Photo-process Survey of India Offices, Calcutta 1929.

COLONEL MAURICE O'CONNOR TANDY, D.S.O., O.B.E., R.E.

DIRECTOR GEODETIC BRANCH, SURVEY OF INDIA, 1925–28.

Colonel Maurice O' Connor Tandy., d.s.o., o.b.e., r.e.

Col. M. O'C. Tandy, whose portrait forms the frontispiece to this volume, was commissioned in the Royal Engineers in July 1893, and after six years military duty he joined the Survey of India at Dehra Dūn. In 1901 he was placed on deputation as Survey Officer with the Aden Boundary Commission, on the completion of which he served with the Foreign Department in Simla for 6 months, and returned to the Survey of India in 1905, when he was employed on topographical surveys in the Punjab. From April 1907 he held charge of the Calcutta Drawing Office for 4½ years, where his work in organizing the new system of mapping, and putting the Map Record and Issue Office on a satisfactory footing, was of permanent value to the Department.

On the outbreak of war he reverted to military duty and was wounded at Loos. After having some connection with the preparation of the first tanks he was transferred to Mesopotamia, where he remained until the end of the war, receiving the D.S.O., and O.B.E. He was again employed on military duty during the Afghān War in 1919.

From 1920 to 1925 he was employed in topographical surveys in the Southern Circle, interrupted by a period of 6 months as Director, Frontier Surveys, arranging preliminaries for the creation of the new Frontier Circle.

The last post which he held in India was that of the Director of the Geodetic Branch from November 1925 to June 1927. Although Col. Tandy had had no previous connection with the Geodetic Branch, he was able to effect many beneficial changes in organization, especially in that part of the branch connected with printing and publication. His wide topographical experience was also of value in connection with liaison between the geodetic and topographical branches, and in rendering data accumulated by one readily accessible to the other. He inaugurated the Geodetic Branch Museum, in which are placed many of the theodolites and other instruments used in the early years of the Trigonometrical Survey. Two photographs of this Museum appeared in the Geodetic Report Vol. III.

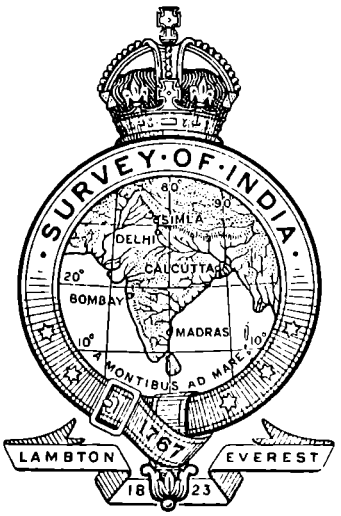
Col. Tandy was an officer who earned the full confidence and respect of those serving under him, and was at his best when faced with difficulties, which gave scope to his energy and organizing ability. He rendered many valuable services to the Department and the State, in improving the methods of work, and set a good example by personal devotion to duty.

He retired in December 1928, with the sincere good wishes of his friends in all ranks of the Department, having previously been appointed Lecturer in Survey at the University of Oxford.

SURVEY OF INDIA

GEODETIC REPORT

VOL. IV



From 1st October 1927
To 30th September 1928

PUBLISHED BY ORDER OF
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CONTENTS

CHAPTER V
Triangulation

CHAPTER VI
Levelling

Charts and plates

INTRODUCTION AND SUMMARY

During the year 1927-28 geodetic and other work was continued at Dehra Dūn, and three field parties were engaged on gravity work, triangulation and levelling respectively.

In the Computing Section all deviation of the plumb-line results have been expressed in terms of the International Spheroid (I, 2). A chart has been produced showing what discrepancies between heights found by spirit-levelling and triangulation are likely to be met with in various parts of the Indian Survey (I, 10).

Work in the Observatory Section has been increased by periodic pendulum observations, taken with a view to ascertaining what variations in g, real or apparent, occur at this base station (II, 9). Regular latitude observations have also been begun (II, 4). Time observations have been continued as usual, and the time signals of Bordeaux and Rugby have been received on most days. The apparent variations in the longitude of Dehra Dūn, resulting from these, are exhibited in tables. Results for each month are meaned and exhibit considerable variations, but not such that cannot be attributed to observational error.

The normal tidal prediction work and inspection of tidal observatories have been carried out (III). The Observatory of Basrah was inspected by the Survey of India for the first time. Basrah tidal predictions have not been satisfactory, and a serious attempt to improve the prediction table has been made (III, 6). Recent tidal observations at Bassein have been harmonically analysed (III, 4).

A description is given of the new pendulum apparatus (IV, 2,6) as well as a brief account of its predecessors (IV, 1,5). The high degree of isochronism of the new pendulums is due to Major E. A. Glennie, and has enabled swings of very long duration to be made with pairs of pendulums (IV, 7). This, with wireless reception of European time signals by a convenient set just obtained (IV, 11) has much reduced the labour of observation.

Major Glennie gives an interesting account of the regions in which this season's work has been done, viz. Las Bela State, Sind, Baluchistān along the Nushki-Duzdāp railway, and Hāmūn-i-Māshkel neighbourhood (IV, 12). No outstanding anomalies of g were revealed.

In addition to the pendulum work, observations with a large prismatic astrolabe were made, which will yield deflections; but the computations had not been completed at the time of going to press (IV, 17).

At the end of the chapter (IV) there is a comprehensive list of results of all (166) modern gravity stations of the Survey of India, followed by a similar list of the stations of the de Filippi Kara-koram Expedition of 1914, and of Dr. Vening Meinesz's submarine determinations in the neighbourhood of India.

Triangulation of secondary precision was executed on the N.W. Frontier by Capt. G.H. Osmaston using a small Wild theodolite (V). He gives an appreciative account of this instrument (V. Appendix). In view of the unsettled nature of the country, work of this class would not have been possible with the older type of theodolite, as stations could only be occupied for short periods by day.

The levelling party has now been relieved of the tertiary levelling work (for industrial purposes) which it undertook in previous years, and can now devote its attention to precision work (VI, 1). Some interesting changes of level have been found at Ambāla and Dehra Dūn (VI, 4). There is also a description of the country in the Rann of Cutch indicating the difficulties of levelling there. A gap of 30 miles in one of the levelling circuits still remains to be done across the Rann on account of these difficulties: and work can only be completed when conditions are more favourable. A favourable opportunity is now awaited.

The total number of miles of levelling of the new level net completed in both directions now amounts to 5,326 (VI, 6). High precision levelling of 1,200 miles in one direction, and 1,000 miles of double levelling of secondary precision were accomplished (VI, 2).

There are important and interesting notes due to Captain Bomford on three difficulties in levelling, (*a*) Crossing of wide unbridged rivers, (*b*) Levelling up persistent slopes, (*c*) Pairing of staves (VI, 7). Rules are given for the guidance of observers.

The Geodetic Branch has not yet reached its full pre-war strength and the Astronomical Party (No. 13) did not take the field. It is hoped that it will be possible after a year or two to send out the party for determination of deflections in longitude. The personnel of the Geodetic Branch is given on the following pages.

DEHRA DŪN,
August 1929.

J. DE GRAAFF HUNTER,
Director of the Geodetic Branch.

PERSONNEL* OF THE GEODETIC BRANCH, 1927-28

Director, Geodetic Branch

LT.-COLONEL R. H. PHILLIMORE, D.S.O., R.E., from 7th November 1927 to 28th June 1928.

DR. J. DE GRAAFF HUNTER, M.A., SC. D., F. INST. P., from 1st Oct. 1927 to 6th Nov. 1927 and from 29th June to 30th September 1928.

COMPUTING AND TIDAL PARTY

(RECORDS AND RESEARCH)

Class I Officers.

Dr. J. de Graaff Hunter, M.A., Sc. D., F. Inst. P., in charge from 7th November 1927 to 26th February 1928.

Major C. M. Thompson, I.A., in charge from 23rd April to 30th September 1928.

Major E. A. Glennie, D.S.O., R.E., in charge from 19th April to 22nd April 1928.

Captain G. Bomford, R.E., in charge from 1st October to 6th November 1927 and from 27th February to 18th April 1928.

Mr. B. L. Gulatee, M.A. (Cantab), from 1st October 1927 to 31st August 1928.

COMPUTING SECTION.

Upper Subordinate Service.

Mr. M. Acharya.
" R. C. Ray.
" M. Chatterjee.
" S. Mitra.
" T. N. Sharma, B.A.
" A. K. Maitra, B.A.
" R. K. Bhattacharya, B.A.
" C. B. Madan, B.A., Geodetic Computer.

Lower Subordinate Service.

5 Computers.

TIDAL SECTION.

Class II Officers.

Mr. D. H. Luxa, Tidal assistant, from 1st October 1927 to 19th April 1928.

Mr. R. B. Mathur, B.A., Tidal assistant, from 20th April to 30th September 1928.

Lower Subordinate Service.

11 Computers.

OBSERVATORY SECTION.

Class II Officers.

Mr. R. B. Mathur, B.A., from 1st October 1927 to 30th September 1928.

Mr. P. K. Ghosh, B.A. (Cantab), from 1st October 1927 to 31st August 1928.

Mr. Abdul Karim, B.A., from 1st November 1927 to 27th April 1928.

Upper Subordinate Service.

Mr. H. C. Banerjea, B.A., from 1st to 7th October 1927 and from 1st April to 31st August 1928.

Mr. H. C. Deb, B.A., from 1st October 1927 to 30th September 1928.

Mr. P. K. Chowdhury, from 21st August to 30th September 1928.

Lower Subordinate Service.

6 Computers.

Magnetic Observatory.

Mr. K. N. Mukerji, M.A.

1 Computer.

OFFICE AND P. & M. SECTION.

Upper Subordinate Service.

Mr. B. B. Lal.

Lower Subordinate Service.

2 Computers & 2 Clerks.

DRAWING SECTION.

Mr. Faiz-Ullah & 5 Draftsmen.

14 PARTY (PENDULUM).

Class I Officers.

Major E. A. Glennie, D.S.O., R.E., in charge from 7th Oct. 1927 to 30th Sept. 1928.

Class II Officers.

Mr. C. West, in charge from 1st October to 6th October 1927.

Mr. Abdul Karim, B.A., from 1st October to 31st October 1927.

Lower Subordinate Service.

4 Computers etc.

15 PARTY (TRIANGULATION).

Class I Officers.

Major E. A. Glennie, D.S.O., R.E., in charge from 5th May to 31st May 1928.

Captain G. H. Osmaston, M.C., R.E., in charge from 1st October 1927 to 4th May 1928.

Mr. B. L. Gulatee, M.A. (Cantab), from 1st September to 30th September 1928.

Class II Officers.

Mr. A. M. Talati, L.C.E., in charge from 1st June to 30th September 1928.

Mr. P. K. Ghosh, B.A. (Cantab), from 1st September to 30th September 1928.

Upper Subordinate Service.

Mr. H. C. Banerjea, B.A., from 1st September 1928.

Mr. L. R. Howard, from 21st August 1928.

Lower Subordinate Service.

4 Computers etc.

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* Excluding No. 2 D.O., Publication and Stores, F.M.O., and 20 Party.

17 PARTY (LEVELLING)

Class I Officers.

Dr. J. de Graaff Hunter, M.A., Sc. D., F. Inst. P., in charge from 27th June to 28th June 1928.

Captain G. Bomford, R.E., in charge from 7th November 1927 to 26th February 1928.

Class II Officers.

Mr. N. R. Mazumdar, from 1st October 1927 to 30th September 1928; in charge from 1st October to 6th November 1927 and from 27th February to 26th June 1928 and from 29th June to 30th September 1928.

Mr. Abdul Karim, B.A., from 28th April to 30th September 1928.

Upper Subordinate Service.

Mr K. K. Das, B.A., 1st October 1927 to 31st March 1928.

Mr. L. D. Joshi.

Mr. P. B. Roy. up to 1st May 1928.

Mr. A. A. S. Matlub Ahmad up to 6th May 1928.

Mr. H. C. Banerjea, B.A., from 8th October 1927 to 31st March 1928.

Mr. Lalbir Singh up to 16th April 1928.

Mr. Abdul Majid from 10th August 1928.

Mr. J. N. Kohli.

Mr. B. P. Rundev

Mr. Muhammad Faizul Hasan from 1st March 1928.

Mr. I. D. Suri, from 21st August 1928.

Lower Subordinate Service.

21 Computers etc.

13 Levellers etc.

TRAINING SCHOOL

Class II Officers.

Mr. S. F. Norman, Survey Instructor, from 8th October to 15th December 1927 and from 16th January to 30th September 1928.

Mr. C. West, Survey Instructor, from 16th December 1927 to 15th January 1928.

CHAPTER I

COMPUTATIONS AND PUBLICATION OF DATA

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

(i) General

1. Dr. Hunter's address at the Indian Science Congress, 1928.—This year Dr. Hunter had the honour of being elected President of the Mathematics' and Physics' Section of the Indian Science Congress which met in Calcutta in January 1928. The subject discussed by him in his presidential address on this occasion was the "Figure of the Earth". The address comprised a brief résumé of the gradual improvement in knowledge of this subject from the earliest times to the present day. In ancient times scientists held the view that the earth was a sphere, though the popular and more orthodox idea was that it was flat. There was but little advance on these conceptions until Newton by his laws of gravitation established that the figure of the earth was an oblate spheroid. Since then the controversy has mainly centred round the numerical exactitude of the elements of the figure or earth constants i. e. :—of the length of the semi-major axis a, and of the flattening f. Laplace in 1799 derived the values, $a = 6376 \cdot 34$ km., $1/f = 312 \cdot 2$. Thirty years later Sir George Everest obtained his values of the elements, $a = 6377 \cdot 276$ km., $1/f = 300 \cdot 8$ from the reduction of part of the Great Arc of the meridian in India. Bessel in 1841 and Clarke in 1857 introduced further improvements in the results. In 1863 Archdeacon Pratt of Calcutta made a determination of the earth constants by applying compensation for the effects of Himālayan attraction. Of recent years the idea of compensation has been more fully developed and presented as the theory of isostasy by Mr. John Hayford of the U. S. Coast and Geodetic Survey. In 1909 he applied his theory of isostasy to derive a value of the elements of the earth's figure from observations in the United States. The values, $a = 6378 \cdot 388$, $1/f = 297 \cdot 0$, found by Hayford, were adopted for the International Spheroid in 1924 by the International Union of Geodesy and Geophysics, though the wisdom of their choice was not admitted by all concerned. The view has been emphasized in the address, that the Hayford Spheroid does not fit in well with the conditions in India, and that for a figure of reference it is sufficient to select a spheroid correct to the nearest 100 metres in a and to one unit in $1/f$. A value of 295 appears to be about the best compromise among the various values found for $1/f$. Such a figure would serve astronomical purposes well. For geodetic needs and the study of

crustal anomalies either this or the best local spheroid might be used. The full text of the address has been published by the Asiatic Society of Bengal, Calcutta. The table, which follows, gives the elements of the earth's figure as determined up-to-date by various authorities.

TABLE 1.—*Values of a and 1/f found from triangulation.*

Year	Author	a in km	$1/f$	Data used
1799	Laplace	6376·34	312·2	Arcs: European, Peruvian, African, American.
1830	Everest	7·276	300·80	Indian and French arcs.
1830	Airy	6·542	299·33	14 meridian and 4 parallel arcs.
1841	Bessel	7·397	299·15	10 meridian arcs.
1863	Pratt	8·297	295·26	Arcs: Anglo-Gallic, Russian, Indian.
1857	Clarke I	8·345	294·26	Arcs: Anglo-Gallic, Russian, Indian, Prussian, Peruvian, Hanoverian, Danish.
1866	Clarke II	8·258	294·98	Arcs: Anglo-Gallic, 2nd Indian, Russian, Peruvian, Cape.
1880	Clarke III	8·301	293·47	Above reconsidered.
1909	Hayford	8·388	297·0 ±·5	U.S.A. only on basis of isostatic compensation.
1927	Survey of India I	6378·508	292·4	Geoid in India only.
1927	,, II	8·516	292·6	Geoid in India with isostatic compensation.
1927	,, III	8·213	293·6	Geoid in U.S.A. only.
1927	,, IV	8·354	297·7	Geoid in U.S.A. with isostatic compensation.
1927	,, $\frac{I+III}{2}$	8·368	293·0	Geoid in India and U.S.A.

TABLE 2.—*Values of 1/f from pendulum results and corresponding factors in formula for* $g = G\left\{1 + A\sin^2\phi - B\sin^2 2\phi + C\cos^2\phi\cos 2(\lambda - \lambda_0)\right\}$.

Year	Author	$1/f$	G	10^6A	10^6B	10^6C	λ_0 (+ ve when E)
1901	Helmert I	298·3	978·030	5302	7	0	...
1915	do. II	296·7 ±0·4	978·052	5285	7	18±4	17° ±6 W.
1917	Bowie	297·4 ±1·0	978·039	5294	7	0	...
1924	Heiskanen	294·3* in 18° E. 299·0 in 72° W.	978·052	5285±6	7	27±3	18° ±5 E.

* This implies a difference of 345 metres in semi-equatorial axes. The major axis is in longitude 18° E.

TABLE 3.—*Values of 1/f from lunar observations.*

Year	Author	1/f	Method
1899	Darwin	296·4	Precession
1914	Brown	293·7	Lunar theory
1914	Crommelin	294·4	Moon's parallax
1924	Spencer Jones	294·8 ±·2 294·9 ±·3	Moon's perigee Moon's node
1924	de Sitter	296·92± ·14	Precession

(ii) Computations

2. Plumb-line deflections referred to the International Spheroid.—The deflections of the plumb-line in India both in meridian and prime vertical have already been computed with reference to the Everest and Helmert Spheroids, and included in Professional Paper No. 16., Table XCV. Their recalculation with reference to the International Spheroid has been partially completed. The divergences of the Everest from the International Spheroid, viz, $\delta a = +1\cdot112$ km. and $\delta b = +0\cdot834$ km. have been taken into account in the calculation. The geoid in India has been found to coincide most closely with the International Spheroid with the deflection at Kalīānpur 3″·02 S. and 3″·17 W. To bring Table XCV of Professional Paper No. 16 up-to-date, it has been extended to include all deflections observed up to 1927. These addenda to Professional Paper No 16 will be published in due course.

3. Adjustment of triangulation.—28 charts for the graphical adjustment of minor triangulation on the North-West Frontier were completed and supplied to the Director Frontier Circle during the year. For a description of the method of adjustment *vide* Geodetic Report Vol. III, Chap. II. § 4.

The triangulation carried out in 'Irāq during the Great War (1914-1918) was in many disconnected portions. The various series have now been harmonized by a method of rapid adjustment and the whole of the triangulation brought into terms of the co-ordinates of Fāo, viz. latitude 29° 58′ 23″, longitude 48° 28′ 55″. This point was selected as its position was well fixed in connection with the Turco-Persian Boundary Commission, its latitude being astronomically determined by observations to Polaris and its longitude electro-telegraphically connected with Bushire, a main longitude station between England and India.

4. Astronomical.—The astronomical latitudes observed prior to 1885 and published in G. T. S. Vols. XI and XVIII were not corrected for the height of stations above mean sea-level. The height corrections for all the stations have now been computed by the formula,

$\cdot 000052h \times \sin 2\lambda$, where h is the height in feet above mean sea-level and λ the latitude of the station, and the corrected values of the latitudes incorporated as addenda to the above volumes.

The times of sunrise and sunset for Calcutta were computed for inclusion in the Tide-Tables for 1929. They were also computed for Benares in compliance with an extra-departmental request.

5. Traverse.—A large number of traverse co-ordinates and azimuths were computed to assist No. 20 Party (Cantonment and Special Survey) which lacked personnel to complete this work. The computations of co-ordinates were effected by means of a comptometer.

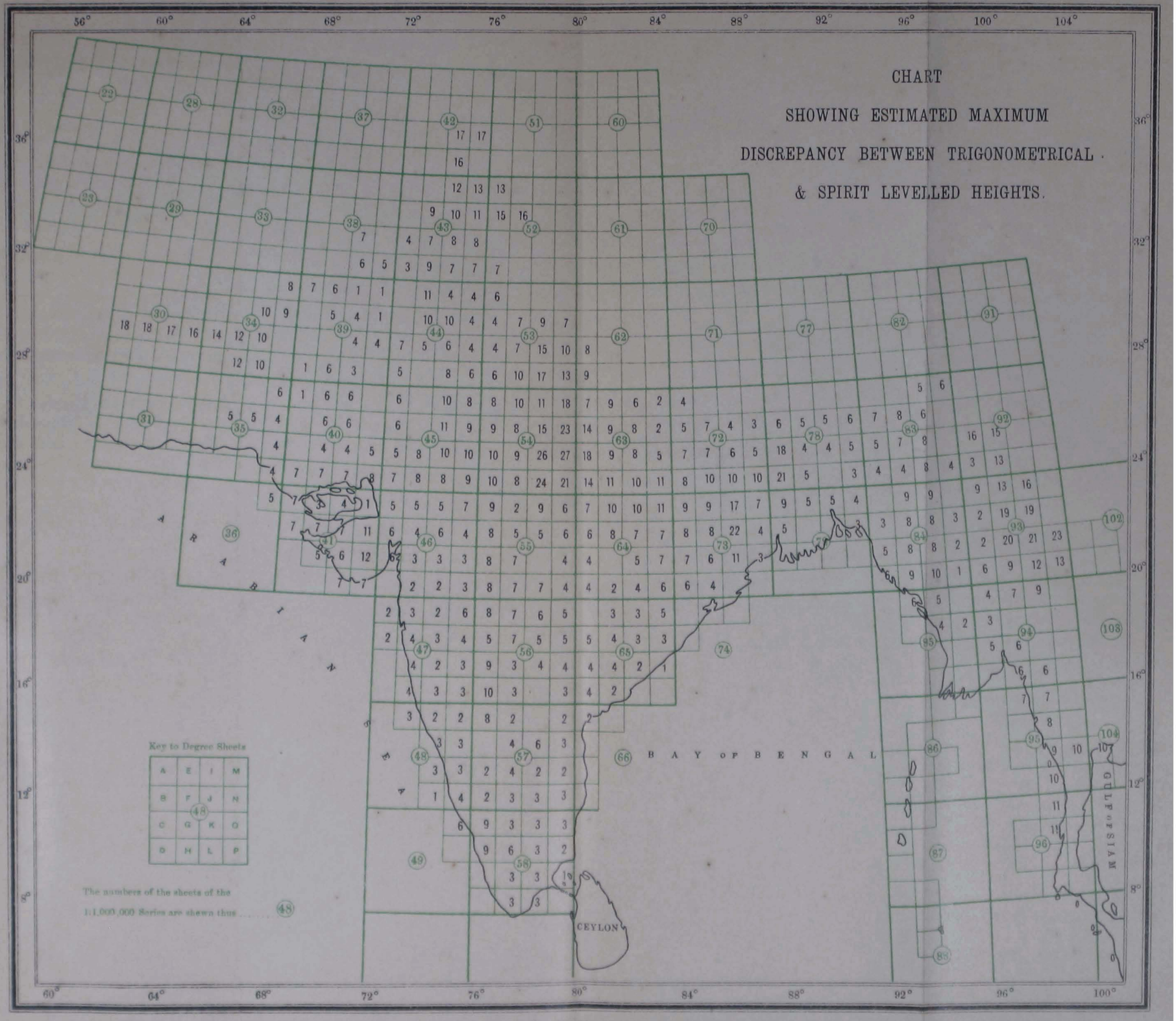
6. Chart showing Hayford deflection anomalies in India.—An attempt was made to show the Hayford anomalies in meridian deflection, obtained from the observations in India, graphically on a chart. The data were taken from Professional Paper No. 13 and from the observations in Kashmīr, 1925-26. The attempt had to be abandoned, the anomalies being too irregular to admit of reliable curves being traced.

7. Lambert's Orthomorphic Projection.—Pending the decision of the question of changing the origin of projection to latitude 32° 30′ and the limiting parallels of the grid to latitudes 28° 30′ and 36° 30′ (*vide* page 2 of Geodetic Report Vol. II), a request was received from the Director Frontier Circle to show the corners of sheets 30,000 by 40,000 yards on an index map of the Frontier Circle on the altered projection. Necessary computations were carried out and the gridded index supplied to the Director.

8. Suitability of Professional forms for machine computation.—Trial computations were made to see whether any gain in time could be effected by machine computation on the minor Topo., Trian. and Trav. forms of the department. It was found that all the calculations, with the exception of those for traverse co-ordinates (northings and eastings), were not suitable for machine computation and the deductions could be carried out more expeditiously with log tables on the existing forms than on the machine.

9. Old records.—The old manuscript records preserved in the Computing Office, which are mostly connected with the simultaneous reduction of the Indian triangulation, are being examined with a view to their re-arrangement. In the course of this examination some valuable papers, previously unnoticed, on the solution of certain complicated problems relating to the simultaneous reduction have come to light and are now being recorded for future reference.

10. Chart showing extreme errors of height in the Indian triangulation.—This chart which was mentioned in last year's report as under preparation, *vide* page 27, Geodetic Report Vol. III, has been completed, and appears opposite. It exhibits the estimated extreme errors in trigonometrical heights that are likely to be met with in each degree sheet.



Reg. No. 1810 D.D.D. 1929 (C.G.) S. I- 500.

Scale $\frac{1}{22,500,000}$ or 1·013 Inches to 360 Miles

Miles 100 50 0 100 200 300 400 500 Miles

Hellozincographed at the Survey of India Offices, Dehra Dūn.

To accompany Geodetic Report Vol. IV

(iii) Publication of data

11. Auxiliary Tables.—The stock of Part III, Auxiliary Tables 1923 being exhausted, an enlarged edition of this part has been published. Six new tables, including those for the computation of grid co-ordinates on the Lambert projection, and two sets of star charts, one for latitude 15° and the other for 30°, have been added.

Part IV of the Auxiliary Tables is under compilation. About a third of the tables has been completed.

12. Field Traverse Tables.—These tables, which formed appendices to Topo. Chap. IV., 1924, have been revised and printed as a separate pamphlet for the convenience of traverse computers and surveyors.

13. Forms.—The following new forms were published during the year. The Computing Section merely advised on some points in connection with the preparation of these forms, which were prepared by the parties concerned :—

13, 14 Pend., 24, 25 Trian., 9 Tid. Pred., 15 and 16 Lev.

14. Theodolite resection.—A pamphlet, explaining the various problems in theodolite resection, has been compiled and printed as an addendum to Topo. Chap. VII., 1925. Semi-graphic methods are illustrated by means of two diagrams and sample computations both in spherical and rectangular data.

15. Levelling pamphlets.—The following have been published:—(i) An addendum to levelling pamphlet for Sheet 73 revised up to 1926.

(ii) The data of the following lines of high precision levelling for insertion as loose pages in appropriate pamphlets :—

151 (Rānīganj to Dinājpur) 1924-26. Bench-marks in sheet 73 M. only.

101 (Jacobābād to Khānpur)) 1924-26. Bench-marks in sheet 39.

105 (Khānpur to Jhang).

57A (Ferozepur to Ahmadābād).

102 (Khānpur to Mārwār Pāli).

(iii) Pamphlets containing following lines of secondary precision :—

Lines 70 E to 70 J & 70 M
" 74 C to 74 H
" 77 Q & 77 R
" 87 A to 87 D
" 88 B to 88 F
" 89 A to 89 F
" 90 A to 90 E

Pamphlets containing lines 52A to 52 H have been reproduced by Gestetner. Revised editions of Levelling pamphlets for sheets 53 (1920) and 54 (1921) are at press. Press copy for revision of pamphlet for sheet 72 has also been completed.

16. Triangulation pamphlets.—Triangulation pamphlets for Bhutān, the Andaman Islands, the Nicobar Islands, and Aden, comprising 41 degree sheets, and two pamphlets for 'Irāq have been published. Triangulation data for 33 degree sheets for new pamphlets, and 11 degree sheets for addenda to old pamphlets have been compiled. 31 triangulation pamphlets, covering 52 degree sheets, have been republished by photozincography to meet shortage of stock.

17. Geodetic Reports.—Volumes I and II of the Geodetic Reports have been published, and Volume III is at press. The first chapter of this volume which contains the results of the observations at Dehra Dūn in connection with the International Longitude Project was printed in advance and submitted to the conference of the International Union at Leyden, which Captain G. Bomford, R.E. attended in July 1928.

18. Miscellaneous publications.—(i) *Distribution list.*—A comprehensive distribution list has been compiled and Gestetnered in order to facilitate the distribution of geodetic publications in future.

(ii) *Booklet of instructions with descriptions and tables for the Hunter Short Base.*—This booklet was compiled by Major C. M. Thompson from notes by Dr. Hunter and Major Glennie in a form suitable for issue with the Hunter Short Base Line Sets to R. A. Survey sections, or Survey units in the field. (*vide* also Chap. II § 6). The book was reproduced by photozincography from typescript.

(iii) *Investigations regarding Gravity and Isostasy by W. Heiskanen.*—The rough translation of part of this publication of the Finnish Geodetic Institute (Helsinki 1924) was made from the German by V. Pelts Esq. The translation has been entirely revised and completed by Major Thompson and reproduced, mainly by Gestetner, for departmental use.

19. Computing Office Drawing Section.—A small drawing section consisting of six draftsmen under Surveyor Faiz-Ullah was formed and attached to the Computing Office to expedite the preparation of triangulation charts for the pamphlets, charts for the Geodetic Report etc., and to carry out other plotting and drawing work in connection with the work of the Computing Office. This section has proved very useful, and, since its formation two sets of star charts consisting of 8 pages each and 17 charts, including those for the Geodetic Report Vol. II, have been completed. 33 other cases were also dealt with, for which miscellaneous figures, diagrams and plans had to be prepared.

20. Supply of data.—About 450 requisitions for data were received from departmental and extra-departmental sources during the year. Some of these were met by the supply of printed publications, while for others data had to be extracted from manuscript records. In many cases computations were necessary before the data could be compiled.

CHAPTER II

OBSERVATORIES

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

1. Summary.—The principal work of the observatories consisted of :—

(1) regular time observations and reception of wireless time signals for determination of longitude variations.
(2) latitude observations.
(3) comparison of standards of length.
(4) seismograph and meteorological observations.
(5) pendulum observations.
(6) maintenance and adjustment of delicate scientific instruments stored in the Geodetic Branch.
(7) professional instruction to Upper and Lower Subordinate Computers of the Computing & Tidal Party.
(8) miscellaneous experiments.
(9) magnetic observations.

2. Time observations.—The large astrolabe, which was used in addition to one of the transits for time observations last season, was taken to the field by No. 14 Party. Consequently the regular bi-weekly time observations were made by one of the transit instruments only. The rates of the Riefler Clock, as derived from these, are given in Table 1, which also shows the changes of pressure and temperature in the clock room for the period under review. It will be noticed from the table that during the hot months it becomes almost impossible to maintain the temperature of the cell at a standard of 80° F., as the temperature during even the coldest hours of night in the hot season hardly drops to the standard, and so the temperature rises gradually as the hot season advances. It is proposed now to work the automatic temperature control at 83°F. This control has worked satisfactorily except for a break-down of the excavating fan during the winter, fortunately at a period when it was least required. The pressure of the clock was adjusted on four different occasions during the year. The errors of the clock as derived from observations by the transits are given in Table 2.

Correct time, for which there is a growing demand in the station, is telephoned on every working day to many of the local Government offices, and for convenience a telephone was installed in the Hennessey observatory in June 1928 for this purpose. A proposal was also made to broadcast time to Dehra Dūn and Mussoorie, through the Electrical

Department, which would arrange to give the daily time signal by lowering the lights for an instant at 9 o' clock every night. The scheme, however, cannot be brought into force till that department is in a position to install the necessary apparatus to effect this.

3. Reception of wireless time signals.—The $8^h\ 01^m$ G.M.T. radio signals from Bordeaux were listened for daily, and received, except when atmospheric disturbance and other causes intervened. In addition to these the Rugby $10^h\ 00^m$ G.M.T. time signals were picked up daily since January 1928, the latter service having been inaugurated since 19th December 1927. The longitude values and divergences of these results since December 1926, from the value derived from the Longitude Project of October and November 1926, are given in Tables 3 and 4, the latter embodying the values derived from both the wireless signals. Monthly means are given in Table 5. The published corrections to the times of emission have been included as given in the Admiralty Notices to Mariners, and in the Bulletin horaire (demi-definatif).

The dry high tension batteries of the wireless set having run down after about 2 years' service, accumulators of a more durable type were substituted in August 1928 and it is expected that these will prove more useful. It is proposed to purchase a good type of rectifier to keep these accumulators charged. The present one has often proved troublesome in use.

4. Latitude observations.—The old zenith telescope No. 1 by Messrs Troughton and Simms, London, as well as the new and larger instrument by Messrs T. Cooke and Sons, London, have been installed in the reconstructed Haig observatory on two pillars built on the meridian of the Haig observatory, Dehra Dûn, mentioned on page 15 of triangulation pamphlet for sheet 53 J. The former telescope, which has been in use for about 40 years in the department, was overhauled and repainted before installation. The values of the two levels attached to this telescope were redetermined in July 1928, and a comparison of these values with those obtained in 1924 and 1925 is given in Table 6. The instrument was rewired, and the fixed vertical, and movable horizontal wire intervals were redetermined in September 1928 after the rains. The new values are given below :—

Wire intervals 1928.

I	27·7	Equatorial
II	14·0	
IV	13·6	
V	27·7	
A-B	−997·5	Movable wire
B-C	+999·3	

Regular latitude observations were commenced in October 1928. A programme composed of all star couples available in the Nautical Almanac, American Ephemeris and Connaissance des Temps was made out for use throughout the 24 hours. The other zenith telescope, which was constructed in 1910 after Col. Cowie's design, will be brought into use in the course of next year.

5. Standards of length.—8 steel tapes for use of the field detachments of No. 17 Party were compared before and after the field season against standard bar I_S, and the results supplied to No. 17 Party.

12 pairs of newly graduated staves, received by No. 17 Party from M.I.O., were tested for regularity of graduation errors against standard bar 1/1900. The results are given in two forms in Tables 7 and 8 respectively.

A 50 feet measuring tape, made by the Poldi Steel Works of non-corrosive steel, was received from the M.I.O. during the year for examination and report as to its suitability for survey purposes. This tape was tested against the standard 50 feet plugs laid in the floor of the base-line alley for two periods of a fortnight each. Although necessary facilities are not as yet available to measure the coefficient of expansion of tapes with the requisite degree of accuracy, fairly accordant results were obtained, which show that the tape is made of a material with a coefficient of expansion somewhat less than that of steel. It was used for actual measurement of bases in the compound, and found generally useful for survey work, standing up well to rough handling.

6. Hunter Short Base.—The idea of using a short base for topographical purposes was first put forward by Dr. Hunter in notes, circulated to the Directors of Survey Circles under Geodetic Branch letter No. 5151/65 dated 11th August 1925. The type of short base therein suggested consisted of a single span of the measuring tape pulled taut by means of a simple straining device between posts, the tension of the tape being tested by a spring balance. Further experiments led to the evolution of the Hunter Short Base in its present form. This pattern of short base has been tested on the Frontier and found satisfactory. It should prove useful for general exploratory purposes or for use by Artillery Survey Sections in the field. Two such sets have been constructed and supplied to the Royal Artillery Survey Section, Kakūl, a booklet of instructions being compiled by Major C. M. Thompson for issue with the apparatus, (*vide* also Chap. I § 18). The Hunter Short Base, as issued, is made up of 4 sections of tape, suspended on 2 terminal and 3 intermediate posts. The tapes were standardized in the Observatory Section, and correction tables for the lengths of tape supplied with each set. The tapes hitherto used have been made of steel, which have proved sufficiently accurate for ordinary purposes. Experiments are also being made with invar tapes, which should give still better results for measurements of high precision. The high extra cost of the invar tapes hardly justifies their use for ordinary purposes.

7. Seismograph observations.—The Omori seismograph was in operation throughout the year, except for the period June to August 1928, when it was being removed and reinstalled in the newly built Haig observatory. The instrument has been set up east and west on its new site and not north and south, as it was previously in the Burrard observatory.

An attempt was made to increase the period of about 30 seconds per swing from its normal, but it was not found possible to do so beyond 45 seconds, at which point the smooth working of the needle was

interfered with by the change, the needle being deflected considerably from the line of the minute-marker during the 24 hours. The period is now being reduced until no such interference with the markings on the trace occurs. One of the two new steel points made by the Mathematical Instrument Office to replace the old and worn out one, has been used with the instrument in its new position. Table 9 gives a list of the earthquakes recorded at Dehra Dūn during the year.

The earthquake data for 1927 were sent to Professor H. H. Turner F.R.S., Oxford, early this year.

8. Meteorological observations.—These observations were continued throughout the year. Daily values of the recorded temperatures and pressures were supplied to five different offices, and weekly abstracts to the local press and the Health Officer, Dehra Dūn. Monthly abstracts of rainfall were sent to the Meteorological Office Poona, and those of humidity to the Royal Indian Military College, Dehra Dūn.

In August 1928, the meteorological hut and rain gauge were removed from the old site to a more convenient open space east of the Haig observatory.

Since the end of the year 1911, owing to financial stringency Dehra Dūn ceased to record and report complete meteorological data to the Meteorological Department, and has since only sent in rainfall returns. Owing to the growing importance of the town as a scientific headquarters, and the interest taken in weather conditions by the heads of the several departments located here, the necessity of reporting and publishing full records in the Weather Bulletins has been keenly felt.

The Meteorological Department has accordingly arranged for an inspector to make a periodical inspection to test the accuracy of the instruments. As soon as the instruments have been pronounced suitable by the inspector, the daily observations at 8. a. m. will be resumed.

9. Pendulum observations.—The Officer in charge No. 14 Party (Pendulums) is endeavouring to find an explanation of apparent changes in the value of gravity at Dehra Dūn. Continuous pendulum observations have never been taken at Dehra Dūn previously, and in order to obtain data it has been decided to take periodical gravity observations at Dehra Dūn with the old brass pendulums Nos. 137, 138, 139 and 140. This investigation has been taken up by the Observatory Section, and work commenced at the end of August 1928. The value of "g" derived from the first set of observations is 979·071, the adopted value being 979·063

10. Maintenance and examination of delicate scientific instruments.—17 levels of different types were received from No. 17 Party and were returned duly examined, and repaired before the commencement of the field season 1928-29.

10 theodolites stored in the Publication and Stores godown were cleaned and adjusted.

