1880	$6378 \cdot 301$	$6356 \cdot 871$	$293 \cdot 47$

Everest's axes are distinctly too small. Clarke's are intermediate to those of Hayford and Helmert. But as regards the inverse of the ellipticity Everest is large and Clarke small compared with Hayford and Helmert. Clarke however is in good accord with values of

inverse of ellipticity derived from lunar theory (E. W. Brown $293 \cdot 7 \pm 0 \cdot 3$; Crommelin $294 \cdot 4 \pm 1 \cdot 5$). Darwin derived 296·4 by astronomical means, which is intermediate to these and Hayford.

Clarke in 1878 also solved for three unequal axes getting 6378·431 in longitude 8° 15′ W, (revised values) 6377·966, and 6356·439; and as far as I am aware this is the last determination of its kind.

7. Now, with no very precise definition of the spheroid, what are its uses? To my mind its chief value is as a reference figure, and for this purpose it is not necessary to find a rigid definition for it. For any one survey a spheroid is selected and all results, whether topographical or geodetical, can be correctly expressed in terms of it. Such a spheroid admits of the formation of relatively simple formulae for calculating all ordinary survey operations; it serves as a reference figure in relation to which the form of the geoid may be exhibited, and it gives a basis for a formula for gravity, which should approximate to the actual geoidal value. It has a value in giving approximate bases for astronomical purposes, for it is simple to calculate the distance apart of any two points on the spheroid, and this gives the nearest possible approximation to the actual geoidal distance. It is only an approximation, less precise than what is possible after continuous survey joins the points.

8. It is most important that existing geodetic surveys should be fully linked up as soon as possible. Suppose by some means the axes of the spheroid most closely approximating to the geoid over the whole earth were accurately known, and consider what use could be made of it by the surveyor. He can determine at any point of his area, which he selects to use as origin, the direction of the axis of rotation of the earth. This will enable him to direct his spheroid properly. But after he has found his latitude and longitude astronomically and his height by spirit-levelling above some mean sea-level at a tidal station, he does not know to what point on the spheroid his origin corresponds; for the geoid at his origin may be tilted to the spheroid and raised above it. In other words he has no means of locating himself with regard to the centre of the spheroid. He must make the best assumptions for this that he can, *e. g.* that the mean deflections in meridian and prime vertical, over his area, are zero; and that the mean geoidal rise above the spheroid is zero. Obviously the larger his area the more satisfactory will his assumptions be.

I am just pointing out the difficulty of expressing results of a geodetic survey in terms of a universal spheroid, even of given axes. The point I want to make is that the pressing further in the effort to determine numerical values of the axes of a hypothetical spheroid is not very useful. Let us rather try to get all results into terms of one reference spheroid—either Hayford or Helmert's will serve quite well and equally well—by linking up existing surveys as far as possible.

9. It may be thought that I am insisting too much on the difference of the geoid from any spheroid which has been or might be proposed. To give an idea of the deviation liable to be met with, I have taken out the figures for meridian 77°·7. I have not had time to go more fully into the geoidal form, even in India, for the present discussion. In 1916 I applied a similar process to the whole of the Indian survey, and this single meridian may be considered typical. The process followed now is to take the mean of all observed meridian deflections for each square degree of latitude between longitudes 77° and 78°, and also the mean latitudes and longitudes of the stations. These deflections are then plotted against latitude and a curve drawn through the points, from which the mean deflection of each degree of latitude is read off. The mean of all the deflections in each degree between latitude 8° and 28° is found and removed, leaving residual deflections on the basis of a deflection of amount equal to the mean, but of opposite sign, at the origin (Kalianpur). These amount to 1·″77 and 4·″08, corresponding to a shift of the centre of the spheroid of 58 and 134 metres parallel to the meridian at the origin in the cases of the Everest and Helmert spheroids respectively. The deflections in seconds multiplied by a factor give the rise of the geoid in the corresponding degree; and the summation of these separate quantities give the rise of geoid at any point in relation to the starting point. This process has been carried out for deflections expressed in terms of both Everest's and Helmert's spheroids, and the results are shown by curves.

Deflections of the plumb-line and Rise of geoid in longitude 77°·7

n = number of observation stations in degree sheet.
λ_m, L_m are mean latitudes and longitudes of all stations in degree sheet.
δ = deflection of plumb-line in meridian ($+^{ve}$ if southerly) with reference to (1) Everest's (2) Helmert's spheroid.
$\delta_o = \delta + 1''\cdot77$ for Everest's spheroid corresponding to deflection 1″·77 S at Kalianpur.
$= \delta + 4''\cdot08$ Helmert's " " " " 4·08 S "

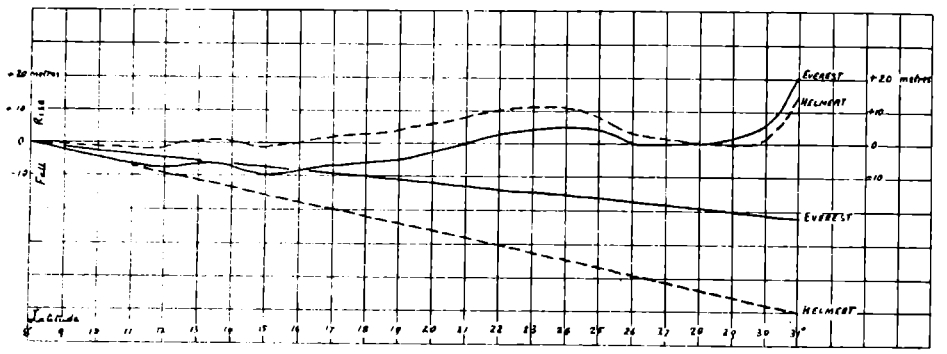
Degree Sheet.	n	λ_m	L_m	δ Everest	δ Helmert	λ	Deflection Everest N —	Deflection Everest S +	δ Helmert N −	δ Helmert S +	Everest $-\delta_o$	Everest $-\Sigma\delta_o$	Helmert $-\delta_o$	Helmert $-\Sigma\delta_o$	λ	Rise of geoid in meters $= -0\cdot537\Sigma\delta_o$ Everest	Rise of geoid in meters $= -0\cdot537\Sigma\delta_o$ Helmert
		°	°	″	″	°		″	″		″	″	″	″	°		
58 H	6	8·2	77·7	+ 2·2	− 3·6	8·5	...	2·3	3·2	...	− 4·1	− 4·1	− 0·9	− 0·9	8	0	0
G	1	9·5	·9	+ 2·3	− 3·1	9·5	...	2·2	3·0	..	− 4·0	− 8·1	− 1·1	− 2·0	9	− 2·40	− 0·48
F	2	11·0	·7	+ 0·8	− 4·1	10·5	...	1·6	3·6	...	− 3·3	− 11·4	− 0·5	− 2·5	10	− 4·35	− 1·07
E	1	11·1	·8	+ 2·1	− 2·8	11·5	...	0·8	3·8	...	− 2·6	− 14·0	− 0·2	− 2·7	11	− 6·12	− 1·34
57 H	1	13·0	·6	− 4·2	− 8·4	12·5	3·6	...	7·8	...	+ 1·8	− 12·2	+ 3·7	+ 1·0	12	− 7·52	− 1·45
G	3	13·4	·6	− 0·5	− 4·6	13·5	0	0	3·8	...	− 1·7	− 13·9	− 0·3	+ 0·7	13	− 6·55	+ 0·54
F	5	14·8	·1	+ 2·6	− 1·1	14·5	...	2·5	0·8	...	− 4·3	− 18·2	− 3·3	− 2·6	14	− 7·46	+ 0·38
E	1	15·1	·6	− 0·7	− 4·2	15·5	3·6	...	6·5	...	+ 1·8	− 16·4	+ 2·4	− 0·2	15	− 9·79	− 1·40
56 H	5	16·2	·7	− 5·4	− 8·6	16·5	4·9	...	7·6	...	+ 3·2	− 13·2	+ 3·6	+ 3·4	16	− 8·80	− 0·11
G	5	17·1	·6	− 3·8	− 6·6	17·5	3·2	...	5·7	...	+ 1·4	− 11·8	+ 1·6	+ 5·0	17	− 7·09	+ 1·83
F	1	18·1	·7	− 2·4	− 4·9	18·5	3·4	...	5·5	...	+ 1·6	− 10·2	+ 1·4	+ 6·4	18	− 6·34	+ 2·68
E	4	19·1	·7	− 5·2	− 7·3	19·5	6·2	...	8·0	...	+ 4·5	− 5·7	+ 3·9	+ 10·3	19	− 5·48	+ 3·44
55 H	4	20·7	·6	− 7·3	− 8·9	20·5	7·2	.	8·6	...	+ 5·4	− 0·3	+ 4·5	+ 14·8	20	− 3·06	+ 5·53
G	1	21·1	·6	− 6·6	− 8·0	21·5	6·2	...	7·4	...	+ 4·4	+ 4·1	+ 3·4	+ 18·2	21	− 0·16	+ 7·95
F	0	...	...	...	...	22·5	4·8	...	5·7	...	+ 3·1	+ 7·2	+ 1·6	+ 19·8	22	+ 2·20	+ 9·78
E	3	23·6	·7	− 3·2	− 3·7	23·5	3·2	...	3·6	...	+ 1·4	+ 8·6	− 0·5	+ 19·3	23	+ 3·67	+ 10·66
54 H	8	24·3	·6	+ 0·5	+ 0·2	24·5	...	1·5	...	1·3	− 3·3	+ 5·3	− 5·4	+ 13·9	24	+ 4·61	+ 10·30
G	1	25·8	·7	+ 5·8	+ 6·1	25·5	...	4·8	...	5·0	− 6·5	− 1·2	− 9·1	+ 4·8	25	+ 3·84	+ 7·47
F	1	27·0	·6	− 5·7	− 4·9	26·5	1·8	...	1·2	...	0	− 1·2	− 2·9	+ 1·9	26	− 0·64	+ 2·58
E	2	27·5	·8	− 2·2	− 1·2	27·5	3·0	...	2·1	...	+ 1·2	0	− 1·9	0	27	− 0·64	+ 1·02
53 H	3	28·4	·7	− 4·0	− 2·7	28·5	4·2	...	2·8	...	+ 2·5	+ 2·5	− 1·3	− 1·3	28	0·00	0·00
G	3	29·7	·7	− 10·0	− 8·2	29·5	9·0	...	7·5	...	+ 7·2	+ 9·7	+ 3·4	+ 2·1	29	+ 1·34	− 0·70
F	7	30·3	·9	− 28·8	− 26·7	30·5	30·3	...	28·3	.	+ 28·5	+ 33·2	+ 24·2	+ 26·3	30	+ 5·21	+ 1·13
							51·1	15·7	87·9	6·3							
E	1	31·0	·9	− 34·1	− 31·7	Sum to 27·5	− 35·4		− 81·6		...	...	...	...	31	+ 20·05	+ 14·13
						Mean	− 1·77		− 4·08								

10. The deviation of geoid from either spheroid is small compared with the dimensions of the spheroid. A rise of 20 metres in comparison with a radius of over 6000 km. is less than 1 in 300,000; but the deviation carried over the whole globe may attain to considerably greater amount, and Clarke's 3-axes ellipsoid indicates a deviation of 25 times this amount. I do not say that Clarke's figures are accurate; but I feel that deviations of amount even 0·5 km. have not yet been *proved* not to exist. At present the deviations can only be traced in areas of continuous survey, and cannot be well estimated beyond such limits.