To facilitate the overhauling of delicate instruments in the Stores Section, Director, Geodetic Branch, has approved that delicate scientific instruments be separated from the other stores. These are to be in charge

of the Observatory Section, which will be responsible for their maintenance and issue in proper working order.

11. Course of instruction for the Upper and Lower Subordinate Computers of the Computing and Tidal Party.—The U.S.S. and L.S.S. computers of this party, though versed in geodetic computations, were not always able to appreciate the difficulties which the triangulator, traverser or leveller had to encounter in the field, so that it was considered advisable to give these officers a course of practical training in the use of instruments and other field work.

This work was entrusted to Mr. R. B. Mathur, the officer in charge of this section, and a class of about 10 to 12 officers has been attending on Saturdays since April 1928.

Triangulation, traversing and levelling are the subjects, in which instruction has been given up to the present.

12. Miscellaneous experiments.—*Use of Nicol prism and yellow screens.*—An experiment was made to see whether a Nicol prism fitted to the eye-piece of a theodolite, or a yellow screen fitted to the eye-piece or object end of a telescope, tended to improve the visibility of distant objects in misty or hazy weather. As regards the yellow screen it appears that this screen is more effective when attached to the eye-piece instead of to the object glass. Accordingly it is intended to experiment further with yellow and also green screens of different shades, and test them on theodolites and levels under field conditions.

The use of the Nicol prism seems to afford no particular advantage over the ordinary eye-piece in hazy weather, as though perhaps it improves the visibility in some cases, it also unduly reduces the amount of light, which reaches the eye, and so the total improvement in clearness is inappreciable.

Use of buff-coloured levelling staves.—Experiments were carried out to test whether black and buff divided levelling staves, afford any advantages over black and white ones, as regards visibility in clear and dull weather. The results show that there is very little to choose between them, and if anything, the black and white staves are preferable.

13. Magnetic observations.—The usual programme of magnetic observations was carried out during the year. It consisted of a continuous photographic record of declination, horizontal force and vertical force, daily observation of dip and bi-weekly observations of declination and horizontal force. Five severe magnetic storms were recorded during the year, namely:—on April 14th, July 22nd, August 21st, October 12th and 22nd.

Sub-soil water percolated into the underground magnetograph room between August 24th and September 15th.

A record of the magnetic character of the days for each quarter of the year was regularly sent to the De Bilt Royal Meteorological Observatory.

Owing to the long interval that has elapsed since the Magnetic Survey of India was completed, and the consequent uncertainty in the secular variations, it is no longer possible to supply precise values of magnetic declination for publication on maps. Consequently it has

been decided to supply values for 1-inch, ½-inch and ¼-inch sheets for every fifth year, and to the nearest 10 minutes only. This change was brought into effect from March 1928.

Mean values of the declination and H. F. constants.—Table 10 gives the mean monthly values of the magnetic collimation, the distribution constants $P_{1\cdot2}$ and $P_{2\cdot3}$, the accepted value of $\log\left(1+\frac{P}{r^2}+\frac{Q}{r^4}\right)^{-1}$ and the values of "m" (computed with the new value of the moment of inertia of Magnet No. 17, determined in December 1927).

Mean base-line values.—Table 11 gives the mean monthly observed values of the declination and horizontal force base-lines.

Mean scale values and temperature range.—The mean scale values for 1927 for an ordinate of 1/25 inch were:—

Horizontal force	4·31 gammas
Vertical ,,	7·66 to 9·69 gammas
Declination	1·03 minutes.

The mean temperature of the year was 26°·6 C. with maximum and minimum monthly values of 27°·2 C. and 25°·9 C., the temperature of reduction being 27°·0 C.

Mean monthly values and annual changes.—Table 12 shows the mean values of the magnetic elements for 1926 and 1927, and the annual changes for the period.

Classification of the magnetic character of days and the mean monthly values of elements with their mean hourly deviations.—Tables 13 to 17 show the classification of the daily trace and the dates of magnetic disturbances, the mean monthly values of the magnetic elements from 5 selected quiet days in each month and the hourly deviation from the mean.

TABLE 1.—*Temperature and pressure of Riefler clock No. 450 and its rate, by transit instruments, 1927-28.*

Date	Cell temperature	Clock			Remarks
		Rate* during preceding period per day	Pressure	Temperature	
1927	F	s	m m	C	
	°			°	
Sept. 29	...	...	...	...	
Oct. 11	80·7	+ 0·19	560	27·0	
14	79·4	+ 0·10	558	26·2	
18	79·4	+ 0·10	558	26·1	
21	79·3	+ 0·13	557	26·2	} Inner fan dismantled
27	81·2	+ 0·12	559	27·2	} & replaced by another.
Nov. 1	80·1	+ 0·10	558	26·6	
6	79·4	+ 0·12	556	26·3	
10	81·2	+ 0·10	558	27·6	
16	79·8	+ 0·10	556	27·0	
20	79·9	+ 0·13	556	26·8	
26	79·8	+ 0·15	556	26·5	

* +ve rate = gaining
−ve rate = losing

(Continued)

TABLE 1.—*Temperature and pressure of Riefler clock No. 450 and its rate, by transit instruments, 1927-28—(contd.).*

Date		Cell temperature	Clock			Remarks
			Rate* during preceding period per day	Pressure	Temperature	
1927		F	s	m m	C	
Dec.	1	79°·9	+ 0·12	556	26°·9	
	5	79·6	+ 0·09	556	26·7	
	11	81·0	+ 0·10	556	27·3	
	16	79·1	+ 0·14	555	26·4	
	22	78·9	+ 0·11	555	26·2	
	26	79·7	− 0·09	...	26·5	Pressure unsteady from 25th to 30th reduced to 570 mm. on 27th Dec.
	30	78·4	− 0·82	...	26·3	
1928						
Jan.	8	77·5	− 0·15	...	25·5	Pressure 587 mm. from 31st Dec. to 5th Jan. reduced to 562 mm. on 5th Jan.
	11	80·2	0·00	563	27·0	
	16	79·5	0·00	564	26·7	
	21	79·8	− 0·04	565	26·7	
	28	80·2	− 0·05	570	27·1	
Feb.	8	79·7	− 0·13	574	26·7	
	15	80·0	− 0·18	579	26·8	
	26	79·6	− 0·26	580	26·6	
Mar.	2	79·9	− 0·20	584	26·6	
	8	79·8	− 0·33	584	26·6	
	12	79·9	− 0·30	587	26·6	
	16	80·0	− 0·06	556	26·6	Pressure 588 mm. reduced to 555 mm. on 14th March.
	19	80·1	+ 0·11	557	26·6	
	26	80·0	+ 0·07	559	26·5	
April	4	79·8	+ 0·05	561	26·4	
	10	80·3	+ 0·01	564	26·8	
	18	80·4	+ 0·02	566	26·8	
	23	80·6	− 0·01	568	26·8	
	30	80·3	− 0·06	569	26·9	
May	4	81·2	− 0·08	571	27·6	
	9	84·0	− 0·11	577	28·8	
	14	84·3	− 0·13	578	28·6	
	19	84·7	− 0·12	580	28·9	
	23	85·6	− 0·19	582	29·6	
	28	86·1	− 0·25	587	29·9	
June	2	86·7	− 0·33	593	30·2	
	9	86·7	− 0·38	601	30·3	
	15	85·6	− 0·46	607	29·6	
	21	85·4	− 0·43	...	29·5	Pressure 608 mm. from 16th to 20th reduced to 558 mm. on 20th June.
	27	86·4	+ 0·13	570	30·0	
July	3	85·9	− 0·03	575	29·8	From 22nd to 28th June pressure unsteady due to leakage.
	6	84·7	− 0·04	576	29·2	
	11	84·2	− 0·02	578	28·9	
	17	84·0	− 0·06	579	28·7	
	20	83·8	− 0·04	580	28·7	
	27	83·6	− 0·06	580	28·5	

* +ve rate = gaining
−ve rate = losing

(*Continued*)

TABLE 1.—*Temperature and pressure of Riefler clock No. 450 and its rate, by transit instruments, 1927-28—(concld.).*

Date	Cell temperature	Clock			Remarks
		Rate* during preceding period per day	Pressure	Temperature	
1928	F	s	m m	C	
Aug. 5	83·1°	− 0·07	581	28·3°	
10	83·4	− 0·08	582	28·4	
15	83·8	− 0·12	584	28·6	
18	83·9	− 0·10	584	28·7	
22	83·5	− 0·11	585	28·5	
25	82·7	− 0·17	585	28·2	
28	82·2	− 0·03	584	27·8	
Sept 2	81·9	− 0·06	584	27·6	
10	82·3	− 0·13	584	27·9	
14	83·1	− 0·12	585	28·4	
20	83·6	− 0·15	586	28·6	
25	83·7	− 0·16	586	28·5	
Oct. 1	82·5	− 0·17	586	28·0	

* +ve rate = gaining
−ve rate = losing

TABLE 2.—*Error of Riefler clock No. 450, at 20 hours, Indian Standard Time, by transit instruments, 1927-28.*

Date	South Transit	North Transit	Date	South Transit	North Transit
1927	*m s*	*m s*	1928	*m s*	*m s*
Oct. 11	−0 34·98	...	April 10	−0 40·86	−0 40·84
14	34·67	...	18	...	40·66
18	34·27	...	23	...	40·69
21	33·89	−0 33·64	30	...	41·14
27	33·17	32·85	May 4	...	41·44
Nov. 1	32·67	...	9	...	42·01
6	32·05	...	14	...	42·68
10	31·64	31·50	19	...	43·29
16	31·02	31·03	23	...	44·05
20	30·51	...	28	...	45·28
26	29·64	29·55	June 2	...	46·91
Dec. 1	29·04	...	9	...	49·58
5	28·69	...	15	...	52·36
11	28·07	...	21	...	54·92
16	27·39	...	27	...	54·15
22	26·74	...	July 3	...	54·32
26	27·09	..	6	...	54·45
30	30·38	...	11	...	54·54
1928					
Jan. 8	31·69	...	17	...	54·90
11	31·68	...	20	...	55·01
16	31·67	..	27	...	55·45
21	31 86	..	Aug. 5	...	56·05
28	32·22	...	10	56·47	...
Feb. 8	33 62	...	15	57·09	...
15	34·90	...	18	57·39	...
26	37·80	...	22	57·82	...
Mar. 2	38·78		25	58·34	...
8	40·73	...	28	58·43	...
12	41·91	...	Sept. 2	58·75	...
16	42·15	...	10	59·83	...
19	41·82	...	14	−1 00·28	...
26	41·31	41·34	20	01·16	...
31	...	40·91	25	01·96	...
April 4	40·90	40·78	Oct. 1	02·97	...

TABLE 3.—*Longitude of Dehra Dūn in time, from the first wireless signal of Bordeaux at $8^h\ 01^m$ G.M.T.*

Date Greenwich	By Transit	By Astrolabe	Observed value *minus* Accepted value*		Date Greenwich	By Transit	By Astrolabe	Observed value *minus* Accepted value*	
			By Transit	By Astrolabe				By Transit	By Astrolabe
1926	*h m s*	*h m s*	*s*	*s*	1927	*h m s*	*h m s*	*s*	*s*
Dec. 1	5 12 11·87	...	+0·08	...	Mar. 11	5 12 11·74	5 12 11·81	−0·05	+0·02
3	11·85	5 12 11·69	+0·06	−0·10	15	11·78	12·00	−0·01	+0·21
7	11 82	11·63	+0 03	−0·16	19	11·77	11·97	−0·02	+0·18
10	11·84	11·90	+0·05	+0·11	26	11·88	...	+0·09	...
15	11·82	11·85	+0·03	+0·06	31	11·93	12·06	+0·14	+0·27
18	11·84	11·77	+0·05	−0·02	Apr. 5	11·83	11·87	+0·04	+0·08
22	11·70	11·81	−0·09	+0·02	11	11·79	11·85	0·00	+0·06
25	11·86	11·86	+0·07	+0·07	18	11·78	..	−0·01	...
29	11·86	11·89	+0·07	+0·10	22	11·82	11·86	+0·03	+0·07
1927									
Jan. 1	11·61	11·72	−0·18	−0·07	29	11·84	11·99	+0·05	+0·20
4	11·88	11·88	+0·09	+0·09	May 10	11·99	11·86	+0·20	+0·07
8	11·85	11·73	+0·06	−0·06	26	11·81	11·98	+0·02	+0·18
12	11·77	11·74	−0·02	−0·05	Oct. 27	11·89	..	+0·10	...
15	...	11·84	...	+0·05	Nov. 1	11·89	...	+0·10	...
18	11 87	11·99	+0·08	+0·20	6	11 87	...	+0·08	...
21	11·96	11·91	+0·17	+0·12	10	11·85	...	+0·06	..
26	11·82	11·91	+0·03	+0·12	16	11·93	...	+0·14	...
Feb. 3	11·83	...	+0·04	...	20	11·59	...	−0·20	...
5	11·86	11·82	+0·07	+0·03	26	11·89	...	+0·10	...
10	11·86	11·84	+0·07	+0·05	Dec. 1	11·81	...	+0·02	...
18	11·82	11·86	+0·03	+0·07	5	11·93	...	+0 14	...
24	11·85	..	+0·06	...	11	11·92	...	+0·13	...
28	11·85	...	+0·06	...	16	11·85	...	+0·06	...
Mar. 4	11·72	...	−0·07	...	22	11·82	...	+0·03	...

* Accepted value derived from the International Longitude Project is $5^h\ 12^m\ 11^s{\cdot}79$.

TABLE 4.—*Longitude of Dehra Dūn and its variation from accepted value, as determined from reception of wireless time signals from Bordeaux and Rugby.*

Greenwich Date	Bordeaux		Rugby	
	Longitude in time	Observed value *minus* Accepted value *	Longitude in time	Observed value *minus* Accepted value *
1928	*h m s*	*s*	*h m s*	*s*
Jan. 8	5 12 11·64	− 0·15	5 12 11·76	− 0·03
11	11·82	+ 0·03	11·80	+ 0·01
16	11·86	+ 0·07	11·87	+ 0·08
21	11·68	− 0·11	11·70	− 0·09
28	11·73	− 0·06	11·75	− 0·04
Feb. 8	11·84	+ 0·05	11·87	+ 0·08
15	11·63	− 0·16	11·62	− 0·17
26	11·76	− 0·03	11·78	− 0·01
Mar. 2	11·82	+ 0·03	11·82	+ 0·03
8	11·80	+ 0·01	11·76	− 0·03
12	11·75	− 0·04	11·69	− 0·10
16	11·77	− 0·02	11·65	− 0·14
19	11·78	− 0·01	11·74	− 0·05
26	11·80	+ 0·01	11·77	− 0·02
April 4	11·88	+ 0·09	11·81	+ 0·02
10	11·80	+ 0·01	11·75	− 0·04
18	11·76	− 0·03	11·82	+ 0·03
23	11·73	− 0·06	11·69	− 0·10
30	11·89	+ 0·10	11·88	+ 0·09
May 4	11·95	+ 0·16	11·77	− 0·02
9	11·84	+ 0·05	11·76	− 0·03
14	11·90	+ 0·11	11·82	+ 0·03
19	11·80	+ 0·01	11·73	− 0·06
23	11·90	+ 0·11	11·75	− 0·04
June 15	11·73	− 0·06	...	...
21	11·68	− 0·11	11·71	− 0·08
27	11·78	− 0·01	11·72	− 0·07
July 3	11·88	+ 0·09	11·71	− 0·08
6	11·95	+ 0·16	11·93	+ 0·14
11	11·86	+ 0·07	11·83	+ 0·04
17	11·90	+ 0·11	11·94	+ 0·15
20	11·87	+ 0·08	11·87	+ 0·08
27	11·85	+ 0·06	11·83	+ 0·04
Aug. 5	11·88	+ 0·09	11·88	+ 0·09
10	11·86	+ 0·07	11·86	+ 0·07
15	11·89	+ 0·10	11·86	+ 0·07
18	11·80	+ 0·01	11·61	− 0·18
22	...	...	11·75	− 0·04
25	11·88	+ 0·09	11·90	+ 0·11
28	...	...	11·82	+ 0·03
Sept. 2	...	...	11·88	+ 0·09
10	11·80	+ 0·01	11·87	+ 0·08
14	11·83	+ 0·04	11·80	+ 0·01
20	11·78	− 0·01	11·85	+ 0·06
25	11·75	− 0·04	11·73	− 0·06

Accepted value derived from the International Longitude Project is $5^h\ 12^m\ 11^s{\cdot}79$.

TABLE 5.—*Longitude of Dehra Dūn. Monthly means. Time by Transit.*

Month	Number of observations	Longitude	Month	Number of observations	Longitude
		h m s			*h m s*
December 1926 ...	9	5 12 11·83	January 1928 ...	5	5 12 11·77
January 1927 ...	7	11·82	February ...	3	11·75
February ...	6	11·85	March ...	6	11·76
March ...	6	11·80	April ...	5	11·80
April ...	5	11·81	May ...	5	11·83
May ...	2	11·90	June ...	3	11·73
October ...	1	11·89	July ...	6	11·87
November ...	6	11·84	August ...	7	11·84
December ...	5	11·87	September ...	5	11·81

TABLE 6.—*Values of 1 division of levels attached to Zenith Telescope No. 1.*

Date of observation	Length of bubble No. 6/10 in divisions											
	40	41	45	50	51	55	60	62	65	70	75	Mean
	"	"	"	"	"	"	"	"	"	"	"	"
14,15 Oct. 24	0·8283	...	...	0·8185	...	...	0·7776	..	...	0·7792	...	0·8009
27 Mar. 25	...	...	0·8620	...	...	0·8600	0·0000	...	0·8620	...	0·9240	0·8816
											Mean	0·841
2,3 July 28	0·8527	...	...	0·7461	...	...	0·8458	...	...	0·7920	...	0·8092
10,13 July 28	...	0·7811	...	...	0·7252	...	...	0·7800	...	0·7740	...	0·7601
											Mean	0·785

Date of observation	Length of bubble No. 9 in divisions											
	40	41	45	50	52	55	60	62	65	70	75	Mean
	"	"	"	"	"	"	"	"	"	"	"	"
14,15 Oct. 24	...	0·9481	..	0·0450	...	...	0·9236	...	...	0·9259	...	0·9352
27 Mar. 25	0·8470	...	0·8220	...	...	0·9000	...	...	0·9180	0·9650	...	0·8904
											Mean	0·913
2,3 July 28	0·8537	..	..	0·9145	...	...	0·9471	...	...	0·8687	...	0·8961
10,13 July 28	0·8687	...	...	...	0·8757	...	0·9381	...	...	0·9025	...	0·8963
											Mean	0·896

TABLE 7.—*Graduation error of new Levelling Staves*
(Actual length—Reputed length).

Reputed Length	Staff No. 018A	Staff No. 018B	Staff No. 017A	Staff No. 017B	Staff No. 016A	Staff No. 016B
feet	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*
1	+ ·0001	− ·0003	+ ·0004	− ·0001	+ ·0005	− ·0001
2	+ ·0007	− ·0001	+ ·0005	+ ·0003	+ ·0009	+ ·0008
3	+ ·0001	− ·0002	+ ·0005	− ·0001	+ ·0007	+ ·0004
4	+ 0004	+ ·0002	+ ·0005	+ ·0001	+ ·0012	+ ·0008
5	+ ·0005	+ ·0003	+ ·0008	− ·0001	+ ·0010	+ ·0008
6	+ ·0006	+ ·0008	+ ·0007	- ·0002	+ ·0011	+ ·0007
7	+ ·0007	+ ·0005	+ ·0007	− ·0002	+ ·0009	+ ·0008
8	+ ·0006	+ ·0010	+ ·0010	+ ·0001	+ ·0013	+ ·0010
9	+ ·0008	+ ·0006	+ ·0008	− ·0002	+ ·0013	+ ·0011
10	+ ·0010	+ ·0006	+ ·0009	+ ·0001	+ ·0015	+ ·0014

Reputed Length	Staff No. 015A	Staff No. 015B	Staff No. 07A	Staff No 07B	Staff No. 06A	Staff No. 06B
feet	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*
1	− ·0003	+ ·0003	+ ·0003	− ·0001	+ ·0003	− ·0004
2	+ ·0004	+ ·0004	+ ·0005	+ ·0002	+ ·0007	+ ·0001
3	+ ·0001	+ ·0001	+ ·0001	·0000	+ ·0003	− ·0003
4	+ ·0001	+ ·0006	+ ·0002	+ ·0002	+ ·0006	+ ·0001
5	+ ·0002	+ ·0004	+ ·0005	+ ·0004	+ ·0009	+ ·0002
6	+ ·0002	+ ·0007	+ ·0001	+ ·0005	+ 0005	+ ·0003
7	+ ·0004	+ ·0005	+ ·0007	- ·0001	+ ·0004	+ ·0004
8	+ ·0003	+ ·0007	·0000	+ ·0005	+ ·0008	+ ·0003
9	·0000	+ ·0006	− ·0005	− ·0004	+ ·0006	+ ·0005
10	+ ·0003	+ ·0007	+ ·0005	+ ·0005	+ ·0006	+ ·0006

TABLE 8.—*Graduation error of new Levelling Staves*

$$\text{Actual length} - (\text{Reputed length}) \times \frac{\text{Actual total length}}{10 \text{ feet}}.$$

Reputed Length	Staff No. 018A	Staff No. 018B	Staff No. 017A	Staff No. 017B	Staff No. 016A	Staff No. 016B
feet	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*
1	·0000	− ·0004	+ ·0003	− ·0001	+ ·0003	− ·0003
2	+ ·0005	− ·0003	+ ·0004	+ ·0003	+ ·0006	+ ·0006
3	− ·0002	− ·0004	+ ·0002	− ·0002	+ ·0002	·0000
4	·0000	− ·0001	+ ·0002	+ ·0001	+ ·0006	+ ·0003
5	·0000	·0000	+ ·0004	− ·0002	+ ·0002	+ ·0001
6	·0000	+ ·0005	+ ·0001	− ·0002	+ ·0002	− ·0001
7	− ·0001	·0000	+ ·0001	− ·0002	− ·0002	− ·0001
8	− ·0002	+ ·0005	+ ·0003	·0000	+ ·0001	− ·0001
9	− ·0001	·0000	+ ·0001	− ·0003	− ·0001	− ·0001
10	·0000	·0000	·0000	·0000	·0000	·0000

Reputed Length	Staff No. 015A	Staff No. 015B	Staff No. 07A	Staff No. 07B	Staff No. 06A	Staff No. 06B
feet	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*
1	− ·0004	+ ·0002	+ ·0004	·0000	+ ·0002	− ·0005
2	+ ·0004	+ ·0002	+ ·0005	+ ·0003	+ ·0006	·0000
3	·0000	− ·0001	+ ·0002	+ ·0001	+ ·0001	− ·0005
4	·0000	+ ·0003	+ ·0004	− ·0004	+ ·0003	− ·0001
5	+ ·0001	·0000	+ ·0007	+ ·0007	+ ·0006	− ·0001
6	·0000	+ ·0002	+ ·0004	+ ·0008	+ ·0001	·0000
7	+ ·0002	·0000	·0000	+ ·0004	− ·0001	·0000
8	+ ·0001	+ ·0001	+ ·0004	+ ·0009	+ ·0003	− ·0001
9	− ·0003	− ·0001	− ·0001	+ ·0001	·0000	− ·0001
10	·0000	·0000	·0000	·0000	·0000	·0000

TABLE 9.—*Earthquakes recorded at Dehra Dūn during 1927-28.*

o.	Date	Time of beginning. Indian Standard Time				Duration	Distance of epicentre		Intensity	Remarks
		Dehra Dūn		Simla*			Dehra Dūn	Simla*		
	1927	*h*	*m*	*h*	*m*	*m*	*miles*	*miles*		
1	Oct. 8	16	06	16	06	5	250	200	slight	
2	,, 24	21	53	21	42	...	6,000	6,000	considerable	
3	,, 26	15	12	15	10	2	...	...	slight	
4	Nov. 1	5	04	...		8	400	...	slight	
5	,, 8	8	51	...		41	1,500	...	slight	
6	,, 14	5	51	5	51	47	3,500	3,200	slight	
7	,, 14	10	46	10	37	30	1,600	2,200	slight	
8	,, 17	2	48	2	49	30	2,600	3,300	slight	
9	Dec. 29	0	02	0	01	58	3,000	4,400	moderate	
	1928									
0	Jan. 7	1	11	1	10	60	3,400	3,700	moderate	
1	Feb. 3	19	31	19	33	20	2,500	5,000	slight	
2	,, 7	5	37	5	39	60	2,500	2,500	considerable	
3	,, 22	1	39	...		36	4,300	...	slight	
4	,, 26	7	24	...		34	3,300	...	slight	
				Bombay*				Bombay*		
5	Mar. 8	4	20	4	20	22	1,700	2,300	slight	
	,, 8	23	53	...		8	800	...	slight	
6	,, 9	23	44	23	41	120	2,300	1,900	great	Seistān 1000 miles
7	,, 16	10	46	10	45	120	5,800	5,900	moderate	
8	,, 22	10	58	10	07	15	2,300	8,700	slight	(Bombay says severe. It is doubtful if these are the same shock)
9	,, 29	10	46	10	46	30	2,600	3,700	slight	North Italy. Jugo Slavia
0	May 27	15	33	15	31	88	4,000	4,300	moderate	
1	,, 28	21	34	21	16	12	400	3,300	slight	
2	June 1	5	16	5	04	60	3,000	3,300	slight	
3	,, 1	19	01	18	53	55	3,300	4,300	slight	
4	,, 3	14	15	14	10	60	2,300	3,700	slight	
5	,, 21	22	10	22	11	171	6,000	5,800	moderate	
6	,, 30	4	35	4	36	120	4,700	5,200	slight	
7	July 19	0	55	0	55	133	5,700	5,900	moderate	
8	Aug. 5	0	21	0	16	120	2,300	8,700	moderate	Dutch Indies
9	,, 10	21	06	21	08	28	550	1,200	slight	
0	,, 12	13	56	13	48	26	...	3,700	slight	
1	,, 22	0	39	0	37	18	750	1,500	slight	
2	,, 23	9	29	9	29	19	350	1,700	slight	
3	Sep. 1	11	39	11	42	84	300	900	considerable	
4	,, 18	23	26	...		31	3,600	...	slight	
5	,, 19	1	29	1	27	60	900	1,500	slight	

* From Daily Weather Report.

TABLE 10.—*Mean values of the constants of Magnet No. 17 at Dehra Dūn in 1927.*

Months	Declination constants	H. F. CONSTANTS				
		Distribution factors			Mean values of m	
	Mean magnetic collimation	$P_{1\cdot2}$	$P_{2\cdot3}$	Accepted value of $\log\left(1+\frac{P}{r^2}+\frac{Q}{r^4}\right)^{-1}$	Monthly means	Accepted m
	′ ″	cm^2	cm^2		C.G.S.	C.G.S.
January ...	− 6 27	5·80	6·93		806·32	
February ...	− 6 26	5·79	6·93		·40	
March ...	− 6 24	5·72	6·74		·32	
April ...	− 6 21	5·71	6·89		·30	
May ...	− 6 24	5·83	7·09		·24	
June ...	− 6 25	5·85	7·01		·20	
July ...	− 6 22	5·90	7·12		·18	
August ...	− 6 26	5·86	6·96		·17	
September ...	− 6 29	5·82	7·14		22	
October ...	− 6 24	5·92	6·94		·33	
November ...	− 6 16	5·95	7·04		·35	
December ...	− 6 20	5·89	7·09		·42	
				$\bar{1}\cdot99385$ throughout		806·18 throughout

TABLE 11.—*Base-line values of Magnetographs at Dehra Dūn in 1927.*

Months	Declination	Horizontal force
	Mean value of base-line	Mean value of base-line
	° ′	C.G.S.
January ...	0 46·1	0·32614
February ...	0 46·2	·32618
March ...	0 46·1	·32614
April ...	0 46·0	·32620
May ...	0 46·2	·32621
June ...	0 46·2	·32627
July ...	0 46·2	·32630
August ...	0 46·1	·32627
September ...	0 46·4	·32625
October ...	0 46·5* / 0 35·3†	·32621
November ...	0 35·2	·32617
December ...	0 35·2	·32614

* Up to 10^h on 18th Oct.
† From 11^h on ..

TABLE 12.—*Monthly mean values of the Magnetic elements and annual changes at Dehra Dūn in 1926-27.*

Months	Horizontal force ·32000 C.G.S. +			Declination E. 1° +			Dip N. 45° +			Vertical force ·33000 C.G.S. +		
	1926	1927	Annual change	1926	1927	Annual change	1926	1927	Annual change	1926	1927	Annual change
	γ*	γ*	γ*	′	′		′	′	′	γ*	γ*	γ*
January ...	925	919	− 6	28·2	24·1	− 4·1	24·4	27·6	+ 3·2	397	452	+ 55
February ...	918	931	+ 13	28·1	23·7	− 4·4	24·7	28·2	+ 3·5	395	476	+ 81
March ...	921	928	+ 7	28·1	23·6	− 4·5	25·6	28·5	+ 2·9	414	479	+ 65
April ...	927	929	+ 2	27·4	22·6	− 4·8	25·3	27·6	+ 2·3	415	463	+ 48
May ...	941	934	− 7	26·9	22·5	− 4·4	25·7	28·0	+ 2·3	437	474	+ 37
June ...	941	949	+ 8	26·3	22·0	− 4·3	26·2	28·0	+ 1·8	446	491	+ 45
July ...	948	946	− 2	25·9	21·6	− 4·3	26·0	29·3	+ 3·3	450	514	+ 64
August ...	949	931	− 18	25·3	21·2	− 4·1	26·2	30·3	+ 4·1	455	518	+ 63
September ...	941	932	− 9	25·0	21·1	− 3·9	27·0	30·5	+ 3·5	462	520	+ 58
October ...	924	914	− 10	25·0	21·4	− 3·6	27·6	30·5	+ 2·9	457	502	+ 45
November ...	931	930	− 1	24·5	20·8	− 3·7	27·0	30·3	+ 3·3	453	515	+ 62
December ...	932	925	− 7	24·4	20·6	− 3·8	27·0	31·1	+ 4·1	452	526	+ 74
Means	933	931	− 3	26·3	22·1	− 4·2	26·1	29·2	+ 3·1	436	494	+ 58

* γ = ·00001 C.G.S.

TABLE 13.—*Classification and dates of Magnetic disturbances at Dehra Dūn observatory in 1927.*

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

C = Calm. S = Slight. M = Moderate G = Great. V.G. = Very great. (C) = Selected quiet day. * — H.F. & Declination trace partly lost.

TABLE 14.—*Declination at Dehra Dūn in 1927,* (determined from 5 selected quiet days in each month).

Months	Monthly means	Hourly deviations from the mean																							
		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
	E+	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	24·1	0	−0·1	−0·1	−0·1	−0·3	−0·5	−0·6	−0·5	+0·6	+2·4	**+2·6**	+0·8	−0·4	**−0·9**	−0·9	−0·5	0	+0·1	−0·2	−0·1	−0·1	−0·1	−0·1	0	+0·1
Feb.	23·7	+0·2	+0·2	+0·1	+0·2	+0·2	0	+0·1	+0·8	+1·8	**+2·1**	+1·3	−0·3	−1·5	**−1·6**	−0·8	−0·2	0	−0·2	−0·5	−0·4	−0·3	−0·2	−0·1	+0·1	+0·1
Mar.	23·6	−0·1	−0·2	0	+0·1	−0·2	−0·3	−0·2	+1·1	+2·6	**+3·1**	+2·6	+0·8	−0·9	**−2·1**	−2·0	−1·3	−0·6	−0·2	−0·5	−0·6	−0·5	−0·5	−0·4	−0·2	−0·1
Oct.	21·4	+0·2	+0·2	+0·3	+0·3	0	+0·1	+0·2	+1·3	**+2·7**	+2·3	+1·2	0	−1·4	**−2·3**	−2·0	−1·3	−0·4	−0·4	−0·5	−0·3	−0·3	−0·1	−0·1	0	+0·1
Nov.	20·8	+0·2	+0·2	+0·2	+0·1	0	−0·1	−0·1	+0·3	+1·1	**+1·6**	+1·1	−0·1	**−1·1**	−1·1	−0·9	−0·5	−0·3	−0·4	−0·3	−0·2	−0·2	−0·3	−0·2	−0·1	+0·1
Dec.	20·6	0	0	−0·1	−0·1	−0·2	−0·2	−0·3	−0·1	+0·4	**+1·0**	+0·6	−0·1	**−0·6**	−0·6	−0·2	0	+0·1	0	−0·1	−0·1	−0·2	−0·2	−0·1	−0·1	−0·1
Winter Means*	22·4	+0·1	0	0	+0·1	−0·1	−0·2	−0·2	+0·5	+1·5	**+2·1**	+1·5	+0·2	−1·0	**−1·5**	−1·2	−0·7	−0·2	−0·2	−0·4	−0·3	−0·3	−0·3	−0·2	−0·1	0
April	22·6	+0·2	+0·4	+0·3	+0·3	+0·1	+0·4	+1·0	+3·0	**+4·4**	**+4·5**	+2·5	−0·3	−2·6	**−4·1**	−3·7	−2·7	−1·3	−0·2	+0·1	−0·5	−0·4	−0·1	−0·1	0	+0·2
May	22·5	+0·6	+0·3	+0·5	+0·3	+0·4	+0·5	+1·8	+3·3	**+3·9**	+2·9	+1·0	−1·1	−3·0	**−3·3**	−3·1	−2·3	−1·1	−0·6	0	−0·1	−0·2	0	+0·1	+0·3	+0·3
June	22·0	+0·1	+0·2	+0·3	+0·4	+0·4	+0·8	+2·3	**+3·5**	+3·5	+2·4	+0·7	−1·3	−2·2	−2·9	**−3·1**	−2·7	−1·8	−0·8	+0·2	−0·1	−0·3	−0·2	−0·1	0	+0·2
July	21·6	−0·1	−0·2	+0·1	+0·1	+0·2	+0·7	+2·5	+3·6	**+3·7**	+2·6	+1·2	−1·3	−2·7	**−3·4**	−3·3	−2·4	−1·0	−0·1	+0·6	+0·1	−0·4	−0·4	−0·4	−0·4	−0·3
Aug.	21·2	0	+0·1	+0·3	+0·5	+0·4	+0·8	+2·3	+3·3	**+3·8**	+2·9	+0·6	−1·8	−2·9	**−3·3**	−3·1	−2·2	−0·8	0	+0·4	+0·1	−0·1	−0·3	0	+0·1	+0·1
Sept.	21·1	+0·2	+0·3	+0·5	+0·5	+0·7	+0·9	+1·2	+1·4	**+2·9**	+2·1	+0·7	−1·1	−2·4	**−2·9**	−2·5	−1·6	−0·4	+0·3	0	−0·4	−0·3	−0·2	−0·1	0	+0·2
Summer Means*	21·8	+0·2	+0·2	+0·4	+0·4	+0·4	+0·7	+1·9	+3·1	**+3·7**	+2·9	+1·2	−1·1	−2·6	**−3·3**	−3·1	−2·3	−1·0	−0·2	+0·3	−0·1	−0·2	−0·2	−0·1	0	+0·2

* Derived from the actual difference between the value for any hour and the general mean for all hours for the 6 months.

NOTE—The mean declination for any hour may be obtained by applying the hourly deviation for that hour with the sign given, to the mean hourly value for the month.

Figures in thick type indicate the maximum and minimum values of the hourly deviation.

TABLE 15.—*Horizontal force at Dehra Dūn in 1927,* (determined from 5 selected quiet days in each month).

Months	Monthly means	Hourly deviations from the mean																							
		Mid	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Jan.	32919	− 4	− 4	− 5	− 4	− 3	− 2	+ 2	+ 4	+ 7	+ 2	− 3	− 2	+ 4	+ 7	+ 7	+ 4	+ 1	0	− 1	0	− 1	0	+ 2	+ 2	+ 2
Feb.	931	− 8	− 6	− 8	− 7	− 7	− 5	− 1	− 1	− 2	− 3	− 7	0	+10	+16	+18	+12	+ 6	+ 1	− 1	− 1	− 1	0	0	− 1	− 1
Mar.	928	− 6	− 3	− 6	− 9	−10	− 7	− 9	− 9	− 8	− 3	+ 4	+12	+16	+23	+22	+15	+ 7	− 1	− 1	− 2	− 4	− 5	− 4	− 4	− 3
Oct.	914	− 5	− 2	− 4	− 3	− 2	− 4	− 3	− 4	− 8	− 8	− 5	+ 1	+ 6	+10	+11	+ 9	+ 4	0	− 1	− 1	− 2	− 1	− 2	+ 1	+ 1
Nov.	930	− 7	− 6	− 7	− 6	− 5	− 5	− 2	+ 1	+ 4	+ 6	+ 7	+11	+15	+13	+ 8	+ 2	− 2	− 4	− 4	− 3	− 4	− 5	− 3	− 3	− 4
Dec.	925	− 6	− 3	− 4	− 5	− 5	− 4	− 3	− 2	− 2	− 3	− 2	+ 4	+10	+ 9	+ 5	+ 5	+ 2	− 1	− 1	− 2	− 2	− 2	0	0	0
Winter Means*	925	− 6	− 4	− 6	− 6	− 6	− 5	− 3	− 2	− 2	− 2	− 1	+ 4	+10	+13	+11	+ 7	+ 3	− 1	− 2	− 2	− 3	− 3	− 2	− 1	− 1
April	32929	− 5	− 4	− 5	− 4	− 4	− 4	− 3	− 3	− 6	− 8	− 3	+ 8	+18	+23	+17	+ 9	+ 2	− 3	− 6	− 6	− 4	− 3	− 2	+ 1	+ 1
May	934	− 8	− 7	− 8	− 8	− 7	− 7	− 5	− 7	− 8	− 9	− 2	+ 9	+17	+21	+21	+16	+ 8	+ 3	− 3	− 5	− 5	− 4	− 4	− 2	− 2
June	949	− 7	− 6	− 6	− 5	− 4	− 2	− 2	− 4	− 4	− 2	+ 6	+11	+13	+16	+14	+12	+ 6	0	− 7	−10	− 6	− 6	− 5	− 3	− 2
July	946	− 4	− 3	− 4	− 3	− 4	− 2	− 1	− 3	− 5	− 4	− 2	+ 5	+12	+16	+16	+10	+ 2	− 7	− 9	− 8	− 7	− 5	− 2	− 2	− 1
Aug.	931	− 7	− 8	− 8	− 6	− 3	− 3	− 3	− 6	−13	−10	− 1	+ 9	+14	+17	+15	+13	+ 6	0	− 2	− 1	0	+ 1	− 2	− 1	0
Sept.	932	− 5	− 7	− 7	− 5	− 7	− 7	− 6	− 5	−11	− 9	− 1	+ 8	+13	+18	+22	+17	+ 7	0	− 2	− 4	− 7	− 6	− 5	− 4	− 4
Summer Means*	937	− 6	− 6	− 6	− 5	− 5	− 4	− 3	− 5	− 8	− 7	− 1	+ 8	+14	+18	+17	+13	+ 5	− 1	− 5	− 6	− 5	− 4	− 3	− 2	− 1

* Derived from the actual difference between the value for any hour and general mean for all hours for the six months.

NOTE—The mean horizontal force for any hour may be obtained by applying the hourly deviation for that hour with the sign given, to the mean hourly value for the month.

Figures in thick type indicate the maximum and minimum values of the hourly deviation.

$\gamma = 0{\cdot}00001$ C.G.S.

TABLE 16.—*Vertical force at Dehra Dūn in 1927,* (determined from 5 selected quiet days in each month).

Months	Monthly means	Hourly deviations from the mean																								
		Mid	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Jan.	33452	− 1	− 1	− 2	− 2	− 2	− 2	− 1	− 1	+ 1	− 1	− 9	**−10**	− 8	− 5	− 3	+ 2	+ 5	+ 6	+ 6	+ 6	+ 6	+ 7	+ 7	+ 7	+ 7
Feb.	476	+ 8	+ 8	+ 6	+ 6	+ 6	+ 6	+ 6	+ 8	+ 7	+ 3	− 6	−11	**−12**	−11	− 7	− 4	− 2	− 2	− 2	− 1	0	0	0	+ 1	0
Mar.	479	+ 4	+ 4	+ 3	+ 2	+ 3	+ 3	+ 2	+ 5	+ **6**	+ 1	− 7	−11	**−12**	− 8	− 5	− 1	+ 2	+ 2	+ 1	+ 1	+ 2	+ 3	+ 4	+ 4	+ 3
Oct.	502	0	+ 1	0	0	0	− 1	+ 1	+ 6	+ 4	0	− 8	−14	**−15**	−11	− 6	− 1	+ 2	+ 2	+ 3	+ 5	+ 5	+ 6	+ 7	+ 7	+ 6
Nov.	515	+ 4	+ 4	+ 3	+ 2	+ 2	+ 2	+ 2	+ 3	+ 3	− 2	− 7	− 8	− 8	− 7	− 6	− 6	− 2	+ 1	+ 3	+ 2	+ 2	+ 3	+ 3	+ 3	+ 3
Dec.	526	+ 1	+ 1	0	0	− 1	0	− 1	− 1	0	− 1	− 3	− 4	− 3	− 3	− 2	0	+ 1	+ 2	+ 2	+ 1	0	0	0	0	0
Winter Means*	492	+ 2	+ 3	+ 1	+ 1	+ 1	+ 1	+ 1	+ 3	+ 3	0	− 7	**−10**	−10	− 8	− 5	− 2	+ 1	+ 2	+ 2	+ 2	+ 2	+ 3	+ 3	+ **3**	+ 3
April	33463	0	0	+ 1	+ 1	+ 1	+ 2	+ 5	+ 7	+ 6	− 4	−14	**−21**	−19	−15	− 9	− 4	+ 2	+ 6	+ **7**	+ 6	+ 8	+ 9	+ 9	+11	**+12**
May	474	+ 3	+ 4	+ 3	+ 4	+ 4	+ 6	**+11**	+ 9	+ 5	− 5	−12	**−21**	−19	−16	− 9	− 2	+ 1	+ 4	+ 4	+ **4**	+ 6	+ 7	+ 8	+ 8	+ 8
June	491	− 4	− 3	− 3	− 3	− 3	− 1	+ **4**	+ 1	− 4	−10	**−16**	−14	−13	−11	− 8	+ 1	+ 4	+ 8	+10	+10	+11	+12	+13	**+14**	+14
July	514	+ 2	+ 3	+ 3	+ 2	+ 3	+ 6	+ **9**	+ 7	+ 3	− 4	− 8	**−19**	−16	−12	− 8	− **3**	+ 1	+ 4	+ 3	+ 2	+ 5	+ 6	+ 6	+ 6	+ 7
Aug.	518	+ 2	+ 2	+ 2	+ 2	+ 3	+ 4	+ 7	+ 7	+ 1	− 7	−20	**−21**	−14	−10	− 5	− 1	+ 3	+ 4	+ 4	+ 4	+ 5	+ 6	+ 5	+ 6	+ 6
Sept.	520	+ 7	+ 7	+ 7	+ 7	+ 7	+ 7	+ 9	**+11**	+ 8	+ 1	+ 2	**−17**	−17	−15	−11	− 5	0	+ 1	0	0	+ 1	+ 2	+ 3	+ 3	+ 4
Summer Means*	497	+ 1	+ 2	+ 2	+ 2	+ 2	+ 4	+ 8	+ **7**	+ 3	− 5	−12	**−19**	−17	−13	− 9	− **3**	+ 2	+ 4	+ 4	+ 4	+ 6	+ 7	+ 7	+ 8	+ **8**

* Derived from the actual difference between the value for any hour and the general mean for all hours for the six months.

NOTE—The mean vertical force for any hour may be obtained by applying the hourly deviation for that hour with the sign given, to the mean hourly value for the month.

Figures in thick type indicate the maximum and minimum values of the hourly deviation.

$\gamma = 0{\cdot}00001$ C. G. S.

TABLE 17.—*Dip at Dehra Dūn in 1927*, (determined from 5 selected quiet days in each month).

Months	Monthly means	Hourly deviations from the mean																							
		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
	N46°+	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	27·6	+0·2	+0·2	+0·2	+0·1	+0·1	0	−0·1	−0·2	−0·3	−0·1	−0·3	−0·4	−0·6	**−0·6**	−0·5	−0·1	+0·2	+0·3	**+0·4**	+0·3	+0·4	+0·4	+0·3	**+0·3**	+0·3
Feb.	28·2	**+0·8**	+0·7	+0·7	+0·7	+0·7	+0·6	+0·4	+0·5	+0·5	+0·3	+0·1	−0·5	**−1·1**	**−1·4**	−1·3	−0·8	−0·4	−0·1	0	0	+0·1	0	0	+0·1	+0·1
Mar.	28·5	+0·6	+0·4	+0·5	+0·6	+0·7	+0·6	+0·6	**+0·8**	+0·8	+0·2	−0·5	−1·2	−1·4	**−1·6**	−1·4	−0·9	−0·2	+0·2	+0·1	+0·2	+0·3	+0·4	+0·4	+0·4	+0·3
Oct.	30·5	+0·2	+0·1	+0·2	+0·1	0	+0·1	+0·2	+0·5	**+0·6**	+0·4	−0·2	−0·8	−1·1	**−1·1**	−0·9	−0·6	−0·2	0	+0·1	+0·3	+0·3	+0·3	+0·4	+0·2	**+0·2**
Nov.	30·3	**+0·5**	+0·5	+0·5	+0·4	+0·3	+0·3	+0·2	+0·1	−0·1	−0·4	−0·7	−1·0	**−1·2**	−1·1	−0·8	−0·4	0	+0·2	+0·3	+0·2	+0·3	+0·4	+0·3	+0·3	+0·3
Dec.	31·1	**+0·4**	+0·2	+0·2	+0·3	+0·2	+0·2	+0·1	+0·1	+0·1	+0·1	−0·1	−0·4	**−0·7**	−0·6	−0·4	−0·3	−0·1	+0·2	+0·2	+0·2	+0·1	+0·1	0	0	0
Winter Means*	29·4	**+0·4**	+0·3	+0·4	+0·3	+0·3	+0·3	+0·2	+0·3	+0·2	+0·1	−0·3	−0·7	−1·0	**−1·1**	−0·9	−0·5	−0·1	+0·1	+0·2	+0·2	+0·2	+0·2	+0·2	+0·2	+0·2
April	27·6	+0·3	+0·3	+0·4	+0·3	+0·3	+0·4	+0·5	+0·6	**+0·7**	+0·3	−0·5	−1·4	−1·9	**−1·9**	−1·3	−0·6	+0·1	+0·5	+0·7	+0·7	+0·7	+0·7	+0·6	+0·6	+0·6
May	28·0	+0·5	+0·5	+0·5	+0·6	+0·5	+0·6	+0·8	**+0·8**	+0·6	+0·2	−0·5	−1·6	−1·9	**−2·0**	−1·6	−1·0	−0·4	0	+0·3	+0·4	+0·5	+0·5	+0·6	+0·5	+0·5
June	28·0	+0·2	+0·2	+0·2	+0·2	+0·1	+0·1	+0·4	+0·3	+0·1	−0·4	−1·1	−1·2	−1·3	**−1·3**	−1·1	−0·5	−0·1	+0·5	+0·9	**+1·1**	+0·9	+1·0	**+1·0**	+0·9	+0·9
July	29·3	+0·4	+0·4	+0·5	+0·3	+0·5	+0·5	+0·6	+0·6	+0·5	+0·1	−0·2	−1·1	−1·4	**−1·4**	−1·2	−0·6	0	−1·3	**+0·7**	+0·6	+0·7	+0·7	+0·5	+0·5	+0·5
Aug.	30·3	+0·5	+0·6	+0·6	+0·5	+0·4	+0·4	+0·6	+0·7	**+0·8**	+0·2	−0·9	**−1·5**	−1·4	−1·3	−1·0	−0·7	−0·1	+0·3	+0·4	+0·3	+0·3	+0·3	+0·4	**+0·4**	**+0·4**
Sept.	30·5	+0·5	+0·7	+0·7	+0·5	+0·7	+0·7	+0·7	+0·8	**+0·9**	+0·4	+0·1	−1·4	−1·6	**−1·8**	−1·8	−1·2	−0·4	0	0	+0·1	+0·3	+0·3	+0·3	+0·3	+0·3
Summer Means*	29·0	+0·4	+0·4	+0·4	+0·4	+0·4	+0·4	**+0·6**	**+0·6**	+0·6	+0·1	−0·6	−1·4	−1·6	**−1·7**	−1·4	−0·8	−0·2	0	+0·5	+0·5	+0·5	+0·5	+0·5	+0·5	+0·5

* Derived from the actual difference between the value for any hour and the general mean for all hours for the six months.

NOTE—The mean dip for any hour may be obtained by applying the hourly deviation for that hour with the sign given, to the mean hourly value for the month.

Figures in thick type indicate the maximum and minimum values of the hourly deviation.

CHAPTER III

TIDES

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

1. Tidal observatories.—During the year under report, registration by automatic tide-gauges was continued at the following stations:—Aden, Karāchi, Bombay (Apollo Bandar), Madras, Kidderpore, Rangoon, Bassein, Pilakat or Deserters' Creek and Basrah. These operations were carried out under the supervision of this department, the immediate control of each observatory being entrusted to the local officers of the port concerned. In addition, the actual times and heights of high- and low-waters were observed on tide-poles (during daylight only) under the supervision of the local officials at Bhāvnagar, Chittagong and Akyab. The results of these actual observations were compared against the predicted values, with a view to testing whether the predictions based on tidal observations taken many years ago, still maintained a sufficient degree of accuracy.

Table 1 gives a complete list of stations where tidal registrations have been carried out since the commencement of tidal operations in India in 1874. The stations at which automatic tide-gauges are still working are shown in italics. Minor stations were closed after a few years, when sufficient data were available from the tidal registrations.

TABLE 1.—*List of tidal stations.*

Serial No.	Station	Automatic or personal observations	Date of commencement of observations	Date of closing of obesrvations	Number of years of observations	Remarks
1	Suez ...	auto-matic	1897	1903	7	
2	Perim ...	,,	1898	1902	5	
3	*Aden* ...	,,	1879	still working	49	
4	Maskat ...	,,	1893	1898	5	
5	Bushire ...	,,	1892	1901	8	
6	*Karāchi* ...	,,	1868 1881	1880 still working	*13 47 } 60	*Small tide-gauge working

(*Continued*)

TABLE 1.—*List of tidal stations—(contd).*

Serial No.	Station	Automatic or personal observations	Date of commencement of observations	Date of closing of observations	Number of years of observations	Remarks
7	Hanstal ...	,,	1874	1875	1	Tide-tables not published
8	Navānar ...	,,	1874	1875	1	
9	Okha Point ...	,,	1874	1875	1	Year 1904-05 is excluded
			re-started 1904	1906	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	Bhāvnagar ...	,,	1889	1894	5	
13	*Bombay (Apollo Bandar)*	,,	1878	still working	50	
14	Bombay (Prince's Dock)	,,	1888	1924	37	
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	1895	6	
24	Pāmban Pass ...	,,	1878	1882	4	
25	Negapatam ...	,,	1881	1888	5	Years 1883 to 1885 are excluded
26	*Madras* ...	,,	1880 re-started 1895	1890 still working	10 33 (43)	
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	47	
33	Chittagong ...	,,	1886	1891	5	
34	Akyab ...	,,	1887	1892	5	

(*Continued*)

TABLE 1.—*List of tidal stations*—(*concld*).

Serial No.	Station	Automatic or personal observations	Date of commencement of observations	Date of closing of observations	Number of years of observations	Remarks
35	Diamond Island ...	automatic	1895	1899	5	
36	*Bassein* (Burma ...	,,	1902 re-started 1923	1903 still working	2 } 7 5 }	
37	Elephant Point ...	,,	1880 re-started 1884	1881 1888	1 } 5 4 }	Year 1880-81 is excluded
37A	*Pilakat or Deserters' Creek*	,,	re-started 1927	1928	1	Observatory damaged and dismantled in July 1928
38	*Rangoon* ...	,,	1880	still working	48	
39	Amherst ...	,,	1880	1886	6	
40	Moulmein ...	,,	1880 re-started 1909	1886 1924	6 } 22 16 }	
41	Mergui	,,	1889	1894	5	
42	Port Blair ...	,,	1880	1925	45	
43	Basrah ...	personal	1916	1922	7 } 13	
43A	*Basrah*	automatic	1922	still working	6 }	

2. Inspections.—*Burma.*—The tidal observatories at Bassein, Rangoon and Pilakat or Deserters' Creek in Burma, were inspected by Mr. D.H. Luxa, the tidal assistant, between February and March 1928.

India.—In addition, Mr. Luxa had intended inspecting the new idal observatory at the Kidderpore Docks, Calcutta, which was to have eplaced the old tidal observatory. The latter had been badly damaged n the 5th November 1927, when a steamer collided with it, necessitating the immediate dismantling and removal of the tide-gauge and uxiliary instruments. The new observatory, however, was not ready n Mr. Luxa's return from Burma to Calcutta, and as he had to proceed o Basrah almost immediately, the Deputy Conservator to the Port ommissioners, Calcutta, decided to delegate the duty of installing the de-gauge in the new observatory to one of the port officials. This as accordingly done and tidal registration recommenced by the 28th ugust 1928.

The Harbour Surveyor, Port Trust Karāchi, carried out an inspection of the tidal observatory at Manora Point, Karāchi, in January 1928. The tidal observatory at Apollo Bandar, Bombay, was inspected by the Bombay Port Trust Surveyor in April 1928. No reports have been received from the port authorities at Aden and Madras as to whether the observatories at those places have been inspected or not. These observatories were last inspected by officers of the Survey of India in October and November 1924. Except for minor stoppages, all the tide-gauges have worked satisfactorily.

'Irāq.—The inspection of the tidal observatories in 'Irāq, was carried out as a result of the correspondence which arose between the Home, Indian and 'Irāq Governments, concerning the claim made by the Indian Government for the payment of the costs that had been incurred annually in the computation, preparation, publication and supply of tide-tables for Basrah, which had been held in abeyance for several years. On the 'Irāq Government consenting to meet these charges, as well as the cost of inspection of the tidal observatory at Basrah by a Survey Officer, the work was undertaken and the following tidal observatories in 'Irāq were inspected by Mr. Luxa during March and April 1928:–Tanūmah (Basrah), Muttwa, Abādān, Fāo and the Outer Bar Semaphore Observatory on the Shatt-al-'Arab.

3. Tidal observations in the Rangoon river.—The tide-gauge installed by Mr. Luxa in the Pilakat or Deserters' Creek near Elephant Point on the 16th March 1927, continued to work quite satisfactorily until 3-30 a.m. on the 18th July 1928, when the tidal observatory was seriously damaged by a gale, necessitating the immediate dismantling and removal of the tide-gauge. The Port Commissioners, Rangoon, being unwilling to incur fresh expenditure on rebuilding this tidal observatory, in view of the rapid erosion that is taking place both in river and the creek, decided to dismantle and return the tide-gauge to Dehra Dūn. The Port authorities are arranging, however, to continue to record the times and heights of high- and low-waters, on a tide-pole, in order to enable comparisons of the results of predictions at Elephant Point to be made, and to test whether the regular errors between predicted and actual values noticed at Rangoon from 1922 to 1925 are being repeated at Elephant Point.

4. Reduction of Bassein tidal observations.—The registrations of the year 1926 have been fully reduced by harmonic analysis. The results are given in Table 2, where those for 1924 and 1925 are also shown.

TABLE 2.—*Values of the tidal constants for Bassein 1924, 1925, and 1926.*

Tide symbol	1924* $A_0 = 8 \cdot 330$				1925† $A_0 = 8 \cdot 162$				1926* $A_0 = 8 \cdot 076$			
	R	ζ	H	κ	R	ζ	H	κ	R	ζ	H	κ
Short period	*feet*		*feet*		*feet*		*feet*		*feet*		*feet*	
S_1	0·078	149°·29	0·078	149°·29	0·060	160°·50	0·060	160°·50	0·060	148°·13	0·060	148°·13
S_2	0·696	92·29	0·696	92·29	0·743	91·99	0·743	91·99	0·746	95·95	0·746	95·95
S_4	0·009	93·86	0·009	93·86					0·013	89·13	0·013	89·13
S_6	0·002	242·10	0·002	242·10					0·004	154·65	0·004	154·65
S_8	0·040	92·03	0·040	92·03					0·002	241·70	0·002	241·70
M_1	0·030	244·65	0·028	267·11					0·018	101·76	0·011	145·54
M_2	2·242	274·64	2·175	50·14	2·271	200·36	2·222	51·71	2·260	101·34	2·256	53·12
M_3	0·022	213·76	0·021	57·01					0·006	311·10	0·006	58·77
M_4	0·252	61·04	0·237	332·03					0·240	78·76	0·235	342·32
M_6	0·092	198·15	0·084	244·65					0·082	38·37	0·080	253·71
M_8	0·022	340·87	0·020	162·87					0·020	38·93	0·019	206·05
O_1	0·142	90·81	0·167	45·52	0·148	1·55	0·164	34·33	0·164	262·68	0·169	37·32
K_1	0·335	222·95	0·369	46·81	0·344	222·70	0·366	45·22	0·358	226·91	0·365	48·21
K_2	0·147	279·05	0·185	107·62					0·217	271·55	0·232	94·37
P_1	0·120	252·03	0·120	62·42	0·135	243·55	0·135	53·19	0·135	215·12	0·135	55·00
J_1	0·022	292·24	0·025	93·42	0·009	267·43	0·010	168·19	0·004	3·27	0·004	351·31
Q_1	0·021	106·83	0·024	81·15	0·012	89·50	0·013	40·10	0·017	64·36	0·017	28·10
L_2	0·212	109·99	0·187	38·57					0·208	118·40	0·216	74·89
N_2	0·381	256·35	0·372	51·46					0·366	262·67	0·362	43·55
ν_2	0·143	107·36	0·139	359·96					0·126	341·96	0·125	58·47
μ_2	0·254	261·40	0·239	172·39					0·275	275·02	0·260	178·58
T_2	0·065	46·01	0·065	48·03					0·132	48·51	0·132	50·07
$(MS)_4$	0·183	210·97	0·178	16·47					0·186	73·86	0·184	25·04
$(2SM)_2$	0·086	83·75	0·084	308·25					0·089	262·25	0·087	310·47
$2N_2$	0·138	143·87	0·134	318·59					0·099	98·11	0·098	68·08
$(M_2N)_4$	0·093	32·35	0·088	322·95					0·084	247·17	0·082	339·82
$(M_2K_1)_3$	0·052	317·38	0·056	276·74	0·093	260·80	0·096	294·67	0·091	185·03	0·092	318·11
$(2M_2K_1)_3$	0·057	187·38	0·059	274·52	0·061	26·57	0·062	266·75	0·064	187·84	0·064	270·10
Long period Mm	0·191	53·38	0·172	33·77					0·143	195·53	0·138	6·43
Long period Mf	0·091	351·41	0·130	37·49					0·048	144·26	0·052	0·76
Long period MSf	0·226	196·00	0·219	60·51					0·229	357·53	0·227	45·75
Long period Sa	2·304	233·48	2·301	153·10					2·183	241·72	2·183	161·84
Long period Ssa	0·126	88·12	0·426	287·34					0·416	122·57	0·416	322·81

* In 1924 and 1926 harmonic analysis for all components was carried out as for an open coast station.

† In 1925 the analysis was confined to components as for a riverain port.

5. Corrections to predictions.—Comparison of the predicted times and heights of high- and low-waters with those actually recorded, has indicated that the corrections which were applied to the predictions of Rangoon and Chittagong for 1928, (see Geodetic Report Vol. III) should be repeated for 1929. They have been included in the tide-tables for 1929, and are instead of (and not additional to) the corrections included in the 1927 tide-tables referred to in the Geodetic Report Vol. II.

6. Basrah.—From comparisons between predicted and actual values of times and heights of high- and low-waters from year to year, it was seen that the results were far from satisfactory. The predictions were hitherto based on the tables of monthly means supplied by the National Physical Laboratory, Teddington. These tables were dependent on the results of a few years' observations only, and this fact might have accounted for the large discrepancies in the predictions. With a view to improving the predictions, the tide-tables for 1927 and 1928 received empirical corrections, as regards times only. In the 1927 tide-tables, a correction of +44 minutes was applied to all high- and low-water times, while in the 1928 tide-tables, a variable correction, tabulated for periods of 5 days, of from +10 to +63 minutes was applied. In the course of these attempts to improve the predictions, it was considered necessary to revise the original tables of monthly means, but as neither funds nor staff were available for this purpose, the 'Irāq Government was approached to contribute Rs. 1000/- towards the cost, and on their consenting to do so, the work was undertaken in the following manner:—

(*a*) *Time and Height corrections.*—Before comparing the P−A values (Predicted *minus* actual differences in times and heights of high- and low-waters with respect to sign) of one year with those of other years, the following time and height corrections were applied.

Time correction.—The mean correction of + 44 minutes, derived from the results of 1924-1925, and already applied to the predicted times for 1927, was removed.

Height correction.—A correction of −1·1 feet, due to difference in height between the zeros of the old and new tide-gauges in use at Basrah before and after 1st April 1922, was applied to the P−A differences in height for 1923.

(*b*) *Tables.*—The values of P−A for both time and height of high- and low-waters for all the months of each year from 1923 to 1927 were classified according to mean time of moon's transit, and a table of means abstracted. Since we deal with differential quantities, (excess or defect from the mean time of moon's transit) these mean values were next applied with opposite sign to the original monthly mean values supplied by the National Physical Laboratory.

(*c*) *Time and Height charts.*—For the preparation of Time charts, the mean values of P−A were applied with opposite sign to the differential quantities in the case of high-water, and with the same sign in the case of low-water.

For the preparation of Height charts, the mean values of P−A were applied with opposite sign, both in the case of high- and low-water, to

the original values supplied by the National Physical Laboratory. These corrected monthly mean values (differential quantities in the case of time and actual values in the case of height) were plotted, and 8 charts for high-water and 8 charts for low-water were prepared.

The Basrah predictions for 1929 have been based on these new tables and charts.

7. Tide-tables.—The tide-tables for Basrah and the Indian ports for 1929 were prepared and published. Distribution was completed by October 1928. Advance copies of the 1929 tide-tables for the ports Suez, Aden, Bushire, Karāchi, Bhāvnagar, Bombay, Marmagao, Colombo, Trincomalee, Madras, Dublat (Sāgar Island), Chittagong, Elephant Point and Mergui were prepared and despatched to the Hydrographer to the Admiralty by the end of March 1928 for incorporation in the Admiralty tide-tables for 1929. The amount realized by the sale of tide-tables during the year ending 30th September 1928, amounted to Rs. 7,220/2/-, exclusive of agents' commission charges and cost of copies issued gratis.

8. Accuracy of predictions.—From comparisons made between predicted and actual times and heights of high-and low-water, the predictions for 1927 were found to be as accurate as those for the preceding year, except at Kidderpore, where a slight deterioration had taken place, and at Basrah, where the predicted heights did not continue to show the very marked improvement that had been obtained in 1926. On the other hand, improvements in the predicted times at Chittagong, Basrah, Rangoon, and to a lesser extent, at Madras, and Bassein were apparent. The greatest differences between the predicted and actual heights of low-water at the riverain ports were as follows:—

Port	Difference (predicted *minus* actual)	Date
	feet	
Kidderpore ...	+ 3·2	22nd September 1927
Rangoon ...	− 2·8	13th October 1927
Pilakat or Deserters' Creek ...	− 1·6	16th November 1927
Bassein ...	− 3·4	27th July 1927
Basrah ...	+ 3·9	12th April 1927

Tables 3 to 14 give the fortnightly mean errors of the predictions for all stations at which comparisons were made.

TABLE 8.—*Mean errors E_1 and E_2 for 1927.*

ADEN

PERIOD 1927	MEAN ERRORS (Predicted — actual)												Number of errors exceeding			
	E_1*								E_2*				*30 minutes* of time		*0·7 feet* of height	
	H. W. Time		H. W. Height		L. W. Time		L. W. Height		H. W. Time	H. W. Ht.	L. W. Time	L. W. Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	−	+	−	+	−	+	−								
Jan. 1-15	0·6		0·2			0·4	0·1		8·7	0·2	8·8	0·1	0	0	0	0
16-31		4·7		0·1	4·3			0·1	13·3	0·2	10·2	0·2	2	1	0	0
Feb. 1-15	0·5			0·0	4·7			0·0	10·5	0·1	13·5	0·1	1	2	0	0
16-28	0·5			0·0	6·1			0·0	7·3	0·1	9·8	0·1	0	0	0	0
Mar. 1-15	2·3			0·0	7·1			0·0	7·6	0·1	13·9	0·2	0	1	0	0
16-31	1·0		0·1		3·2		0·1		5·8	0·2	7·4	0·1	1	1	0	0
April 1-15	2·8		0·0			4·7		0·0	9·3	0·1	12·9	0·2	2	2	0	0
16-30	4·2		0·1		0·4		0·1		9·1	0·2	11·1	0·1	2	2	0	0
May 1-15	4·0		0·1			2·6	0·1		12·0	0·1	11·1	0·1	2	0	0	0
16-31	7·1		0·0		1·1		0·0		9·0	0·1	6·5	0·1	0	0	0	0
June 1-15	6·3			0·1	4·6		0·0		9·8	0·1	14·8	0·1	0	4	0	0
16-30	7·2			0·1	8·0			0·1	8·0	0·1	9·3	0·1	0	0	0	0
July 1-15	4·0			0·1	6·9			0·0	5·7	0·2	9·9	0·1	0	0	0	0
16-31	0·6		0·1		5·3		0·2		5·8	0·2	8·7	0·2	0	0	0	0
Aug. 1-15	2·6		0·2		8·1		0·1		14·5	0·2	9·7	0·2	3	1	0	0
16-31	8·2			0·2	5·6			0·1	12·2	0·3	10·1	0·1	2	0	0	0
Sept. 1-15		3·4		0·1	3·6			0·1	11·3	0·2	7·2	0·2	2	1	0	0
16-30	8·6			0·1	13·7			0·0	14·4	0·2	15·8	0·1	1	2	0	0
Oct. 1-15	10·2			0·0	9·3			0·1	11·1	0·1	10·0	0·1	1	0	0	0
16-31	12·6		0·1		13·0		0·1		13·6	0·1	13·4	0·1	1	1	0	0
Nov. 1-15		2·2	0·1			0·5		0·0	12·1	0·1	14·4	0·1	1	3	0	0
16-30	9·8		0·0		7·7		0·1		12·0	0·1	9·5	0·1	3	1	0	0
Dec. 1-15	5·2		0·0		4·6		0·0		7·9	0·1	11·2	0·1	0	0	0	0
16-31	9·1		0·1		7·3		0·1		12·0	0·2	11·1	0·1	3	1	0	0
TOTALS ...	107·4	10·3	1·1	0·8	124·6	8·2	1·0	0·5	243·0	3·6	260·3	3·0	27	23	0	0
MEANS ...	+ 4·0		+ 0·0		+ 4·9		+ 0·0		10·1	0·2	10·8	0·1	...	...	...	...

* E_1 is with regard to sign; E_2 is without regard to sign.

TABLE 4.—*Mean errors E_1 and E_2 for 1927.*

BASRAH

PERIOD 1927	MEAN ERRORS (Predicted—actual)												Number of errors exceeding			
	E_1*								E_2*				*30 minutes* of time		*0·5 feet* of height	
	H. W. Time		H. W. Height		L. W. Time		L. W. Height		H. W. Time	H. W. Ht.	L. W. Time	L. W. Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	−	+	−	+	−	+	−								
Jan. 1-15	30·0		0·5		13·1			0·0	40·8	0·7	54·4	0·7	16	21	14	16
16-31	18·6		0·4		24·3		0·3		28·1	0·5	47·5	0·6	14	18	11	16
Feb. 1-15	35·0		0·3		28·4		0·1		44·2	0·4	61·3	0·6	12	14	6	11
16-28	25·9		0·8		30·8		1·3		33·6	0·8	52·2	1·3	12	19	18	21
Mar. 1-15	26·9		1·1		36·7		1·5		50·9	1·1	64·2	1·5	17	20	25	29
16-31	12·3		1·5		31·7		2·1		27·5	1·5	39·9	2·1	7	14	24	26
April 1-15		43·3	1·6			23·6	2·6		50·9	1·6	42·7	2·6	11	11	13	16
16-30	16·0		2·1		30·3		3·1		52·4	2·1	39·3	3·1	17	9	26	25
May 1-15	30·7		1·8		33·0		2·7		44·0	1·8	45·3	2·7	17	18	29	29
16-31	27·5		1·8		21·9		2·4		42·5	1·8	41·6	2·4	14	14	26	24
June 1-15	44·5		1·2		39·1		1·6		50·5	1·2	55·8	1·6	17	20	25	27
16-30	56·9		1·2		62·9		1·6		58·5	1·2	68·1	1·6	22	20	27	29
July 1-15	22·4		1·5		37·7		2·0		38·0	1·5	56·1	2·0	18	18	29	29
16-31	10·1		1·4		21·5		1·8		37·4	1·4	61·7	1·9	19	24	30	30
Aug. 1-15	30·3		1·4		32·8		1·9		47·1	1·4	58·2	1·9	23	19	29	27
16-31	23·7		0·7		30·0		1·0		35·2	0·7	53·7	1·0	11	16	17	26
Sept. 1-15	8·2		0·8		25·0		1·0		32·1	0·8	42·5	1·0	9	15	17	22
16-30	2·8		0·6		8·7		0·9		31·1	0·6	38·8	0·9	10	16	12	26
Oct. 1-15	7·8		1·3		7·0		1·2		37·7	1·3	35·0	1·3	12	12	22	24
16-31		57·2	0·9			40·8	1·3		61·3	0·9	49·2	1·3	23	18	24	30
Nov. 1-15	0·2		0·8		9·8		0·7		46·6	0·9	44·7	1·0	15	21	16	22
16-30		12·0	1·3			1·5	1·5		36·5	1·3	36·4	1·5	16	16	26	24
Dec. 1-15	15·0		1·3		17·0		1·2		40·7	1·3	49·2	1·2	19	17	21	19
16-31	30·0		1·2		44·8		1·4		43·2	1·2	53·6	1·4	17	15	29	28
TOTALS ...	474·8	112·5	27·5		586·5	65·9	35·2	0·0	1010·8	28·0	1194·4	37·2	368	405	516	576
MEANS ...	+ 15·1		+ 1·1		+ 21·7		+ 1·5		42·1	1·2	49·8	1·6	...	...	...	...

* E_1 is with regard to sign: E_2 is without regard to sign.

Note.—The predicted times of high- and low-water have received a correction of + 44 minutes.

TABLE 5.—*Mean errors E_1 and E_2 for 1927.*

KARĀCHI

PERIOD 1927	MEAN ERRORS (Predicted—actual)												Number of errors exceeding			
	E_1*								E_2*				30 minutes of time		0·9 feet of height	
	H. W. Time		H. W. Height		L. W. Time		L. W. Height		H. W. Time	H. W. Ht.	L. W. Time	L. W. Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		feet		minutes		feet		minutes	feet	minutes	feet				
	+	−	+	−	+	−	+	−								
Jan. 1-15		9·0		0·2	1·4			0·1	10·7	0·3	9·0	0·2	1	0	0	0
16 31		4·5		0·1	1·7		0·3		13·1	0·2	16·4	0·3	1	4	0	0
Feb. 1-15		1·6		0·3	1·5		0·0		7·8	0·3	7·9	0·2	0	1	0	0
16-28		4·2		0·1	0·6		0·1		10·8	0·3	10·4	0·2	0	1	0	0
Mar. 1-15		3·2		0·1	6·7		0·1		6·5	0·2	11·2	0·2	0	0	0	0
16-31	4·2			0·3	6·3			0·1	8·6	0·3	11·2	0·2	1	2	0	0
April 1-15	2·7		0·1		2·7		0·3		7·6	0·1	11·1	0·3	0	1	0	0
16-30		2·9		0·2	1·3		0·0		8·9	0·3	9·1	0·2	0	2	0	0
May 1-15		0·4		0·2		0·2		0·0	8·4	0·3	9·2	0·2	1	0	0	0
16-31		2·0		0·0	7·3		0·3		6·9	0·3	10·2	0·4	0	0	0	1
June 1-15		3·2		0·5	0·6			0·4	8·1	0·5	12·6	0·4	1	2	3	2
16-30		4·0		0·2	2·5		0·2		6·7	0·2	12·5	0·2	0	0	1	0
July 1-15	2·4			0·2	4·3		0·0		8·8	0·2	16·7	0·1	0	5	0	0
16-31	6·0		0·1		6·2		0·4		8·2	0·3	12·0	0·4	1	0	0	0
Aug. 1-15	2·7			0·4	11·6			0·2	8·9	0·4	14·7	0·2	0	2	0	0
16-31	0·2			0·6	3·5			0·3	8·0	0·6	8·7	0·3	0	0	0	0
Sept. 1-15	7·4			0·2	7·5			0·0	8·5	0·3	9·2	0·1	0	1	0	0
16-30		1·9		0·6	5·5			0·4	8·4	0·6	9·1	0·4	0	0	5	0
Oct. 1-15	2·1			0·4	10·1			0·1	8·6	0·4	11·1	0·1	0	1	0	0
16-31		0·8		0·4	0·6			0·2	8·6	0·4	9·7	0·2	1	1	0	0
Nov. 1-15		0·6		0·5	3·5			0·3	10·2	0·5	10·7	0·3	0	2	2	1
16-30		4·0		0·3	3·8			0·1	8·4	0·3	11·1	0·2	0	1	0	0
Dec. 1-15		1·0		0·5	0·8			0·4	8·3	0·5	12·4	0·4	0	2	0	0
16-31		5·3		0·2		0·3		0·1	9·8	0·3	10·1	0·2	0	1	0	0
Totals .	27·7	48·6	0·2	6·5	90·0	0·5	1·7	2·7	208·8	8·1	266·3	5·9	7	29	11	4
Means ...	− 0·9		− 0·3		+ 3·7		− 0·0		8·7	0·3	11·1	0·2	...	...	...	...

* E_1 is with regard to sign : E_2 is without regard to sign.

TABLE 6.—*Mean errors E_1 and E_2 for 1927.*

BHĀVNAGAR

PERIOD 1927	MEAN ERRORS (Predicted — actual)												Number of errors exceeding			
	E_1*								E_2*				*30 minutes* of time		*1·0 feet* of height	
	H. W. Time		H. W. Height		L. W. Time		L. W. Height		H. W. Time	H. W. Ht.	L. W. Time	L. W. Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	−	+	−	+	−	+	−								
Jan. 1-15	8·5		0·1			24·6		0·7	18·7	0·6	24·9	0·9	0	5	3	6
16-31	8·7			0·2		16·3	0·5		17·8	0·6	22·1	0·9	1	6	4	6
Feb. 1-15	6·7			0·3		32·3		0·8	11·5	0·7	32·3	1·4	1	6	4	9
16-28	10·5			0·1		9·3	0·8		14·9	0·7	21·6	1·0	2	3	3	5
Mar. 1-15	9·1			0·0		23·1		1·2	11·6	1·0	26·5	1·6	1	6	6	8
16-31		0·1		0·2		11·8	0·6		9·0	0·4	14·8	0·7	0	1	2	7
April 1-15	1·1			0·2		22·1		0·9	8·2	0·5	22·7	1·4	0	5	1	6
16-30	3·5			0·1		9·7	0·3		12·3	0·5	13·6	0·9	1	1	1	6
May 1-15	0·5			0·6		30·3		0·7	12·0	1·1	30·3	1·1	0	5	8	4
16-31		10·4		0·3		13·8	0·1		10·4	0·4	13·8	0·5	2	2	0	0
June 1-15		4·5		0·9		6·9	0·2		9·6	1·3	9·7	0·8	0	0	6	4
16-30		3·6	0·1			14·0	0·3		11·9	0·4	14·4	0·4	1	3	0	1
July 1-15	1·0			0·7		3·4	1·1		7·5	0·7	12·6	1·1	0	2	4	7
16-31		0·9		1·0		21·8	0·5		10·9	1·1	24·2	1·1	1	6	5	9
Aug. 1-15	6·7			0·9		7·3	0·3		15·2	1·0	13·5	1·0	1	1	5	7
16-31	1·4			1·3		20·5	0·3		8·2	1·4	20·5	0·9	0	2	10	5
Sept. 1-15	13·5			0·3		16·7	0·0		15·9	0·7	26·5	1·5	3	7	0	10
16-30	2·4			1·2		14·5	0·6		5·6	1·3	15·7	0·8	0	1	8	3
Oct. 1-15	1·4			0·2		21·2		0·2	13·1	0·7	27·3	1·4	2	7	4	10
16-31	1·8			0·6		8·7	0·5		6·0	0·7	9·8	1·2	0	1	5	10
Nov. 1-15	2·1		0·3			12·3		0·5	10·5	0·5	14·5	0·8	0	2	3	3
16-30		4·3		0·3		9·3	0·7		7·5	0·4	9·8	0·8	0	0	1	3
Dec. 1-15		0·5		0·4		17·1		0·3	17·3	0·6	18·8	0·8	3	2	2	4
16-31	3·9			0·2		10·4	0·4		8·0	0·5	10·4	0·4	0	0	1	0
TOTALS	82·8	21·3	0·5	10·0		377·4	7·2	5·3	273·6	17·8	450·3	23·4	19	74	86	133
MEANS ...	+ 2·4		− 0·4		− 15·7		+ 0·1		11·4	0·7	18·8	1·0	...	...	...	...