11. An inspection of the curves reveal to my mind the fact that there is not a great deal to choose between these two spheroids as representing meridian 77°·7 E in India; and that in this specimen case Everest's spheroid of 1830 is not much less satisfactory than Helmert's spheroid of 1907. The deviation of the geoid at latitude 31° does not allow us to form much

idea of the geoidal form in and beyond the Himalayas. Had the mean deflection not been removed, the choice would have been in favour of Everest's spheroid for, then, the deviation must be measured from the sloping lines in the diagram, which show a rise of 42 metres (Everest) against 64 metres on Helmert's spheroid. The point I wish to make is *not* that Everest's spheroid is as near to the geoid as Helmert's—I have no such opinion—but that *neither spheroid fits the geoid*, and that the geoid differs from any spheroid by easily appreciable amounts, of magnitude perhaps as great as the two spheroids differ *inter se*. The two spheroids used differ by nearly 1 km. in semi-major axis; and their ellipticities are 1/300·8 and 1/298·3. Everest's spheroid was mainly determined from results on this very meridian and Helmert's from all available values of "g" throughout the world.

Form of GEOID along meridian 77°·7 E. between latitude 8° and 31°.



Read ordinates from sloping lines to get rise of geoid in metres in terms of no deflection at origin (Kalianpur).

Ordinates from line 00 give geoid in terms of mean deflections at Kalianpur 1·"77 S for Everest Spheroid
4·08 S for Helmert Spheroid

12. Hayford has also obtained values only slightly different from Helmert's, from results in the U. S., using his method of introducing the theory of isostasy in a practical form. This form of isostasy when applied to India went some way to account for deflections there; and Sir Sidney Burrard's extension of it, which takes account of anomalies of crustal density, gives, apparently, a complete explanation. In this work Burrard has *derived* values of depth of anomalous density, which will explain observed deflections; and I submit that if he had sought for a solution of deflections with regard to Everest's spheroid, he would have been able to obtain it with different values of the depths.

13. Each separate gravity survey and each individual measure of gravity not forming part of a comprehensive survey, makes a separate assumption of the local height of the geoid above the spheroid of reference; that is, all can assume a spheroid of equal size and direction of polar axis, but cannot assure identical location in each case. Hayford's method applied to India shows the mean formula values for gravity to be too small by ·011 dynes precisely the same as the free air hypothesis yields. I submit that the ·011 dynes might be accounted for by the mean deviation of the geoid in India from the spheroid, derived from whole world results, being 35 metres below the spheroid. Clarke's ellipsoid gives 230 metres depression below the spheroid: and this is derived from triangulation arcs, but, determination of longitude of major axis is very weak ranging from 41° 4′ E (Schubert) to 8° 15′ W (Clarke).

14. But it appears to me that the theory of isostasy, in trying to explain *why* the geoid differs from a spheroid, causes attention to be withdrawn from the fundamental reality, viz. *the actual form of the geoid*. There are two important problems, *first* to determine the actual form of the geoid, and *second*, to explain why it is that form, and thereby derive information as to the crustal distribution of matter, as Burrard has done.

15. Each survey should produce a contoured map showing the form of the geoid with relation to a selected spheroid. Necessary data is usually scant; its scantiness might be reduced when realised but some idea of the form could be obtained. If the geoidal contours are drawn

in this way for two separate surveys, they are essentially in different terms. This must be so until the two surveys are linked by a comprehensive geodetic survey; and all that can be assured before this, is that the selected spheroid has the axes of the same lengths and the same direction of polar axis. To locate its position in space three conditions are required, derivable from assumptions at the origin of latitude, longitude and height.

As an example suppose that the meridian 77°·7 E shown on the slide was expressed in terms of two distinct surveys with a gap between latitudes 24° and 25°. In fitting the geoid to either spheroid, quite different values of deflection at origin would be deduced: and both portions would give evidence of a smaller spheroid even than Everest's.

16. It may be suitable to refer at this stage to an alternative way of tracing geoidal deviation. In the one used above the objection is that observations are not sufficiently frequent to admit of reliable values of the deflection being interpolated. The alternative is to make use of vertical angles with triangulation for determining heights. These angles have to be freed from the effects of plumb-line deflection, as well as of refraction. The heights then resulting are in terms of the adopted spheroid. Spirit levelling will give the heights of the same points above the geoid; and the difference of the two heights is accordingly the separation of spheroid from geoid. Atmospheric refraction has not hitherto been dealt with in a way which is satisfactory for this purpose, and triangulated heights have generally been *adjusted* on spirit levelled heights. Such a course has been unavoidable owing to the paucity of deflection results; and the deflections have been ignored. The following equation relates observed angles of elevations, plumb-line deflections and refractions at two stations:— $\omega_1 + \omega_2 = E_1 + E_2 + \chi - \delta_1 + \delta_2$, χ being angle between spheroidal verticals at the two stations. To compute refraction ω it has been customary to assume it equal at both stations, and neglect deflections δ. As these are liable in hilly country to be of the same order as the refraction, highly erratic values of the latter have been obtained. Recent research indicates that probably in many cases the refraction may be computed from terminal measurements of temperature, pressure and temperature gradient. This will open up a more accurate way of tracing the form of the geoid.

17. Every effort must be made to link existing surveys. Sir David Gill initiated the Cape to Cairo triangulation, and this has now progressed over many degrees of latitude. It is not quite so complete* geodetically as might be desired, but this could be remedied. Fifteen months ago I put up a proposal to the Surveyor General of India for geodetic work from India to the Mediterranean and Europe. If this and Gill's project were completed we could find out much more of the geoid as well as the spheroid.

18. Practically all existing triangulation of the old world would then be connected. Even this covers but a small portion of the land area; and a correspondingly smaller proportion of the whole globe.

The sea areas offer advantages as regards accessibility. But methods suitable for these are not of the same precision as the land methods. The sea, however, dispenses with the need of spirit levelling.

19. Hecker has already made determinations of gravity at sea—I am not prepared to say what precision of result is available. In 1914 Duffield tried an apparatus for the same purpose on the voyages to and from Australia for the B.A. meeting there. I have not heard of this work passing beyond the experimental stage. But with isolated values of gravity, anomalies due to unknown local irregularities of density must occur, and I do not think that the actual form of the geoid—*i. e.* its height above any reference spheroid—can be derived from them.

20. A few months ago I had the pleasure of meeting Captain Douglas, C.M.G., R.N., of the Hydrographic Department, Admiralty, who, I understand, introduced a system of sound ranging at sea. Positions of points up to 100 miles away were fixed by means of the differences of time at which sound waves, emitted from the point by explosion of a depth charge,

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* A full geodetic programme, to determine the Figure of the Earth, should comprise:—

(1) Triangulation, with additional bases and Laplace stations.

(2) Deflections of the plumb-line in meridian *and* prime vertical, at *all* triangulation stations; or at least continuously along a series of intervisible stations.

(3) Vertical angles and necessary observations for studying and computing refraction.

(4) Continuous spirit levelling, connected to tidal stations.

It is also most desirable that "g" should be observed at frequent intervals and for its proper reduction contoured topographical maps of the neighbourhood are necessary.

and transmitted through the water, reached three coast stations. If wireless signals were emitted simultaneously with the sound, only two land stations would be necessary—the work would be simple trilateration. If forward stations were recording simultaneously, their positions could also be fixed, and the interval covered would be doubled. I do not know what intervals could be spanned in this way or the precision attainable. Sound travels about 1 mile per second in water, or about 60″ of arc. Perhaps the timing could measure less than 1″ of arc. Again sound travels 3600 knots, so that the effect of currents could be considered. If positions could be fixed to about 1″ of arc in this way, combined with the ordinary astronomic observations they would yield highly satisfactory values of the deflections in meridian and prime vertical.

Conclusion.

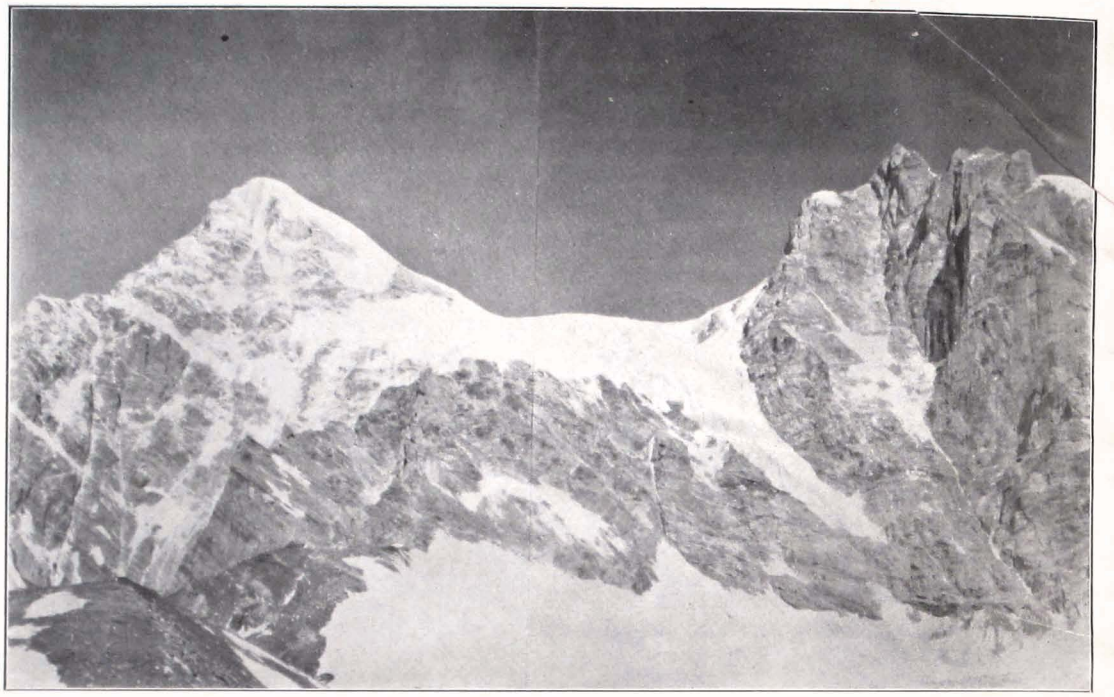
The conclusion that I draw may be briefly put:—

(1) The spheroid as recently determined by Hayford and Helmert gives a good approximation to the figure of the earth in various districts. When such a spheroid is applied to any geodetic area so placed as to fit as well as possible, the deviation of the geoid from it may well not exceed 20 metres. But there is no assurance that spheroids thus placed for each survey are coincident in position.

(2) It is most important that areas of geodetic survey should be linked up as far as is feasible, so that larger areas of the geoid could be placed in a single set of terms. Until this is done little further progress can be expected from geodesy in the determination of the figure of the earth as a whole, or of the dimensions of the ellipsoid most closely approximating to it.

(3) An important aid to the study of the geoid will result if atmospheric refraction is studied and brought within the compass of accurate computation.

(4) Sound ranging through water may possibly be of sufficient precision and scope to permit of the study of the geoid across certain oceans from island to island.



KAMET AND E. ABI GAMIN CAMP 20,620′ IN FOREGROUND.

RESCUING SHEEP FROM CREVASSE ON E. KAMET GLACIER.

From photographs supplied by Major H. T. Morshead, D. S. O., R. E.

YAKS SWIMMING THE DHAULI RIVER.

APPENDIX II.

(Published in the R.E. Journal, April, 1921.)

REPORT ON THE EXPEDITION TO KAMET, 1920.

By Major H. T. Morshead, D.S.O., R.E.

INTRODUCTION, PREVIOUS ATTEMPTS ON KAMET, ORIGIN AND SCOPE OF THE PRESENT EXPEDITION.

The mountain known in India as Kamet and to the Tibetans as Kangmed* or Abi Gamin—the 30th in order of magnitude of the known high peaks of Asia and of the world—is situated in latitude 30° 55′ and longitude 79° 36′, in the Garhwal district of the United Provinces just south of the Tibetan border. Rising to a height of 25,445 feet, it forms the culminating point of the Zaskar Range—a northern bifurcation of the Great Himalaya—and, though forming a conspicuous landmark from the Tibetan province of Ngari Khorsum on the north, yet from the south, owing to its position behind the Great Himalayan Range, its appearance is so modest that till 1849 it remained unnoticed and unmeasured, though but 250 feet lower than the King of the Kumaon Himalaya, Nanda Devi.†

The earliest attempted ascent of Kamet was made in June 1855 by the brothers A. and R. Schlagintweit who reached a height of 22, 240 feet on a mountain which they called Ibi Gamin, and believed to be identical with Kamet. Subsequent investigation has however tended to the belief that the mountain on which they actually climbed must have been the satellite known as E. Abi Gamin or Strachey's peak (24, 180 feet).

During the succeeding half century, the only recorded adventurers on the mountain were the members of the Great Trigonometrical Survey who triangulated and mapped the area in the years 1872-75. It was near here in the latter year that the late Mr. I. S. Pocock made what remains to this day one of the world's highest planetable fixings—setting up his board at 22,040 feet.‡

In recent times, numerous attempts have been made on the mountain. The approaches both from the east and the west were reconnoitred in July and August 1907 by Messrs. Bruce, Longstaff and Mumm, but serious climbing was prevented by the onset of an unusually violent monsoon. C. F. Meade, accompanied by Alpine guides made three strenuous efforts to conquer the mountain, in 1910, 1912, and 1913. On the latter occasion approaching *via* the Raikane valley he succeeded in reaching the col ("Meade's saddle," 23,500 feet) between Kamet and E. Abi Gamin, when his party succumbed to mountain sickness just as success seemed within its grasp.

The late Capt. A. L. Slingsby twice attacked the mountain unsuccessfully from the western side, while Dr. A. M. Kellas of Aberdeen, the well known mountaineer, also reconnoitered the western approaches in 1911 and again in 1914—the expedition in the latter year, which had for its special object the scientific investigation of the effects of high altitude on the human body, being summarily cut short by the outbreak of war.

On the conclusion of peace the Royal Geographical Society, recognising the desirability of collecting further data regarding the physiological effects of high altitude, persuaded Dr. Kellas to resume the experiments cut short in 1914. They further arranged

* Kangmed = "the lower snows," as distinguished from the higher snows of the Kailas Range, culminating in Mt. Gurla Mandhāta 100 miles to the E. S. E. The name has, I think erroneously, been spelled Kangmen in N. Frontier 4″ Sheet No. 9 N. E. and on the R. G. S. map of Tibet.

† Burrard and Hayden, *A sketch of the Geography and Geology of the Himalaya Mountains.* Kamet now shares the 30th place in the world's list of high peaks with Namcha Barwa, the mountain of identical height overlooking the big bend of the Tsangpo River in the Assam Himalaya, which was discovered during the Abor and Mishmi Expeditions of 1912-13.

‡ *General Report on the Operations of the G. T. Survey of India during 1874-75.* I have searched the original planetable sections of this area in vain in the hope of discovering the exact site of this fixing.

for the loan of oxygen cylinders and other scientific apparatus from the Medical Research Committee in England, for its despatch to Bombay through the agency of the India Office Stores Department, and for the assistance of the Survey of India in taking delivery of the apparatus in Bombay and transporting it by rail and coolie *via* Kathgodam to the base of the mountain beyond the extreme Himalayan village of Niti.

I was fortunate enough to be deputed for the latter task, together with Mr. Laltan Khan I. D. S. M., Sub-Assistant Superintendent, Survey of India.

The objects of the expedition may thus briefly be summarised as follows :—

(1) To study the physiological effects of high altitude on the human body, with special reference to the problem of acclimatisation.

(2) To obtain further information regarding the altitude to which ascent is possible without resort to artificial means of respiration, and to record the temperatures, wind velocities etc., prevailing at extreme altitudes.

(3) To experiment with the use of different forms of oxygen apparatus.

(4) To make as complete a revision as possible of the 1″ to 1 mile reconnaissance Survey of 1872-75 in the Kamet area.

The scientific observations contemplated by Dr. Kellas fall under five main heads, viz :—

(1) Comparative records at different altitudes of the pulse-rate, respirations, lung-pressure etc. of a number of selected subjects, on similar lines to the tests for physical fitness devised by Col. Flack for use in the Royal Air Force.

(2) Comparative measurements of the haemoglobin content of a measured quantity (20 c. mm.) of peripheral blood at different altitudes.

(3) Microscopic estimation of the number of red corpuscles in a measured quantity (5 c. mm.) of peripheral blood at different altitudes.

(4) Estimation of the amount of skin-evaporation by means of Hill's apparatus, known as the "kata-thermometer."

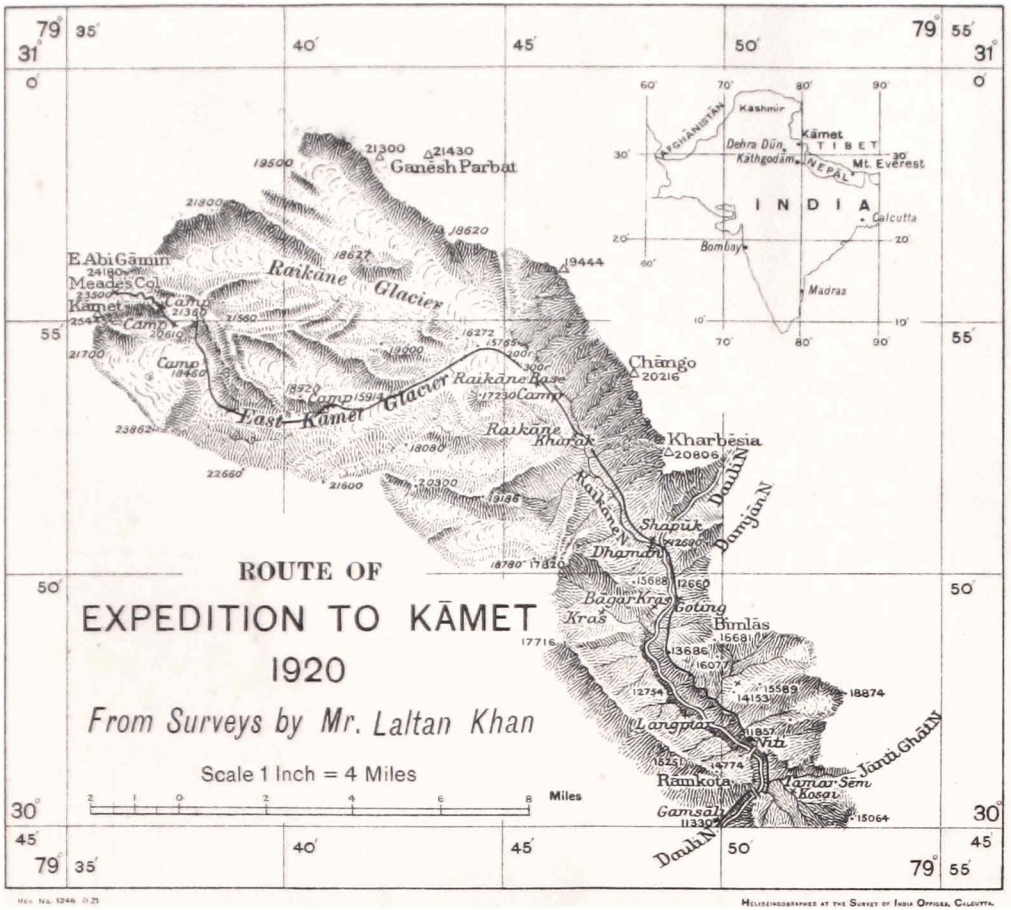
(5) Analysis of the alveolar air (*i. e.* air from the ultimate ramifications of the lungs) for oxygen and CO_2 content, by means of Haldane's apparatus for gas-analysis.

These observations, if commenced near the level of the plains at Kathgodam and continued as far as the highest point reached, might, it was hoped, yield valuable information regarding the rate and degree of acclimatisation to altitude.

The oxygen apparatus, which was provided by the Oxygen Research branch of the Medical Research Committee, consisted of :—

(1) 3 sets of oxylith portable breathing apparatus, manufactured by Messrs. Siebe Gorman and Co.; these each consisted of a large rubber bag holding a sufficient supply of oxygen for 15 or 20 minutes consumption—the oxygen being generated on the spot by the chemical combination of oxylith and water.

(2) 60 steel cylinders of compressed oxygen, each weighing 15 lbs. when charged, and holding 280 litres of gas at 0° and 760 mm. Web belts and straps were provided for enabling these cylinders to be carried on the back, also a flow-meter for regulating the flow of gas to the face-mask at 1, 2, or 3 litres per minute as desired.



Heliolithographed at the Survey of India Offices, Calcutta.

NARRATIVE ACCOUNT OF THE EXPEDITION.

It was hoped that the apparatus might have arrived from England by the end of June, so as to enable Niti to be reached by easy stages on about 7th August. This would allow of the remainder of the month of August being devoted to laying out advanced depôts of oxygen cylinders, firewood, etc., as far forward as climatic conditions admitted, with a view to utilising the first fine weather after the monsoon for the final climb, before the arrival of the winter snow. These plans were unfortunately frustrated by a very serious delay in the shipping of the oxygen cylinders—due, apparently, to the unexpected decision of the shipping authorities in England to classify the cargo as "high explosives". Consequently it was not until early August that the kit reached Kathgodam—whence, after hastily repacking the cylinders into loads suitable for coolie transport, the expedition started in pouring rain on 8th August.

This unfortunate delay at the start involved the complete abandonment of Dr. Kellas' plans for comparative observations on acclimatisation en route, and the paramount consideration now became that of pushing forward with all possible speed in the endeavour to reach the high ground before the onset of winter conditions; leaving the comparative observations or the return journey. Travelling *via* the rolling hills and fertile stuffy valleys of Kumaon, we reached Joshimath on 22nd August, and Niti five days later. Here we halted for a day to arrange for food supplies and for permanent coolies and yaks for our further progress.

Resuming our journey on 29th with a retinue of 24 yaks and 40 coolies, we encountered our first obstacle on the following day in the shape of the unfordable Dhauli River which separated us from the Raikane valley, at the confluence of the latter river. This necessitated a day's halt while the coolies constructed a cantilever bridge, the timbers for which had to be fetched from the tree-zone below Niti.

The foot of the Raikane glacier was reached on 1st September. Dwarf juniper scrub (*bhitaru*) grows plentifully in this neighbourhood and forms an excellent fuel, which can be pulled up by hand by the roots without the use of an axe, and burns with a pleasant aromatic odour. Above this point no further fuel occurs, nor is the valley passable for yaks. We, accordingly made this our base camp (15,380 ft.) and determined on a brief halt, in which survey operations and scientific observations could be carried on, while the coolies collected a reserve of fuel for our needs on the mountain. The yaks meantime returned to Niti for fresh supplies of provisions.

Marmots abound in the Raikane valley, and some excitement was caused on our first arrival at the base camp by one of my khalasis catching a tailless "mouse-hare" (*Lagomys Roylei*) in his hat. The alpine flowers on the hillsides made a striking and memorable display in their brief autumn glory,—edelweiss, fleshy-leaved saxifrages, blue cranesbill, yellow and orange ranunculus and dwarf primula being among the commonest and most conspicuous.

The thermometer at this altitude usually registered 6 or 8 degrees of frost each night, while the morning spectacle of a powdering of fresh snow covering the hillsides down to 16,000 or 17,000 ft. served to remind us that winter was at hand, and that our sojourn on the higher slopes must perforce be brief.