* E_1 is with regard to sign: E_2 is without regard to sign.

TABLE 7.—*Mean errors E_1 and E_2 for 1927.*

BOMBAY (APOLLO BANDAR)

PERIOD 1927	MEAN ERRORS (Predicted—actual)												Number of errors exceeding			
	E_1*								E_2*				30 minutes of time		1·0 feet of height	
	H. W. Time		H. W. Height		L. W. Time		L. W. Height		H. W. Time	H. W. Ht.	L. W. Time	L. W. Ht.				
	minutes		feet		minutes		feet		minutes	feet	minutes	feet	H. W.	L. W.	H. W.	L. W.
	+	−	+	−	+	−	+	−								
Jan. 1-15	1·0		0·1			11·6	0·1		7·0	0·2	14·9	0·2	1	3	0	0
16-31		1·9	0·2			0·4	0·5		7·8	0·3	7·4	0·6	0	0	0	4
Feb. 1-15	0·3		0·1		0·2		0·2		6·2	0·2	7·6	0·3	0	1	0	0
16-28		0·1	0·1			0·0	0·4		8·7	0·3	5·0	0·5	1	0	0	0
Mar. 1-15	0·0			0·1		1·7	0·1		4·3	0·2	4·9	0·3	0	0	0	1
16-31	1·2			0·1	1·5		0·1		5·5	0·3	3·9	0·3	0	0	0	0
April 1-15	4·9		0·2			0·2	0·3		7·3	0·3	6·5	0·4	2	0	0	0
16-30		3·3		0·4		1·7		0·1	7·7	0·5	5·5	0·3	0	0	0	0
May 1-15	3·1			0·1		0·3	0·1		7·8	0·3	5·1	0·2	1	0	0	0
16-31	3·7			0·1		6·9	0·2		6·5	0·2	9·1	0·3	0	2	0	0
June 1-15	4·5			0·3	0·9			0·3	5·7	0·4	4·8	0·3	0	0	2	0
16-30	5·4			0·2	2·5		0·1		7·8	0·3	4·8	0·2	0	1	0	0
July 1-15	1·1			0·3	2·6			0·2	6·1	0·3	7·9	0·3	0	0	0	0
16-31	6·5		0·1		10·3		0·1		9·0	0·2	12·3	0·2	0	3	0	0
Aug. 1-15		2·3	0·0		7·8			0·2	7·9	0·2	8·0	0·3	1	2	0	0
16-31		1·0		0·2	1·1			0·3	6·6	0·2	7·8	0·3	0	0	0	0
Sept. 1-15		2·4	0·2			3·8	0·1		9·3	0·2	11·2	0·3	0	3	0	0
16-30		1·2		0·1	2·4			0·3	10·3	0 2	6·7	0·3	1	1	0	1
Oct. 1-15		1·3		0·0		3·1		0 0	9·0	0·2	7·4	0·2	0	0	0	0
16-31	5·2		0·1		5·5		0·1		6·5	0·3	8·3	0·2	0	1	0	0
Nov. 1-15		2·8		0 0		6·4	0·0		6·6	0·2	11·3	0·3	0	1	0	0
16-30		1·0	0·2			5·0	0·2		4·0	0·2	10·3	0·3	0	2	0	0
Dec. 1-15		2·8		0·2		2·6		0·1	7·7	0·3	5·4	0·2	0	0	0	0
16-31		3·2	0·1			3·7	0·1		7·1	0·3	7·1	0·3	0	0	0	0
TOTALS ...	36·9	23·3	1·4	2·1	34·8	47·4	2·7	1·5	172·4	6·3	183·2	7·1	7	20	2	6
MEANS	+ 0·6		− 0·0		− 0·5		+ 0·1		7·2	0·3	7·6	0·3	...	...	...	...

* E_1 is with regard to sign: E_2 is without regard to sign.

TABLE 8.—*Mean errors E_1 and E_2 for 1927.*

MADRAS

PERIOD 1927	MEAN ERRORS (Predicted—actual)												Number of errors exceeding			
	E_1*								E_2*				*30 minutes* of time		*0·4 feet* of height	
	H. W. Time		H. W. Height		L. W. Time		L. W. Height		H. W. Time	H. W. Ht.	L. W. Time	L. W. Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	−	+	−	+	−	+	−								
Jan. 1-15		7·5	0·1			10·3	0·1		9·3	0·2	13·4	0·2	1	0	0	0
16-31																
Feb. 1-15																
16-28	NOTE:—The actual registrations recorded between the 16th January and the 17th April 1927 were rejected as the inlet hole of the float cylinder was partially blocked, and the registrations were considered to be faulty.															
Mar. 1-15																
16-31																
April 1-15																
18-30		0·9	0·0			5·6	0·1		6·2	0·2	10·0	0·2	0	1	0	1
May 1-15		0·2		0·2		3·4		0·0	4·9	0·2	10·3	0·1	0	2	1	0
16-31		1·7		0·1		1·8		0·1	4 7	0·2	4·8	0·1	0	0	2	0
June 1-15	1·5			0·3	5·1			0·1	5 8	0·3	5·4	0·2	0	0	4	4
16-30	0·8			0·0	1·3		0·1		3·7	0·2	3·1	0·2	0	0	2	5
July 1-15		0·6	0·1		0·7		0·2		5·6	0·2	4·8	0·3	0	0	0	6
16-31	0·6		0·1			0·9	0·2		3·9	0·3	4·9	0·3	0	0	3	6
Aug. 1-15	0·1		0·1		2·4		0·2		2·1	0·1	3·3	0·2	0	0	0	0
16-31		5·1	0·1			6·7	0·1		6·2	0·1	7·7	0·1	0	0	0	0
Sept. 1-15	0·9		0·2			1·0	0·2		4·9	0·2	5·2	0·2	0	0	1	1
16-30		2·5	0·0			2·9	0·2		3·4	0·1	5·0	0·2	0	0	0	0
Oct. 1-15	2·3		0·2			0·9	0·2		3·4	0·2	5·9	0·2	0	0	3	5
16-31		0·7	0·1			0·2	0·3		3·7	0·2	4·5	0·3	0	0	3	2
Nov. 1-15	1·5		0·2		0·5		0·3		9·7	0·3	4·9	0·3	2	0	2	4
16-30		1·9	0·3			3·5	0 4		5·0	0·3	6·3	0·4	0	0	4	7
Dec. 1-15		3·7	0·1		1·0		0·0		7·5	0·1	4·4	0 2	0	0	0	0
16-31	0·4		0 1		2·2		0·2		4·1	0·1	4·2	0 2	0	0	0	0
TOTALS ...	8·1	24·8	1·7	0·6	13·2	37·2	2·8	0·2	91·1	3·5	108·1	3·9	3	3	25	41
MEANS ...	− 0·9		+ 0·1		− 1·3		+ 0·1		5·2	0·2	6·0	0 2	...	...	...	...

* E_1 is with regard to sign : E_2 is without regard to sign.

TABLE 9.—*Mean errors E_1 and E_2 for 1927.*

KIDDERPORE

PERIOD 1927	MEAN ERRORS (Predicted — actual)												Number of errors exceeding			
	E_1*								E_2*				30 minutes of time		1·0 feet of height	
	H. W. Time		H. W. Height		L. W. Time		L. W. Height		H. W. Time	H. W. Ht.	L. W. Time	L. W. Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		feet		minutes		feet		minutes	feet	minutes	feet				
	+	−	+	−	+	−	+	−								
Jan. 1-15	17·7			0·4	6 6			0 0	17 9	0·4	10 0	0·3	1	0	0	0
16-31	16·6			0·3	21·9			0·1	19·8	0·4	21·9	0·4	6	5	1	1
Feb. 1-15	19·7			0·3	7·7		0·3		22 3	0·4	16·7	0·4	7	5	0	0
16-28	24 0			0·2	22·7		0·1		24·0	0·3	23 6	0 3	8	7	0	0
Mar. 1-15	8·3		0·1		0·8		0·5		12·8	0·3	11·0	0·6	3	1	0	2
16-31	12·6			0·2	14·0		0·0		13·4	0·6	14·8	0·2	2	0	3	0
April 1-15	14 9			0 7	7·9			0·1	15·6	0·7	12·8	0·4	2	2	4	1
16-30	13·7			0 7	3·3			0·0	15·5	0·8	12 6	0·4	0	0	9	0
May 1-15	9·2			0 3	4·6		0·2		15·2	0·5	19 4	0·5	3	3	3	3
16-31	13·8			0·4		0·8	0 2		15·0	0·5	10·1	0·3	1	1	0	0
June 1-15	14·3			0·7	15·6			0·2	15 3	0·7	17·0	0·5	2	2	6	2
16 30	13 4		0·1		6·0		0·5		14·4	1·0	14·4	0·8	4	3	11	6
July 1-15	4·7		1·3		17·3		1 3		13·0	1·3	17·3	1·3	1	1	26	23
16 31	3·2		1·8		7·5		1 6		8 7	1·8	13·5	1·6	0	0	27	27
Aug. 1-15	0·8		1·2		12 9		1 8		9 8	1 2	14·8	1·8	0	4	17	27
16-31		3·8	1·6		4·6		2·1		7 8	1 6	13 0	2·1	0	3	22	30
Sept. 1-15		7 8	1·5			6·0	2 2		10 6	1·5	16 7	2·2	0	1	22	29
1-30		15 3	1·5			4 6	2 4		15 4	1·5	9 3	2·4	1	1	25	29
Oct. 1-15		10 2	0·7			7·7	1·8		10·9	0 8	18·1	1 8	0	2	10	28
16-31		16·6	0·7			8·5	1·7		16·6	0·7	10 7	1 7	1	0	8	31
Nov. 1-5		5·3	0·2		5·4		1·4		7·8	0·3	10·3	1·4	0	0	0	9
16-30																
Dec. 1-15	Observatory damaged on the 5th of November 1927. Tide-gauge dismantled and the observations discontinued.															
16-31																
TOTALS	186 9	59·0	10·7	4·2	158·8	27·6	18·1	0·4	301·8	17·3	308·0	21·4	42	41	194	246
MEANS	+ 6·1		+ 0·3		+ 6·2		+ 0·8		14·4	0·8	14·7	1·0	...	...	...	...

* E_1 is with regard to sign: E_2 is without regard to sign.

TABLE 10.—*Mean errors E_1 and E_2 for 1927.*

CHITTAGONG

PERIOD 1927	MEAN ERRORS (Predicted—actual)												Number of errors exceeding			
	E_1*								E_2*				30 *minutes* of time		1·0 *feet* of height	
	H. W. Time		H. W. Height		L. W. Time		L. W. Height		H. W. Time Ht.		L. W. Time Ht.		H. W.	L. W.	H. W.	L. W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	−	+	−	+	−	+	−								
Jan. 1-15		4·9		0·7		3·6		0·5	8·9	0·8	6·1	0·5	1	0	4	1
16-31	2·3			0·5	9·4			0·3	4·5	0·5	12·1	0·5	0	1	1	3
Feb. 1-15	2·2			0·3	6·1			0·4	7·3	0·7	9·8	0·5	0	0	5	1
16-28	4·5			0·7	12·7			0·1	5·4	0·8	13·3	0·7	0	1	5	3
Mar. 1-15	0·2		0·4		6·2			0·0	8·9	0·5	10·5	0·4	0	1	1	0
16-31	5·3			0·2	13·1			0·0	12·1	0·7	13·6	0·2	1	1	2	0
April 1-15	1·1			0·8	3·1			0·7	7·0	1·0	5·4	1·0	0	0	7	3
16-30		0·7		1·2		3·5		0·7	9·0	1·3	4·7	1·2	0	0	9	6
May 1-15		7·1		0·1		6·0		0·0	9·3	0·9	7·2	0·6	0	0	6	2
16-31		0·5	0·1		6·2		0·4		5·3	0·4	10·9	0·4	0	3	0	1
June 1-15	5·5			0·3		0·1		0·5	7·3	0·5	4·9	0·6	0	0	1	3
16-30		2·4		0·1		2·7		0·1	7·7	0·7	6·5	0·5	0	0	2	2
July 1-15		6·3		0·0		4·7	0·1		7·4	0·4	7·5	0·2	0	0	1	0
16-31		6·3	0·1			3·4	0·1		6·6	0·5	8·1	0·3	0	0	2	0
Aug. 1-15		2·7		0·1		0·0		0·2	5·0	0·5	8·1	0·3	0	0	1	2
16-31		11·9	0·2			8·6	0·2		11·9	0·5	9·0	0·3	0	0	0	0
Sept. 1-15		7·9		0·3		8·1		0·6	9·0	0·6	9·9	1·1	0	1	4	9
16-30		8·5		0·6		10·9		0·2	11·5	0·6	10·9	0·6	0	1	1	1
Oct. 1-15		3·4		0·8		3·4		0·6	4·9	0·9	4·2	0·4	0	0	6	2
16-31		9·7		0·3		13·6		0·1	11·6	0·7	13·6	0·7	0	1	1	3
Nov. 1-15		8·9	0·0			13·9	0·4		11·6	0·4	14·3	0·4	1	1	0	0
16-30		7·9		0·6		8·4	0·1		10·1	0·7	10·8	0·3	0	0	3	0
Dec. 1-15		10·8		0·5		9·1		0·2	11·3	0·5	10·5	0·3	0	0	0	0
16-31		13·1		0·3		13·6	0·2		13·1	0·3	13·6	0·3	0	0	0	0
TOTALS...	21·1	113·0	0·8	8·4	56·8	113·6	1·5	5·2	206·7	15·4	225·5	12·5	3	11	62	42
MEANS...		− 3·8		− 0·3		− 2·4		− 0·2	8·6	0·6	9·4	0·5	...	...	..	...

* E_1 is with regard to sign: E_2 is without regard to sign.

Note:—Predicted times have received a correction of + 10 minutes, and predicted low-water heights a correction of + 0·6 of a foot.

TABLE 11.—*Mean errors E_1 and E_2 for 1927.*

AKYAB

PERIOD 1927	MEAN ERRORS (Predicted—actual)												Number of errors exceeding			
	E_1*								E_2*				30 *minutes* of time		0·8 *feet* of height	
	H. W. Time		H. W. Height		L. W. Time		L. W. Height		H. W. Time	H. W. Ht.	L. W. Time	L. W. Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	−	+	−	+	−	+	−								
Jan. 1-15	6·9			0·2	6·8			0·5	6·9	0·3	6·8	0·6	0	0	0	4
16-31	6·9			0·5	6·6			0·4	6·9	0·5	6·6	0·5	0	0	2	4
Feb. 1-15	6·8			0·3	7·2			0·1	6·8	0·4	7·2	0·3	0	0	2	0
16-28	6·4			0·4	7·5			0·2	6·4	0·5	7·5	0·4	0	0	3	3
Mar. 1-15	7·0			0·2	6·9			0·0	7·0	0·2	6·9	0·2	0	0	0	0
16-31	6·3			0·4	6·8			0·1	6 3	0·4	6·8	0·3	0	0	0	0
April 1-15	7·7			0·2	6·4			0·1	7·7	0·3	6·4	0·5	0	0	0	2
16-30	7·6			0·2	6·8			0·0	7·6	0·2	6·8	0·2	0	0	0	0
May 1-15	6·7			0·2	6·3		0·3		6·7	0·3	6·3	0·5	0	0	1	2
16-31	5·8			0·4	7·0			0·4	5·8	0·4	7·0	0·4	0	0	2	1
June 1-15	6·3			0·2	6·4			0·3	6·3	0·4	6·4	0·4	0	0	1	1
16-30	5·7			0·0	7·1			0·3	5·7	0·3	7·1	0·3	0	0	0	1
July 1-15	5·9			0·3	6·2		0·1		5·9	0·3	6·2	0·1	0	0	0	0
16-31	5·3			0·3	5·8			0·5	5·3	0·3	5·8	0·5	0	0	0	0
Aug. 1-15	4·7			0·3	4·5			0·3	4·7	0·3	4·5	0·4	0	0	0	3
16-31	6·3			0·1	6·4		0·1		6·3	0·2	6·4	0·1	0	0	0	0
Sept. 1-15	6·7			0·1	6·3			0·0	6·7	0·1	6·3	0·1	0	0	0	0
16-30	7·0			0·2	6·0		0·1		7·0	0 3	6·0	0·1	0	0	0	0
Oct. 1-15	5·7		0·1		6·2		0·1		5·7	0·2	6·2	0·2	0	0	0	0
16-31	6·4			0·0	5·2		0·1		6·4	0·1	5·2	0·1	0	0	0	0
Nov. 1-15	6·2			0·1	6·7		0·1		6·2	0·2	6·7	0 2	0	0	0	0
16-30	6·0			0·1		5·7		0·0	6·0	0·2	5·7	0·1	0	0	0	0
Dec. 1-15	6·5		0·1		6·3		0·0		6 5	0·1	6·3	0·1	0	0	0	0
16-31	6·5			0·0	6·1		0·1		6 5	0·2	6·1	0·1	0	0	0	0
TOTALS	153·3		0·2	1 7	147 5	5 7	1·0	3·2	153·3	6·7	153·2	6·7	0	0	11	21
MEANS ...	+ 6·4		− 0·2		+ 5·9		− 0·1		6·4	0·3	6·4	0·3	...	...	...	...

* E_1 is with regard to sign : E_2 is without regard to sign.

TABLE 12.—*Mean errors E_1 and E_2 for 1927.*

RANGOON

PERIOD 1927	MEAN ERRORS (Predicted—actual)												Number of errors exceeding			
	E_1*								E_2*				*30 minutes* of time		*1·0 feet* of height	
	H. W. Time		H. W. Height		L. W. Time		L. W. Height		H. W. Time	H. W. Ht.	L. W. Time	L. W. Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	−	+	−	+	−	+	−								
Jan. 1-15		5·2		0·0		7·8		0·2	6·5	0·3	9·9	0·4	0	0	0	0
16-31	1·2			0·3	5·8			0·1	6·0	0·4	12·8	0·4	0	0	2	2
Feb. 1-15		4·4		0·0		9·2		0·4	7·6	0·3	12·7	0·6	0	0	0	5
16-28		0·8		0·1	4·5		0·1		8·8	0·3	9·6	0·4	0	1	0	1
Mar. 1-15		2·6		0·1		5·0		0·5	7·9	0·4	10·8	0·6	0	0	0	7
16-31		6·7		0·5		4·3		0·0	7·3	0·5	7·9	0·4	1	0	1	0
April 1-15		10·1		0·2		3·8		0·8	14·1	0·4	8·0	0·8	2	0	0	10
16-30		7·2		0·2		4·6		0·0	9·4	0·4	8·8	0·5	1	0	0	1
May 1-15		6·3		0·0		3·4		0·5	9·1	0·3	10·1	0·6	2	0	0	5
16-31		5·7		0·4		2·5		0·4	7·6	0·4	9·0	0·6	0	0	0	3
June 1-15		13·9		0·2		1·8		0·4	14·3	0·5	12·0	0·5	2	0	3	3
16-30		6·4		0·0		7·3		0·0	7·1	0·4	12·1	0·4	0	0	2	1
July 1-15		10·3	0·1		1·8			0·1	12·6	0·3	13·9	0·5	2	2	0	1
16-31		5·8		0·3		5·6		0·4	8·3	0·4	12·0	0·6	0	0	2	4
Aug. 1-15		12·3		0·0	2·8			0·0	13·6	0·3	12·1	0·2	2	2	0	0
16-31		21·1	0·1			8·2	0·2		21·1	0·4	12·2	0·4	6	0	0	0
Sept. 1-15		7·6	0·4		1·3		0·5		10·0	0·6	11·0	0·5	1	1	7	1
16-30		13·6		0·0		1·6	0·3		14·1	0·4	6·1	0·3	4	0	0	0
Oct. 1-15	11·9			0·3	0·3			1·3	14·3	0·5	12·6	1·3	2	0	3	15
16-31	4·7			0·3		5·7		0·7	8·1	0·4	8·1	0·7	0	0	2	5
Nov. 1-15		0·3	0·4			11·9		0·3	6·9	0·5	14·4	0·4	0	1	1	5
16-30		3·7	0·1		2·0		0·1		7·3	0·4	9·4	0·6	0	0	0	2
Dec. 1-15		6·2	0·5			6·6	0·2		7·9	0·6	13·9	0·5	1	1	1	3
16-31	2·7		0·5		6·2		0·7		6·0	0·6	13·8	0·8	0	0	6	9
TOTALS	20·5	150·7	2·1	2·9	24·7	89·3	2·1	6·1	235·9	10·0	263·2	13·0	26	8	30	83
MEANS	− 5·4		− 0·0		− 2·7		− 0·2		9·8	0·4	11·0	0·5	...	...	...	...

* E_1 is with regard to sign: E_2 is without regard to sign.

TABLE 13.—*Mean errors E_1 and E_2 for 1927.*

PILAKAT OR DESERTERS' CREEK

PERIOD 1927	MEAN ERRORS (Predicted—actual)												Number of errors exceeding			
	E_1*								E_2*				30 minutes of time		1·0 feet of height	
	H. W. Time		H. W. Height		L. W. Time		L. W. Height		H. W. Time	H. W. Ht.	L. W. Time	L. W. Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		feet		minutes		feet		minutes	feet	minutes	feet				
Jan. 1-15																
16-31	NOTE:—The new tide-gauge was installed in the Pilakat or Deserters' Creek on the 5th March 1927 and registrations were commenced on the 20th March 1927.															
Feb. 1-15																
16-28																
Mar. 1-15																
	+	−	+	−	+	−	+	−								
20-31	23·9			0·8	25·0		0·2		24·0	0·8	25·0	0·5	4	6	2	1
April 1-15	12·8			0·4	11·1			0·7	17·2	0·5	13·4	0·7	6	1	2	6
16 30	20·6			0·4	16·2		0·3		20·6	0·5	16·9	0·5	3	0	0	2
May 1-15	10·9			0·1	8·4			0·2	14·9	0·4	9·1	0·5	1	1	1	1
16-31	6·6			0·4	5·1		0·0		7·8	0·5	8·0	0·6	0	0	2	4
June 1-15	0·4			0·3		1·3		0·1	9·6	0·5	8·8	0·4	0	0	3	0
16-30	2·3			0·0		7·0	0·4		10·0	0·5	10·6	0·6	0	3	2	5
July 1-15	11·9			0·0	13·6		0·3		13·7	0·3	14·7	0·6	1	2	0	4
16-31	7·9			0·2	4·1		0·2		9·8	0·4	8·3	0·4	0	0	2	0
Aug. 1-15	7·3			0·1	6·0		0·5		9·6	0·3	9·1	0·5	0	0	0	1
16-31		17·8	0·2			11·3	0·5		19·3	0·5	12·8	0·6	3	1	2	1
Sept. 1-15	2·9		0·3			0·7	0·3		8·3	0·5	9·5	0·4	0	0	2	1
16-30		7·7		0·1		4·7	0·2		13·7	0·5	9·7	0·5	4	1	3	2
Oct. 1-15	2·3			0·2	4·1			0·4	8·5	0·5	11·1	0·7	0	1	3	7
16-31		3·6		0·3		7·5	0·3		9·9	0·5	10·5	0·6	2	1	2	3
Nov. 1-15	3·7		0·1			6·1	0·1		9·2	0·3	11·6	0·4	0	1	0	1
16-30		2·0		0·5		1·4	0·0		8·0	0·7	8·6	0·6	1	0	5	2
Dec. 1-15	3·6		0·1			4·1	0·0		7·6	0·3	9·5	0·4	0	0	0	1
16-31	16·1		0·1		10·4		0·5		17·0	0·4	14·4	0·7	1	3	1	4
TOTALS ...	133·2	31·1	0·8	3·8	104·0	44·1	3·8	1·4	238·7	8·9	221·6	10·2	26	21	32	46
MEANS ...	+ 5·4		− 0·2		+ 3·2		+ 0·1		12·6	0·5	11·7	0 5	...	...	...	...

* E_1 is with regard to sign ; E_2 is without regard to sign.

TABLE 14.—*Mean errors E_1 and E_2 for 1927.*

BASSEIN

PERIOD 1927	MEAN ERRORS (Predicted — actual)												Number of errors exceeding			
	E_1*								E_2*				0 minutes of time		0·6 feet of height	
	H. W. Time		H. W. Height		L. W. Time		L. W. Height		H. W. Time	H. W. Ht.	L. W. Time	L. W. Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		feet		minutes		feet		minutes	feet	minutes	feet				
	+	−	+	−	+	−	+	−								
Jan. 1-15		0·6		1·0		15·4		0·6	16·5	1·0	15·4	0·6	4	0	27	3
16-31	11·5			0·9	9·7		0·2		22·0	0·9	19·7	0·4	10	1	18	0
Feb. 1-15	4·9			0·6	3·0		0·3		11·7	0·6	3·0	0·3	4	0	11	0
16-28	23·5			0·5	12·0		0·9		24·8	0·5	23·5	0·9	8	6	9	18
Mar. 1-15		1·1		0·3		25·2	0·5		13·2	0·3	30·4	0·5	1	15	0	7
16-31	13·4			0·6	1·7		0·5		17·0	0·6	23·2	0·5	6	9	13	10
April 1-15		1·0		0·8		21·7		0·2	16·0	0·8	24·9	0·3	3	13	26	0
16-30	26·1			0·7	11·1		0·3		26·1	0·7	15·8	0·4	8	6	15	9
May 1-15		3·1		1·0		31·8		0·3	12 6	1·0	33·2	0·5	1	19	25	11
16-31		1·1		0·8		18·9		0·3	13·0	0·8	19·1	0·4	1	7	20	7
June 1-15		6·5		0·5		22·7	0·1		15·2	0·5	26·3	0·5	2	11	8	8
16-30	2·4			0·5		16·7		0·1	12·5	0·5	17·5	0·4	0	4	8	3
July 1-15	5·5			0·1		19·4	0·2		16·2	0·3	19·4	0·3	5	8	3	1
16 31		11·2		0·0		22·6		1·3	20·8	0·4	22·6	1·4	7	8	5	22
Aug. 1-15		14·9	0·3			21·2		1·2	22·7	0·4	22·1	1·2	8	5	4	28
16-31		8·8	0·7			24·3		0·7	11·8	0·7	24·4	0·7	2	9	20	16
Sept. 1-15	0·5		1·1			22·0	0·1		11·3	1·1	23·8	0·5	1	11	29	9
16-30		11 6	0·6			29·1		0·5	16·2	0·6	29·8	0·9	5	13	12	19
Oct. 1-15		11·2		0·2		20·6		2·3	16·1	0·3	24·6	2·3	3	14	2	29
16-31		18·9		0·6		44·2		2·0	20·9	0·6	44·2	2·0	8	20	14	31
Nov. 1-15		5·4		0·7		38·1		1·2	13·1	0·7	38·3	1·2	3	23	18	27
16-30		24·4		1·0		52·3		0·5	21·4	1·0	52·3	0·5	9	21	29	6
Dec. 1-15		14·6		0·8		35·8		0·3	16·8	0·8	35·8	0·4	5	22	32	8
16-31		6·7		0·5		52·8	0·4		11·5	0·5	52 8	0 4	2	5	10	0
TOTALS ...	87·8	141·1	2·7	12·1	37·5	534·8	3·5	11·5	40 ·4	15·0	642·1	17·5	106	250	348	272
MEANS ...	− 2·2		− 0·4		− 20·7		− 0·3		16·8	0·7	26·8	0·7	...	...	...	..

* E_1 is with regard to sign: E_2 is without regard to sign.

CHAPTER IV

GRAVITY AND DEVIATION OF THE VERTICAL

BY MAJOR E. A. GLENNIE, D.S.O., R.E.

1. Pendulum Apparatus of the Survey of India.— This season a new pendulum apparatus has been brought into use. This is the third type of apparatus used in India. The three types are:—

(i) The Basevi apparatus, in use from 1865 to 1873 (*vide* G.T.S. Vol. V.)

(ii) The Survey of India Potsdam (1902) apparatus, in use from 1902 to 1925 (*vide* Professional Papers Nos. 10 and 15).

(iii) The Survey of India Cambridge (1926) apparatus, now brought into use.

The Basevi apparatus was used by Captains Basevi and Heaviside, observations being made at thirty stations in India from Cape Comorin to the Moré Plain; but, in spite of the meticulous care with which these observations were made, later experience has led to the rejection of all the results.

The reason for this is that no correction was made for the sway of the apparatus, due to the motion of the pendulum. Sway of the apparatus increases the time of vibration of the pendulum. If the sway were the same at all stations, no error in the deduced value of gravity would result. This is, however, by no means the case, as is clearly shown in § 138 of Geodetic Report Vol. I, page 178. Hence, no correction having been made for sway, all results in India prior to 1904 are unreliable.

The modern series of Gravity Observations in India was initiated with the Potsdam (1902) apparatus. As in the case of the Basevi apparatus, only one pendulum can be swung at a time, but a correction (the "flexure" correction), was applied to compensate for the sway caused by the motion of the pendulum. This correction was determined by a special "flexure" observation, made several times at each station.

Though the "flexure" observation provided a satisfactory correction for sway due to pendulum motion, it did not correct for sway effects due to actual ground motion, i.e. not caused by the pendulum. In fact, if the ground is appreciably in motion, the "flexure" observation cannot be made. At Calcutta in 1904 the observations had to be abandoned owing to ground motion.

INDIA

LATITUDE STATIONS

Corrected to Sept. 1928

Rakaposhi 25550 · Kunjut 26460 · K² 28250 · Gasherbrum 26470 · Nanga Parbat 26620 · 24370 · 24690 · 21140 · 20410 · 22210 · 20720 · Kamet 25447 · 22028 · Nanda Devi 25645 · Gurla Mandhata 25355 · 22050 · 23390 · Dhaulāgiri 26795 · XXX 26658 · Gosainthān 26291 · Mount Everest 29002 · Makalu 27790 · 23180 · 23030 · 24740 · Kinchinjunga 28146 · 23460 · Namcha Barwa 25445

HERĀT · KĀBUL · PESHĀWAR · Murree · SRINAGAR · Rāwalpindi · INDUS R. · NASRATĀBĀD · KANDAHĀR · Dera Ismail Khān · LAHORE · Amritsar · QUETTA · Multān · Sutlej R. · Ludhiāna · Debra Dūn · Jumna R. · Ganges R. · Meerut · DELHI · Jacobābād · Sukkur · Bikaner · AGRA · Lucknow · Fyzābād · Cawnpore · Gwalior · Jodhpur · Hyderābād · KARĀCHI · Benares · Allahābād · Deesa · Kalianpur · Mouths of the Indus · Ahmadābād · Jubbulpore · Navānar · Okha Point · Hanstal · Mhow · Narbadā R. · Bhaunagar · Porbandar · Port Albert Victor · NĀGPUR · Hinganghāt · Sambalpur · Dublat (Sagar I.) · Mouths of the Ganges · False Point · Princes Dock · BOMBAY · Apollo Bandar · Poona · Godāvari R. · Waltair · Vizagapatam · Bolārum · Secunderābād · Cocanāda · Ragalkot · Raichūr · Kistna R. · Belgaum · Mārmagao · Kārwār · Bellary · Bangalore · Mangalore · MADRAS · Calicut · Beypore · Trichinopoly · Negapatam · Cochin · Madura · Pamban Pass · Tuticorin · Trincomalee · Minicoy · Nagarkoil · Cape Comorin · Colombo · CEYLON · Galle

LHĀSA · BRAHMAPUTRA R. · Darjeeling · Jalpaiguri · Dibrugarh · Shillong · Myitkyinā · Chindwin R. · SALWEEN R. · MEKONG R. · Dacca · CALCUTTA · Kidderpore · Diamond Harbour · Chittagong · MANDALAY · Salin · Akyab · IRRAWADDY R. · Prome · RANGOON · Elephant Pt. · Moulmein · Pitakat Creek · Amherst · Bassein · Diamond I. · Mouths of the Irrawaddy · BANGKOK · Mergui · ANDAMAN ISLANDS · Port Blair · NICOBAR ISLANDS

B A Y O F B E N G A L

A R A B I A N S E A

REFERENCES

Latitude stations (Departmental) ..... ●
Additions since 1927 ..... Nil
Latitude stations (Non Departmental Minor) ..... ■

By reason of the small scale of this chart 15 Latitude stations have been omitted in the neighbourhood of Dehra Dūn.

Scale 1 Inch = 250 Miles or 1 / 15,840,000

Miles 100 0 100 200 300 400 Miles

60° 64° 68° 72° 76° 80° 84° 88° 92° 96° 100° 104°

32° 28° 24° 20° 16° 12° 8°

INDIA

PENDULUM STATIONS

Corrected to Sept 1928

60° 64° 68° 72° 76° 80° 84° 88° 92° 96° 100° 104°

32° 28° 24° 20° 16° 12° 8°

Rakaposhi 25550 · Kunjut 25400 · K² 28250 · Gasherbrum 26470 · Nanga Parbat 26620 · 24370 · 24390

HERÁT · KÁBUL · PESHÁWAR · Murree · SRINAGAR · Rāwalpindi · INDUS R. · 21140 · 20410 · 22210

NASRATÁBÁD · KANDAHÁR · Dera Ismail Khān · LAHORE · Amritsar · QUETTA · Multān · Sutlej R. · Ludhiana · INDUS R. · 20720 · Kamet 25447 · 22028 · Nanda Devi 25645 · Gurla Mandhata 25355 · Dehra Dūn · 22650 · 23399

LHĀSA · 23460 · Namcha Barwa 25445 · BRAHMAPUTRA R.

Jacobābād · Sukkur · Bikaner · DELHI · Meerut · Jumna R. · Ganges R. · Dhaulāgiri 20795 · XXX 26658 · Gosainthān 26291 · Mount Everest 29002 · Makalu 27790 · 23180 · 24740 · 23930 · Kinchinjunga 28146

Darjeeling · Jalpaiguri · Dibrugarh · BRAHMAPUTRA R.

AGRA · Lucknow · Fyzābād · Cawnpore · Gwalior · Jodhpur · Hyderābād · KARĀCHI · Benares · GANGES R. · Allahābād · Shillong · Myitkyinā

Mouths of the Indus · Deesa · Kalianpur · Dacca · Chindwin R.

Ahmadābād · Juhbulpore · Navānar · Hanstal · Okha Point · Mhow · Narbadā R. · Bhaunagar · Porbandar · Port Albert Victor · NĀGPUR · Hinganghāt · Samlalpur · CALCUTTA · Kidderpore · Diamond Harbour · Dubiat (Sagar I.) · Mouths of the Ganges · False Point · Chittagong · MANDALAY · SALWEEN R. · MEKONG R.

ARABIAN SEA · Prince's Dock · BOMBAY · Apollo Bandar · Poona · Godāvari R. · Bolārum · Secunderābād · Waltair · Vizagapatam · Akyab · Salin · IRRAWADDY R. · Prome

Cocanāda · BAY OF BENGAL · RANGOON · Bassein · Moulmein · Elephant Pt. · Pisakat Creek · Amherst · Diamond I. · Mouths of the Irrawaddy

Belgaum · Bāgalkot · Raichūr · Kistna R. · Marmagao · Kārwār · Bellary · BANGKOK

Bangalore · MADRAS · Mangalore · ANDAMAN ISLANDS · Port Blair · Mergui

Calicut · Beypore · Negapatam · Trichinopoly · Cochin · Madura · Pamban Pass · Tuticorin · Trincomalee · Minicoy · Nagarkoil · Cape Comorin · NICOBAR ISLANDS · CEYLON · Colombo · Galle

REFERENCES

- Pendulum stations (Departmental)
- Additions since 1927
- Pendulum stations (Non Departmental)
- Dr Vening Meinesz's submarine stations (Non Departmental)

The work of Basevi and Heaviside has been omitted from this chart which shows only the operations carried out with the half-seconds pendulums subsequent to 1903

Scale 1 Inch = 250 Miles or 1 / 15,840,000

Miles 100 0 100 200 300 400 Miles

INDIA

TELEGRAPHIC LONGITUDE STATIONS

Corrected to Sept. 1928

60° 64° 68° 72° 76° 80° 84° 88° 92° 96° 100° 104°

32° 28° 24° 20° 16° 12° 8°

Rakaposhi 25550 · Kunjut 25460 · K 2 28250 · Gasherbrum 26470 · Nanga Parbat 26620 · 24370 · 24090 · 21140 · 20410 · 32210 · 20720 · 22025 · Kamet 25447 · Nanda Devi 25645 · Gurla Mandhata 25355 · 22650 · 23309 · 23460 · Namcha Barwa 25445 · XXX 26658 · Gosainthan 20291 · Dhaulagiri 26795 · Mount Everest 29002 · Makalu 27790 · 23180 · 23930 · 24740 · Kinchinjunga 28146

HERÁT · KÁBUL · PESHÁWAR · Murree · SRÍNAGAR · Rawalpindi · INDUS R. · NASRATÁBÁD · KANDAHÁR · Dera Ismail Khán · LAHORE · Amritsar · QUETTA · Multán · Sutlej R. · Ludhiana · Dehra Dún · LHÁSA · BRAHMAPUTRA R. · INDUS R. · Jacobábad · Sukkur · Bikaner · DELHI · Meerut · Jumna R. · Ganges R. · AGRA · Lucknow · Fyzábad · Jalpaiguri · Darjeeling · Dibrugarh · BRAHMAPUTRA R. · Shillong · Myitkyina · Cawnpore · Gwalior · Jodhpur · Benares · GANGES R. · Hyderábad · from Bushire · from Jask · KARACHI · Allahábad · Deesa · Kalianpur · Mouths of the Indus · Ahmadábád · Jubbulpore · Dacca · CALCUTTA · Kidderpore · Diamond Harbour · Chittagong · Chindwin R. · MANDALAY · SALWEEN R. · MEKONG R. · Navánar · Okha Point · Hanstal · Mhow · Narbadá R. · Bháunagar · Porbandar · Port Albert Victor · NÁGPUR · Sambalpur · Dublat (Sagar I.) · Mouths of the Ganges · Salin · Akyab · IRRAWADDY R. · Prome · Hingaghát · False Point · Prince's Dock · BOMBAY · Apollo Bandar · Poona · Godávari R. · Waltair · Vizagapatam · from Aden · Bolárum · Secunderábad · Cocanáda · BAY OF BENGAL · RANGOON · Moulmein · Elephant Pt. · Pilakat Creek · Amherst · Bassein · Diamond Pt. · Mouths of the Irrawaddy · Bagalkot · Raichúr · Kistna R. · Belgaum · Marmagao · Kárwár · Ballary · BANGKOK · Mergui · ANDAMAN ISLANDS · Port Blair · Bangalore · MADRAS · Mangalore · NICOBAR ISLANDS · Calicut · Beypore · Negapatam · Trichinopoly · Cochin · Madura · Pámban Pass · Tuticorin · Trincomalee · Nagarkoil · Cape Comorin · Minicoy · Colombo · CEYLON · Galle

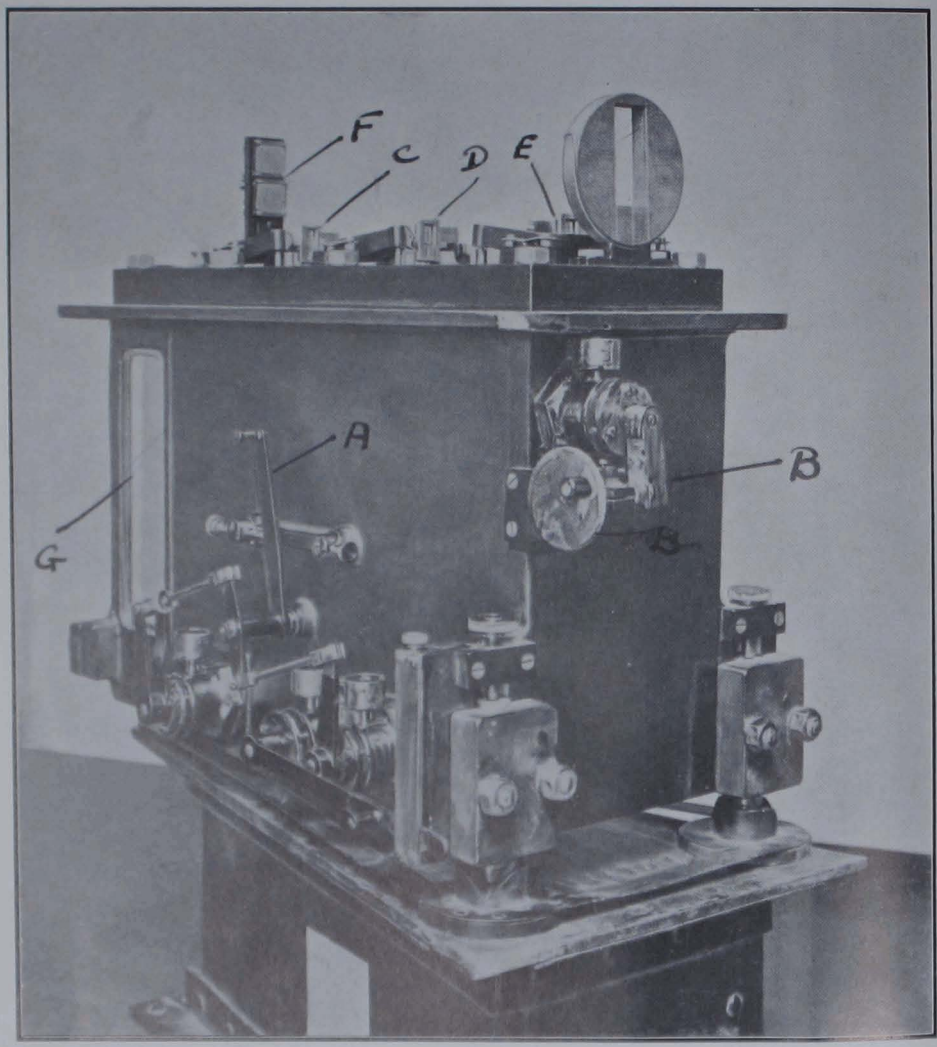
ARABIAN SEA

REFERENCES

- Longitude stations
- Longitude arcs
- Wireless Longitude station (Departmental)
- Wireless Longitude stations (Non Departmental)
- Chronometer Longitude stations (do)

Scale 1 Inch = 250 Miles or 1/15,840,000

Miles 100 0 100 200 300 400 Miles



THE SURVEY OF INDIA, CAMBRIDGE (1926)

PENDULUM APPARATUS (without cover)

A. Arm to release front and back pendulums
B. Lever to raise or lower all three pendulums
C. Back pendulum
D. Middle pendulum
E. Front pendulum
F. Back adjustable mirrors
G. Window for reading thermometer and manometer

Photo.-engraved and printed at the Offices of the Survey of India, Calcutta, 1929

In 1923 Dr. F. A. Vening Meinesz published his able treatise on the theory of pendulums ("observations de pendule dans les Pays Bas"). He had been led to make a detailed investigation owing to the fact that in many places in Holland the ground is constantly in motion.

Dr. Vening Meinesz showed theoretically that, if two nearly isochronous pendulums were swung simultaneously on the same stand, and the changes in their phase-differences and amplitudes taken into account, the times of vibration, unaffected by ground motion, could be obtained. The same method also eliminated sway effects due to the motion of the pendulums.

In the following year he showed in practice the truth of his theories by a remarkable series of gravity determinations at sea, during a voyage in a submarine to Java. His gravity determinations in the Indian Ocean are shown in Table 6.

These results led Colonel Sir G. P. Lenox Conyngham, F.R.S., formerly Superintendent of the Great Trigonometrical Survey of India, and now Reader in Geodesy at Cambridge, to design a new apparatus for the gravity base station established by him at the Cambridge Observatory. The apparatus, so designed, was constructed by the Cambridge Instrument Company and proved entirely satisfactory. In 1926 one was ordered for the Survey of India, which is now designated the Survey of India Cambridge (1926) apparatus.

2. Description of the Survey of India Cambridge (1926) apparatus.—The apparatus consists of a massive gun-metal box, in size 1½ ft. long, 9 in. wide and 1 ft. high, without the cover, which is semi-circular in section. When the cover is in position, the box can be hermetically sealed, and the pressure inside reduced. The box is divided by metal partitions into three compartments, one for each pendulum.

The three pendulums are placed in the box, each resting on two agates, the top surface of all six agates being carefully ground in position, so as to be all in the same plane.

The three pendulums are five inches apart, and can all swing in the same vertical plane, parallel to the long axis of the box.

During observations, the centre pendulum is held still by a lever pressing on its bob, so as to give it a slight tilt; the two mirrors on its knife-head form part of the optical system to be described later. The two outer pendulums can be given the required initial tilt by two levers, which are interconnected, so that one quick motion of a single arm A, (*vide* Plate VI) releases the levers, and sets the two pendulums swinging with a phase-difference of 180°.

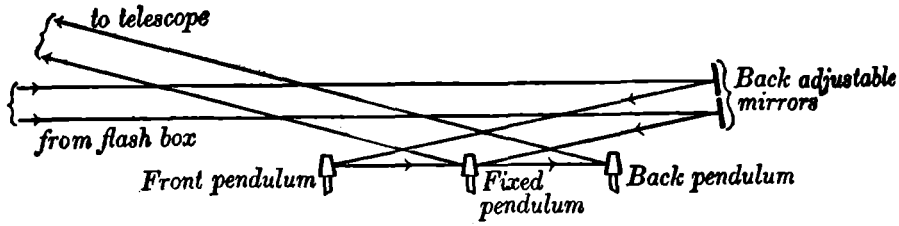
The pendulums can be raised off the agates, when observations are not being made.

A plate-glass window in the cover enables the pendulums to be observed, and another, at one side of the box, permits the reading of a thermometer, placed in a dummy pendulum, and of a small mercury manometer, both inside the box near the back pendulum.

The construction of the flash-box and method of observing the flashes and reading the amplitudes are exactly the same in principle as those employed with the Potsdam apparatus in India since 1904, and described in Professional Paper No. 10. The flash-box is however lighter in design, and the observing telescope is on a separate stand, as the optical system requires it to be placed about six inches above the flash-box. The diaphragm of the telescope has two horizontal wires, one of which is used for the front pendulum, and the other for the back pendulum.

The optical system is shown in the diagram below and is as follows:-

Diagram of optical system



Two adjustable mirrors, one above the other are set at the back of the pendulum box; each pendulum has two mirrors on either side of its knife-head which are inclined to the stem of the pendulum at a slope of 1 in 12.

The flash from the flash-box travels as follows:-

(i) Front pendulum.–Flash-box to upper adjustable mirror, thence to back mirror of front pendulum, thence to front mirror of centre fixed pendulum, thence to observing telescope.

(ii) Back pendulum.–Flash-box to lower adjustable mirror, thence to back mirror of fixed pendulum, thence to front mirror of back pendulum, thence to telescope.

Any of the three pendulums can be used as the fixed pendulum, and in practice two different pairs of outer pendulums are observed at each station.

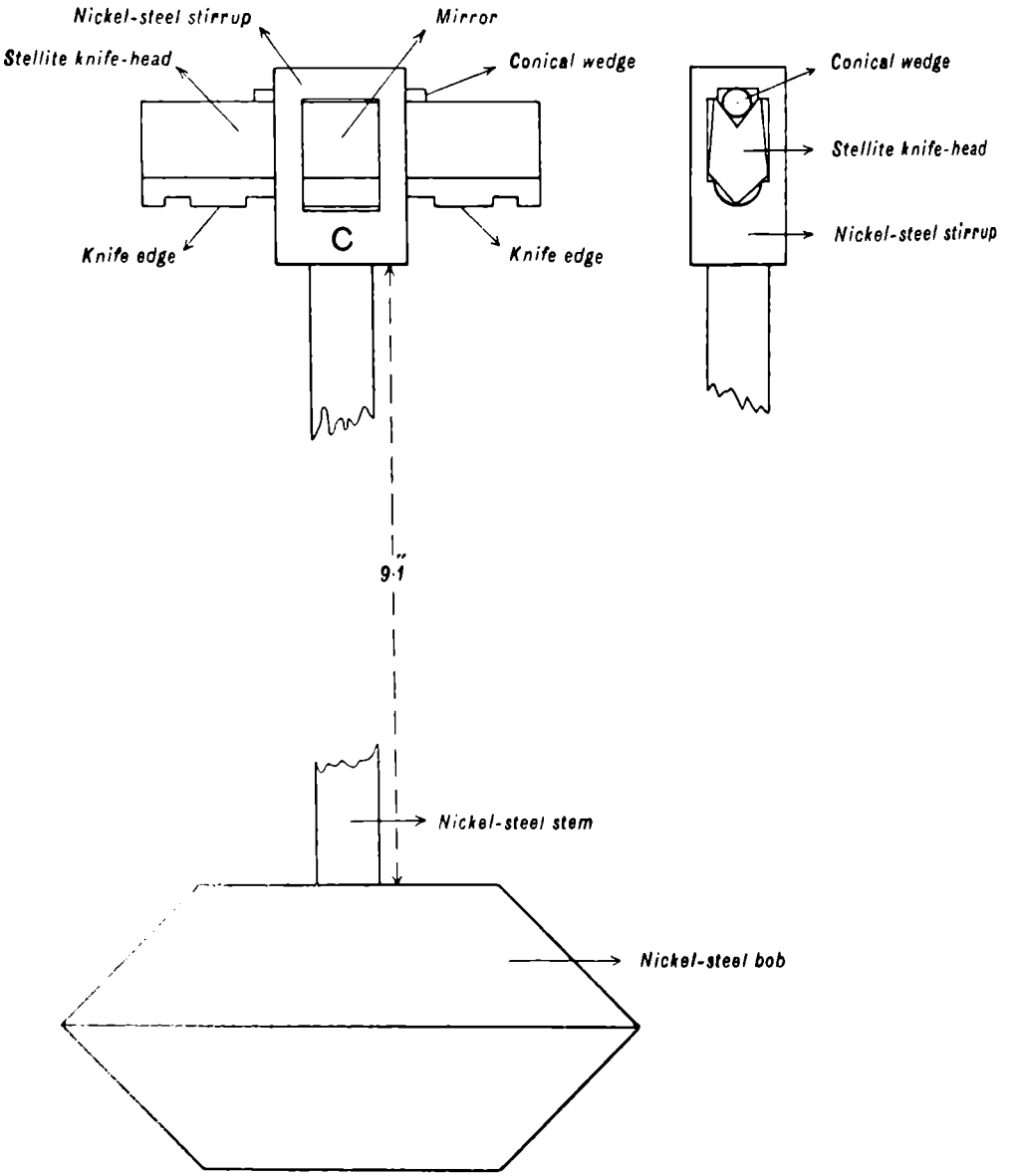
3. Observations.—There is no essential change in the method of observation. First a series of coincidences of the front pendulum is recorded, followed immediately by a series of the back pendulum; then, after an interval, a second series, is recorded for each. Before and after each series, the amplitudes, dummy thermometer, and manometer are read.

As the pendulums are nearly isochronous, they can swing for periods as long as eight hours without their phase-difference changing too much, so that the pendulums can be swung practically continuously between time signals, thus almost entirely eliminating errors due to irregular fluctuations of clock rate. Observations for a pair of pendulums are completed in 36 hours, six time signals being received in this period (i. e. three from Rugby and three from Bordeaux).

FIG. 1

Detail of Cambridge (1926) Pendulum

Full size



4. Sway correction.—Since the pendulums swing in opposite phases, there is normally no sway of the apparatus due to the motion of the pendulums, but the observations require scrutiny to see whether ground-motion corrections have to be applied. These corrections can be computed from the ordinary observations ; no special sway observations are required.

5. Pendulums of the Survey of India.—The pendulums which have been used in India are :–

(i) Seconds pendulums used with the Basevi apparatus :—

(a) Kater's invariable pendulums Nos. 4 and 1821 in use from 1865 to 1871.

(b) Russian reversible pendulums Nos. I & II used in 1873.

(ii) The four brass, Potsdam (1902), pendulums, used since 1902 with the Potsdam apparatus. These are numbered 137 to 140. Mean time of vibration 0·50725s.

(iii) The three brass, Dehra Dūn (1924), pendulums, numbered 1 to 3 and used in Kashmīr in 1925. The knife-edges of Nos. 2 & 3 have deteriorated. Mean time of vibration 0·50731s.

(iv) The nickel-steel Cambridge (1926) pendulums, now in use with the Cambridge apparatus. These are lettered A, B, C. Mean time of vibration 0·50795s.

6. Description of the Survey of India Cambridge (1926) pendulums.—Quartz pendulums having been found too fragile in 1924 (*vide* Geodetic Report Vol. I § 126), the late Lt.-Colonel H. McC. Cowie, R.E., then in England, ordered three nickel-steel pendulums from the Cambridge Instrument Company for use with the Survey of India Potsdam apparatus. In 1926 these were ready, but the knife-heads had to be changed, so as to be suitable for the Cambridge apparatus, the chief difference being the provision of two mirrors inclined to the pendulum stem. A pendulum is shown in detail in Fig. 1, Plate VII.

The bob, stem and stirrup at the top for holding the knife-head are all in one piece of nickel-steel. Nickel-steel was chosen since the coefficient of expansion of this alloy, when suitably proportioned, is exceedingly small. The coefficient of expansion of these pendulums is + 0.0000 0167 per degree Centigrade, whereas that of the brass Survey of India Potsdam (1902) pendulums, formerly in use, is + 0.0000 1934 per degree Centigrade. Hence the new pendulums are much less affected by temperature changes.

The knife-head is of stellite, a material of great hardness, which can be polished sufficiently to form a good metal mirror. The knife-head is permanently fixed by means of conical wedges in the stirrup under hydraulic pressure.

7. Adjusting the length of the pendulums.—The new apparatus requires the pendulums to be as nearly isochronous as possible. On receipt of the pendulums from the makers the differences in time of vibration were found to be as follows:—

$$B-C \quad 28^s \times 10^{-7}$$
$$A-C \quad 368^s \times 10^{-7}$$

This compared very favourably with the Potsdam pendulums previously in use, two of which differed by as much as $4105^s \times 10^{-7}$, whilst the smallest difference was $716^s \times 10^{-7}$. Closer equality was considered necessary for the Cambridge pendulums. This was attained by grinding the flat base of the bob of the longest pendulum on a sheet of fine carborundum paper, lubricated with kerosine oil and laid on a flat plate of glass. After about three minutes grinding a series of coincidences was observed, and finally, when near the right length, a complete observation lasting about one hour was necessary between each grinding. Thus the whole operation of obtaining close isochronism was long and tedious, and took about a fortnight of fairly continuous work. The greatest departure from isochronism is now $11^s \times 10^{-7}$.

8. Determination of correction factors.—The next step was to determine the correction factors.

These are:—(1) the density factor, k'.
(2) the temperature factor, k.

This was done at the pendulum house of the Cambridge Observatory, kindly lent for the purpose by Colonel Sir G.P. Lenox Conyngham, who, during the course of the work, gave much valuable assistance and advice.

In order to save time and eliminate clock-rate errors as far as possible, a Von Sterneck pendulum apparatus with a single pendulum was set up alongside the Cambridge apparatus, and all observations of the pendulums under test were bracketted between observations to a brass pendulum No. 38), whose density and temperature factors were known.

By subtracting the observed time of vibration, S^1_A (or S^1_B etc), of the pendulum under test from that of No. 38, (S_{38}), reduced for temperature and density, we get the relation:—

$S_{38} - S^1_A = (S_{38} - S_A) - k'_A D - k_A T - F$, where F is the sway correction for the Cambridge Pendulums. This is zero, when two pendulums are swung simultaneously, and can be determined, when one pendulum only is swung, by means of a special flexure observation. $(S_{38} - S_A)$ is a constant, depending on the two pendulums 38 and A. $k'_A D$ and $k_A T$ are the density and temperature corrections for pendulum A, similar expressions applying to pendulums B and C.

The equation involves three unknowns, so three groups of observations were arranged with the Cambridge apparatus under different conditions. These were:—

G group— Atmospheric pressure & low temperature
H „ — do. do. & high temperature
L „ — Reduced pressure & low temperature.

The low temperature was the room temperature. The high temperature was obtained by placing an electric bulb in the front compartment of the Cambridge apparatus and observing to one pendulum only, at a time, placed in the back compartment. The apparatus was covered with a blanket, to reduce loss of heat, and observations started about 18 hours after the bulb had been lighted, when the apparatus had reached a fairly constant temperature. The bulb remained lighted during the observations.

In this case sway correction had to be determined, and was found to be $6^s \times 10^{-7}$.

Details of the observations are given in Table 1. By the method of least squares, the values of k & k' were obtained for the three pendulums from these three groups of observations.

The constants obtained were:—

Pendulum	A	B	C
Temperature factor (k)	$4^s \cdot 4 \pm 0 \cdot 27$	$4^s \cdot 4 \pm 0.20$	$4^s \cdot 2 \pm 0 \cdot 26$
Density factor (k')	$669 \pm 5 \cdot 7$	$664 \pm 5 \cdot 0$	$660 \pm 4 \cdot 7$

The unit is the 7th decimal place of a second of time. For comparison, the constants of the brass Potsdam (1902) pendulums are given below, in the same units:—

Pendulum No.	137	138	139	140
Temp. factor	$49^s \cdot 2 \pm 0 \cdot 1$	$48^s \cdot 9 \pm 0 \cdot 2$	$49^s \cdot 1 \pm 0 \cdot 2$	$48^s \cdot 9 \pm 0 \cdot 1$
Density factor	$594 \pm 2 \cdot 5$	$572 \pm 6 \cdot 5$	$606 \pm 1 \cdot 0$	$606 \pm 1 \cdot 7$

9. Reduced time of vibration at Cambridge and deduced value of gravity at Dehra Dun.—With a view to redetermining the value of g at Dehra Dūn, the L group of observations were observed between wireless time signals (Paris rhythmics), so that the reduced value S_0 of the time of vibration at Cambridge could be obtained.

The value of g at Cambridge is 981·265 cm/sec^2, obtained independently by Dr. F.A. Vening Meinesz from Potsdam, and by Sir G. P. Lenox Conyngham from Kew. On arrival in India the pendulums were swung at Dehra Dūn in November 1927. The results are tabulated below:—

Station	Date	A	B	C
		s	s	s
Cambridge ...	May 1927	0·507 3845	0·507 3861	0·507 3855
Dehra Dūn ...	Nov. 1927	9526	9537	9534
Difference		− 5681	− 5676	− 5679
Deduced value of g at Dehra Dūn		979·0715	979·0732	979·0722 cm/ sec^2

10. Observer.—All the above observations and the isochronization of the pendulums were done by Major E. A. Glennie.

11. Wireless receiving set.—In order to receive wireless time signals with certainty in India, a highly efficient wireless receiving set was obtained. This set was the R.P. 11, specially designed by the Marconi Wireless Telegraph Company for time signal reception at wave lengths of over 15,000 metres.

It has 4 valves with a 3-foot square frame aerial, and consists of a detector, a note-filter amplifying stage, a plain note magnifier stage and a local oscillator. With this, no difficulty is experienced in receiving time signals in India from Rugby, Bordeaux and Nauen, though signals from Nauen are rather faint. The directional properties of the frame aerial enables atmospherics to be greatly reduced.

A device, known as the "phazing unit" P. B. 1 with a fifth valve, can be coupled to the receiver, bringing in a small vertical aerial 30 ft. high. This gives increased directional properties, and was intended to further eliminate atmospherics. In practice its use gives a great increase in the volume of sound, but atmospherics are not reduced, and, if there are thunder-storms near by, the time signals are best received without the phazing unit. A picture of the wireless set is given in Plate VIII.

12. Field Season 1927-28.—The field season was planned to extend our knowledge of gravity and the geoid to the extreme north-west borders of India, and also to discover whether any exceptional Hayford gravity anomalies would be found in the neighbourhood of the Hāmūn-i-Māshkel in the Chāgai district, upper Baluchistān.

The party took with it a large prismatic astrolabe, so that astronomical latitudes and longitudes could be obtained. The field season's work is conveniently divided into two main portions, which are described below:–

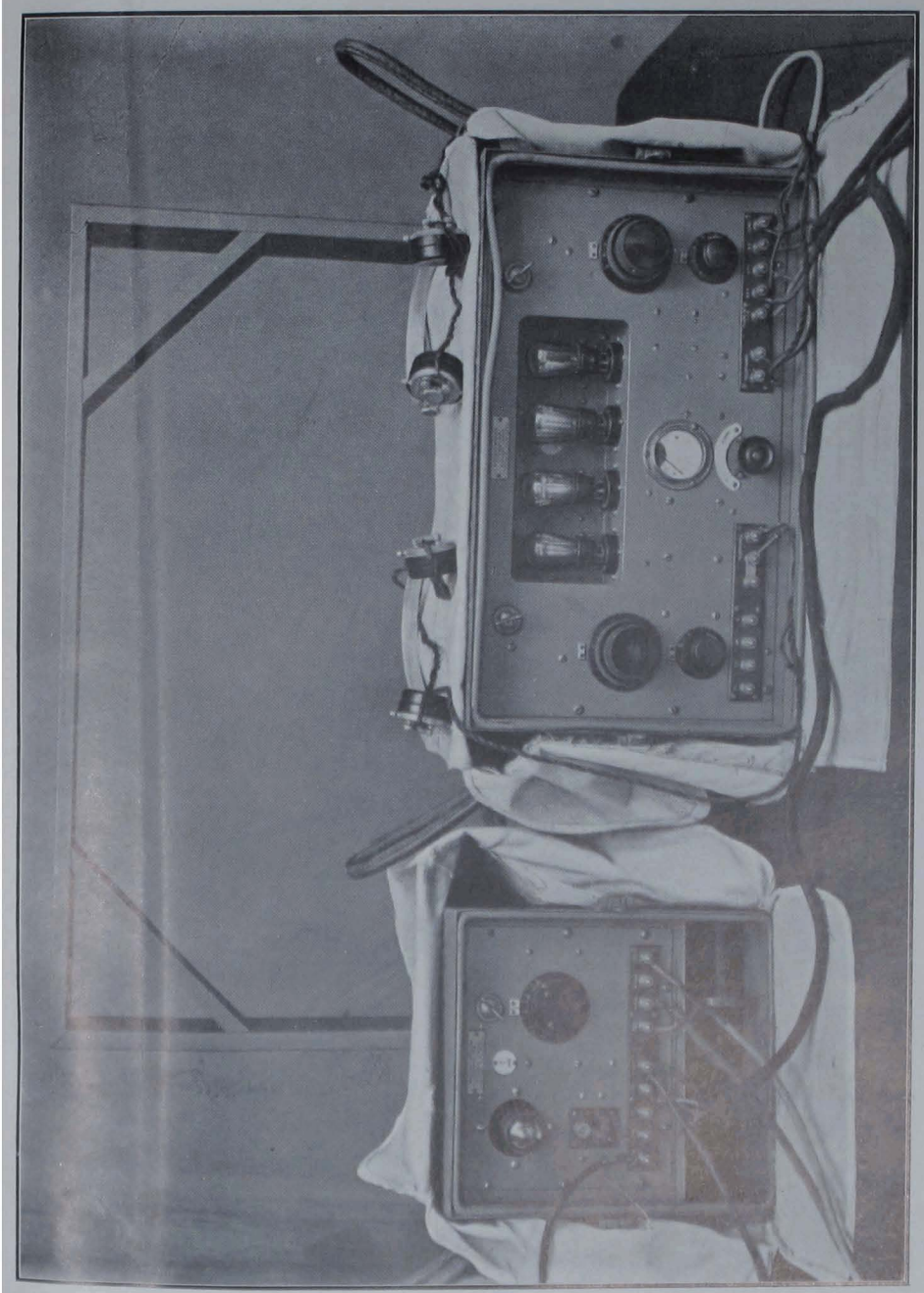
I. Observations in Las Bela State and Sind.

Stations.—Observations were made at seven stations on a line running roughly from west to east through Karāchi, (the line extending from Chandragup, 150 miles west, to Kakeja, near the Rann of Cutch, 100 miles to the east of Karāchi) as well as at Hyderābād (Sind).

Observations were first made at Karāchi, while camels were being collected by the Wazīr of Las Bela for the journey to Chandragup. These camels proving satisfactory, they were retained for the whole time until the party entrained at Badin for Hyderābād.

Nature of the country.—Las Bela, though very sandy and dry, presented a charmingly variable type of scenery, and abounded in small game. Ibex and panther are plentiful in the low Haro Range, west of the Relu station.

Chandragup, which is a triangulation station of the Makrān Coast series of 1896, turned out to be an active mud volcano, and, in the hills around, are numberless mud cones, some of them active. An exceptionally big one over 1,000 feet high is shown in the back ground of Plate IX. In the foreground can be seen the valley, filled with mud,

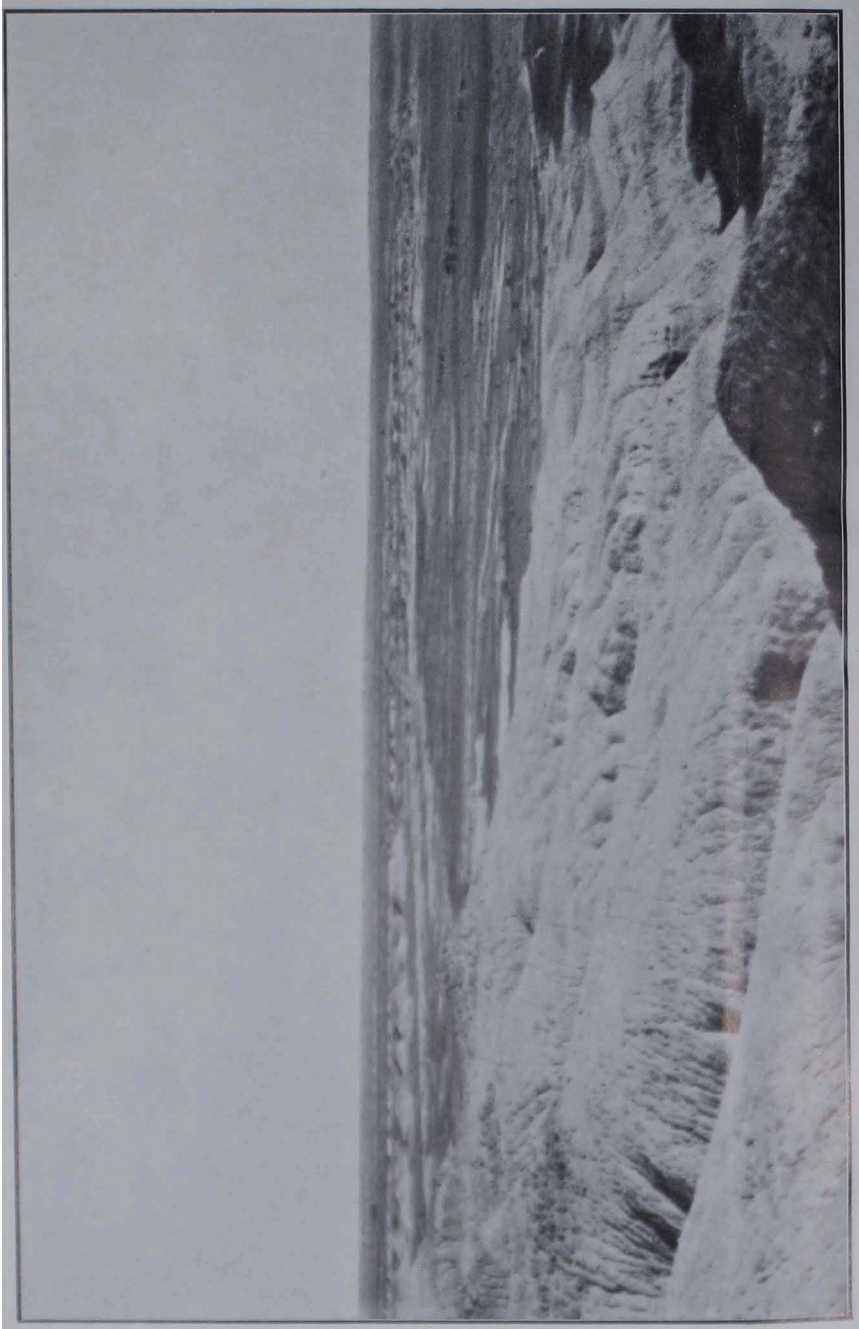


THE WIRELESS RECEIVING APPARATUS

Photo.-engraved and printed at the Offices of the Survey of India, Calcutta, 1929

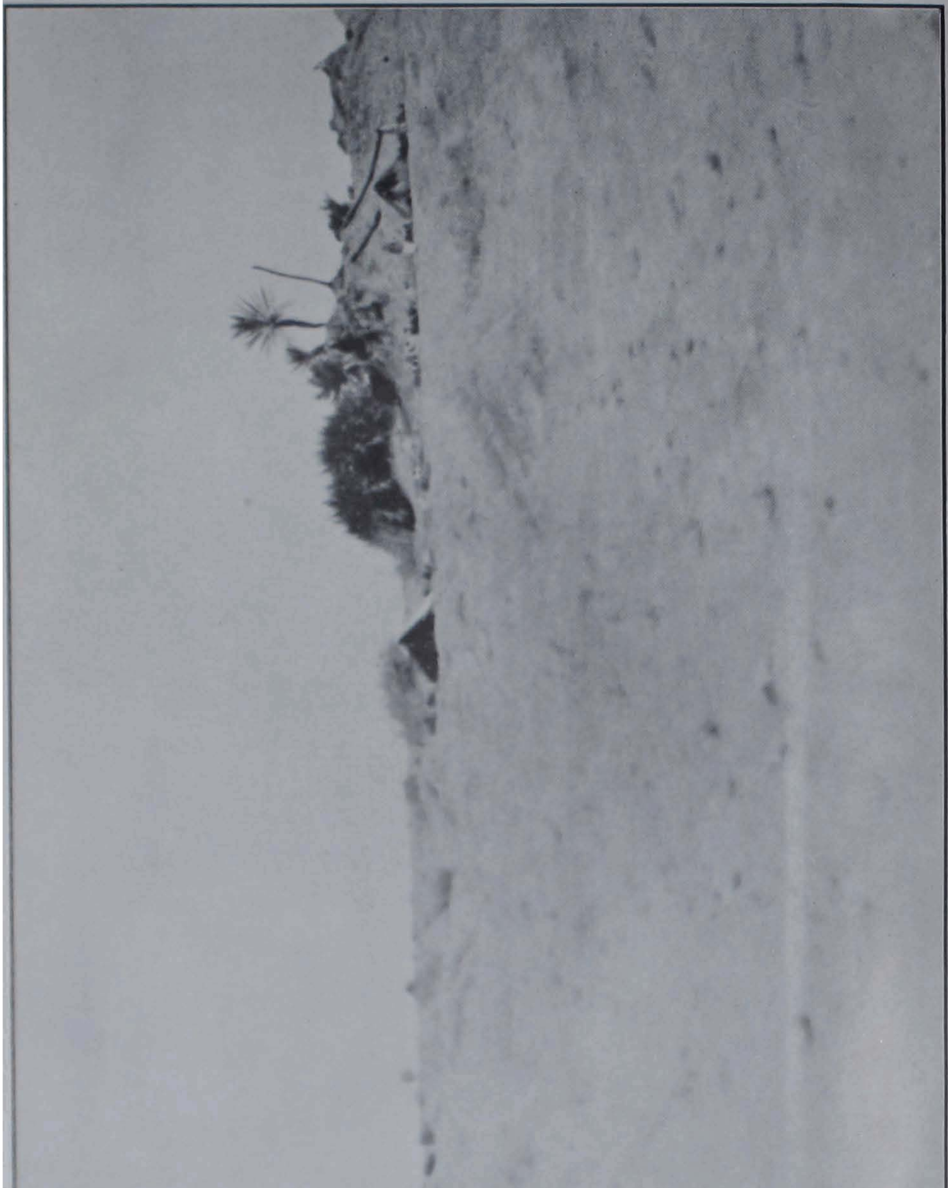
MUD VOLCANO IN THE HARO RANGE, LAS BELA STATE, WITH "MUD GLACIERS"
The mud volcano is in the back-ground about 3 miles away

Photo.-engraved and printed at the Offices of the Survey of India, Calcutta, 1929



HĀMŪN-I-MĀSHKEL, LOOKING SOUTH FROM THE ESCARPMENT

Photo.-engraved and printed at the Offices of the Survey of India, Calcutta, 1929



THE KALANDI OASIS, HĀMŪN-I-MĀSHKEL

The Spring is to the left of the clump of dwarf palm

Photo-engraved & printed at the Offices of the Survey of India, Calcutta, 1929

which being impregnated with hygroscopic salts, remains plastic and flows exactly like a glacier.

Oil was seen on the surface of a stream in this neighbourhood. The Sind country, in comparison with Las Bela, was most uninteresting, mainly a flat clayey plain.

II. On the Nushki-Duzdap railway extension and in the neighbourhood of the Hamun-i-Mashkel

Stations.—Observations were made at five stations on the railway more or less equally spaced from Nushki to Warechah. The Hāmūn-i-Māshkel stations were spaced about twelve miles apart on a line run roughly north from Galugah Fort across the east end of the depression.

Special reasons for observations in the Hāmūn.—The Hāmūn-i-Māshkel area was specially selected by the Surveyor General for gravity observations, because the topographical surroundings were similar to those of Seattle in America, where exceptionally large negative Hayford anomalies have been found and Brigadier Tandy was of opinion that, if similar anomalies were found in this region, some progress towards the solution of the problem raised by them might be made. The observations however show conclusively that there are no exceptional anomalies in this region.

The Hāmūn-i-Māshkel itself is a vast expanse of saltpetre. Only a narrow arm of this at the eastern end, known as the Wadi-i-Sultān, was crossed by the party. For about six hours the party crunched through a white efflorescence of saltpetre, gleaming like snow in the moonlight.

South of the Hāmūn the ground rises rapidly to the hills. On the north, for 15 miles or more, it is flanked by a flat desolate plain of light salt-impregnated soil, covered thickly with small black pebbles; then the ground rises abruptly a hundred feet in an escarpment to a plain, which slopes gently northwards. The black pebbles are a very pleasant feature, since, as a result, there is no glare.

Everywhere there are signs of volcanic activity, the active volcano Koh-i-Taftān, over 13,000 feet high, is to the west; to the north is Miri Sultān, which is apparently a great cinder cone.

It seems likely that this is an area of subsidence resulting from the volcanic outpourings round it. In the part traversed by the party, except for a line of high sand dunes near Galugah Fort, there is practically no sand. The area round Rahro is fertile and cultivated, the population migrating to the fertile date groves of Lādgasht for the hot weather.

Water supply in the Hāmūn area.—It was most fortunate that exceptional rains occurred, filling the water-holes a fortnight before the party entered this area. The water was green and very lively, but no ill health resulted, At the Wadi-i-Sultān station, water had to be carried to the camp from the Kalandi spring, 15 miles away.

Climatic conditions in the Hāmūn area.—Remarkable changes in temperature occur at this time of the year, thus on the 3rd of March the maximum day temperature was over 90° in the shade and the

night was oppresssively hot, but, two days later, there was an icy wind from the west and the temperature at noon was barely above freezing point in the shade. During the next week there was frost at night, 8° of frost being recorded on two occasions, after which it again became hot.

Visibility.—Owing to sand haze visibility in the Hāmūn area was very limited, so that resections from points on the distant mountains were not possible. The astrolabe was used to give the position of the gravity stations astronomically, except at Galugah, which was close to a triangulated point, and heights had to be estimated. This was easy owing to the extreme flatness of the country, so that the estimated heights are not likely to be as much as 20 feet in error. Local thunderstorms made barometric pressure very variable, so barometric or hypsometric heights could not be relied on.