From the Raikane base camp our route was identical with that of C. F. Meade in 1913 and led over the moraines and crevasses of the E. Kamet glacier for a distance of 10 miles. Frequent and terrific avalanches from the steep S. and W. faces of the valley are a feature of this portion of the route, and form a danger to incautious travellers. Safe camping sites may be found however here and there on the opposite side of the valley. We were fortunate in having with us some of Meade's old coolies whose knowledge of previous camping grounds etc., proved invaluable, and I am glad to take this opportunity of acknowledging our indebtedness to his gallant pioneering. Profiting, however, by Meade's experiences of mountain sickness after a series of long and rapid marches, we decided on adopting a programme of short and easy stages with frequent days of halting for acclimatisation; which latter incidentally enabled the coolies to return for further supplies of much-needed fuel and provisions. Advancing in this manner, on 10th September we reached a camping ground at 18,460 ft., beyond which the route leaves the main glacier and ascends a steep side-valley.

The only incident worthy of mention in this portion of the trip, was the loss of two

live sheep by slipping through the thin mantle of snow which concealed one of the numerous large crevasses of the glacier. Two and a half days later we managed to lower a coolie by a rope 40 feet into the crevasses, whence he succeeded after half an hour's work with an ice-axe in releasing the two sheep, which were hauled to the surface—one still alive, and one reduced to frozen mutton.

On 11th September we advanced a further 2 miles and pitched a light camp on rock at a height of 20,620 ft. The majority of the coolies showed signs of distress and complained of violent headaches on arrival at this altitude; we accordingly sent them back to the last camp, keeping only two as guides for the 600 ft. of rock climbing which lay ahead. After a day's halt for acclimatisation we successfully reconnoitred the rock-face on 13th, finally emerging at the top on to a smooth dome of glassy ice up which we had time to cut 45 large steps before returning to camp—a delightful day of real mountaineering.

Next morning the thermometer recorded 28 degrees of frost, while the small patch of rock around our tents was white with freshly fallen snow. Both Kellas' and my own servants were at this period completely *"hors de combat"* from the effects of the cold, and we had the greatest difficulty in preparing ourselves any cooked food. The daily convoy of provisions and firewood ceased to function in the absence of responsible superintendence at the various posts on our line of communications, and this in turn re-acted on the spirits of our coolie guides who became extremely despondent regarding the prospects of any further progress at this late season of the year.

Our position was manifestly too precarious to warrant any further advance pending an overhaul of the line of communication, and this I accordingly undertook at once. Retracing my steps down the valley on 15th, I installed my own private servant, who now showed signs of convalescence, as commander of the Raikane base camp, with orders to institute a regular system of *chālāns* or invoices notifying the daily number of loads of fuel and stores despatched. Dr. Kellas' Lepcha servant took charge of the forwarding arrangements at No. 1 camp (16,914 ft.) and Mr. Laltan Khan at No. 2 camp (18,460 feet).

This accomplished, I rejoined Dr. Kellas at camp No. 3 on September 17th, and found that he had meanwhile got his 2 coolies to complete the 35 more ice-steps required to negotiate the difficult ice at the head of the rock-cliff. After waiting one day, to ensure the arrival of the minimum necessary reserves of supplies, we advanced with very light kit and pitched our small single-fly tent on snow at 22,000 ft. Owing to sickness the number of coolies was now reduced to 8, who consequently had to descend again for the night to camp No. 3, returning next day with a second tent (for themselves) and a small supply of ready-cooked food. It was impossible to get firewood carried up the difficult rock-face which separated us from the camp below; both we and our coolies were dependent on food sent up ready cooked from below, aided by such cooking as could be done by a spirit stove in the shelter of the tent. The thermometer next morning registered a minimum night temperature 15° below zero (47° of frost) on the surface of the snow, and our blankets were as stiff as boards where one's breath had congealed on them. Rising from our beds on the snow was consequently more than the work of a moment. However, after heating ourselves a tin of soup on the spirit stove, and thawing sufficient snow to fill the thermos flask with bovril, we started forward at 9 a. m.—our two selves and three coolies on the rope. Taking the lead in turns, and steering a winding course to avoid the giant crevasses, we gradually emerged on to the wide flat valley which separates Kamet from E. Abi Gamin. On our left, the summit of Kamet showed clearly 2000 ft. above us, connecting with the valley by means of two well-defined *arêtes* of easy slope, either of which must have been easily climbable had time permitted. It was now 3 p. m. however and our coolies were dead beat, so after a brief halt for food and a round of photographs, we had to turn regretfully homewards from Meade's col, in order to avoid being benighted. The view from this col is magnificent—comprising the whole Tibetan portion of the Sutlej valley to the north, while 100 miles to the E. S. E. the stupendous *massif* of Gurla Mandhāta towered head and shoulders above the intervening army of lesser ranges.

It was interesting to observe that wild life by no means ceases, even at these great heights. For our approach disturbed a pair of ravens who kept hovering round the rocky crannies of the saddle, seemingly resentful of the unexpected disturbance of their nesting operations; while overhead—so distant as to be scarcely distinguishable without the aid of glasses—a huge lammergier* circled and soared.

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* The bearded vulture *(Gypætus Barbatus)*, said to measure 9 feet from tip to tip of outstretched wings.

Had we been able to induce the coolies to carry our camp one march further forward to the flat open *névé* near Meade's col, it is hard to believe that anything could have prevented our reaching the summit. Lack of properly cooked food, combined with the intense cold, had however undermined the stamina of the coolies, who absolutely refused to carry forward any further loads. My period of deputation had nearly expired, and realising with regret that the season was now too far advanced for further efforts, I reluctantly bade goodbye to Dr. Kellas on September 22nd and turned my steps towards home, reaching Dehra Dun by double marches on October 15th—precisely two months from my date of departure. Dr. Kellas, with Mr. Laltan Khan, remained a further month in Garhwal, and succeeded in completing the essentials of his scientific work, which will form the subject of a separate report.

CONCLUSIONS AND RESULTS.

A few remarks may not be amiss in conclusion regarding the results of the expedition from the purely layman's point of view.

(*a*) *Physiological.*—The fact that neither Dr. Kellas nor myself suffered the slightest discomfort at any time from mountain sickness, seems to indicate that our method of attack by a process of gradual acclimatisation is correct. That it is essential also to avoid undue fatigue is shown by the fact that our coolies who were carrying daily loads suffered considerable discomfort from the effects of altitude. The reasons for this it is beyond my province to discuss, I am merely concerned with observed results.

(*b*) *Mountaineering and practical.*—Under this heading, it may be profitable to discuss briefly the reasons of our failure to reach the summit of the mountain. Undoubtedly the first and foremost cause, was the lateness in the year, due to the unfortunate and unforeseen delay in the arrival of the oxygen cylinders from England.

A second cause lay in the failure of the Survey khalasis, recruited from the middle Himalayas, to stand the climate and altitude of the higher ranges. I had enlisted a dozen strong Garhwali khalasis, with the double object of forming a *corpus vile* for the scientific observations of Dr. Kellas, and of providing a *corps d'élite* of porters for the higher altitudes. With the latter object in view they had been lavishly equipped with warm clothing on the "arctic" scale. Unfortunately, one half of their number succumbed to mountain sickness at 15,000 feet while the other half proved so extravagant of our precious firewood that they had to be sent back to the base camp as "hewers of wood and drawers of water", and their places taken by the hardier "Bhotia" men of Niti and the neighbouring villages. The provision of boots and warm clothing for the latter on the spur of the moment was however a matter of difficulty, and proved a direct contributory cause of our failure.

A third cause of failure must be traced to the inadequacy of our arrangements for cooking at the higher altitudes. I was unaware until too late that the large Primus stove, on which I had been relying, would not work in the rarified atmosphere of 20,000 feet, beyond which point methylated spirit is the only possible fuel; while Dr. Kellas had only one small spirit stove, which took an hour to thaw sufficient snow to fill a teapot. Had our equipment included a dozen large spirit stoves, and two or three 2-gallon petrol-cans full of methylated spirit, both our own and the coolies' cooking would have been assured.

I have nothing but praise for the Bhotia coolies of the higher Himalaya. On rock they can climb like goats, while on ice they readily learn step-cutting. It appears very doubtful if the present-day expense of importing Alpine guides can ever justify their employment in future Himalayan exploration.

The following table may be of interest as showing a few of the highest climbs recorded:—

Duke of Abruzzi	1909	Karakoram	24,600
W. W. Graham	1886	Kabru	23,970?
W. H. Johnson	1865	Pk.1/61A	23,890?
Rubensen & Monrad Aas ...	1908	Kabru	23,800
C. F. Meade	1913	Kamet	23,500
A. M. Kellas and H. T. Morshead	1920	do.	23,500

Nos. 2 and 3 on this list are doubtful.

(*c*) *Oxygen apparatus.*—This will form the subject of a separate detailed report by Dr. Kellas. Neither of us felt the slightest need for artificial stimulants in the form either of oxygen or alcohol up to the highest point reached, and my impression is that one could have gone several thousand feet higher without distress of breathing, had other conditions admitted.

On the other hand the handicap of 15 lbs. additional weight on one's back, supported by a system of tight belts and straps, proved more than I for one could cope with.

(*d*) *Surveys.*—I obtained a special blue print on drawing paper on the old 1″=1 mile Sheet No. 19. This was mounted on a light 20″ × 20″ planetable for Laltan Khan's use. 115 sq. miles of country were revised and contoured in modern style, disclosing considerable discrepancies in the old reconnaissance surveys. Roads, streams and watersheds were found sometimes as much as ¾ mile in error, while the original surveyors had evidently never visited the upper portions of the Raikana and Kamet glaciers.

The oxygen apparatus is being temporarily stored in the office of the Trigonometrical Survey at Dehra Dun pending further occasion for its use, which it is to be hoped may soon be forthcoming.

The total expense borne by the Survey of India budget on account of the expedition is Rs. 17,826 which is made up as follows:—

Salaries etc., of Survey of India personnel	4,800
Coolies, tents, warm clothing, railway freight and other contingent expenditure	13,026
	17,826

It only remains to express my gratitude at being privileged to serve my apprenticeship in mountaineering under so experienced a hand as Dr. Kellas. Failure is often more instructive than success, and I can only hope that this expedition, on which I shall always look back with feelings of pleasure, may be the prelude to other more successful future efforts in the same genial company.

APPENDIX III.

(Reprinted by permission from the Geographical Journal Vol. LVI, 1920).

A NOTE ON THE TOPOGRAPHY OF THE NUN KUN MASSIF IN LADAKH.

By Major Kenneth Mason, M. C., R. E.

After the early reconnaissances of the Nun Kun in the sixties, little attention was devoted to the region for many years; only the lower valleys around the base of the massif were visited by sportsmen. In 1898, however, Majors C.G. Bruce and Lucas climbed the lower slopes of the Ganri glacier, and the former crossed the Sentik La on to the Barmal glacier, and followed it down to the Bhot-Khol.* In 1902 Dr. A. Neve and the Rev. C. E. Barton ascended nearly the whole length of the Shafat glacier lying to the east of the massif, and during the same year they crossed the basin of the Barmal glacier from Tongul, *viâ* the Sentik La, descending south-westwards into the valley of the Bara Zaj Nai.† In 1904 Dr. Neve again crossed this glacier.‡

In 1903 Dr. Sillem, a Dutch mountaineer, explored this region, and reached and photographed the high snow plateau crowning the massif. In 1906, Dr. and Mrs. Bullock Workman visited the district, claimed to have discovered Dr. Sillem's plateau and made a complete tour of the mountain knot. Unfortunately their work was not based on the few trigonometrical points fixed in the region; their results led to much controversy, and some of them were not accepted. Since those days a certain amount of evidence has been collected on the points of difference raised by them.