Escort.—As there was danger of raiding from lawless bands from across the Persian border, an escort of eighteen tribal levies was provided for the party. This escort and the camel men were a very cheery lot, in marked contrast to those in Las Bela, and the marches were enlivened with song throughout the night.

They were remarkable athletes; several could clear a height of over five and half feet with a bad take off. They were however poor marksmen, a two-foot square target remaining nearly intact after about a hundred rounds had been fired at it from a distance of a hundred yards. The party was undisturbed by raiders.

13. Strength of party, transport and health.—The party consisted of two officers, a clerk, two computers and 24 khalāsis. The gravity and astronomical observations were done by Major E. A. Glennie and Mr. B. L. Gulatee, B. A.

Camel transport was employed throughout the season. Owing to the heat and arid nature of the country the party nearly always marched at night, frequently striking camp at 5 p.m. and reaching the next camp at 8 a.m. or later; and then observations would commence at nightfall the same day.

Except for some fever at Hyderabād, health was excellent.

14. Clock rates.—The clock used for gravity work was the Strasser and Rohde pendulum clock No. 238. This had been overhauled at the Mathematical Instrument Office, Calcutta, after the Kashmir season, and gave excellent results.

The rates were obtained by getting time signals twice daily from Bordeaux, and twice daily from Rugby, the times of receipts of signals, in Indian Standard Time, being:—

Bordeaux	1.30 p.m. and 1.30 a.m.
Rugby	3.30 p.m. and 11.30 p.m.

A relay was used to break the ear-phone circuit of the wireless receiver, so that the signals vanished, as coincidence with the clock beats approached, the first wireless signal after the silent period marking the coincidence.

CHART OF OBSERVATIONS FOR GRAVITY IN BALUCHISTĀN AND SIND

Chart V

Reg. No. 1811 D.D.D. 1929 (C.O.)-S. I.–

Helio. S. I. O. Dehra Dūn

REFERENCES

Gravity Stations season 1927-28 ○

" " previous seasons ⊙

Free air Gravity anomalies +0·005 Cm/Sec²

Scale $\frac{1}{5{,}000{,}000}$ or 1·014 Inches to 80 Miles

Miles 50 25 0 50 100 Miles

Note:- Height Contours are in feet and show average heights or depths.

Hayford gravity anomaly contours

−·060 C m/Sec²

−·040

−·020

+·000

+·020

+·040

To accompany Geodetic Report Vol. IV

15. Pendulum results.—The differences between individual and mean pendulums are shown in Table 2.

Times of vibration at Dehra Dūn are given in Table 3, and mean times of vibration and deduced values of g in Table 4. A summary of results is given in Table 5, which also includes all other modern gravity observations in India, arranged by seasons. "The average height map of India" (*vide* Geodetic Report Vol. 1. § 150), now approaching completion, was used to get out the effects of topography and isostatic compensation for all Hayford zones outside a radius of 32 miles, and saved an immense amount of labour.

16. Astronomical observations.—At all stations a programme of astronomical observations was carried out, using the large prismatic astrolabe. The positions of three stations in the Hāmūn-i-Māshkel area (viz Hāmūn, Rahro, and Wadi-i-Sultān), which, owing to bad visibility, could not be fixed by theodolite resection, were obtained in this way.

At other stations the observations give the deflections of the plumb-line in the meridian, and prime vertical.

The astronomical programme usually consisted of about four hours work on three or four consecutive nights at each station, and was planned to give about twenty groups of stars.

The clock used was a break-circuit chronometer No. 12831 by Messrs T. Mercer & Co. of St. Albans. The pendulum clock was not used, so that the star programme could be carried out without any interruption to the pendulum work. The star clock was compared each evening with the pendulum clock, as the latter was used for the wireless time signals. A portable drum chronograph by the same makers was employed for the star observations and the clock comparisons.

17. Results.—There has not been sufficient time in recess to complete the astronomical results rigorously. Deflections have been got out hastily by the graphical method from two or three groups of stars only at each station.

Chart V shows in figures the free-air gravity anomalies and by contours the Hayford gravity anomalies. The height and depth contours in this chart are average height contours from the average height map. Until the astrolabe work has been rigorously computed, and corrections for topography and compensation have been applied to the deflections, it would be premature to form any definite conclusions. The deflections are in all cases towards the nearer visible masses. A spur of high density evidently runs south of Karāchi under the shallow sea, Manora Point and the Oyster Rocks being projections from this spur. In the case of the Dālbandin and Yakmach deflections which appear inconsistent, the nearer masses have been concealed in the process of averaging out the height. Negative Hayford gravity anomalies were expected near Chandragup; these agree with the negative anomalies obtained in other oil-bearing regions.

There are no exceptional anomalies in the Hāmūn-i-Māshkel area. This is probably an area of subsidence which is not overlaid by a great depth of alluvium.

TABLE 1.—*Observations at Cambridge.*

Low temperature and Atmospheric pressure (4th May to 6th May 1927)				*High temperature and Atmospheric pressure* (9th May to 11th May 1927)				*Low pressures* (14th and 15th May 1927)			
Group	$S'_{38}-S'_{A}$ sec. × 10^{-7}	Air density	Temperature °C	Group	$S''_{38}-S''_{A}$ sec × 10^{-7}	Air density	Temperature °C	Group	$S'''_{38}-S'''_{A}$ sec. × 10^{-7}	Air density	Temperature °C
Pendulum A											
G_3	13187	0·9468	11·59	H_9	13136	0·9072	28·97	L_1	13750	0·10910	10·34
G_4	13198	0·9417	12·36	H_{10}	13148	0·9071	28·97	L_2	13754	0·10919	10·74
G_6	13182	0·9398	13·42	H_{11}	13128	0·9069	29·04	L_3	13755	0·10922	11·29
G_7	13185	0·9403	13·66	H_{12}	13149	0·9060	29·24	L_4	13748	0·10939	12·13
G_8	13183	0·9403	13·83								
Mean	13187	0·9418	12·97	Mean	13140	0·9068	29·05	Mean	13752	0·10922	11·12
Pendulum B											
G_3	13175	0·9468	11·59	H_5	13119	0·8914	31·95	L_5	13708	0·13768	12·13
G_4	13180	0·9417	12·35	H_6	13128	0·8918	31·85	L_6	13704	0·16194	12·58
G_9	13165	0·9488	12·66	H_7	13119	0·8926	31·71	L_7	13705	0·13866	13·17
G_{11}	13174	0·9480	13·12	H_8	13125	0·8951	31·30	L_8	13692	0·14666	13·67
Mean	13173	0·9463	12·43	Mean	13123	0·8927	31 70	Mean	13702	0·14623	12·89
Pendulum C											
G_6	13187	0·9398	13·42	H_1	13166	0·9039	27·01	L_1	13746	0·10924	10·31
G_7	13184	0·9403	13·67	H_2	13157	0·9043	26·84	L_2	13748	0·10919	10·75
G_8	13190	0·9403	13·83	H_3	13162	0·9048	26·61	L_3	13747	0·10936	11·27
G_9	13181	0·9488	12·65	H_4	13149	0·9041	26·80	L_4	13740	0·10941	12·09
G_{11}	13190	0·9481	13·10								
Mean	13186	0·9435	13·33	Mean	13159	0·9043	26·82	Mean	13745	0·10930	11·11

TABLE 2.—*Difference between individual and mean pendulums, season 1927-28.* (The unit is 10^{-7} sec.).

Name of station	A	v	B	v	C	v
Dehra Dūn ...	+ 6	+ 2	− 5	− 5	− 2	+ 1
Chandragup ...	+ 8	+ 4	+ 3	+ 3	−11	− 8
Relu ...	+ 4	0	0	0	− 3	0
Gadāni ...	+ 8	+ 4	−16	−16	+ 9	+12
Karāchi ...	+ 5	+ 1	− 3	− 3	− 2	+ 1
Sāhiji ...	− 4	− 8	+10	+10	− 6	− 3
Vikia ...	−15	−19	+29	+29	−13	−10
Kakeja ...	+ 4	0	− 4	− 4	− 1	+ 2
Hyderābād (Sind) ...	+ 8	+ 4	+ 4	+ 4	−12	− 9
Dālbandin ...	+ 1	− 3	+ 1	+ 1	− 3	0
Galugah ...	+ 3	− 1	− 1	− 1	− 3	0
Hāmūn ...	+ 5	+ 1	− 6	− 6	+ 1	+ 4
Rahro ...	− 4	− 8	+17	+17	−13	−10
Wadi-i-Sultān ...	+ 5	+ 1	− 3	− 3	− 1	+ 2
Nokkondi ...	+11	+ 7	− 2	− 2	− 8	− 5
Warechah ...	+ 4	0	−10	−10	+ 6	+ 9
Yakmach ...	+ 3	− 1	− 5	− 5	+ 3	+ 6
Nushki ...	+12	+ 8	− 4	− 4	− 7	− 4
Dehra Dūn ...	+ 5	+ 1	− 6	− 6	+ 2	+ 5
Means ...	+ 4		0		− 3	

TABLE 3.—*Times of vibration at Dehra Dūn.*

Date	A	B	C	Mean
1927-28	*s*	*s*	*s*	*s*
November 3, 4	0·5079523	0·5079534	...	
,, 4	9528	9540	...	
,, 4, 5	9507	...	0·5079518	
,, 5	9542	...	9545	
,, 5, 6	9527	...	9534	
,, 6	9528	...	9538	
Mean	0·5079526	0·5079537	0·5079534	0·5079532
April 17	0·5079522	..	0·5079524	
,, 17	9524	...	9524	
,, 18	9510	...	9511	
,, 18	...	0·5079537	9528	
,, 19	...	9523	9517	
,, 19	...	9531	9527	
Mean	0·5079519	0·5079530	0·5079522	0·5079524
General Mean ..	0·5079523	0·5079533	0·5079528	0·5079528
Difference Apr.−Nov.	−7	−7	−12	−8

TABLE 4.—*Mean times of vibration and deduced values of g, season 1927-28.*

Name of station		A	B	C	Mean
Chandragup	s	0·5079803	0·5079808	0·5079822	0·5079811
	$s - s_0$	+280	+275	+294	+283
	g	978·955	978·957	978·950	978·954
Relu	s	0·5079778	0·5079782	0·5079785	0·5079782
	$s - s_0$	+255	+249	+257	+254
	g	978·965	978·967	978·964	978·965
Gadāni	s	0·5079777	0·5079801	0·5079776	0·5079785
	$s - s_0$	+254	+268	+248	+257
	g	978·965	978·960	978·968	978·964
Karāchi	s	0·5079787	0·5079795	0·5079794	0·5079792
	$s - s_0$	+264	+262	+266	+264
	g	978·961	978·062	978·960	978·961
Sāhiji	s	0·5079820	0·5079806	0·5079822	0·5079816
	$s - s_0$	+297	+273	+294	+288
	g	978·949	978·958	978·950	978·952
Vikia	s	0·5079864	0·5079820	0·5079862	0·5079849
	$s - s_0$	+341	+287	+334	+321
	g	978·932	978·952	978·934	978·939
Kakeja	s	0·5079832	0·5079840	0·5079837	0·5079836
	$s - s_0$	+309	+307	+309	+308
	g	978·944	978·945	978·944	978·944
Hyderābād (Sind)	s	0·5079738	0·5079742	0·5079758	0·5079746
	$s - s_0$	+215	+209	+230	+218
	g	978·980	978·982	978·974	978·979
Dālbandin	s	0 5079741	0·5079741	0·5079745	0·5079742
	$s - s_0$	+218	+208	+217	+214
	g	978·979	978·983	978·979	978·980
Galugah	s	0·5079746	0·5079750	0·5079752	0·5079749
	$s - s_0$	+223	+217	+224	+221
	g	978·977	978·979	978·977	978·978
Hāmūn	s	0·5079713	0·5079724	0·5079717	0·5079718
	$s - s_0$	+190	+191	+189	+190
	g	978·990	978·989	978·990	978·990
Rahro	s	0·5079696	0·5079675	0·5079705	0·5079692
	$s - s_0$	+173	+142	+177	+164
	g	978·996	979·008	978·995	979·000
Wadi-i-Sultān	s	0·5079611	0·5079619	0·5079617	0·5079616
	$s - s_0$	+088	+086	+089	+088
	g	979·029	979·030	979·029	979·029

(*Continued*)

TABLE 4.—*Mean times of vibration and deduced values of g, season 1927-28—(contd.).*

Name of station		A	B	C	Mean
Nokkondi	s	0·5079616	0·5079629	0·5079635	0·5079627
	$s - s_0$	+093	+096	+107	+099
	g	979·027	979·026	979·022	979·025
Warechah	s	0·5079592	0·5079606	0·5079590	0·5079596
	$s - s_0$	+069	+073	+062	+068
	g	979·036	979·035	979·039	979·037
Yakmach	s	0·5079681	0·5079689	0·5079681	0·5079684
	$s - s_0$	+158	+156	+153	+156
	g	979·002	979·003	979·004	979·003
Nushki	s	0·5079744	0·5079760	0·5079763	0·5079756
	$s - s_0$	+221	+227	+235	+228
	g	978·978	978·975	978·972	978·975

TABLE 5.—*Modern gravity observations in India.*

No.	Sheet No.	Station	Date	Height	Latitude N.	Longitude E.	g	$g-\gamma_A$	$g-\gamma_C$
				feet	° ′ ″	° ′ ″	*cm/sec²*	*cm/sec²*	*cm/sec²*
1	53J	Dehra Dūn ...	1 2 04	2239	30 19 29	78 03 22	979·063	−0·074	+0·006
2	66C	Madras ...	5 3 04	20	13 04 08	80 14 54	978·279	−0·013	−0·053
3	47B	Colāba ...	20 3 04	34	18 53 45	72 48 47	978·631	+0·063	+0·063
4	53J	Mussoorie ... (Dunseverick)	24 4 04	7129	30 27 28	78 03 33	978·776	+0·087	...
5	„	„ (Camel's Back)	17 5 04	6924	30 27 35	78 04 32	978·793	+0·085	+0·053
6	73H	Cuttack ...	14 12 04	92	20 29 05	85 52 01	978·659	+0·006	+0·006
7	78D	Chātra ...	1 1 05	64	24 12 40	88 23 27	978·878	−0·014	+0·005
8	78C	Kisnapur ...	19 1 05	113	25 02 26	88 28 29	978·956	+0·012	+0·039
9	78B	Jalpaigurī ...	1 2 05	268	26 31 16	88 44 13	978·922	−0·113	−0·020
10	„	Kesarbāri ...	16 2 05	204	26 07 41	88 31 26	978·952	−0·060	+0·003
11	78C	Rāmchāndpur ...	26 2 05	132	25 40 57	88 32 58	978·968	−0·019	+0·021
12	78B	Siligurī ...	14 3 05	387	26 41 47	88 24 50	978·887	−0·149	−0·039
13	78A	Darjeeling ...	21 3 05	6966	27 02 47	88 16 08	978·501	+0·055	+0·032
14	78B	Kurseong ...	29 3 05	4913	26 52 51	88 16 45	978·626	0·000	+0·010
15	78A	Sandakphū ...	12 4 05	11766	27 06 06	88 00 15	978·190	+0·189	+0·048
16	53E	Simla ...	16 12 05	7043	31 06 19	77 09 50	978·840	+0·091	+0·036
17	53B	Kālka ...	23 12 05	2202	30 50 08	76 56 22	979·147	−0·034	+0·018
18	44N	Ludhiāna ...	2 1 06	835	30 55 25	75 51 09	979·274	−0·042	+0·002
19	44 I	Miān Mīr ...	11 1 06	708	31 31 37	74 22 32	979·383	+0·007	+0·040
20	44J	Ferozepore ...	19 1 06	647	30 55 48	74 37 04	979·341	+0·007	+0·038
21	43P	Pathānkot ...	3 2 06	1088	32 16 33	75 39 03	979·237	−0·165	−0·076
22	44F	Montgomery ...	18 2 06	557	30 39 47	73 06 18	979·321	0·000	+0·019
23	39J	Dera Ghāzi Khān	1 3 06	397	30 03 49	70 45 38	979·192	−0·097	−0·064
24	39N	Multān ...	9 3 06	404	30 11 11	71 25 51	979·243	−0·055	−0·031
25	39D	Jacobābād ...	17 3 06	183	28 16 34	68 27 05	979·186	+0·014	+0·038
26	34O	Sibi ...	23 3 06	434	29 32 46	67 52 31	979·119	−0·127	−0·059
27	„	Mach ...	30 3 06	3522	29 52 25	67 18 20	978·960	−0·021	−0·003
28	34N	Quetta ...	4 4 06	5520	30 12 15	67 00 41	978·851	+0·031	+0·007
29	53K	Hardwār ...	8 12 06	949	29 56 29	78 09 19	979·122	−0·106	−0·017
30	53G	Roorkee ...	18 12 06	867	29 52 20	77 53 59	979·129	−0·101	−0·044
31	„	Nojli ...	27 12 06	879	29 53 28	77 40 25	979·143	−0·088	−0·029
32	„	Kaliāna ...	6 1 07	810	29 30 55	77 39 06	979·154	−0·054	−0·007
33	„	Meerut ...	18 2 07	734	29 00 26	77 41 40	979·151	−0·024	+0·008
34	53H	Gesupur ...	5 3 07	691	28 33 02	77 42 03	979·125	−0·020	+0·005
35	53F	Mohan ...	17 3 07	1660	30 10 53	77 54 37	979·109	−0·070	+0·003
36	„	Asarori ...	26 3 07	2467	30 14 25	77 58 03	979·059	−0·050	+0·004

(Continued)

TABLE 5.—*Modern gravity observations in India—(contd.).*

No.	Sheet No.	Station	Date	Height	Latitude N.	Longitude E.	g	$g-\gamma_A$	$g-\gamma_C$
				feet	° ′ ″	° ′ ″	*cm/sec²*	*cm/sec²*	*cm/sec²*
37	53F	Fatehpur ...	5 4 07	1434	30 25 53	77 43 37	979·147	−0·074	+0·019
38	,,	Kālsī ...	10 4 07	1684	30 31 08	77 50 26	979·131	−0·073	+0·033
39	53J	Rājpur ...	19 4 07	3321	30 24 2	78 05 47	979·002	−0·040	+0·026
40	57G	Bangalore ...	2 2 08	3118	13 00 41	77 35 01	978·025	+0·025	−0·025
41	57D	Mysore ...	7 2 08	2501	12 18 52	76 40 20	978·045	+0·014	−0·023
42	57L	Edgar Shaft (Surface) ...	21 2 08	2945	12 55 47	78 15 41	978·076	+0·064	+0·009
43	58 I	Salem ...	1 3 08	948	11 40 05	78 09 10	978·116	−0·036	−0·048
44	,,	Yercaud ...	6 3 08	4493	11 46 56	78 12 29	977·908	+0·083	−0·033
45	58A	Ootacamund ...	15 3 08	7395	11 24 37	76 42 03	977·735	+0·195	+0·012
46	58F	Kodaikānal ...	22 3 08	7665	10 13 50	77 27 56	977·643	+0·167	−0·032
47	46M	Ujjain ...	31 12 08	1612	23 11 00	75 47 00	978·677	−0·002	−0·011
48	46N	Mhow ...	8 1 09	1903	22 33 10	75 45 40	978·620	+0.009	−0·015
49	,,	Mukhtiāra ...	15 1 09	926	22 23 40	75 58 40	978·664	−0·028	−0·019
50	55B	Mortakkā ...	22 1 09	576	22 13 20	76 02 50	978·703	−0·011	+0·005
51	55C	Khandwā ...	29 1 09	1014	21 49 30	76 21 30	978·692	+0·044	+0·047
52	,,	Asirgarh ...	8 2 09	2077	21 28 10	76 17 50	978·584	+0·057	+0·030
53	46O	Jālgaon ...	18 2 09	760	21 00 00	75 33 50	978·633	+0·011	+0·020
54	55H	Amraotī ...	2 3 09	1123	20 55 50	77 45 40	978·609	+0·025	+0·026
55	55G	Ellichpur ...	13 3 09	1314	21 18 20	77 30 40	978·618	+0·030	+0·031
56	55F	Hoshangābād ...	26 3 09	1002	22 45 00	77 43 50	978·719	+0·011	+0·021
57	,,	Shāhpur ...	4 4 09	1286	22 11 30	77 54 10	978·663	+0·017	+0·023
58	55G	Badnūr ...	11 4 09	2103	21 54 10	77 54 10	978·607	+0·056	+0·038
59	55I	Saugor ...	26 11 09	1757	23 51 47	78 48	978·731	+0·021	+0·011
60	55M	Damoh ...	5 12 09	1213	23 49 54	79 26	978·758	−0·001	+0·004
61	64A	Katnī ...	12 12 09	1254	23 50 25	80 26	978·757	+0·001	+0·007
62	,,	Umariā ...	20 12 09	1499	23 31 37	80 54	978·740	+0·027	+0·029
63	64F	Pendra ...	30 12 09	1996	22 46 41	82 00	978·638	+0·021	+0·008
64	64J	Bilāspur ...	10 1 10	878	22 03 53	82 12	978·681	+0·005	+0·013
65	64G	Raipur ...	20 1 10	996	21 13 56	81 41	978·612	−0·002	−0·003
66	64C	Amgaon ...	31 1 10	1032	21 21 31	80 28	978·614	−0·004	−0·003
67	55F	Seonī ...	13 2 10	2032	22 05 29	77 29	978·622	+0·052	+0·036
68	55M	Jubbulpore ...	25 2 10	1467	23 08 54	79 59	978·719	+0·028	+0·039
69	63D	Maihar ...	15 3 10	1161	24 15 38	80 48	978·784	−0·009	−0·003
70	63G	Allahābād ...	25 3 10	288	25 25 55	81 55	978·943	−0·012	+0·009
71	63J	Sultānpur ...	7 4 10	314	26 16 06	82 04 36	978·959	−0·053	−0·027
72	94D	Rangoon ...	18 11 10	164	16 47 55	96 09 08	978·467	+0·021	+0·016

(*Continued*)

TABLE 5.—*Modern gravity observations in India—(contd.).*

No.	Sheet No.	Station	Date	Height	Latitude N.	Longitude E.	g	$g-\gamma_A$	$g-\gamma_C$
				feet	° ′ ″	° ′ ″	*cm/sec²*	*cm/sec²*	*cm/sec²*
73	85N	Prome ...	28 11 10	101	18 49 40	95 13 40	978·543	−0·016	−0·004
74	85O	He zada ...	10 12 10	46	17 39 17	95 27 18	978·481	−0·020	−0·018
75	85L	Bassein ...	17 12 10	23	16 47 11	94 44 06	978·475	+0·017	+0·005
76	94B	Toungoo ...	2 1 11	159	18 55 50	96 27 03	978·558	0·000	+0·026
77	94A	Pyinmanā ...	14 1 11	409	19 44 25	96 11 56	978·577	−0·004	+0·026
78	84P	Meiktila ...	23 1 11	799	20 51 26	95 51 58	978·617	+0·008	+0·023
79	93C	Mandalay ...	2 2 11	244	21 59 44	96 06 28	978·714	−0·017	+0·028
80	93B	Maymyo ...	11 2 11	3495	22 01 13	96 28 24	978·490	+0·061	+0·018
81	,,	Mogok ...	2 3 11	3685	22 54 51	96 29 51	978·539	+0·071	+0·031
82	84O	Myingyan ...	19 3 11	248	21 28 56	95 23 50	978·690	−0·009	+0·016
83	63P	Japla ...	22 11 11	474	24 31 58	84 00	978·856	−0·020	+0·002
84	72D	Daltonganj ...	6 12 11	707	24 02 05	84 04	978·827	+0·007	+0·025
85	73E	Rānchi ...	30 12 11	2167	23 23 05	85 19	978·691	+0·051	+0·030
86	73D	Gayā ...	12 1 12	361	24 47 42	85 00	978·884	−0·020	+0·009
87	72K	Monghyr ...	19 1 12	154	25 22 53	86 28	978·909	−0·056	−0·025
88	72C	Arrah ...	30 1 12	188	25 34 10	84 39	978·918	−0·056	−0·028
89	63P	Sasarām ...	9 2 12	340	24 57 21	83 59	978·903	−0·014	+0·009
90	63O	Moghal Sarai ...	18 2 12	257	25 17 03	83 06	978·919	−0·029	−0·005
91	,,	Buxar ...	27 2 12	207	25 34 42	83 59	978·933	−0·040	−0·014
92	72F	Muzaffarpur ...	8 3 12	179	26 07 05	85 25	978·934	−0·080	−0·042
93	63N	Majhauli Rāj ...	15 3 12	219	26 17 46	83 58	978·928	−0·094	−0·057
94	,,	Gorakhpur ...	25 3 12	257	26 44 58	83 23	978·936	−0·116	−0·070
95	54L	Lalitpur ...	4 12 12	1199	24 41 29	78 24 26	978·814	−0·005	−0·002
96	,,	Bīna ...	11 12 12	1355	24 10 41	78 11 46	978·795	+0·026	+0·026
97	55E	Bhopāl ...	18 12 12	1630	23 15 58	77 25 00	978·711	+0·029	+0·022
98	54H	Goona ...	27 12 12	1569	24 38 48	77 19 13	978·807	+0·026	+0·019
99	,,	Kalīānpur ...	7 1 13	1763	24 07 11	77 39 17	978·777	+0·050	+0·039
100	54K	Jhānsi ...	19 1 13	858	25 27 02	78 33 43	978·910	+0·007	+0·014
101	54J	Gwalior ...	28 1 13	658	26 13 57	78 12 49	978·958	−0·019	−0·007
102	54G	Sipri ...	9 2 13	1533	25 25 52	77 39 25	978·876	+0·038	+0·029
103	54F	Dholpur ...	19 2 13	577	26 42 01	77 54 47	978·999	−0·019	−0·005
104	54I	Agra ...	26 2 13	535	27 10 20	78 01 07	979·056	−0·001	+0·017
105	54E	Muttra ...	6 3 13	562	27 28 25	77 41 48	979·072	−0·004	+0·015
106	54I	Hāthras ...	13 3 13	587	27 36 52	78 03 22	979·075	−0·009	+0·011
107	,,	Aligarh ...	21 3 13	612	27 53 32	78 00 31	979·075	−0·028	−0·008
108	53H	Khurja ...	28 3 13	649	28 14 19	77 51 53	978·082	−0·043	−0·019

(*Continued*)

TABLE 5.—*Modern gravity observations in India—(contd.).*

No.	Sheet No.	Station	Date	Height	Latitude N.	Longitude E.	g	$g-\gamma_A$	$g-\gamma_O$
				feet	° ′ ″	° ′ ″	*cm/sec²*	*cm/sec²*	*cm/sec²*
109	47B	Alībāg ...	27 12 13	12	18 38 30	72 52 10	978·551	−0·005	...
110	46C	Surat ...	12 1 14	30	21 10 05	72 48 05	978·727	+0·027	+0·032
111	46F	Baroda ...	28 1 14	109	22 18 35	73 11 05	978·749	−0·015	−0·008
112	46A	Ahmadābād ...	4 2 14	156	23 01 20	72 33 55	978·836	+0·031	+0·036
113	46D	Damān ...	5 2 14	15	20 24 45	72 50 05	978·700	+0·043	+0·049
114	45D	Deesa ...	10 2 14	465	24 15 20	72 11 30	978·900	+0·043	+0·047
115	„	Abu ...	19 2 14	3836	24 35 40	72 43 00	978·679	+0·114	+0·029
116	46C	Broach ...	21 2 14	51	21 42 05	72 59 00	978·740	+0·009	+0·015
117	45G	Erinpura ...	26 2 14	872	25 08 55	73 03 35	978·896	+0·016	+0·023
118	„	Pāli Mārwār ...	5 3 14	719	25 47 30	73 19 25	978·950	+0·010	+0·020
119	54N	Etāwah ...	26 11 23	492	26 47 00	79 00 55	978·998	−0·035	−0·013
120	54M	Fatehgarh ...	6 12 23	493	27 22 06	79 38 00	979·023	−0·052	−0·029
121	53P	Pīlībhīt ...	16 12 23	610	28 39 05	79 49 31	979·045	−0·114	−0·055
122	54M	Shāhjahānpur ...	26 12 23	510	27 54 21	79 55 52	979·040	−0·073	−0·039
123	63A	Sītāpur ...	12 1 24	449	27 33 13	80 41 08	979·003	−0·090	−0·054
124	62D	Sonārīpur ...	22 1 24	514	28 27 39	80 44 24	979·013	−0·142	−0·067
125	63E	Bahraich ...	2 2 24	403	27 34 02	81 35 41	978·977	−0·121	−0·062
126	„	Gondā ...	7 2 24	352	27 08 21	81 56 25	978·949	−0·123	−0·085
127	63I	Gainsari ...	11 2 24	364	27 31 43	82 35 45	978·943	−0·156	−0·091
128	72A	Bagaha Ghāt ...	19 2 24	298	27 08 06	84 03 05	978·923	−0·153	−0·088
129	72B	Motīhāri ...	26 2 24	220	26 39 10	84 54 35	978·895	−0·153	−0·099
130	43L	Wazīrābād ...	27 2 25	756	32 26 48	74 06 28	979·394	−0·052	0·000
131	43H	Jhelum ...	3 3 25	764	32 55 20	73 42 41	979·396	−0·088	−0·022
132	43G	Rāwalpindi ...	10 3 25	1754	33 36 41	73 01 07	979·346	−0·103	−0·047
133	„	Murree ...	15 3 25	6885	33 54 07	73 23 15	979·024	+0·032	−0·025
134	43F	Domel ...	22 3 25	2239	34 21 08	73 28 07	979·298	−0·167	−0·048
135	43J	Shādipur ...	14 4 25	5193	34 11 14	74 41 00	979·058	−0·116	−0·030
136	„	Gandarbal ...	1 5 25	5200	34 12 48	74 46 09	979·082	−0·094	+0·010
137	„	Hayan ...	12 5 25	6084	34 13 54	74 58 29	978·990	−0·105	+0·017
138	43N	Sonāmarg ...	22 5 25	9050	34 18 02	75 16 19	978·810	−0·013	+0·043
139	43J	Churawan ...	14 6 25	8151	34 39 32	74 54 01	978·881	−0·056	+0·032
140	43N	Minmarg ...	20 6 25	9351	34 47 30	75 04 49	978·803	−0·033	+0·035
141	„	Deosai I ...	29 6 25	13311	34 57 21	75 14 41	978·625	+0·146	+0·090
142	43M	Deosai II ...	4 7 25	12805	35 02 04	75 23 47	978·627	+0·094	+0·062
143	43N	Deosai III ...	9 7 25	12391	34 55 47	75 25 38	978·674	+0·111	+0·095
144	43J	Lālpur ...	28 7 25	5633	34 05 37	74 32 12	979·080	−0·045	+0·017

(*Continued*)

TABLE 5.—*Modern gravity observations in India—(concld.).*

No.	Sheet No.	Station	Date	Height	Latitude N.	Longitude E.	g	$g-\gamma_A$	$g-\gamma_C$
				feet	° ′ ″	° ′ ″	*cm/sec²*	*cm/sec²*	*cm/sec²*
145	43J	Srīnagar ...	4 8 25	5198	34 04 36	74 49 27	979·095	−0·070	+0·021
146	43K	Pingalan ...	17 8 25	5227	33 54 23	74 55 59	979·075	−0 073	+0·012
147	,,	Yūs Maidān ...	22 8 25	7867	33 49 57	74 39 57	978·918	+0·024	+0·008
148	43K	Korag ...	27 8 25	10952	33 48 32	74 33 19	978·752	+0·149	+0·034
149	,,	Tosh Maidān ...	31 8 25	10315	33 55 18	74 29 58	978 808	+0·135	+0·050
150	35P	Karāchi ...	24 11 27	29	24 50 17	67 02 47	978·961	+0·023	+0·019
151	35G	Chandragup ...	13 12 27	43	25 26 38	65 50 34	978·954	−0 025	−0·023
152	35K	Relu ...	22 12 27	35	25 39 58	66 22 24	978·965	−0·031	−0·019
153	,,	Gadāni ...	31 12 27	67	25 06 36	66 43 42	978·967	+0·010	+0·007
154	35P	Sāhiji ...	15 1 28	211	24 51 18	67 36 06	978·952	+0·031	+0·025
155	40D	Vikia ...	23 1 28	47	24 41 51	68 03 39	978·939	+0·012	+0·010
156	,,	Kakeja ...	30 1 28	33	24 42 55	68 34 26	978·944	+0·014	+0·014
157	40C	Hyderābād (Sind)	9 2 28	41	25 22 59	68 21 17	978·979	+0·004	+0·008
158	34D	Dālbandin ...	24 2 28	2786	28 53 31	64 24 54	978·980	+0·005	+0·009
159	31M	Galugah ...	6 3 28	1634	27 56 29	63 02 55	978·978	−0·033	−0·008
160	30P	Hāmūn ...	9 3 28	1600	28 01 15	63 04 25	978·990	−0·028	−0·008
161	,,	Rabro ...	12 3 28	1600	28 07 18	63 14	979·000	−0·027	−0·007
162	30L	Wadi-i-Sultān ...	16 3 28	1600	28 21 14	62 59 52	979·029	−0·016	+0·006
163	,,	Nokkondi ...	21 3 28	2281	28 40 34	62 44 42	979·025	+0·009	+0·019
164	30H	Warechah ...	24 3 28	2468	28 51 57	61 54 26	979·037	+0·034	+0·048
165	30P	Yakmach ...	29 3 28	2403	26 44 39	63 50 52	979·003	+0·004	+0·014
166	34K	Nushki ..	1 4 28	3339	29 32 27	66 02 43	978·975	+0·002	+0·016

TABLE 6.—*Observations in or near India made by non-departmental observers.*

Sheet No.	Station	Date & observer	Height	Latitude N.	Longitude E.	g	$g-\gamma_A$	$g-\gamma_C$
	The de Filippi Kara-koram Expedition 1914							
			feet	° ′	° ′	*cm/sec²*	*cm/sec²*	*cm/sec²*
53J	Dehra Dūn	Alessio 1914	2229	30 19·5	78 03·2	979·079	−0·059	
43J	Srīnagar ...	,, ,,	5217	34 04·3	74 49·8	979·090	−0·073	
52F	Leh ...	,, ,,	11546	34 10·1	77 35·1	978·529	−0·050	
52B	Lamayaru ...	,, ,,	11319	34 17·0	76 46·4	978·575	−0·035	
43N	Drās ...	,, ,,	10108	34 25·8	75 45·4	978·778	+0·043	
52B	Kargil ...	,, ,,	8901	34 33·7	76 07·5	978·845	−0·014	
52A	Tolti ...	,, ,,	7904	35 02·0	76 06·3	978·853	−0·140	
43M	Wozul Hadur	,, ,,	13921	35 11·9	75 32·3	978·536	+0·093	+0·036
52E	Depsang ...	,, ,,	17582	35 17·4	77 58·4	978·165	+0·056	
43M	Skārdu ...	,, ,,	7326	35 17·8	75 38·5	978·924	−0·145	+0·014
51L	Suget Karaul	G. Abetti 1914	12002	36 20·9	78 01·6	978·741	+0·019	
51F	Yārkand ...	,, ,,	3937	38 24·4	77 15·8	979·530	−0·126	
42M	Kashgar ...	,, ,,	1312	39 28·3	75 59·1	979·537	−0·178	
...	Tashkent ...	,, ,,	479	41 19·5	69 17·7	980·078	−0·059	
	*Dr. Vening Meinesz's Submarine Expedition**							
				° ′	° ′			
...		19 11 23		7 57	61 54	978·136	+0·002	+0·015
...		20 11 23		7 53	65 58	978·111	−0·021	−0·011
...		21 11 23		7 56	68 46	978·102	−0·032	−0·014
49D		22 11 23		8 06	72 48	978·113	−0·024	
59E		24 11 23		7 20	77 28	978·099	−0·020	
59N	Colombo ...	28 11 23		6 56·5	79 51	978·118	+0·012	
68C		5 12 23		5 5·5	80 12	978·168	+0·080	
,,		5 12 23		5 32	80 12·5	978·014	−0·069	
...		8 12 23		5 44	87 07	978·065	−0·020	−0·013
88B		10 12 23		6 02	92 50	978·024	−0·068	
88O	Subang ...	12 12 23		5 55·5	95 19	978·181	+0·097	
97B		18 12 23		6 01	96 55			
97B		18 12 23		6 01	96 59			
97L		19 12 23		4 26	98 53			

* *Vide* Vol. III International Geodetic Report 1926.

Chapter V

TRIANGULATION

BY CAPTAIN G. H. OSMASTON, M.C., R.E.

1. General.—No principal triangulation was undertaken, but No. 15 Party was engaged throughout the season, at the special request of the Director, Frontier Circle, on secondary work in the North-West Frontier Province, where a reliable framework was required to co-ordinate the elaborate network of minor triangulation executed during the last half century.

This work consisted of two extensions connecting the main primary series to recent minor triangulation on the frontier, and the commencement of a secondary series through Wazīristān.

The headquarters moved at the beginning of November 1927 from Murree to Peshāwar, remaining there till work was completed in the middle of April 1928, when the party returned to Dehra Dūn.

2. Personnel.—The party took the field under Captain G. H. Osmaston, R. E., with two computers and 35 khalāsis; the latter were recruited about equally from Pūnch State and Kohāt District with the exception of a few old hands who were taken from the United Provinces as skilled helio men.

3. Triangulation.—*Kurram Series.*—Taking the different series in the order in which they were completed, the first series (Kurram) breaks off from the stations of the North Baluchistān series, a few miles N.W. of Bannu, and extends northwards astride the Kurram river for 70 miles as far as Pārachinār and thence by a minor figure to the Safed Koh Watershed.

The stations were built on bare hill tops ranging in height from 8,000 feet in the north to 2,500 feet in the south.

The preliminary reconnaissance was complicated by the fact that the series was flanked by the politically inaccessible Tīrāh on the east and the Afghān frontier on the west. The problem of avoiding small figures up the Kurram valley proper was finally solved by means of a long ray passing over the former country. All the observations were taken by daylight to signals consisting of helios whenever possible, otherwise to Lucas daylight signalling lamps or X signals of black and white cloth. The lamps were used with success up to a range of 24 miles and the cloth signals up to 35 miles with the sky as a background. The sky was generally overcast but visibility on the whole was good.

Reference numbers and Values of "*m*" and "M" for all Geodetic Series of the Indian Triangulation. (*See* Records of the Survey of India Vol. IX, p. 137).

For 42 Series entering the Simultaneous Grinding (shown in italics below) Mean Square M = ± 1·04
For Series up to No. 99 ... ... Mean Square M = ± 1·33

No.	Name of Series	Seasons	± *m*	± M
1	South Pārasnāth Mer. ...	1831-39	3·308	3·26
2	Budhon Meridional ...	1833-43	2·242	2·46
3	*Amāa Meridional* ...	1834-38	1·647	1·88
4	*Rangir Meridional* ...	1834-64	1·643	1·79
5	*Calcutta Longitudinal* ...	1834-69	0·369	0·32
6	*Great Arc Meridional, Section 24°-30°* ...	1835-66	0·708	0·71
7	*Bombay Longitudinal* ...	1837-63	0·844	0·74
8	*Great Arc Meridional, Section 18°-24°* ...	1838-41	0·567	0·59
9	*Great Arc Meridional, Section 8°-18°* ...	1840-74	0·390	0·36
10	*Singi Meridional* ...	1842-62	1·187	1·14
11	*South Konkan Coast* ...	1842-67	2·176	1·93
12	*Karāra Meridional* ...	1843-45	1·507	1·81
13	*North Malūncha Mer.* ...	1844-46	1·266	1·42
14	*Chendwār Meridional* ...	1844-69	0·841	1·06
15	*Gora Meridional* ...	1845-47	0·973	1·21
16	*Calcutta Meridional* ...	1845-48	1·173	1·99
17	South Malūncha Mer. ...	1845-53	1·606	1·97
18	*Khānpisura Meridional* ...	1845-62	1·227	1·07
19	*Gurwāni Meridional* ...	1846-47	1·165	1·55
20	*North-East Lon.* ...	1846-55	0·446	0·65
21	*Hurilāong Meridional* ...	1848-52	1·502	1·92
22	*North-West Himālaya* ...	1848-53	0·641	0·55
23	*Gurhāgarh Meridional* ...	1848-62	0·914	1·21
24	*East Coast* ...	1848-63	0·608	0·70
25	*Karāchi Longitudinal* ...	1849-53	0·558	0·60
26	*Abu Meridional* ...	1851-52	0·617	0·68
27	*North Pārasnāth Mer.* ...	1851-52	0·895	1·25
28	*Kāthiāwār Meridional* ...	1852-56	0·990	1·11
29	*Gujarāt Longitudinal* ...	1852-62	0·859	1·12
30	Kāthiāwār Lon. ...	1853	1·481	1·34
31	Sābarmati ...	1853-54	1·348	2·84
32	*Great Indus* ...	1853-61	0·359	0·43
33	*Rāhon Meridional* ...	1853-63	0·327	0·37
34	*Assam Longitudinal* ...	1854-60	0·579	0·71
35	*Cutch Coast* ...	1855-58	0·986	1·27
36	Kashmīr Principal ...	1855-60	0·824	0·86
37	*Jogī-Tila Meridional* ...	1855-63	0·481	0·59
38	Sambalpur Lon. ...	1856-57	0·806	0·87
39	(Cutch) Coast Line ...	1856-60	0·975	1·47
40	Kāthiāwār Meridional No. 1 ...	1858-59	0·930	1·51
41	Kāthiāwār Meridional No. 2 ...	1859-60	1·247	1·75
42	Kāthiāwār Meridional No. 3 ...	1859-60	0·969	1·48
43	*Bīdar Longitudinal* ...	1859-72	0·311	0·30
44	*Eastern Frontier or Shillong Meridional* ...	1860-64	0·409	0·49
45	*Sutlej* ...	1861-63	0·346	0·53
46	*Madras Mer. and Coast* ...	1861-68	0·426	0·40
47	Kāthiāwār Meridional No. 4 ...	1863-64	1·154	1·73
48	*East Calcutta Lon.* ...	1863-69	0·379	0·57
49	*Mangalore Meridional* ...	1863-73	0·440	0·45
50	Kumaun and Garhwāl ..	1864-65	1·742	1·50
51	Nāsik ...	1864-65	2·033	3·12
52	Burma Coast ...	1864-82	0·380	0·39
53	*Jubbulpore Meridional* ...	1865-67	0·340	0·31
54	*Madras Longitudinal* ...	1865-80	0·384	0·37
55	Assam Valley Triangulation ...	1867-78	1·690	2·65
56	*Brahmaputra Mer.* ...	1868-74	0·564	0·70
57	Coimbatore No. 1 ...	1869-71	1·547	2·07
58	*Bilāspur Meridional* ...	1869-73	0·302	0·33
59	Cuddapah ...	1871-72	0·826	0·96
60	Hyderābād ...	1871-72	1·405	1·56
61	Malabar Coast ...	1871,74-80	1·532	1·82
62	Jodhpur Meridional ...	1873-76	0·291	0·32
63	*South East Coast* ...	1875-79	0·522	0·65
64	Eastern Sind Mer. ...	1876-81	0·244	0·30
65	Siam Branch Triangulation ...	1878-81	3·711	4·34
66	Mandalay Meridional ...	1889-95	0·418	0·35
67	Mong Hsat ...	1891-93	3·054	3·01
68	Manipur Longitudinal...	1894-99	0·453	0·36
69	Makrān Longitudinal ...	1895-97	0·285	0·26
70	Mandalay Lon. ...	1899-1909	1·696	1·96
71	Manipur Mer. ...	1899-1902 / 1913-1916	0·750	0·81
72	Great Salween ...	1900-11	0·404	0·32
73	Kidarkanta ...	1902-03	1·323	1·62
74	Kalāt Longitudinal ...	1904-08	0·365	0·25
75	Baluchistān Triangulation ...	1908-09	1·348	1·08
76	North Baluchistān ...	1908-10	0·221	0·17
77	Gilgit ...	1909-11	0·443	0·37
78	Khāsi Hills ...	1909-11	2·038	3·01
79	Mawkmai ...	1909-11	1·575	2·35
80	Upper Irrawaddy ...	1909-11	0·596	0·49
81	Jaintiā Hills ...	1910-11	0·986	1·86
82	Bhīr ...	1911-12	0·794	0·94
83	Rānchī ...	1911-12	1·840	2·34
84	Villupuram ...	1911-12	1·184	1·78
85	Sambalpur Meridional...	1911-14	0·250	0·21
86	Indo-Russian Connection	1912-13	2·790	3·92
87	Khandwā ...	1912-13	0·999	1·27
88	Ashta ...	1913-15	1·048	1·33
89	Buldāna ...	1913-14	0·304	0·43
90	Naldrug ...	1913-14	1·465	1·85
91	Nāga Hills ...	1913-14	0·913	0·96
92	Middle Godāvari ...	1914-15	0·913	1·08
93	Kohīmā ...	1914-15	1·094	1·39
94	Cāchār ...	1914-15	1·077	1·65
95	Bombay Island ...	1911-14		
96	Madura ...	1916-17	1·148	1·53
97	Bāgalkot ...	1916-17	0·701	0·89
98	Sind Sāgar Triangulation	1917-18	1·875	3·24
99	Rangoon ...	1925-27	1·246	1·25

Mer. = Meridional. Lon. = Longitudinal.

Chart XIII


INDIA
TRIANGULATION SERIES
AND
AZIMUTH STATIONS
Corrected to Sept. 1928
REFERENCES
Series of Triangulation
Addition Since 1927
Number of Series (vide table opposite) 23
Base Line
Astronomical Azimuths
By reason of the small scale of this chart 4 Azimuth stations have been omitted in the neighbourhood of Dehra Dūn
Scale 1 Inch = 250 Miles or 1/15,840,000
Miles 100 0 100 200 300 400 Miles
BAY OF BENGAL
ARABIAN SEA
CALCUTTA
BOMBAY
MADRAS
DELHI
LAHORE
NĀGPUR
RANGOON
MANDALAY
CEYLON
BANGKOK
ANDAMAN ISLANDS
NICOBAR ISLANDS
Mount Everest 29002
BRAHMAPUTRA R.
INDUS R.
GANGES R.
IRRAWADDY R.
SALWEEN R.
MEKONG R.

Unfriendly tribesmen were effectively countered by militia escorts, which accompanied the observer as well as the signallers at every station.

Several of the new stations were apparently close to the sites of old minor stations, but the old mark was found only in one case. The new stations have auxiliary marks cut on rocks near by and are therefore much less likely to be lost.

Peshāwar Series.—The second series (Peshāwar) extends westwards from the Great Indus series about Campbellpore as far as Peshāwar, where it connects directly with recent minor triangulation in the Khyber area.

The country consists of the broad Kābul river valley bounded on the north by the main Himālayan ranges and on the south by the Cherāt hills. Persistent dust haze in the valley held up both reconnaissance and observations for a time; but owing to the excellent road communications it was possible to seize the occasional opportunities to observe, when visibility was at its best. Connection was made at Takht-i-Bhai and Karamār (Kaloo Khan) with the work of 'A' Company's triangulators, who were commencing a new series northwards towards Chitrāl.

Jalāla Sar was the only station at which the mark-stone of the previous minor triangulation was not found, but from the appearance of the site, it is probable that the new mark differs in position by less than one foot from the old.

Escorts were provided at Jalāla Sar and Michni.

All the observations were made by day to 5-inch helios.

N. Waziristān Series.—The third series (Wazīristān) was commenced in March, breaking off from the same two primary stations as the Kurram series but progressing southwards.

The intention was to run this new series roughly parallel to the frontier from the Tochi valley in the north through Razmak and Wānā to the North Baluchistān series in the vicinity of Fort Sandeman.

Three figures were completed by the middle of April, the terminal stations being a few miles on either side of the Razmak plateau. Unfavourable weather then cut short further work and the party returned to recess headquarters.

As far as Razmak the hills are bare and easy to climb, but a certain amount of clearing on the hill tops will be necessary in the next section southwards.

The uncertain behaviour of the local tribesmen is the only serious difficulty. This season *Khāsadār* escorts were taken to all stations and no trouble was encountered.

The marks of the stations of the old minor triangulation were picked up at Shuidār and Shakāwat.

Observations were taken only in the day time, to helios when possible, otherwise to opaque signals.

It is considered that the results would have been considerably improved if night work had been possible. During the season work was done as a rule between 11 a.m. & 4 p.m. and sometimes considerable shimmering of the helios was unavoidable.

Wild Theodolite.—The small Wild Universal Theodolite with a 3¾-inch horizontal circle was used throughout the season; and as this is the first time that this type of instrument has been used in the Survey of India on any but minor work a detailed account of the results obtained is given in the Appendix to this Chapter.

The strength of the detachment i.e. 35 khalāsis, was almost exactly half the number taken to Burma in the preceding season, when a 12-inch theodolite was used, and other things being equal, a saving of from 15 to 20 men is effected by using the Wild theodolite, a saving which covers the cost of one of these instruments in a single season.

4. Computations.—Adjustment has been carried out by dispersing the errors in individual triangles and taking the means of common sides (i.e. braced quadrilaterals have not been adjusted as such). The data for the triangulation pamphlets have been abstracted in a form suitable for publication.

The values of *m* and M, triangular error and order of merit etc., have been calculated for the three series and these as well as other details of the triangulation are given in the table which follows :—

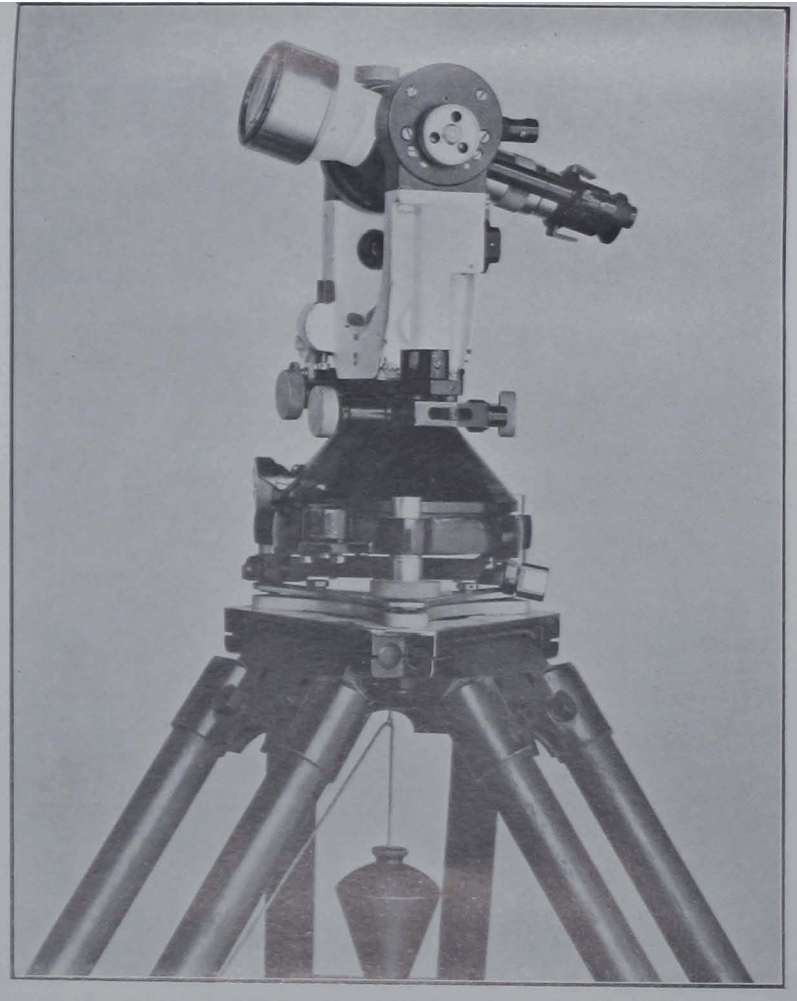
TABLE 1.—*Particulars of triangulation.*

Name of Series	Kurram Series	Peshāwar Series	N. Waziristān Series
Number of new stations built	6	3	3
Number of stations observed at ...	7	7	8
No. of triangles observed ...	7	11	10
Length of Δ^n in miles ...	70	60	41
Area of Δ^n in square miles ...	864	1908	427
Mean length of sides in miles	21·8	34·2	13·7
Average triangular error in seconds ...	2·67	1·58	2·72
Value of *m* (mean square error of an angle) ...	2·012	1·181	1·905
Value of M (criterion of strength of the series) ...	2·13	1·00	2·54
Order of merit ...	83(A)	43 (A)	86 (A)
Instruments used ...	3¾-inch Wild Theodolite No. 1702	3¾-inch Wild Theodolite No. 1702	3¾-inch Wild Theodolite No. 1702

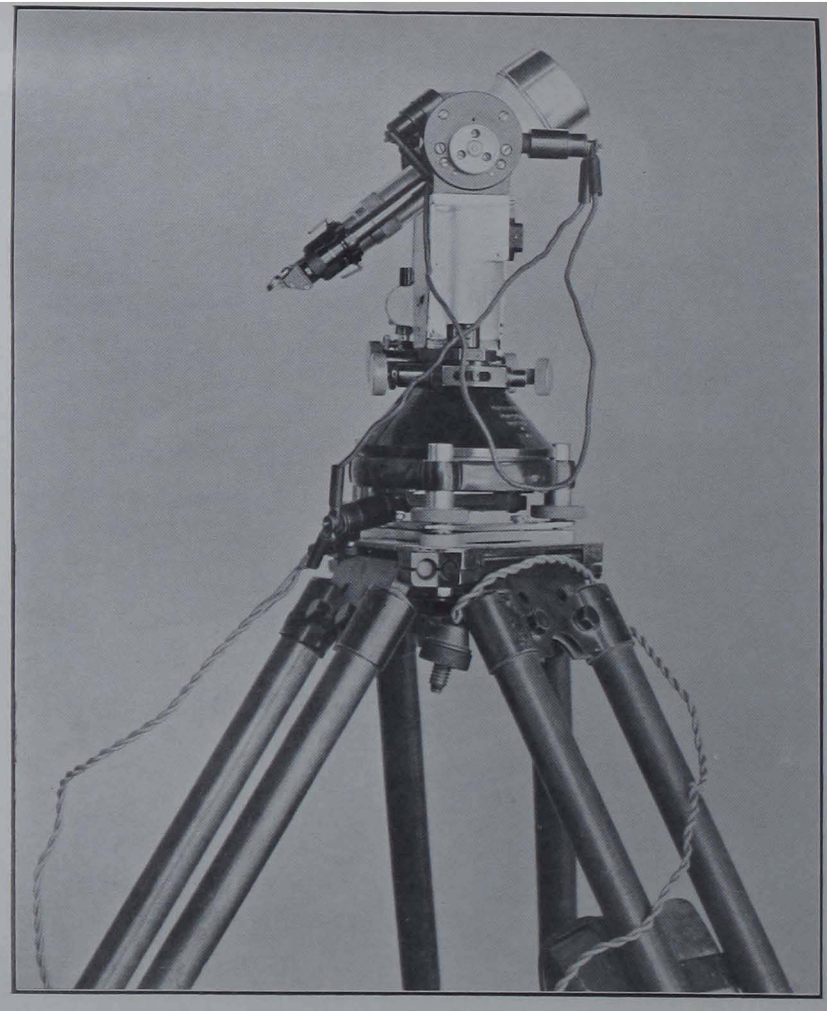
APPENDIX

Field performance of the 3¾-inch Wild Theodolite.

During the cold weather, from October 1927 to April 1928, the small type Wild theodolite was employed on three short extensions on the North-West Frontier of India. The desired accuracy was of secondary order, i.e. the average triangular error was to be within the limit of three seconds of arc.



WILD UNIVERSAL $3\frac{3}{4}''$ THEODOLITE, AS USED FOR DAY OBSERVATIONS.



WILD UNIVERSAL $3\frac{3}{4}''$ THEODOLITE, AS USED FOR NIGHT OBSERVATIONS.

PLATE XIV.

Photo-engraved & printed at the Offices of the Survey of India, Calcutta, 1929.

The instrument used was No. 1702 fitted with telescopic centering, a diagonal eye-piece, and special electric bulbs, holders etc. for night work. This instrument had already seen a year's service in India, and had been well reported on.

Sights for the telescope had been suggested as a necessary addition, and these were fitted before work commenced: no difficulty was then found in picking up small distant objects.

The country was hilly, with communications by motor road and mountain tracks. The theodolite and stand could easily be carried by two men up any mountain, though often during this season one man carried the whole outfit alone.

A leather man-pack equipment, on the principle of a 'rucksack' was constructed which proved very satisfactory and enabled the instrument and stand to be carried comfortably on horseback. It was found that the clamps at the base of the theodolite, inside the dome shaped case, worked loose, and a thin plush cap was therefore provided, which slipped over the theodolite, inside the metal cover, and held every thing firm.

Although this theodolite embodies many entirely new features, the essential qualities to be examined in order to make a trustworthy comparison with other similar instruments, are two only; viz :—those of "portability" and "rapidity of operation", taken in conjunction with some given standard of accuracy.

Accuracy—As the manufacture of instruments has improved, theodolites for work of geodetic accuracy have gradually decreased in size: the old 36-inch theodolite with hand-divided circle has given way to the 24-inch and the latter in its turn has been replaced by smaller models down to the 12-inch theodolite of the beginning of this century, which has held the field for all the most precise work for the last twenty years. The results obtained with these smaller instruments are of the same order of accuracy as with the larger, or perhaps slightly better, and greater accuracy is hardly called for. The results obtained with the $3\frac{1}{4}$-inch Wild are not as good as those taken with a modern 12-inch theodolite, and therefore it cannot replace this instrument for geodetic triangulation. The accuracy was found to be about equal to that of an 8-inch theodolite, with which the best secondary triangulation has generally been associated.

Portability.—Comparing the portability of the Wild with that of an 8-inch theodolite of accepted design it has already been stated that two men are amply sufficient to carry the Wild theodolite and stand under all conditions, also no observatory tent is required; whereas it takes at least 6 men to carry an 8-inch theodolite with its stand in difficult country, and four more are necessary to carry the observatory tent, so that the proportion is 5 to 1 in favour of the Wild, indicating an outstanding advance in design.

Rapidity of operation.—Again comparing the rapidity of operation of the Wild with that of an 8-inch two microscope theodolite, the accuracy may be taken as equal, that is to say the same average triangular error is obtainable from either, if the same number of measures is

taken in each case. The question to be considered is how long the same number of observations takes with each instrument.

The setting up and adjusting of the 8-inch, with its microscopes, takes the best part of two hours, perhaps three hours, including the time taken to level a platform and pitch the observatory tent: this time is wholly saved with the Wild, which has no field adjustments except levelling, and for which an observatory tent is unnecessary.

The intersection as well as the reading and booking of a pointing with the Wild take about the same time as the intersection of the object only, on the larger instrument; walking round and reading the two microscopes takes up at least as much time again. It is therefore fair to say that the observations of both vertical and horizontal angles taken with the Wild theodolite are twice as rapid as those taken with the old 8-inch theodolite.

For secondary work, where an average triangular error of two or three seconds is not to be exceeded, observations, on one afternoon and during part of the following night, would be sufficient with the Wild; whereas the same work would undoubtedly take at least two days with the other instrument. Here again the superiority of the Wild is very marked, and it needs little imagination to see the economical advantages of this instrument over the old type.

If we make a comparison with the smaller and less precise theodolites at present in use, with 6, 5, or even 3-inch circles, the Wild is more accurate, as well as lighter and quicker to operate than any of them; and there is little doubt that it thoroughly deserves its title of 'The Universal Theodolite'.

Observations.—It is not proposed to describe here the details of the Wild theodolite but merely to discuss points of interest which arose during the field season and the resulting conclusions.

It was found that an observatory tent was unnecessary and definitely unsuitable for use with the small Wild, which requires as much light as possible for the reading of its circles; the problems of dust and unequal expansion due to the direct rays of the sun are eliminated by the excellent protection afforded to the circles, which are completely enclosed. The instrument is unaffected by any but a strong wind, when some vibration occurs, but a screen to protect the observer's head would probably improve matters in this respect.

The non-collapsible stand was used throughout and was quite satisfactory; sometimes it appeared to twist during the first twenty minutes or so after being set up, but always settled down after this and remained quite steady in spite of wind and changes of temperature.

The cross-wires in the telescope are somewhat thick, especially for observations to opaque signals, but in other respects nothing better can be desired than the telescope which has plenty of magnification, and a bright clear field.

The diagonal eye-piece enables stars to be observed comfortably up to an elevation of 50°, and the lighting arrangements for night work are adequate, when a battery of sufficient power is provided to maintain the lights for several hours on end.

Six zeros only were observed at each station, and the results show that an increase in accuracy will be obtained by taking more, also the results might have shown considerable improvement had night observations been possible in addition to day.

Regarding adjustments, it has been mentioned in a previous paragraph that the only field adjustment is for level: nevertheless the instrument must be thoroughly tested before use, and from time to time afterwards, to make sure that the factory adjustments have not altered.

Three defects in the permanent adjustments came to light during the season.

Firstly, a difference of $\frac{3}{4}$ inch was found between the telescopic centering and that of a plumb-bob. Telescopic centering however has decided advantages over centering by the plumb-line; it is quite unaffected by wind, and it is easy to centre over a point some considerable distance below the instrument with the telescope, whereas for this purpose the plumb-bob is a clumsy substitute.

A more serious defect than the last was that, after the theodolite had been levelled, the transit axis was permanently tilted from the horizontal by an angle of about 2 minutes. The direct effect was that the 'face right' value of the horizontal angle between two objects differed from the 'face left' value, if the two objects were at different elevations, the mean of the two results giving the correct answer. The readings of vertical angles however were too great on both faces fortunately by quite a negligible quantity for small angles of elevation. It is doubtful whether a fault of this nature can be corrected by any one but the makers.

The third defect was found in reading vertical angles with this particular instrument. The mechanical connection between the vertical circle bubble and the vertical circle, instead of being perfectly rigid, had somehow become loose, allowing as much as twenty seconds play between the two.

The result was that a correct reading could only be obtained when the bubble was centered with a one-way motion of the screw controlling it. If the bubble overshot the mark, it was useless to bring it back by reversing the screw, as this made no change whatever in the position of the vertical circle, till the bubble had been moved back at least 20 seconds. Excellent results were obtained after this defect had been correctly located, by using only a clockwise twist of the screw for centering the bubble on both faces. The bubble itself appeared to be very satisfactory, and sensitive to a single second in the reading of the circle.

It is hardly necessary to point out that although several more or less serious defects have been found and are recorded above, these only involve defects of adjustment and construction in the instrument which was being used, and in no way detract from a sincere admiration for the design and workmanship of this theodolite.

Method of observation.—The general procedure during observation of horizontal angles was as follows:—a 'swing right' was immediately followed by a 'swing left'; the face was then changed and two swings again taken; this completed observations on one zero, unless any of the

measures, so obtained, were inconsistent, in which case the zero was repeated later.

Analysis of the results.—The season's results have been analysed and the main points of interest are shown in Table 2. The three series have been kept separate as they were observed under somewhat different conditions.

1. Kurram Series.—The weather was cloudy, consequently opaque signals were sometimes used; but on the whole conditions were favourable for good observations.

2. Peshāwar Series.—The number of observations taken at each station was increased, and fine weather enabled helios to be used throughout.

3. N. Waziristān Series.—In this work time was an important factor; for political reasons the stations could only be visited for short periods during the day-time, and in one or two cases auxiliary marks close to the stations had to be used instead of helios.

In the first and third series observations at each station were completed in a single afternoon, but, in the second observations frequently extended over two days. No night work was possible.

TABLE 2.—*Analysis of the results.*

Name of Series	Kurram Series	Peshāwar Series	N. Waziristān Series
1. No. of triangles ...	7	11	10
8. No. of angles ...	18	25	21
3. Mean length of sides in miles	21·8	34·2	13·7
4. No. of zeros ...	6	6	6
5. No. of measures per zero ...	4	6	4
6. Greatest zero mean *minus* smallest zero mean in seconds	6·9	6·5	6·8
7. Consistently high zero ...	F. L. 60 F. R. 240	F. L. 60 & 0 F. R. 240 & 180	F. L. 60 F. R. 240
8. Consistently low zero ...	Nil	F. L. 150 F. R. 330	F. L. 150 F. R. 330
9. Weight of an angle ...	0·69	0·80	0·54
10. Average triangular error ...	2·67	1·58	2·72

In the sixth item of the table it is interesting to note that, although better observed, the second series shows but slight improvement on the other two, indicating that a difference of 6·5 seconds is a fairly true measure of the maximum error due to faulty graduation.

Regarding items 7 & 8 of the table, the zeros used were:—

$\left\{\begin{matrix} 0°, 30°, 60°, 90°, 120°, 150°, \text{F. L.} \\ 180, 210, 240, 270, 300, 330, \text{F. R.} \end{matrix}\right\}$. Out of these, the third zero consistently gave high readings, and the last, low readings, though to a less degree, indicating an error in graduation at these two points. The amount seldom exceeded 2 or 3 seconds above or below the other zeros, which was of no consequence in this work.

INDIA

LINES OF

PRECISE LEVELLING

AND

TIDAL STATIONS

Corrected to Sept. 1928

60° 64° 68° 72° 76° 80° 84° 88° 92° 96° 100° 104°

32° 28° 24° 20° 16° 12° 8°

Rakaposhi 25550 · Kunjut 25460 · K² 28250 · Gasherbrum 26470 · Nanga Parbat 26620 · 24370 · 24690 · 21140 · 20410 · 22210 · 20720 · 22028 · Kamet 25447 · Nanda Devi 25645 · Gurla Mandhata 25355 · 22650 · 23359 · Dhaulāgiri 26795 · XXX 26658 · Gosainthān 26291 · Mount Everest 29002 · Makalu 27790 · 23180 · 24740 · 23930 · Kinchinjunga 28146 · 23460 · Namcha Barwa 25445

HERÁT · KÁBUL · PESHÁWAR · Murree · SRINAGAR · Rāwalpindi · INDUS R. · NASRATÁBÁD · KANDAHÁR · Dera Ismail Khān · LAHORE · Amritsar · Ludhiāna · QUETTA · Multan · Sutlej R. · INDUS R. · Jacobabad · Sukkur · Bikaner · DELHI · Jumna R. · Ganges R. · Meerut · Dehra Dūn · AGRA · Lucknow · Fyzabad · Cawnpore · Jodhpur · Gwalior · Benares · Allahabad · Hyderābād · KARÁCHI · Mouths of the Indus · Deesa · Kalianpur · Ahmadābād · Jubbulpore · Navanar · Hanatar · Okha Point · Mhow · Narbada R. · Bhaunagar · Porbandar · Port Albert Victor · NĀGPUR · Hinganghāt · Samlalpur · Prince's Dock · BOMBAY · Apollo Bandar · Poona · Godāvari R. · Bolārum · Secunderābād · Waltair · Vizagapatam · Cocanāda · Bagalkot · Raichūr · Kistna R. · Belgaum · Marmagao · Kārwār · Bellary · Bangalore · MADRAS · Mangalore · Calicut · Beypore · Negapatam · Trichinopoly · Cochin · Madura · Pāmban Pass · Tuticorin · Trincomalee · Minicoy · Nagarkoil · Cape Comorin · Colombo · CEYLON · Galle

BRAHMAPUTRA R. · LHÁSA · Dibrugarh · Darjeeling · Jalpaiguri · Shillong · Chittagong · Myitkyinā · Chindwin R. · SALWEEN R. · MEKONG R. · CALCUTTA · Kidderpore · Diamond Harbour · Dublat (Sagar I.) · Mouths of the Ganges · False Point · Akyab · MANDALAY · Salin · IRRAWADDY R. · Prome · RANGOON · Moulmein · Elephant Pt. · Pilakat Creek · Amherst · Bassein · Diamond I. · Mouths of the Irrawaddy · BAY OF BENGAL · BANGKOK · Mergui · ANDAMAN ISLANDS · Port Blair · NICOBAR ISLANDS

REFERENCES

Levelling of High Precision since 1914

- Projected
- One direction only completed this season
- One direction only completed in previous seasons
- Both directions completed this season
- Both directions completed, one this season and one previously
- Both directions completed previously
- Levelling of precision 1858-1921

Levelling of Secondary Precision (selected lines only)

- Completed 1921-27
- do. this season
- Standard Bench-marks
- Tidal observatory (working) — Madras
- do. do. (closed) — Coghin

Scale 1 Inch = 250 Miles or 1/15,840,000

Miles 100 0 100 200 300 400 Miles

CHAPTER VI

LEVELLING

BY N. R. MAZUMDAR

1. Organization.— No. 17 party was under the charge of Captain G. Bomford, R.E, from 7th November 1927 to 26th February 1928 and of Mr. N. R. Mazumdar from the commencement of the season to 6th November 1927 and from 27th February 1928 to 30th September 1928.

Field work.—The field work was conducted by six detachments; three of them carried out the geodetic levelling of high precision, and three did the secondary levelling of the Lloyd barrage project of the Bombay irrigation department. The torsion balance detachment which was formed to assist the Burma oil company in their torsion balance survey of the oil fields of Upper Assam, was placed under the executive charge of this party.

Transfer of work.—Tertiary levelling of the Haveli irrigation project of the Punjab government was transferred to the Frontier Circle. The commercial levelling group, which had hitherto done levelling work for the local governments, under this party, was amalgamated with the main party.

Distribution of personnel.—The distribution of personnel for the field work is given in the table below:—

Detachment	Officer in charge	Locality	Class of levelling	Out-turn
				miles
1	Mr. L. D. Joshi, S. A. S.	The Punjab	Secondary High Precision	14 413
2	Mr. P. B. Roy, S. A. S.	The U. P. & Bengal	High Precision	445
3	Mr. Matlub Ahmad, S.A.S.	The U. P., the Punjab and Bombay	High Precision	368
4	Mr. J. N. Kohli, S. A. S.	Sind	High Precision Secondary	205 280
5	Mr. Lalbir Singh, S. A. S.	Sind	Secondary	401
6	Mr. B. P. Rundev, S. A. S.	Sind	Secondary	394

Mr. K. K. Das was in charge of the torsion balance detachment with Mr. H. C. Banerjea as his assistant.

2. Summary of out-turn.—Total out-turn was as follows:—

High Precision levelling in both directions	... 302	miles.
,, ,, ,, ,, fore ,, only	... 361	,,
,, ,, ,, ,, back ,, ,,	235	,,
,, ,, ,, (revision) ...	... 231	,,
Secondary levelling	.. 1089	,,

3. Work of detachments.— *No. 1 detachment* under Mr. L. D. Joshi did the following levelling:—

(a) Secondary branch levelling from Jabboāna (bench-mark No. 181/44A of the secondary line Garhmahārāja-Dāmāmiā) to Kot Māldeo. The Punjab irrigation authorities wanted to extend the area of operation of the Haveli project; the branch line was run to provide control for the tertiary levelling of the extended area. As the detachment was a single one, the levelling was done in both directions from Jabboāna to Kot Māldeo and from Kot Māldeo to Jabboāna.

(b) Jhang-Maghiāna-Wazīrābād-Ghakkar and Wazīrābād-Jhang-Maghiāna: these are parts of new net line 136. The route was mostly along railway and partly along canal embankment. In order to have the fore and back levelling done under different conditions, levelling was done in the following order; first from Jhang-Maghiāna via Phularwān, Wazīrābād to Ghakkar then from Phularwān to Jhang-Maghiāna and lastly from Wazīrābād to Phularwān. Ghakkar to Wazīrābād was done in 1926-27. 15 primary and 297 secondary bench-marks were connected during the work.

No. 2 detachment under Mr. P. B. Roy did the following levelling:—

(a) Hāthras-Muttra-Delhi-Meerut and Muttra-Hāthras; these are parts of net lines 140, 106 and 153. The route was along the railway between Hāthras and Muttra and along the Grand Trunk Road for the rest of the way. 21 primary and 270 secondary bench-marks were connected; of the latter, 9 were connected at Delhi at the special request of the Chief Engineer, Delhi Province.

(b) Balasore-Basta-Midnapore-Howrah and Basta-Balasore; these are parts of new net line 121. The route was partly along the Calcutta-Cuttack trunk road, partly along canal embankment and partly along railroad. 12 primary and 184 secondary bench-marks were connected.

(c) Sahāranpur-Dehra Dūn.—Part of this Himālayan line from Dehra Dūn to Mussoorie was levelled in 1926-27.

Dehra Dūn to Sahāranpur was levelled by No. 3 detachment in October and November 1927 and Sahāranpur to Dehra Dūn was levelled by No. 2 detachment in April 1928.

No. 3 detachment under Mr. Matlub Ahmad did the following levelling:—

(a) Dehra Dūn-Sahāranpur.—This line was undertaken to complete the revision of the Himālayan line Saḥāranpur-Mussoorie.

(b) Sahāranpur-Ambāla-Ludhiāna.—These are parts of lines 139 and 137. The route was mostly along main roads and partly along railway. 16 primary and 144 secondary bench-marks were connected.

(c) Anjār-Mamuāra.—Levelling of this branch line which was undertaken at the suggestion of the Director Geological Surveys, was done in 1921-24. As the agreement between the fore and back levelling was not satisfactory, further relevelment was required as pointed out in the Geodetic report Vol. I for 1923-24. This was done during the season.

(d) Connection of the standard bench-mark at Bhūj.—Construction of this bench-mark was not completed when the new net line No. 104 was run through Bḥūj in 1923-24. It was connected this year with a number of bench-marks that were left in the vicinity during the last levelling for the purpose of effecting the connection.

(e) Nakhtarāna Motā to Tatta.—Levelling in one direction was done from Nakhtarāna Motā to Lakhpat and from Unhia Tar to Tatta. The Indus river was crossed between Sujāwal and Tatta at Saidpur ferry *ghāt*. Crossing was made at three places by 3 different methods: the results are given in page 81 under "discussion of results". 17 primary and 87 secondary bench-marks were connected.

Between Lakhpat and Unhia Tar the line runs across the Rann of Cutch. As in 1926-27, no levelling could be done as the country was flooded. The officer in charge of the detachment, however, got some valuable information which would be useful for the future leveller. The following description of the country given by Mr. Matlub Ahmad, officer in charge of the detachment, will be interesting.

"The portion of the Khori creek to the west of Lakhpat is just like a sea, while to the east to a distance of 6 miles it is inundated by high-water; where the creek ends, the swamps start; our 5 feet pegs disappeared in the swamp. It was therefore impossible to cross this portion of the Rann. I crossed the creek in boats and landed at Cutch Kotri earthen platform and lighthouse. The old Kotri *dharmsāla*, where there was an embedded bench-mark, is now in ruins and is

surrounded by water on all sides; every effort was made to reach it; but no passage could be made through the water. Next morning we started further to the west; it was ordinary swamp up to 4 miles and Said Ali T. S. about 2 miles west was seen in the midst of wet salt beds or *kars*. These *kars* contain thick layers of salt and underneath is water and mud. They are so dangerous that animals sink down and can not be extricated. We found several animals thus entangled and abandoned. We could not get at Said Ali T. S. but it was looking like a mound at a distance. Not being able to commence levelling from even Said Ali T. S. we marched further west, crossing many *kars* with great difficulty, the feet of men bleeding from walking over salt beds. Guni T. S. lies in a large *kar*; the guide trying to reach the T. S. had not proceeded a furlong when he began to sink in the *kar*. On reaching the ruined site of *dharmsāla* at Vehr, the embedded bench-mark could not be traced as the *dharmsāla* was totally washed away. Under the circumstances, the work was commenced from Unhia Tar leaving a gap of 36 miles between Lakhpat and Unhia Tar". The detachment officer further reported that in these 36 miles, there was not even a blade of grass nor suitable drinking water for man or beast. This year the state of the Rann is specially bad on account of the last Sind floods; otherwise, the Rann dries up with the exception of the *kars* during February and March; from early April to the end of January it is never dry. It will be necessary to build 3 embedded bench-marks at Vehr, Adhi and Cutch Kotri. Arrangement will have to be made for transport of water, fuel and fodder in addition to usual transport requirements.

The country is a difficult one for running a line of levelling as the *kars* offer formidable obstacles. Nevertheless efforts will be made to complete the line as soon as conditions appear favourable.

No. 4 detachment under Mr. J. N. Kohli did the following levelling:—

(*a*) Sukkur-Hyderābād; the detachment which was a double one, worked in the beginning as 2 single detachments with Mr. J. N. Kohli and P. John as levellers, one levelling from Sukkur to Daur and the other from Hyderābād to Daur. The old levelling of this did not close well; parts suspected to be weak were relevelled in 1926-27, but as it did not disclose any error, the whole line was relevelled. 7 primary and 234 secondary bench-marks were connected during the operation.