The peaks referred to by various travellers are here summarized in tabular form with the accepted values of latitude, longitude and height, deduced from the triangulation of 1859-60:

New number	Name or old number	Latitude	Longitude	Height
		° ′ ″	° ′ ″	*feet*
Pk. 1 / 52 C	Nun, Nana, or Ser ...	33 58 55·8	76 01 31·1	23,410
Pk. 7 / 52 B	Kun, Kana, or Mer ...	34 00 47·6	76 03 22·4	23,250
Pk. 6 / 52 B	Pinnacle Peak ...	34 01 22·0	76 04 50·1	22,810
Pk. 12 / 43 O	Snowy Peak "D 41" ...	33 58 44	75 58 03	—
Pk. 11 / 43 O	Snowy Peak "D 42" ...	33 59 07	75 55 41	—
Pk. 39 / 43 N	Snowy Peak "No. 10" ...	34 00 22·2	75 50 30	19,830

It will be remembered that in her published account,|| Mrs. Bullock Workman claimed to have ascended to 23,300 feet, to the summit of a peak which she named Pinnacle Peak, and which she persistently referred to as "the second highest peak" of the group. Her heights and this statement were at variance with previously triangulated values, and a review of her results (published in the *Pioneer* of 14 Feb. 1910), pointed out the view of the Survey of India, namely, that Pinnacle Peak was the third highest and Kun, (or Mer), was the second highest peak of the district.

This was answered by Mrs. Bullock Workman in the *Pioneer* of 6 May 1910; she claimed that her hypsometric height obtained at the summit of Pinnacle Peak and compared with simultaneous observations at Dras, was more accurate than the Survey height.

The question of the height of Pinnacle Peak relative to others of the neighbourhood was decided by the retriangulation of the peaks in 1911, though in 1910 Dr. A. Neve again visited the region and took some observations with a clinometer lent him by the Survey for that purpose. These observations of Dr. Neve were worked out at Dehra Dun and indicated that Kun was approximately 480 feet higher than Pinnacle Peak.

The original triangulated values made Kun approximately 440 feet higher than Pinnacle Peak, which was therefore believed to be the third highest peak in altitude.

The retriangulation of the peaks in 1911 from different stations and from a different series than the original one gave the following completely independent values for the three peaks:

Nun	33° 58′ 47″·5	76° 02′ 05″·6	23,506 *feet.*
Kun	34° 00′ 52″·6	76° 02′ 56″·2	23,114 *feet.*
Pinnacle	34° 01′ 22″·2	76° 04′ 49″·8	22,741 *feet.*

The triangles from which these results were obtained were ill-conditioned, especially for the longitudes of the peaks, and the new observations for position were now computed in conjunction with the old. Almost perfect triangles of observation were obtained, and the resulting co-ordinates of the three peaks became:—

Nun	33° 58′ 56″·3	76° 01′ 30″·6	23,357 *feet.*
Kun	34° 00′ 47″·8	76° 03′ 22″·6	23,220 *feet.*
Pinnacle	34° 01′ 22″·2	76° 04′ 50″·1	22,742 *feet.*

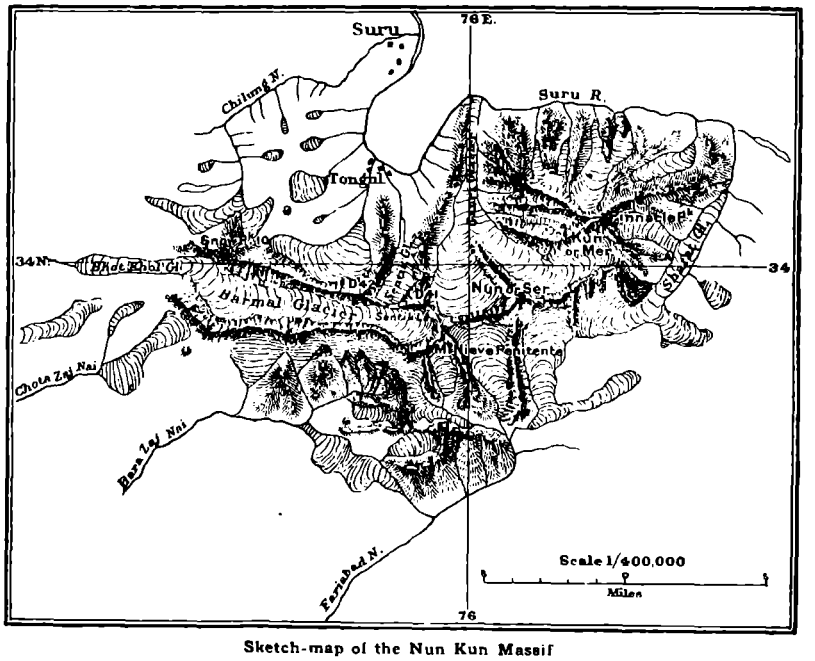
Here we see that Kun is 478 feet higher than Pinnacle Peak. In fact, in every case, Pinnacle Peak is several hundred feet lower than Kun. These last values agree very well with those hitherto accepted, and although they may be nearer the truth than the older ones, the objections to making changes in accepted values of heights, when fresh evidence produces unimportant variations, are so serious that the original values have been retained in all Survey of India publications. The old height of Pinnacle Peak (22,810 feet) was deduced with a coefficient of refraction 0·05, while that used with the modern observations is 0·07. By using the latter coefficient (0·07), for the early observations, the height (22,810 feet) becomes 22,738, and closely agrees with the new height, the weighted mean becoming 22,741 feet, using 0·07 for all observations. Similarly the old heights of Nun and Kun are in excess of those obtained above, owing to the coefficient 0·05 being used instead of 0·07 and the old observations give heights closely in accordance with the later ones, if 0·07 is used. The point at issue is, however, the relative values of the three peaks and is unaffected by any adopted coefficient of refraction.

Another point brought out in the review of Mrs. Bullock Workman's book was one originally noted by Major C. G. Bruce after his expedition in 1898, and raised by Dr. A. Neve after his journey in 1902. The old survey map showed the Barmal glacier rising in a mountainous cirque south of Snowy Peak No. 10 (34° 00′·22″, 75° 50′ 30″), flowing eastwards, bending north-eastwards immediately west of Peak D 42 (33° 59′ 07″, 75° 55′ 41″), and finally draining into the great bend of the Suru river near Tongul. Dr. Neve pointed out that the glacier rose in a rocky cirque south of D 41 (33° 58′ 44″, 75° 58′ 03″), flowed westwards, south of and past D 42, and, at a point almost due south of Snowy Peak No. 10, it changed direction north-westwards and joined the Bhot Khol glacier. He established the connection of Peaks No. 10, D 42, and D 41 by a rocky wall, asserted that the Barmal glacier was the Upper Bhot Khol, and, perhaps rather loosely, referred to the whole extent of ice as the "Great western glacier of Nun Kun". No new edition of the Survey map was published, but Dr. Neve's amendment was admitted by the Survey to be probably correct, and it was supported by Major Bruce's account in the *Alpine Journal*.

The Workmans during their visit in 1906, made some notable ascents on the western outliers of the massif, but they did not follow the Barmal glacier down to its tongue, as had been done by Major Bruce. Yet in their published account, they accused Dr. Neve of "erasing" the rocky wall south-west of Snowy Peak No. 10, "correctly charted by the Survey", in order to show the Bhot Khol—Barmal connection; and they maintained that Dr. Neve's "assertions were not in accordance with fact", and that the Barmal glacier drained into the Bara Zaj Nai; their map was drawn accordingly.

The Survey of India review, mentioned above, referred to the undeserved reprimand of Dr. Neve, pointing out that at any rate the travellers agreed as to the main course of the glacier, though they differed as to the actual hill-stream into which it drained. Dr. Neve, however, was determined to prove or disprove the correctness of his topography, and in 1910

again visited the district. In a letter from Dras, dated 25 September 1910, he wrote: "We ascended the Barmal glacier from the Bhot Khol and took photos and observations from a point due south of No. 10.....I then made a complete circuit round No. 10 *vid* Bhot Khol, Suru, and then up the Tongul-Sentik route; camped at 17,500 feet on the Barmal glacier, and climbed D 41 in spite of the fresh snow. It was cloudless to the west, north, and north-east, and I got a circle of compass bearings.....At the bend of the Barmal glacier south of and west of Peak No. 10, I have three photos showing the continuation of the range on the south and south-west side (Bara Zaj Nai)." This is the range erased by the Workmans. In his book, "*Thirty Years in Kashmir*", Dr. Neve gives a detailed account of this journey. He mentions that during his early expeditions to these parts he was not aware of Major Bruce's journey of 1898, an account of which had been published in the *Alpine Journal* of 1899. But the conclusions of their two expeditions were identical. In "*Twenty Years in the Himalaya*", Major Bruce gives his account of the Barmal glacier to the Bhot Khol, and on p. 99, he says: "In front of us lay the only question of the tramp: *a large and broken icefall* (see photo)," Opposite p. 100 is the photo referred to. This is



Sketch-map of the Nun Kun Massif

almost identical with the photo in the Workmans' book on page 148; here, however, this icefall is singularly described as a "glacier-covered mountain wall separating it (*i.e.* the Bhot Khol) from the Barmal which lies on the south of the wall. This is the wall erased by Dr. Neve from the Survey map to indicate the junction of the Barmal and the Bhot Khol".

Major Bruce descended this icefall. Dr. Neve both ascended and descended it. The Workmans only saw it in the distance. Dr. Neve has not only proved that the Barmal is the Upper Bhot Khol glacier, but his photographs also show that there is no drainage outlet from the Barmal into the Bara Zaj Nai, which was the contention of the Workmans.

Dr. Neve also maintained his assertion that the Barmal glacier came "all the way from Nun Kun" was justified, since it rises in the cirque formed by D 41, the Barmal ridge, and Mount Nieve Penitente, the western boundary and buttresses of the Nun Kun massif.

In addition to this, Dr. Neve, from the summit of D 41, found Nun almost due east of D 41, as originally shown on the Survey map (lat. of D 41, 33° 58′ 44″; lat. of Nun, 33° 58′ 56″). The Workmans had stated that D 41 was a mile too far south on the Survey map, and had therefore displaced this fixed point to another position west-north-west of Nun.

It is difficult to place much reliance on maps that have been based on the shifting of triangulated points: probably the only advance in topographical knowledge gained from this

expedition of the Workmans was the indication of a route up the "North-west Nala" from the Faridabad Nala to the Barmal glacier; and even here the enclosing of a glacier in an amphitheatre of mountains with no outlet for drainage tends to shake confidence in the topographical details of the map.

To sum up: the alterations which should be made on the map of this district, published by the Workmans are as follows:

(1). Pinnacle Peak should be 22,810 feet and not 23,300 feet high.

(2). D 41 and probably the whole glacial basin of the Upper Barmal should be placed a mile further south, as indicated by Dr. Neve.

(3). The connection of the Barmal glacier with the Bara Zaj Nai should be erased, (proved by Dr. Neve's photographs), and an icefall connecting the Barmal and Bhot Khol glaciers in place of the mountain ridge should be shown at the bend of the Barmal glacier south and south-west of Snowy Peak No. 10 (proved by Major Bruce and Dr. Neve independently).

(4). The drainage of the glacier south-east of Mt. Nieve Penitente should be connected with the "North-west Nala".

From a mountaineer's point of view, the fact emerges that the height reached by Mrs. Bullock Workman was not so great as 23,000 feet.

APPENDIX IV

List of Survey of India Publications

(Corrected up to 30th September 1920)

PUBLICATIONS

OF THE

SURVEY OF INDIA

SYNOPSIS

A—HISTORY AND GENERAL REPORTS.

B—GEODETIC WORKS OF REFERENCE.

C—CATALOGUES AND INSTRUCTIONS.

D—MISCELLANEOUS PAPERS.

A—HISTORY AND GENERAL REPORTS.

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

MEMOIRS.

1. A Memoir on the Indian Surveys. *By C. R. Markham*, India Office, London, 1871. *Price Rs. 5 or 10s.*
2. Ditto (second edition). *By C. R. Markham, C.B., F.R.S.*, India Office, London, 1878. *Price Rs. 5-8 or 11s.*
3. Abstract of the Reports of the Surveys and of other Geographical Operations in India, 1869-78. *By C. R. Markham and C. E. D. Black*, India Office, London. Published annually between 1871 and 1879. (Out of print).
4. A Memoir on the Indian Surveys, 1875-1890. *By C.E.D. Black*, India Office, London, 1891. *Price Rs. 5-8 or 11s.*

ANNUAL REPORTS.

Reports of the **Revenue Branch.** 1851-1877.—(1851-67 and 1869-70, out of print). *Price Rs. 3 or 6s.*

Ditto **Topographical Branch** . 1860-1877.—(Out of print).

Ditto **Trigonometrical Branch** . 1861-1878.—(1861-71, out of print). *Price Rs. 2 or 4s.*

In 1878 the three branches were amalgamated, and from that date onwards annual reports in single volumes for the whole department, are available as follows:—

General Reports { from 1877-1900 (1877-79, 1887-88, 1895-96 and 1897-98, out of print) *at Rs. 3 or 6s per volume.*
from 1900-1920 (1902-04 and 1906-08, out of print) *at Rs. 2 or 4s per volume.*

From 1900 onwards the Report has been issued annually in the form of a condensed statement known as the **"General Report"** supplemented by fuller reports, which were called **"Extracts from Narrative Reports"** up to 1909, and since then have been styled **"Records of the Survey of India."** These fuller reports are available as follows:—

(*a*) **"Extracts" Volumes** *at Rs. 1-8 or 3s per volume.*

1900-01—Recent Improvements in Photo-Zincography. G. T. Triangulation in Upper Burma. Latitude Operations. Experimental Base Measurement with Jäderin Apparatus. Magnetic Survey. Tidal and Levelling. Topography in Upper Burma. Calcutta, 1903. (Out of print).

1901-02—G. T. Triangulation in Upper Burma. Latitude Operations. Magnetic Survey. Tidal and Levelling. Topography in Upper Burma. Topography in Sind. Topography in the Punjab. Calcutta, 1904. (Out of print.)

1902-03—Principal Triangulation in Upper Burma. Topography in Upper Burma. Topography in Shan States. Survey of Sāmbhar Lake. Latitude Operations. Tidal and Levelling. Magnetic Survey. Introduction of the Contract System of Payment in Traverse Surveys. Traversing with the Subtense Bar. Compilation and Reproduction of Thāna Maps. Calcutta, 1905.

1903-04—Magnetic Survey. Pendulum. Tidal and Levelling. Astronomical Azimuths. Utilization of old Traverse Data for Modern Surveys in the United Provinces. Identification of Snow Peaks in Nepāl. Topographical Surveys in Sind. Notes on town and Municipal Surveys. Notes on Riverain Surveys in the Punjab. Calcutta, 1906.

1904-05—Magnetic Survey. Pendulum Operations. Tidal and Levelling. Triangulation in Baluchistān. Survey Operations with the Somaliland Field Force. Calcutta, 1907.

1905-06—Magnetic Survey. Pendulum Operations. Tidal and Levelling. Topography in Shan States. Calcutta, 1908.

1906-07—Magnetic Survey. Pendulum Operations. Tidal and Levelling. Triangulation in Baluchistān. Astronomical Latitudes. Topography in Shan States. Calcutta, 1909.

1907-08—Magnetic Survey. Tidal and Levelling. Astronomical Latitudes. Pendulum Operations. Topography in Shan States. Calcutta, 1910.

1908-09—Magnetic Survey. Tidal and Levelling. Pendulum Operations. Triangulation. Calcutta, 1911.

ANNUAL REPORTS—*(Continued).*

(*b*) **"Records of the Survey of India"** *at Rs. 4 or 8ˢ per volume, except where otherwise stated.*

Vol. I—**1909-10**—Topographical Survey. Triangulation, Tidal and Levelling Operations. Geodetic Survey (Astronomical latitudes and pendulum observations). Magnetic Survey. ... ... Calcutta, 1912.

II—**1910-11**—Topographical Survey. Triangulation, Tidal and Levelling Operations. Geodetic Survey. Magnetic Survey. ... ... Calcutta, 1912.

III—**1911-12**—Topographical Survey. Triangulation, Tidal and Levelling Operations. Geodetic Survey, Magnetic Survey. ... ... Calcutta, 1913.

IV—**1911-13**—*Explorations on the North-East Frontier—North Burma, Mishmi, Abor and Miri Surveys* ... ... Calcutta, 1914.

V—**1912-13**—Topographical Survey. Triangulation, Tidal and Levelling Operations. Geodetic Survey. Magnetic Survey. Note on the relationship of the Himalayas to the Indo-Gangetic Plain. ... ... Calcutta, 1914.

VI—**1912-13**—*Link connecting the Triangulations of India and Russia* Dehra Dūn, 1914.

VII—**1913-14**—Topographical Survey. Triangulation. Tidal and Levelling Operations. Geodetic Survey. Magnetic Survey (Annual report and Government Committee's report). Note on Scales and cost rates of Town plans. Calcutta, 1915.

VIII—{**1865-79—Part I**} *Explorations in Tibet and* {**1879-92—Part II**} *neighbouring regions* { Dehra Dūn, 1915. *Price of each part Rs. 4 or 8ˢ.*

IX—**1914-15**—Topographical Survey. Triangulation, Tidal and Levelling Operations. Magnetic Survey. Criterion of strength of Indian Geodetic Triangulation. A traverse signal for City Surveys. The plains of Northern India and their relationship to the Himalaya Mountains by Colonel S. G. Burrard F. R. S. Report on Turco-Persian Frontier Commission. Calcutta, 1916.

X—**1915-16**—Topographical Survey. Tidal and Levelling Operations. Magnetic Survey. Mechanical Integrator for calculating Attractions (illustrated). Traverse Survey of the boundary of Imperial Delhi ... Dehra Dūn, 1917.

XI—**1916-17**—Topographical Survey. Triangulation—use of high trestle for stations and 100 feet mast signals. Tidal and Levelling Operations. Magnetic Survey. Note on Basevi's Pendulum Operations at More. Photo Litho Office—New method of preparing Layer plates—Developments and Improvements in preparing Tint-plates. Dehra Dūn, 1918.

XII—Notes on Survey of India Maps and the modern development of Indian Cartography. *By Lt.-Col. W.M. Coldstream, R.E., Superintendent, Map Publication.* { Calcutta, 1919. *Price Rs. 3 or 6ˢ.*

XIII—**1917-18**—Topographical Survey. Tidal and Levelling Operations. Magnetic Survey. Photo-Litho office—the Powder Process. Problem of the Himalayan and Gangetic Trough—Review by Dr. A. Morley Davies. Dehra Dūn, 1919

XIV—**1918-19**—Topographical Survey. Tidal and Levelling Operations. Levelling in Mesopotamia. Magnetic Survey. ... ... Dehra Dūn, 1920.

XV—**1919-20**—Topographical Survey. Tidal work. Levelling—proposed new level net. Magnetic Survey. The Earth's Axes and Figure by Dr. J. de Graaff Hunter (a paper read at the R. A. S. Geophysical Meeting). Report on the expedition to Kamet. Note on the Topography of the Nun Kun Massif in Ladakh ... ... Dehra Dūn, 1921.

"Notes of the Survey of India" are used monthly. (Stocked in the Surveyor General's Office, Calcutta). *Price as 2 or 3ᵈ.*

B—GEODETIC WORKS OF REFERENCE.

(Obtainable from the Superintendent of the Trigonometrical Survey, Dehra Dūn, U.P.)

EVEREST'S GREAT ARC BOOK.

1. An account of the Measurement of an Arc of the Meridian between the parallels of 18° 3′ and 24° 7′. *By Capt. George Everest.* East India Company, London, 1830. (Out of print).

2. An account of the Measurement of two Sections of the Meridional Arc of India, bounded by the parallels of 18° 3′ 15″, 24° 7′ 11″ and 29° 30′ 48″. *By Lt.-Col. G. Everest, F. R. S.* East India Company, London, 1847. (Out of print).

3. Engravings to illustrate the above. London, 1847. (Out of print).

G.T.S. VOLUMES—describing the Operations of the Great Trigonometrical Survey.

Price Rs. 10-8 or 21s per volume, except where otherwise stated.

Vol. I—**Standards of Measure and Base-Lines,** also an Introductory Account of the early Operations of the Survey, during the period of 1800-1830. Dehra Dūn, 1870. (Out of print).

Appendix No. 1. Description of the method of comparing, and the apparatus employed.
Appendix No. 2. Comparisons of the Lengths of 10-feet Standards **A** and **B**, and determinations of the Difference of their Expansions.
Appendix No. 3. Comparisons between the 10-feet Standards l_B l_S and **A**.
Appendix No. 4. Comparisons of the 6-inch Brass Scales of the Compensated Microscopes.
Appendix No. 5. Determination of the Length of the Inch [7.8] on Cary's 3-foot Brass Scale.
Appendix No. 6. Comparisons between the 10-feet Standard Bars l_S and **A** for determining the Expansion of bar **A**.
Appendix No. 7. Final determination of the Differences in Length between the 10-feet Standards l_B l_S and **A**.
Appendix No. 8. On the Thermometers employed with the Standards of Length.
Appendix No. 9. Determination of the Lengths of the Sub-divisions of the Inch [*a.b*].
Appendix No. 10. Report on the Practical Errors of the Measurement of the Cape Comorin Base.

II—**A History and General Description of the Reduction** of the Principal Triangulation. ... Dehra Dūn, 1879. (Out of print).

Appendix No. 1. Investigations applying to the Indian Geodesy.
Appendix No. 2. The Micrometer Microscope Theodolites.
Appendix No. 3. On Observations of Terrestrial Refraction at certain stations situated on the plains of the Punjab.
Appendix No. 4. On the Periodic Errors of Graduated Circles, &c.
Appendix No. 5. On certain Modifications of Colonel Everest's System of Observing introduced to meet the specialities of particular instruments.
Appendix No. 6. On Tidal Observations at Kurrachee in 1855.
Appendix No. 7. An alternative Method of obtaining the Formulæ in Chapters VIII and XV employed in the Reduction of Triangulation.—Additional Formulæ and Demonstrations.
Appendix No. 8. On the Dispersion of Circuit Errors of Triangulation after the Angles have been corrected for Figural conditions.
Appendix No. 9. Corrections to azimuthal Observations for imperfect Instrumental Adjustments.
Appendix No. 10. Reduction of the N.W. Quadrilateral—the Non-Circuit Triangles and their Final Figural Adjustments.
Appendix No. 11. The Theoretical Errors of the Triangulation of the North-West Quadrilateral.
Appendix No. 12. Simultaneous Reduction of the N.W. Quadrilateral—the Computations.

Vol. III—**North-West Quadrilateral.**—The Principal Triangulation, the Base-Line Figures, the Karāchi Longitudinal, N. W. Himālaya, and the Great Indus Series. ... ... Dehra Dūn, 1873. (Out of print.)

IV—**North-West Quadrilateral**—The Principal Triangulation, the Great Arc—Section 24°-30°, Rahūn, Gurhāgarh and Jogi-Tīla Meridional Series and the Sutlej Series. ... ... Dehra Dūn, 1876.

IVA—**North-West Quadrilateral**—The Principal Triangulation, the Jodhpore and the Eastern Sind Meridional Series with the details of their Reduction and the Final Results. ... ... Dehra Dūn, 1886.

V—**Pendulum Operations** of Captains J. P. Basevi and W. J. Heaviside, and their Reduction. Dehra Dūn and Calcutta, 1879.

Appendix No. 1. Account of the Remeasurement of the Length of Kater's Pendulum at the Ordnance Survey Office, Southampton.
Appendix No. 2. On the Relation between the Indian Pendulum Operations, and those which have been conducted elsewhere.
Appendix No. 3. On the Theory, Use and History of the Convertible Pendulum.
Appendix No. 4. On the Length of the Seconds Pendulum determinable from Materials now existing.
Appendix No. 5. A Bibliographical List of Works relating to Pendulum Operations in connection with the Problem of the Figure of the Earth.

VI—**South-East Quadrilateral**—The Principal Triangulation and Simultaneous Reduction of the following Series:—Great Arc—Section 18° to 24°, the East Coast, the Calcutta and the Bider Longitudinal, the Jabalpur and the Bilāspur Meridionals. ... ... Dehra Dūn, 1880. (Out of print.)

VII—**North-East Quadrilateral**—General Description and Simultaneous Reduction. Also details of the following five series:—North-East Longitudinal, the Budhon Meridional, the Rangir Meridional, the Amua Meridional, and the Karāra Meridional. ... ... Dehra Dūn, 1882.

Appendix No. 1. The Details of the Separate Reduction of the Budhon Meridional Series or Series J of the North-East Quadrilateral.

G.T.S. VOLUMES—(*Continued*).

Appendix No. 2. Reduction of the North-East Quadrilateral. The Non-circuit Triangles and their Final Figural Adjustments.

Appendix No. 3. On the Theoretical Errors generated respectively in Side, Azimuth, Latitude and Longitude in a Chain of Triangles.

Appendix No. 4. On the Dispersion of the Residual Errors of a Simultaneous Reduction of several Chains of Triangles.

Vol. VIII—**North-East Quadrilateral**—Details of the following eleven series:—Gurwāni Meridional, Gora Meridional, Hurīlāong Meridional, Chendwār Meridional, North Pārasnāth Meridional, North Malūncha Meridional, Calcutta Meridional, East Calcutta Longitudinal, Brahmaputra Meridional, Eastern Frontier—Section 23°-26°, and Assam Longitudinal. .. Dehra Dūn, 1882.

IX—**Telegraphic Longitudes**—during the years 1875-77 and 1880-81. Dehra Dūn, 1883.

Appendices to Part I.
1. Determination of the Geodetic Elements of Longitude Stations.
2. Descriptions of Points used for Longitude Stations.
3. Comparison of Geodetic with Electro-Telegraphic Arcs of Longitude.
4. Circuit Errors of Observed Arcs of Longitude.
5. Results of Idiometer Observations made during Season 1880-81.

Appendices to Part II.
1. Situations of the Longitude Stations at Bombay, Aden and Suez.
2. Survey Operations at Aden.
3. Results of the Triangulation.
4. Right Ascensions of Clock Stars.

X—**Telegraphic Longitudes**—during the years 1881-82, 1882-83, and 1883-84. Dehra Dūn, 1887.

Appendices to Part I.
1. Determination of the Geodetic Elements of the Longitude Stations.
2. Descriptions of Stations of the Connecting Triangulation and of those at which the Longitude Observations were taken.
3. On the Errors in ΔL caused by Armature-time and the Retardation of the Electric Current.
4. On the Rejection of some doubtful Arcs of Season 1881-82.
5. On the probable Causes of the Errors of Arc-measurements, and on the Nature of the Defects in the Transit Instruments which might produce them.

Vol. XI—**Astronomical Latitudes**—during the period 1805-1885. Dehra Dūn, 1890.

XII—**Southern Trigon**—General Description and Simultaneous Reduction. Also details of the following two series:—Great Arc—Section 8°-18°, and Bombay Longitudinal. ... ... Dehra Dūn, 1890.

XIII—**Southern Trigon**—Details of the following five series:—South Konkan Coast, Mangalore Meridional, Madras Meridional and Coast, South-East Coast, and Madras Longitudinal. ... ... Dehra Dūn, 1890.

XIV—**South-West Quadrilateral**—Details of Principal Tringulation and Simultaneous Reduction of its component series. ... Dehra Dūn, 1890.

XV—**Telegraphic Longitudes**—from 1885 to 1892 and the Revised Results of Volumes IX and X: also the Simultaneous Reduction and Final Results of the whole Operations. ... ... Dehra Dūn, 1893.

Appendix No. 1. Determination of the Geodetic Elements of the Longitude Stations.

Appendix No. 2. On Retardation. (A numerical mistake was made in this appendix in the conversion of a formula from kilometres to miles: the conclusions drawn cannot therefore be upheld).

XVI—**Tidal observations**—from 1873 to 1892, and the Methods of Reduction. Dehra Dūn, 1901.

XVII—**Telegraphic Longitudes**—during the years 1894-95-96. The Indo-European Arcs from Karāchi to Greenwich. .. ... Dehra Dūn, 1901.

Appendix No. 1. Descriptions of Points used for Longitude Stations.

Appendix No. 2. The Longitude of Madras.

XVIII—**Astronomical Latitudes** from 1885 to 1905 and the Deduced Values of Plumb-line Deflections. ... ... Dehra Dūn, 1906.

Appendix No. 1. On Deflections of the Plumb-line in India

Appendix No. 2. Determination of the Geodetic Elements of the Latitude Stations of Bajamara, Bahuk, Lambatach and Kidarkanta.

Appendix No. 3. On the (N-S) Difference exhibited by Zenith Sector No. 1.

Appendix No. 4. On the Value of the Micrometer of the Zenith Telescope.

Appendix No. 5. On the Azimuth Observations of the Great Trigonometrical Survey of India.

Appendix No. 6. A Catalogue of the Publications of the Great Trigonometrical Survey of India.

Appendix No. 7. On the combination weights employed.

XIX—**Levelling of Precision in India** from 1858 to 1909. Dehra Dūn, 1910.

Appendix No. 1. Experiment to test the changes, due to Moisture and Temperature, in the Length of a Levelling Staff.

G.T.S. VOLUMES—(*Continued*).

Appendix No. 2. On the erection of Standard Bench-Marks in India during the years 1904-1910.

Appendix No. 3. Memorandum on the steps taken in 1905-1910 to enable movements of the Earth's crust to be detected.

Appendix No. 4. Dynamic and Orthometric corrections to the Himâlayan levelling lines and circuit; and a consideration of the order of magnitude of possible refraction errors.

Appendix No. 5. The passage of rivers by the Levelling Operations.

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

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

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

Vol. XIXA—**Bench-Marks** on the **Southern** Lines of Levelling. Dehra Dûn, 1910. *Price Rs. 5 or 10s.*

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II—The Great Arc—Section 24°-30° (*6*). Dehra Dûn, 1874.

III—The Karachi Longitudinal Series (*25*). Dehra Dûn, 1874.

IV—The Gurhâgarh Meridional Series (*23*). Dehra Dûn, 1875.

V—The Rahûn Meridional Series (*33*). Dehra Dûn, 1875.

VI—The Jogi-Tila Meridional Series (*37*). and the Sutlej Meridional Series (*45*). Dehra Dûn, 1875.

VII—The N. W. Himâlaya Series (*22*) and the Triangulation of Kashmîr (*36*). Dehra Dûn, 1879.

VIIA—The Jodhpore Meridional Series (*62*) and the Eastern Sind Meridional Series (*64*). Dehra Dûn, 1887.

South-East Quadrilateral

Vol. VIII—The Great Arc—Section 18°-24° (*8*). Dehra Dûn, 1878.

IX—The Jabalpur Meridional Series (*53*). Dehra Dûn, 1878.

X—The Bider Longitudinal Series (*43*). Dehra Dûn, 1880.

XI—The Bilâspur Meridional Series (*58*). Dehra Dûn, 1880.

XII—The Calcutta Longitudinal Series (*5*). Dehra Dûn, 1880

XIII—The East Coast Series (*24*). Dehra Dûn, 1880.

XIIIA—The South Pârasnâth (*1*) and the South Malûncha Meridional Series (*17*). Dehra Dûn, 1885.

North-East Quadrilateral

Vol. XIV—The Budhon Meridional Series (*2*). Dehra Dûn, 1883.

XV—The Rangîr Meridional Series (*4*). Dehra Dûn, 1883.

XVI—The Amua Meridional Series (*3*) and the Karâra Meridional Series (*12*). Dehra Dûn, 1883.

XVII—The Gurwâni Meridional Series (*19*) and the Gora Meridional Series (*15*). Dehra Dûn, 1883.

XVIII—The Hurîlâong Meridional Series (*21*) and the Chendwâr Meridional Series (*14*). Dehra Dûn, 1883.

XIX—The North Pârasnâth (*27*) and the North Malûncha Meridional Series (*13*). Dehra Dûn, 1883.

XX—The Calcutta Meridional (*16*) and the Brahmapûtra Meridional Series (*56*). Dehra Dûn, 1883.

XXI—The East Calcutta Longitudinal (*48*) and the Eastern Frontier Series—Section 23°-26° (*44*). Dehra Dûn, 1883.

XXII—The Assam Valley Triangulation, E. of Meridian 92° (*55*). Dehra Dûn, 1891. (Out of print.)

XXXV—The North-East Longitudinal Series (*20*) with the volume of charts. Dehra Dûn, 1909. *Price Rs. 5 or 10s.*

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SYNOPTICAL VOLUMES—(*Continued*).

Southern Trigon

Vol. XXIII—The South Konkan Coast Series (*11*). Dehra Dūn, 1891.
XXIV—The Mangalore Meridional Series (*49*). Dehra Dūn, 1891.
XXV—The South-East Coast Series (*63*). Dehra Dūn, 1891.
XXVI—The Bombay Longitudinal Series (*7*). Dehra Dūn, 1892.
XXVII—The Madras Longitudinal Series (*54*). Dehra Dūn, 1892.
XXVIII—The Madras Meridional and Coast Series (*46*). Dehra Dūn, 1892.
XXIX—The Great Arc Meridional Series—Section 8°-18° (*9*). Dehra Dūn, 1899.

South-West Quadrilateral

Vol. XXX.—The Abu Meridional Series (*26*) and the Gujarāt Longitudinal Series (*29*). Dehra Dūn, 1892.
XXXI—The Khānpisura Meridional Series (*18*). Dehra Dūn, 1893.
XXXII—The Singi Meridional Series (*10*). Dehra Dūn, 1893.
XXXIII—The Cutch Coast Series (*35*). Dehra Dūn, 1893.
Addendum to the Cutch Coast Series, *Indus delta*, (separate pamphlet). Dehra Dūn, 1902.
XXXIV—The Kāthiāwār Meridional Series (*28*). Dehra Dūn, 1894.

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Pamphlet Nos.	Latitude.	Longitude.	Published		Pamphlet Nos.	Latitude.	Longitude	Published.
India 34	28°–32°	64°–68°	Dehra Dūn,	1916.	India 44	28°–32°	72°–76°	Dehra Dūn, 1920†.
„ 35	24°–28°	64°–68°	„	1911.	„ 45	24°–28°	72°–76°	„ 1911.
„ 38	32°–36°	68°–72°	„	1912.	„ 46	20°–24°	72°–76°	„ 1912.
„ 39	28°–32°	68°–72°	„	1913.	47	16°–20°	72°–76°	„ 1912.
„ „	Addendum		„	1916.	„ „	*Addendum		„ 1915.
„ 40	24°–28°	68°–72°	„	1911.	„ 48	12°–16°	72°–76°	„ 1912.
„ 41	20°–24°	68°–72°	„	1913.	„ 49*	8°–12°	72°–76°	„ 1911.
„ 43	32°–36°	72°–76°	„	1913.	„ 52	32°–36°	76°–80°	„ 1912.
„ „	Addendum		„	1915.	„ 53	28°–32°	76°–80°	„ 1912.
„ 54	24°–28°	76°–80°	„	1914.‡	„ 78	24°–28°	88°–92°	„ 1912.
„ 55	20°–24°	76°–80°	„	1912.	„ „	*Addendum		„ 1916.
„ 56	16°–20°	76°–80°	„	1912.	„ 79	20°–24°	88°–92°	„ 1912.
„	*Addendum		„	1919	„ „	Addendum		„ 1916.
„ 57	12°–16°	76°–80°	„	1919.‡	„ 83	24°–28°	92°–96°	„ 1912.§
„ 58	8°–12°	76°–80°	„	1914.				
„ 63	24°–28°	80°–84°	„	1911.	Burma 84	20°–24°	92°–96°	„ 1918.‖
„ „	Addendum		„	1920.				
„ 64	20°–24°	80°–84°	„	1912.	„ 85	16°–20°	92°–96°	„ 1917.‖
„ 65	16°–20°	80°–84°	„	1913.	„ 92	24°–28°	96°–100°	„ 1918.‖
„ 66	12°–16°	80°–84°	„	1912.	„ 93	20°–24°	96°–100°	„ 1917.‖
„ 72	24°–28°	84°–88°	„	1912.	„ 94	16°–20°	96°–100°	„ 1916.‖
„ „	Addendum		„	1920.	„ 95	12°–16°	96°–100°	
„ 73	20°–24°	84°–88°	„	1913.				
„ „	Addendum		„	1920.				
„ 74	16°–20°	84°–88°	„	1913.				

Levelling of Precision in Mesopotamia—
Descriptions and heights of bench-marks, Dehra Dūn, 1919. *Price Rs. 3 or 6s.*

TIDE TABLES—

Since 1881 Tidal predictions based on the observations of the Survey of India have been published annually by the India Office, London. The tables give the time and height of high and low water for every day in the year at each port, and are published early in the previous year. Current tables are available for the following 41 ports:—

Western Ports—

Suez (Egypt)—Basrah—Perim—Aden—Maskat—Būshire—Karāchi—Okha Point and Bet Harbour (Gulf of Cutch)—Porbandar—Port Albert Victor (Kāthiāwār)—Bhaunagar—Bombay (Apollo Bandar)—Bombay (Prince's Dock)—Mormugao (Goa)—Kārwār—Beypore (near Calicut)—Cochin—Minicoy (Indian Ocean)—Tuticorin—Pāmban Pass (Island of Rāmeswaram).

* Price Re. 1 or 2s. † 2nd Edition. ‡ 2nd Edition (revised and enlarged). § Heights on pages 45 & 46 revised in 1918. ‖ Heights revised.

TIDE TABLES—(*Continued*).

Eastern Ports—

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

The Tide Tables are issued in the following forms :—

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C—CATALOGUES AND INSTRUCTIONS.

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

DEPARTMENTAL ORDERS.—

From 1878 to 1885 the Surveyor General's orders were all issued as "*Circular Orders.*" Since then they have been classified as follows :—

From 1885 to 1904 as { 1—**Government of India Orders** (called "*Circular Orders*" up to 1898.) 2—**Departmental Orders (Administrative)**. 3—**Departmental Orders (Professional)**.

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

	Number to date.
1.—**Government of India Orders**.—	742
2.—**Circular Orders (Administrative)**.—	390
3.—**Circular Orders (Professional)**.—	196
4.—**Departmental Orders**. (appointments, promotions, transfers, etc.)	

These are numbered serially and had reached the above numbers by September 1920. *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.
   Ditto ditto 1914-1918.—Calcutta, 1920.
2. *Circular Orders (Administrative) 1878-1903.—Calcutta, 1904.
   Ditto ditto 1904-1908.—Calcutta, 1909.
   Ditto ditto 1909-1913.—Calcutta, 1915.
   Ditto ditto 1914-1918.—Calcutta, 1920,
3. * Regulations on the subject of Language Examinations for Officers of the Survey of India. Calcutta, 1914.
4. * Map Publication Orders 1908-1914 (*Superintendent, Map Publication's Orders.*)—Calcutta, 1914.
5. Specimens of papers set at Examinations for the Provincial Service.—Dehra Dūn, 1903.—(Out of print).

CATALOGUES AND LISTS.

1. **Catalogue of Maps** published by the Survey of India. Corrected to 1st October 1917 Calcutta, 1918. *Price Re. 1 or 2s.*

NOTE.—Lists are issued quarterly of new maps published during each quarter, and similar lists for each month appear in the monthly NOTES OF THE SURVEY OF INDIA.

2. **Catalogue of Maps** of the Bombay Presidency, Calcutta, 1913. *Price As. 4 or 6d.*
3. **List of the publications of the Survey of India** (published annually)—Dehra Dūn. *Gratis.*
4. **Price List of Mathematical Instrument Office.** Calcutta, 1913. *Gratis.*
5. Catalogue of Books in the Head-Quarters Library, Calcutta, 1901. (Out of print).

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CATALOGUES AND LISTS—(*Continued*).

6. Catalogue of Scientific Books and Subjects in the Library of the Trigonometrical Survey Office. Dehra Dūn, 1908. *Price Re. 1 or 2s.*

7. Catalogue of Books in the Library of the Trigonometrical Survey Office. Dehra Dūn, 1911. (Out of print.)

8. **Green Lists**—PART I—List of officers in the Survey (*half yearly to dates 1st January and 1st July*)—Calcutta. *Price As. 6 or 9d.*

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PART I—Head quarters and Dehra Dūn offices (published annually to date 1st April)—Calcutta. *Price Re. 1 or 2s.*

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(Nos. 8 and 9 are stocked in the Surveyor General's Office, Calcutta).

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2. **Auxiliary Tables**—of the Survey of India. Fifth Edition, revised and extended by J. de Graaff Hunter, M.A. In parts—

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3. Tables for Graticules of Maps. Extracts for the use of **Explorers.** Dehra Dūn, 1918. *Price As. 4 or 6d.*

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6. Logarithmic Sines, Cosines, Tangents and Cotangents to 5 places of decimals. Dehra Dūn, 1915. (Out of print)

7. Common Logarithms to 5 places of decimals 1885. *Price As. 4 or 6d.*

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1. A Manual of Surveying for India, detailing the mode of operations on the Revenue Surveys in Bengal and the North-Western Provinces. Compiled *by Captains R. Smyth and H. L. Thuillier.* Calcutta 1851. (Out of print.)

2. Ditto ditto ditto. Second Edition. London, 1855. (Out of print).

3. A Manual of Surveying for India, detailing the mode of operations on the Trigonometrical, Topographical and Revenue Surveys of India. Compiled *by Colonel H. L. Thuillier, C.S.I., F.R.S., and Lieutenant-Colonel R. Smyth.* Third Edition, revised and enlarged. Calcutta, 1875. (Out of print.)

4. **Hand-book, Revenue Branch.** Calcutta, 1893. *Price Rs. 2-8 or 5s.*

SURVEY OF INDIA HAND-BOOKS.

1. **Hand-book of General Instructions,** Fourth Edition. Calcutta, 1914. *Price Rs. 3 or 6s*

2. **Hand-book, Trigonometrical Branch,** Second Edition. Calcutta 1902. (Out of print.)

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Chapter VI—Levelling of Precision. Dehra Dun 1920. *Price Re. 1 or 2 s.*

4. **Hand-book, Topographical Branch,** Third Edition. Calcutta, 1905. (Out of print.)

5. **Hand-book of Topography.**—Fourth Edition Calcutta 1911. Chapters, in pamphlet forms—

Chapter I—Introductory.—reprinted with additions, 1917. (Out of print).
" II—Constitution and Organization of a Survey Party.—reprinted, 1913. *Price As. 4 or 6d.*
" III—Triangulation and its Computation.—reprinted, 1914. *Price As. 8 or 1s*
" IV—Traversing and its Computation.—reprinted, 1913. *Price As. 8 or 1s.*
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" IX—Forest Surveys and Maps.—reprinted 1914. *Price As. 4 or 6d.*
" X—Map Reproduction.—reprinted 1919. *Price As. 4 or 6d.*
" XI—Geographical maps.—1917. *Price As. 4 or 6d.*

6. ***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.

7. **The Reproduction (for the guidance of other Departments),** of Maps, Plans, Photographs, Diagrams, and Line Illustrations. Calcutta, 1914 *Price Rs. 3 or 6s.*

NOTES AND INSTRUCTIONS.

Drawing and Paper.

1. *Notes on Printing Papers suitable for Maps, and on Whatman Drawing Paper. *By Major W. M. Coldstream, R. E.* Calcutta, 1911.

Printing and Field Litho processes.

2. *Report on Rubber Offset Printing for Maps. *By Major W. M. Coldstream, R. E.* Calcutta, 1911.

3. *Notes on the "Vandyke" or Direct Zinc Printing Process, with details of Apparatus and Chemicals required for a small section. Compiled in the Photo and Litho Office, Survey of India. Calcutta, 1913.

4. *Report on the Working of the Light Field Litho Press (experimental) in November and December 1910 with Appendices. *By Lieutenant A. A. Chase, R. E.*, Calcutta, 1911.

(1) Notes on some of the Methods of Reproduction suitable for the Field.

(2) Suggested Equipment Tables for the Light Field Litho Press (experimental).

5. *Report on a trial of the equipment of the 1st (Prince of Wales' Own) Sappers and Miners for reproducing maps in the field. *By Lieutenant A. A. Chase, R. E.* Calcutta, 1912. (Out of print).

Base Lines and Magnetic.

6. *Notes on use of the Jäderin Base-line Apparatus. Dehra Dūn. 1904. (Out of print).

7. *Miscellaneous Papers relating to the Measurement of Geodetic Bases by Jäderin Invar Apparatus. Dehra Dūn, 1912.

8. *Instructions for taking Magnetic Observations. *By J. Eccles, M. A.* Dehra Dūn, 1896. (Out of print).

9. **Rectangular Coordinates.**—On a Simplification of the Computations relating to- *By J. Eccles, M. A.* Dehra Dūn, 1911. *Price Re. 1 or 2s.*

10. ***For Explorers.**—Notes on the use of Thermometers, Barometers and Hypsometers with Tables for the Computation of Heights. *By J. de Graaff Hunter, M. A.* Dehra Dūn, 1911. (Out of print).

11. Amended Instructions for the Survey and Mapping of Town Guide Maps. August 1919.

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D—MISCELLANEOUS PAPERS.

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

UNCLASSIFIED PAPERS.

Geography.

1. A Sketch of the Geography and Geology of the Himālaya Mountains and Tibet (in four parts). *By Colonel S. G. Burrard, R. E., F. R S., Supdt., Trigonometrical Surveys, and H. H. Hayden, B. A., F. G. S., Supdt., Geological Survey of India.* Calcutta, 1907-08.

Part I.—The High Peaks of Asia.
„ II.—The Principal Mountain Ranges of Asia.
„ III.—The Rivers of the Himālaya and Tibet.
„ IV.—The Geology of the Himālaya.
} *Price Rs. 2 or 4ˢ per part.*

2. *Report on the Identification and Nomenclature of the Himālayan Peaks as seen from Kātmāndu, Nepāl. *By Capt. H. Wood, R. E.* Calcutta, 1904.

3. Routes in the Western Himālaya, Kashmīr, etc. *By Lieut.-Colonel T. G. Montgomerie, R. E., F. R. S., F. R. G. S.* Third Edition, revised and corrected. Dehra Dūn, 1909. (Out of print.)

Exploration.

1. *Account of the Survey Operations in connection with the Mission to Yārkand and Kashghar in 1873-74. *By Captain Henry Trotter, R.E.* Calcutta, 1875. (Out of print).

2. Report on the Trans-Himālayan Explorations during 1869. (Out of print).

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a Pamphlet with G.T. data available at Trigonometrical Survey Office. *b* Pamphlet with G.T., if any, and Topo. data received from parties. *c* Data with chart.
d Data published in the old style (chart form). *f* No data available at Trigonometrical Survey Office. *S* Area falling in the sea. *A* Addendum in a separate pamphlet.