(*b*) On completion of (*a*) the 2 single detachments were amalgamated; the combined detachment did the secondary levelling of blocks H′, I′, K′, L′, and M′ of the Lloyd barrage project. 84 rectangulation pillar bench-marks and 76 other bench-marks were connected.

No. 5 detachment under Mr. Lalbir Singh did the secondary levelling of blocks Y, Z, C′, D′, part of F′ and G′ of the Lloyd barrage project. 159 rectangulation pillar bench-marks and 73 other bench-marks were connected.

No. 6 detachment under Mr. B. P. Rundev did the secondary levelling of blocks V, T, U, X, Y, B′, C′ and part of F′ of the Lloyd barrage project. 68 rectangulation pillar bench-marks and 216 other bench-marks were connected.

4. Discussion of results.—*1. Jhang-Maghiāna-Wazīrābād-Ghakkar.*—Fore and back levelling of this line was done during the same season as explained in § 3. There was a discrepancy of 1 foot between the two levellings in a distance of 200 miles. Differences of fore and back values between consecutive bench-marks all agreed within permissible limits. Fore values agreed with old levelling; but there was a uniform accumulation of error in back levelling.

A statement of discrepancies is given below:—

Bench-mark	Consecutive distance in miles	Permissible error in feet	Consecutive Heights					
			Fore	Back	Fore − Back	Old	Old − Fore	Old − Back
			feet	*feet*	*feet*	*feet*	*feet*	*feet*
Ghakkar ...	0	·00	·00	·00	·00	·00	·00	·00
Wazīrābād ...	11	·07	+ 1·38	+ 1·29	+0·09	+ 1·24	−0·14	−0·05
Lāla Mūsa ...	23	·13	+ 82·08	+ 81·92	+0·16	+ 81·96	−0·12	+0·04
Sargodha Ry. R. H. ...	95	·43	−217·21	−217·55	+0·34	−216·89	+0·32	+0·66
Sargodha Dt. R. H. ..	1	02	− 1·04	− 1·04	·00	− 1·07	−0·03	−0·03
Killa hill ...	9	·06	+ 17·70	+ 17·66	+0·04	+ 17·76	+0·06	+0·10
Hundewāli ...	4	·04	− 17·94	− 17·98	+0·04	− 17·95	−0·01	+0·03
Sillanwāli ..	11	·07	− 26·81	− 26·83	+0·02	− 26·82	−0·01	+0·01
Sobhaga ...	11	·07	− 31·88	− 31·92	+0·04	− 31·91	−0·03	+0·01
Shāh Jewāna ...	13	·08	− 27·22	− 27·32	+0·10	− 27·21	+0·01	+0·11
Chūnd ...	9	·06	− 10·52	− 10·60	+0·08	− 10·55	−0·03	+0·05
Thetta Māhla ...	7	·05	− 3·17	− 3·22	+0·05	− 3·19	−0·02	+0·03
Jhang Court ...	8	·06	− 7·44	− 7·46	+0·02	− 7·41	+0·03	+0·05
Jhang R. S. ...	1	·02	− 1·40	− 1·40	·00	− 1·40	·00	·00
Total ...	203				+0·98		+0·03	+1·01

From the table it is evident that there was slow progressive error in back levelling. Levelling in both the directions was done by the same observer with the same instrument and staves. All the usual precautions against accumulation of error were observed. The accumulation was uniform; probable systematic errors between Ghakkar-Sargodha and Sargodha-Jhang were ·00165 feet per mile for both the parts. For a high precision levelling the allowable limit of probable systematic error is ·00106. This line will therefore be revised.

2. Mohanpur-Rānīganj—This line was levelled in fore direction in 1924-25 and in back direction in 1925-26. Its starting point Mohanpur is a bench-mark of the line Howrah to Balasore. The height of

this bench-mark was only available this season after completion of the levelling of that line. The line was computed this season. It was adjusted between the value of the new bench-mark at Mohanpur and the old published height of Rānīganj which was derived from the adjustment of the old net; the closing error was 0·88 ft. Howrah-Chāmpdāni-Burdwān-Rānīganj-Mohanpur-Howrah forms a small circuit of the new net. Closing error of the new levelling of this circuit is 0.16 ft. in 308 miles which proves that there is no serious error in the new levelling of Mohanpur to Rānīganj.

3. *Dehra Dūn-Sahāranpur.*—The following table shows the differences of heights obtained between the levellings of 1861-62, 1905-07 and 1927-28:—

Changes of heights between Sahāranpur and Dehra Dūn.—

B.M. No.	Bench-mark	Observed heights					
		1861-62	1905-07	1927-28	1905-07 – 1861-62	1927-28 – 1905-07	1927-28 – 1861-62
		feet	*feet*	*feet*	*feet*	*feet*	*feet*
41/53G	S.B.M. Sahāranpur ...	·000	·000	·000	·000	·000	·000
49/53G	Nojli T.S. (top of tower) ...	...	+ 35·188	+ 35·175	...	−0·013	...
9/53F	Fatehpur D.B.	...	+ 83·205	+ 83·162	...	−0·043	...
17/53F	Mohan ...	+ 586·676	+ 587·003	+ 587·014	+0·327	+0·011	+0 338
150/53F	Boundary stone	...	+1631·274	+1631·399	...	+0·125	...
151/53F	Asarori D.B. ...	...	+1566·328	+1566·486	...	+0·158	...
37/53F	Mohabawālā ...	+1193·834	+1194·197	+1194·258	+0·363	+0·061	+0·424
154/53F	Dehra Dūn Base-Line E. End...	+1056·346	+1056·736	+1056·778	+0·390	+0·042	+0·432
12/53J	Dehra Dūn Iron plug ...	+1326·408	+1326·849	+1326·945	+0·441	+0·096	+0·537

Rises between 1861-62 and 1905-07 were attributed by Sir Sidney Burrard, K.C.S.I., R.E., F.R.S., to the Kāngra Valley earthquake of 1905. Levelling of 1927-28 points to a further rise of the Siwāliks and of Dehra Dūn over Sahāranpur. The rise is however not very phenomenal. As it is not impossible that such differences may be due to ignorance of staff error and other sources of systematic errors, no definite conclusion can be drawn at present.

4. *Sahāranpur-Ambāla-Ludhiāna.*—In the annual report on Standard bench-marks, Garrison Engineer Ambāla reported that there was subsidence of ground near the Standard bench-mark situated in the compound of St. Paul's Church, Ambāla Cant. and that there appeared to be a subterranean crack in the ground. The bench-mark was connected last winter while levelling from Sahāranpur to Ambāla; examination of this levelling showed that the ground about St. Paul's Church has sunk by about ½ inch below that about the Roman Catholic Church which

has itself sunk by ½ inch below the grounds about the Wesleyan Church. This revelation led to further comparison of the old and new levelling between Sahāranpur and Ambāla. The comparison indicated that there was a slow steady rise of ground up to Jagādhri and then a slow fall up to 3 miles beyond Ambāla. The new levelling was done last winter in one direction only. The maximum rise indicated is 2 inches only. It may be noted that in 1912-14, bench-mark 71/53 B at St. Paul's Cathedral was found to have subsided by 7 inches since its original connection in 1860-62. The levelling of this line will be further scrutinised next year when the back levelling is completed.

5. *Nakhtarāna Motā-Tatta*: *Crossing of the Indus river.*—The Indus was crossed between Sujāwal and Tatta near Saidpur ferry *ghāt.* The crossing was made at 3 sites by different methods.

1st site.—One Zeiss Model III and one American binocular level fitted with micrometer eye-piece were on an island; distances of staves from the instruments were 980 and 920 feet for back and fore staves respectively; height of ray was 5 feet above water in each case. Direct readings of staves were taken with Zeiss level and micrometer readings were taken to targets fixed on staves at the height of 4·5 feet with the American binocular level.

2nd site.—(close to 1st. site). Instruments as above were on the right bank of the river. One staff was across the river; the other staff was on the same bank as the instrument but across a bay so that both the rays were over the water, but one ray was close to right bank; distances of the staves from instruments were 1,608 and 1,424 feet for back and fore staves respectively. Height of the eye was 5 feet above water in each case. Readings were taken by Zeiss level on targets sliding on staves and by American binocular level by targets fixed at 1·5 ft. on back staff and 3·0 ft. on fore staff.

3rd site.—(¼ mile below the 1st. site). 2 micrometer levels were on opposite banks. Targets were fixed at object ends of levels. Simultaneous readings of targets were taken by micrometer levels and the nearest staff was directly read. Instruments were on a high bank close to the water; height of rays was 11 feet above water; distance between levels was 1,400 feet.

At the same site another set was taken in the same way but with the instrument of the right bank away from the bank with 680 feet of sand between the instrument and water. Rays were 16 feet above water.

In every site and in all cases the collimations were very carefully determined immediately before observations and were frequently checked during observations.

For determining the length of rays, a base 10 chains long was measured with Gunter's chain and plane-table triangulation was done from this base on a scale of 200 feet = 1 inch.

A summary of the results is given below:—

Site	Level	Target	Distances of crossings	Difference of height	Remarks
			feet	*feet*	
1	Zeiss Model III ...	no target	980 (a) 920 (b)	−1·859	Instruments on island
	American binocular	target fixed to staves	as above	−1·869	
2	Zeiss Model III ...	targets sliding on staves	1608 (a) 1428 (b)	−1·880	Instruments on right bank, one ray across the river another across a bay
	American binocular	targets fixed to staves	as above	−1·877	
3	do. do.	target fixed to instrument	1400	−1·832	Rays across water
	do. do.	do.	2084	−1·848	Rays partly across river partly across sand.
			Mean	−1 861	

(a) back staff (b) fore staff

Undoubtedly the best method of crossing a river is by equidistant rays over water from an island, as this cancels most of the errors. In a short crossing like this where the width of the river is below 2,000 feet, any of the other methods may be adopted, if no island is available.

5. Probable errors.—Probable errors of high precision lines were computed by the formulæ :—$\sigma_r = \frac{S}{3L}$; $\eta_r = \sqrt{\left[\frac{\Sigma \Delta^2}{9L} - \sigma_r^2 \times \frac{\Sigma r^2}{L}\right]}$

where σ_r = probable systematic error.

η_r = probable accidental error.

Δ = discordance of the results of the fore and back levelling between consecutive bench-marks.

S = total discordance.

r = distance between consecutive bench-marks.

L = Total distance

These are given below in foot and mile units:—

	Line	Probable accidental error	Probable systematic error
		feet	*feet*
1	Muttra-Hāthras	± ·00280	± ·00025
2	Howrah-Balasore	± ·00290	± .00050
3	Sahāranpur-Dehra Dūn	± ·00354	± ·00130
4	Buhar-Tatta	± ·00333	± ·00037

Permissible accidental and systematic errors are ± ·00416 ft. and ± ·00106 ft respectively.

Probable error of secondary levelling computed by the formula $p.e. = \frac{1}{3}\sqrt{\frac{\Sigma\Delta^2}{L}}$ is:—

Jabboāna—Kot Māldeo ± ·0051 ft.

6. Progress of the new level net.—The following additions were made to the completed mileage of the new level net:—

Line No.	Name of Line	Miles completd on main line	Remarks.
104	Viramgām-Tatta ...	53	Portion Buhar-Nakhtarāna not yet done
140	Muttra-Bareilly ...	27	Muttra-Bareilly line is completed
121	Calcutta-Bhadrakh ...	153	Portion Balasore-Bhadrakh not yet done.
101A	Sukkur-Hyderābād ...	94	Portion Bāndhi-Hyderābād not yet done.
	Total ...	327	
Previously reported ...		4999	
Total completed ...		5326	

7. Research work.—Results of Capt. Bomford's researches on (1) Levelling across unbridged rivers (2) Error due to refraction when levelling up a hill (3) The correction for staff length, are published in Professional Paper No. 22 "Three Sources of Error in Precise Levelling". His conclusions and recommendations are given below:—

(1) *Levelling across unbridged rivers.*—There are not many wide unbridged river crossings in the primary net, and it will be proper to go to some expense to cross them; it is suggested that some or all of the following recommendations be acted on:—

(*a*) That levels with micrometer eye-pieces be used. The levels to change sides daily. If it is not practicable to change sides, and if an irreversible instrument is used, collimation must be done by Gauss' method, on account of the risk of change of collimation with change of focus.

(*b*) That crossings be made at a number of sites covering some miles of the banks. No elaborate preparations should be made at each site. One day's work should be done at each, and not more than one day should be wasted between each.

(*c*) If suitable sites can be found, and if high level crossings are not available, the level may be set up in the middle of the river on an island. A very firm base is not required. It is only necessary that the level should be steady while the

observer is sitting still, and that it should not change height by more than half an inch while he changes from one side of it to the other.

By using 3 levels in such a case an increase of accuracy can be obtained, each half of the river being crossed by reciprocal angles. The centre observer works with each of the other two in turn. It is not necessary to measure the height of his instrument on a back staff, and if the rays are equal his collimation error is immaterial.

If the crossing is more than 1½ miles wide every endeavour should be made to do this, even to the extent of sinking a wooden frame full of stones in shallow water. Such a crossing is twice as good as a simple crossing at water level.

(*d*) Sites just below river junctions should be avoided as a precaution against systematic differences of water temperature on either side.

(*e*) The whole of the observations should not be made when a prevalent wind is blowing from one side to the other. The observations of any one day may be so done but not the whole of the work

(*f*) Increased height may perhaps be obtained artificially by staging, as is done in triangulation. But it is probable that the necessary preparations would lead to an expenditure of time, which would have been better spent on making more numerous crossings.

(*g*) Water-gauges should also be used in several well separated sites if possible; if the conditions are suitable it is possible that they would give more consistent results than the levels. The observations might perhaps be made on the same days as the other crossings, so avoiding waste of time.

(2) *Errors due to refraction when levelling up a hill.*

Rule 1.—If the rise in any section about 5 miles in length average less than 1 foot per station (i.e. 50 feet in 5 miles), that section is considered flat and no action is necessary.

Note A.—When taking out the average rise, any negative rises are of course numerically subtracted from the positive rises.

Note B.—With shots averaging 4 chains, and $d^2T/dh^2 = \cdot 020\,^{\circ}C$ per ft^2, this rule allows an error of ·002 per mile, which is tolerable for considerable distances.

Rule 2.—If the country is not flat as defined in rule (1), it is considered to have a dangerously persistent gradient after it has risen more than 50 feet, if the length of the shots (station to staff) in which the rise has occurred has averaged 3 chains or more, or 100 feet if the shots have averaged between 1½ and 3 chains. If they have averaged less than 1½ chains there is no limit.

Note C. This rule admits an error of ·010 ft. before any action is taken.

Rule 3. Once a gradient has been found to be persistent (i. e. after it has risen 50 or 100 feet as above) the length of shot must be reduced to 1½ chains, until such time as the gradient is reversed or so reduced that the rise per station does not average more than 1 foot with a longer shot.

Note D. 1½ chain shots admit an error of ·005 per mile (at the worst slope). This can be tolerated for some miles.

Note E. If the gradient be reversed or reduced as above for one or more consecutive shots, the length of these shots should not be restricted, but the dangerously persistent gradient cannot be considered to have ceased until the down hill or level has continued for at least one mile (see also note F). i. e. if the rise be resumed before one mile, the length of shot must immediately be reduced to 1½ chains, without waiting for a second rise of 50 or 100 ft.

Note F. If after reversal the down hill gradient be such as to come under rule (2), the up grade is considered to have ceased and the length of shot must in due course be reduced on account of the down grade.

Rule 4. The above 3 rules are repeated substituting the words "fall" for "rise", "down" for "up" and *vice versa*.

If, in future, temperature measurements should again be made and a correction applied, it would be better to take the temperature at three points vertically above each other near the instrument. For d^2T/dh^2 is the essential quantity which has to be measured, and it is much better determined by 3 such measures at one place, than by measures at 3 places some chains apart.

(3) *The correction for staff length.*—It is concluded that the present method of applying the correction is satisfactory, but that staves should be paired to within ·0004 (i. e. 0·004 ft.). If they start the season within 0·002 ft. the above limit is not likely to be exceeded. If it should be exceeded, the desirability of applying the correction more rigorously should be considered.

TABLE 1.—*Tabular statement of out-turn of work, season 1927-28.*

Detachments and lines levelled	Months	Distance levelled: Main line Mls.	Chs.	Lks.	Extra and branch lines Mls.	Chs.	Lks.	Total Mls.	Chs.	Lks.	Total number of feet: Rises feet	Falls feet	Mean number of stations at which the instruments were set up	Number of bench-marks connected: Primary: Rock-cut Protected old	new	Standard old	new	Primary stations of triangulation old	new	Interred old	new	Musto's type old	new	Secondary: Embedded old	new	Rock-cut old	new	Inscribed old	new	Tertiary: Irrigation and P. W. D. old	new	Railway old	new	Rectangulation pillar old	new	G. I. Pipe old	new	Dr Summer's bench-mark old	new
No. 1 Detachment																																							
Line 55P Jabboāna to Kot Māldeo (1)	Oct. 27 to Nov. 27	...	...	..	13	72	51	13	72	51	58·088	41·380	168	...	..	...	...	...	..	1	...	...	...	...	..	..	...	4	18	...	..	...	...	...	.	...	...	...	...
Line 136 (*a*) Jhang to Wazīrābād (2)	Nov. 27 to May 28	190	21	44	10	00	82	200	22	26	1322·669	1071·778	2660	1	..	...	4*	..	1	7	..	...	...	4	...	6	...	59	193	1	13	2	...	...	...	...	...	...	...
(*b*) Wazīrābād to Ghakkar (3)	Feb. 28	12	67	80	...	...	..	12	67	80	69·338	70·715	130	...	..	...	1*	...	...	1	...	...	...	1	...	...	...	4	14	..	...	...	...	.	...	.	..	...
No. 2 Detachment																																							
Line 140 Muttra to Hāthras (4)	Oct. 27 to Dec. 27	26	58	50	...	...	..	26	58	50	199·645	175·427	277	...	...	1	...	...	...	1	..	...	...	3	...	..	...	17	13		..	...	.	...	..	...	...		...
Line 106 Delhi to Muttra	Oct. 27 to Nov. 27	99	62	00	10	09	00	109	71	00	937·947	739·847	1300	...	...	2	1*	2	...	8	...	...	..	1	...	4	...	97	†40	2	8	...	.	...	...	...	...	...	...
Line 153 Delhi to Meerut	Nov. 27 to Dec. 27	45	22	00	5	55	00	50	77	00	403·950	431·133	558	...	...	2	...	1	...	3	...	..	...	1	...	...	...	66	16	1	1	..	...	...	.	...	...	..	...
Line 121 (*a*) Howrah to Basta (5)	Dec. 27 to Mar. 28	134	42	00	12	04	00	146	46	00	911·248	911·347	1620	..	...	1	6*	1	2	...	2	...	..	3	...	...	1	21	‡147	1	7	3	1	...	...	...	...	...	.
(*b*) Basta to Balasore (6)	Mar. 28	18	32	00	0	01	00	18	33	00	168·888	144·911	191																										

(1) Relevelled 0 ml. 16 chs. 60 lks. (2) Relevelled 18 mls. 61 chs. 00 lk. (3) Relevelled 0 ml. 33 chs. 80 lks. (4) Relevelled 2 mls. 47 chs. 00 lk.
(5) Relevelled 51 mls. 14 chs. 00 lk. (6) Relevelled 8 mls. 03 chs. 00 lk. * Standard (Type M) † Contains 1 metal bolt. ‡ Contains 1 iron screw and 2 metal bolts.

TABLE 1.—*Tabular statement of out-turn of work, season 1927-28—(contd.).*

Detachments and lines levelled	Months	Distance levelled: Main line Mls.	Chs.	Lks.	Extras and branch lines Mls.	Chs.	Lks.	Total Mls.	Chs.	Lks.	Total number of feet: Rises feet	Falls feet	Mean number of stations at which the instruments were set up	Number of bench-marks connected: Primary: Rock-cut Protected old	new	Standard old	new	Primary stations of triangulation old	new	Interred old	new	Musto's type old	new	Secondary: Embedded old	new	Rock-cut old	new	Inscribed old	new	Tertiary: Irrigation and P. W. D. old	new	Railway old	new	Rectangulation pillar old	new	G. I. Pipe old	new	Dr. Summer's bench-mark old	new
No. 2 Detachment.—(contd.)																																							
Line 61A Saharanpur to Dehra Dun (7)	April 28	44	50	00	11	20	00	55	70	00	2105·249	776·712	916	...	...	4	.	3	1	2		.	...	..	..	..	..	†33	22	..	..	..	..	..	..	..	..	.	..
No 3 Detachment																																							
Line 61A Dehra Dun to Saharanpur	Oct. 27 to Nov. 27	44	37	64	11	57	18	56	14	82	778·180	2106·188	806	.	..	4	...	2	1	2		...		1	..	...	..	†33	22	..	.	...	...	..	...	..	..	..	..
Line 139 Saharanpur to Ambala (8)	Nov. 27	56	50	68	5	37	61	62	17	32	417·424	417·256	664	...	...	2	...		..	8	...	..		.	..	...	..	28	30	4	1	...	.	...	...	...	...	..	
Line 187 Ambala to Ludhiana	Dec. 27	72	72	70	3	03	14	75	75	90	342·919	438·161	748	...	...	2		2	...	2	..	.	..	...	...	..	..	68	11	2		...	...	...	..	...	...	..	..
Line 194 (a) S. B. M. connection at Bhu	Jan. 28	..	..	..	0	06	14	0	06	14	...	...	8	...	...		1*	...	..			..	..	.	..	1	..	...	3‡	..		..	..	..	...	...	...	..	...
(b) Anjar to Mundra (9)	Jan. 28	..	..	..	21	33	40	21	33	40	...	...	292	2		..		1	...	1	...	..	.	...	...	5	..	7	...	..	...	..	...	..	...	...		..	...
(c) Nakhatrana to Lakpat	Jan. 28 to Feb. 28	57	18	08	5	01	80	62	22	88	1310·441	1682·355	920	.	...	...	...	1	2	6	...			..	..	2	4	6	18	..	..	...	...	...	...	...	...	..	..

(7) Relevelled 14 mls. 32 chs. 00 lks. (8) Relevelled 3 mls. 38 chs. 54 lks. (9) Relevelled 0 ml. 56 chs. 05 lks. in both directions and 2 mls. 01 ch. 20 lks. in one direction. * Standard (Type M). † Contains 1 metal bolt. ‡ Contains 2 stone prisms and 1 iron bolt.

TABLE I.— *Tabular statement of out-turn of work, season 1927-28—(contd.).*

Detachments and lines levelled	Months	Distance levelled: Main line Mls.	Main line Chs.	Main line Lks.	Extras and branch lines Mls.	Extras and branch lines Chs.	Extras and branch lines Lks.	Total Mls.	Total Chs.	Total Lks.	Total number of feet: Rises feet	Total number of feet: Falls feet	Mean number of stations at which the instruments were set up	Number of bench-marks connected: Primary: Rock-cut Protected old	Rock-cut Protected new	Standard old	Standard new	Primary stations of triangulation old	Primary stations of triangulation new	Interred old	Interred new	Musto's type old	Musto's type new	Secondary: Embedded old	Embedded new	Rock-cut old	Rock-cut new	Inscribed old	Inscribed new	Tertiary: Irrigation and P. W. D. old	Irrigation and P. W. D. new	Railway old	Railway new	Rectangulation pillar old	Rectangulation pillar new	G. I. Pipe old	G. I. Pipe new	Dr. Summer's bench-mark old	Dr. Summer's bench-mark new
No. 3 Detachment —(contd.)																																							
(d) Unhia Tar to Buhar	Feb. 28 to Mar. 28	7	19	58	..	..	..	7	19	58	13·396	9·491	74	..	..	..	..	..	..	1	1	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..
(e) Buhar to Tatta (10)	Mar. 28 to Apr. 28	53	16	75	21	16	65	74	33	40	358·439	309·096	970	..	..	1*	..	1	3	1	..	..	..	3	..	..	2	19‡	31	1	..	..	..	..	..	..	..	..	..
No. 4 Detachment																																							
Line 101A																																							
(a) Sukkur to Daur	Nov. 27 to Dec. 27	107	34	00	5	32	00	112	66	00	440·064	583·175	1180	2	..	1	..	..	..	..	..	..	..	4	4	..	..	26	86	..	..	..	..	..	..	..	..	..	..
(b) Hyderābād to Daur	Nov. 27 to Dec. 27	89	51	10	2	41	50	92	12	60	427·213	410·944	1068	1	..	1	..	..	..	..	..	2	..	5	3	..	..	16	90	..	..	..	..	..	..	..	..	..	..
Block M'	Dec. 27 to Jan. 28	65	10	00	7	14	00	72	24	00	424·145	420 157	826	..	..	..	..	..	..	..	..	..	..	..	2	..	..	9	12	..	..	..	..	..	23	..	..	..	..
Blocks H'&L'	Jan. 28 to Feb. 28	98	48	00	15	38	00	114	06	00	302·045	290·135	916	..	..	..	..	..	..	..	..	..	..	..	2	..	..	11	2	5	2	..	..	..	42	..	..	..	..
Block K'	Feb. 28 to Mar. 28	79	47	00	13	57	00	93	24	00	466·973	468·468	804	..	..	..	..	..	..	..	..	..	..	2	2	..	..	7	12	1	7	..	..	..	19	..	..	..	..
No. 5 Detachment																																							
Blocks Z & Y	Nov. 27 to Dec. 27	114	26	80	3	24	10	117	50	90	633·377	634·708	1094	..	..	..	..	..	..	..	..	1	..	..	1†	..	..	14	7	..	2	..	..	..	31	..	..	1	1

(10) Relevelled 11 mls. 71 chs. 54 lks. * Standard (Type M). † Rectangulation bench-mark. ‡ Contains 2 stone prisms and 1 iron bolt.

TABLE 1.—*Tabular statement of out-turn of work, season 1927-28—(concld.).*

Detachments and lines levelled	Months	Distance levelled: Main line Mls.	Main line Chs.	Main line Lks.	Extras and branch lines Mls.	Extras and branch lines Chs.	Extras and branch lines Lks.	Total Mls.	Total Chs.	Total Lks.	Total number of feet: Rises feet	Total number of feet: Falls feet	Mean number of stations at which the instruments were set up	Number of bench-marks connected: Primary: Rock-cut Protected old	Rock-cut Protected new	Standard old	Standard new	Primary stations of triangulation old	Primary stations of triangulation new	Interred old	Interred new	Musto's type old	Musto's type new	Secondary: Embedded old	Embedded new	Rock-cut old	Rock-cut new	Inscribed old	Inscribed new	Tertiary: Irrigation and P. W. D. old	Irrigation and P. W. D. new	Railway old	Railway new	Rectangulation pillar old	Rectangulation pillar new	G. I. Pipe old	G. I. Pipe new	Dr. Summer's bench-mark old	Dr. Summer's bench-mark new
No. 5 Detachment —(contd.)																																							
Blocks C'&D'	Dec. 27 to Jan. 28	116	73	80	8	38	70	125	32	50	619·489	627·361	1100	.	..	...	.	...	...	...	...	1	...	1	..	...	...	6	3	...	1	...	...	...	46	..	9	..	...
Blocks F',G'&H'	Jan. 28 to Mar. 28	150	60	50	3	53	30	154	33	80	775·517	788·878	1510	..	...	...	.	..	...	.	.	1	..	..	1*	..	...	5	6	1	...	..	...	..	82	1	3	..	7
No 6 Detachment.																																							
Block V"	Nov. 27 to Dec. 27	72	60	60	49	39	70	122	20	30	529·363	529·219	1478	...	...	...	.	...	...	...	..	...	...	1	..	..	..	19	55	1	9	...	...	...	15	2	...	...	25
Block U"	Dec. 27 to Mar. 28	58	54	64	31	30	90	90	05	54	384·862	384·961	1044	...	...	...	.	...	...	...	..	1	...	.	1	.	...	18	26	...	...	...	..	...	16	...	...	...	...
Block T	Dec. 27 to Jan. 28	25	22	10	..	...	...	25	22	10	106·337	97·931	284	.	...	...	.	...	..	...	...	...	..	...	...	..	...	3	6	...	...	...	...	.	4	...	...	...	.
Block Y	Jan. 28 to Mar. 28	38	48	40	20	03	30	58	51	70	229·417	229·296	686	..	.	...	...	...	...	...	...	...	.	..	1	...	...	...	7	...	...	...	...	...	12	...	...	...	...
Block X	Feb. 28 to Mar. 28	12	45	20	...	.	..	12	45	20	28·439	22·803	116	..	.	...	...	...	...	...	..	1	...	.	.	..	...	...	...	...	...	...	...	...	2	.	...	...	...
Block C'	Feb. 28 to Mar. 28	43	61	10	3	59	20	47	40	30	274·759	274·968	548	...	...	..	...	...	...	..	.	...	...	...	1	.	...	4	26	...	...	...	...	..	11	1	...	..	..
Block F'	Feb. 28 to Mar. 28	15	53	50	3	30	50	19	04	00	105·997	105·947	230	...	...	..	...	...	...	..	..	...	...	.	1	...	.	3	1	.	.	..	.	..	3	1	...	...	...
Block B'	Mar. 28	20	04	20	...	...	..	20	04	20	62·778	46·236	190	..	...	..	.	...	...	...	...	.	...	.	..	...	...	...	2	..	.	...	...	..	5	...	...	...	...

* Rectangulation bench-mark.

TABLE 2.—*Check-levelling.*

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

Bench-marks of the original levelling that were connected for check-levelling			Distance from starting bench-mark	Observed height above (+) or below (—) starting bench-mark, as determined by			Difference (check–original). The sign + denotes that the height was greater and the sign – less in 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1927-28	
			miles		*feet*	*feet*	*feet*
Line 55 P (Jabboāna to Kot Māldeo) at Jabboāna							
180	44 A	B.◯M. on tri: pillar ...	0·00	1926-27	0·000	0·000	0·000
181	,,	H.P. B.M. □ A.D. 1926 (Type B) at Jabboāna ...	0·34	,,	+ 0·407	+ 0·391	−0·016
184	,,	B.◯M. on tri: pillar ...	0·57	,,	− 1·657	− 1·662	−0·005
182	,,	B.◯M. on ,, ,, ...	0·48	,,	+ 3·850	+ 3·847	−0·003
183	,,	B.◯M. on plinth of school	0·54	,,	+ 2·782	+ 2·780	−0·002
Line 136 (Jhang to Lahore) at Jhang-Maghiāna							
72	44 A	G.T.S. □ B.M. 1911 (Type B) at Jhang Maghiāna R S.	0·00	1911-13	0·000	0·000	0·000
169	,,	B.◯M. at Deputy Commissioner's office ...	0·78	1921-22 & 23-24	+ 8·987	+ 8·983	−0·004
168 (70)	,,	G.T.S. ◯ B.M. on bridge ...	0·96	,,	+ 7·554	+ 7·550	−0·004
71	,,	G.T.S. □ B.M. 1911 (Type B) at Session house ...	1·22	1911-13	+ 1·398	+ 1·396	−0·002
167	,,	G.T.S. ◯ B.M. on gate pillar of tahsīl ...	1·36	1921-22 & 23-24	+ 8·623	+ 8·618	−0·005
Line 136 (Jhang to Lahore) at Sargodha							
78	43 D	G.T.S. □ B.M. 1911 at Rly. rest house	0·00	1911-12 & 12-13	0·000	0·000	0·000
76	,,	G.T.S. ◯ B.M. near M.S. 17 ...	2·01	,,	+ 7·797	+ 7·757	−0·040
74	,,	,, ,, ,, 15 ...	3·44	,,	+ 13·314	+ 13·300	−0·014
73	,,	↑ on bridge ...	4·82	,,	+ 8·741	+ 8·736	−0·005
72	,,	G.T.S. ◯ B.M. near M.S. 14 ...	4·84	,,	+ 9·467	+ 9·467	0·000
71	,,	G.T.S. ◯ B.M. at flour mill	4·97	,,	+ 5·705	+ 5·688	−0·017

TABLE 2.—*Check-levelling—(contd.)*.

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

Bench-marks of the original levelling that were connected for check-levelling			Distance from starting bench-mark	Observed height above (+) or below (−) starting bench-mark, as determined by			Difference (check − original). The sign + denotes that the height was greater and the sign − less in 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1927-28	
			miles		*feet*	*feet*	*feet*
Line 136 (Jhang to Lahore) at Wazīrābād							
45	43 L	G.T.S. ○ B.M. at S. end of Palkhu bridge ...	0·00	1922	0·000	0·000	0·000
46	,,	+ at railway officer's rest house ...	0·41	,,	−10·121	−10·109	+0·012
47	,,	G.T.S. ○ B.M. at well ...	0·87	,,	−10·142	−10·173	−0·031
48	,,	A.D. 1927 G.T.S. □ B.M. (Type B) at Wazīrābād ..	2·10	,,	−14·991	−15·007	−0·016
Line 140 (Muttra to Bareilly) at Hāthras							
22	54 I	G.T.S. □ B.M. (Type B) at Hāthras R.S. ... A.D. 1905	0·0	1915-16	0·000	0·000	0·000
21	,,	G.T.S. ○ B.M. at Hāthras R.S. ...	0·0	,,	+2·932	+2·929	−0·003
88	,,	G.T.S. ○ B.M. at Mahādeo's temple	0·5	,,	+3·278	+3·290	+0·012
20	,,	G.T.S. ○ B.M. at Hāthras I. B. ...	1·1	,,	+3·375	+3·365	−0·010
13	,,	Stone Bench-mark (no inscription) at Hāthras I.B.	1·2	,,	+0·987	+0·975	−0·012
Line 140 (Muttra to Bareilly) at Muttra							
25	54 E	Standard, Muttra ...	0·0	1905-06	0·000	0·000	0·000
163	,,	G.T.S. ○ B.M. on stone ...	0·1	1925-27	−0·027	−0·028	−0·001

TABLE 2.—*Check-levelling—(contd.)*.

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

Bench-marks of the original levelling that were connected for check-levelling			Distance from starting bench-mark	Observed height above (+) or below (−) starting bench-mark, as determined by			Difference (check − original) The sign + denotes that the height was greater and the sign −, less in 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1927-28	
			miles		*feet*	*feet*	*feet*
		Line 121 (Howrah to Bhadrakh) at Balasore					
78	73 K	Standard, Balasore ...	0·0	1881-83	0·000	0·000	0·000
79	,,	G.T.S. ○ B.M. at municipal office	0·9	,,	+ 4·176	+ 4·171	−0·005
61	,,	G.T.S. ○ B.M. at Mahādeo's temple	1·4	,,	+ 3·817	+ 3·864	+0·047
64	,,	G.T.S. □ B.M. (Type B) at Circuit house ... A.D. 1881	1·9	,,	+14·458	+14·432	−0·026
		Line 104 (Viramgām to Tatta) at Bhūj					
95	41 E	B.○M. on rock in situ ...	0·00	1921-22 & 23-24	0 000	0·000	0·000
83 (21)	,,	G.T.S. ○ B.M. on step ...	0·31	,,	+ 6·193	+ 6·190	−0·003
93	,,	B.○ . on stone ...	0·35	,,	+ 7·969	+ 7·968	−0·001
85	,,	+ at memorial ...	0·41	,,	+ 2·088	+ 2·085	−0·003
86	,,	B.○M. on stone flooring	0·57	,,	+ 4·546	+ 4·540	−0·006
88	,,	○ on plinth ,,	0·79	,,	− 0·300	− 0·337	−0·037
90	,,	B.○M. on stone flooring	0·83	,,	− 5·456	− 5·492	−0 036
91	,,	B.○M. on step ...	0·88	,,	− 5·961	− 6·0 9	−0·038
96	,,	B.○M. on flooring ...	0·03	,,	+ 2·286	+ 2·283	−0·003
		Line 104 (Viramgām to Tatta) at Anjār					
64 (3)	41 I	(Type B) at Anjār ...	0·00	1921-22 & 23-24	0·000	0·000	0·000
65	,,	G.T.S. ○ B.M. on stone ...	0·03	,,	− 4·661	− 4·662	− 0·001
66 (1)	,,	G.T.S. ○ B.M. ,, ,, step ...	2·68	,,	+ 8·549	+ 8·557	+ 0·008
63	,,	G.T.S. ○ B.M. ,, ,, ...	1·89	,,	− 64·683	− 64·671	+ 0·012
62 (4)	,,	G.T.S. ○ B.M. ,, ,, ...	3·26	,,	− 74·293	− 74·292	+ 0·001

TABLE 2.—*Check-levelling—(contd.).*

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

Bench-marks of the original levelling that were connected for check-levelling			Distance from starting bench-mark	Observed height above (+) or below (−) starting bench-mark, as determined by			Difference (check − original). The sign + denotes that the height was greater and the sign −, less in 1927-28 than when originally levelled.
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1927-28	
			miles		*feet*	*feet*	*feet*
Line 104 (Viramgām to Tatta) at Nakhtarāna Motā							
37	41 E	(Type B) at Nakhtarāna...	0·00	1921-22 & 23-24	0·000	0·000	0·000
130	,,	G T.S. ○ B.M on step ...	0·02	,,	+ 2·095	+ 2·092	−0·003
129	,,	B.○M. on rock in situ ...	0·10	,,	+ 3·655	+ 3·656	+0·001
36	,,	G.T.S. ○ B.M. at platform ...	3·76	,,	− 5·506	− 5·525	−0·019
Line 101 (Karāchi to Khānpur) at Sukkur							
98	40 A	(Type C) E. of Loco store	0·0	1921-23	0·000	0·000	0·000
100	,,	(Type C) at King's Hill Battery ...	1·0	,,	+50·310	+50·335	+0·025
249 (49)	,,	G.T.S. ○ B.M. at traveller's bungalow ...	1·2	,,	+35·455	+35·472	+0·017
251	,,	B.○M. on reservoir step	2·0	,,	+13·201	+13·207	+0·006
101	,,	S.B.M. at Sukkur .	2·1	,,	+49·074	+49·112	+0·038
Line 150 (Kotri to Barmer) at Hyderābād							
161	40 C	S.B.M. at Hyderābād ...	0·0	1924-26	0·000	0·000	0·000
217	,,	G.T.S. ○ B.M. at *tappadār's* school	1·1	,,	−29·235	−29·239	−0·004
33	,,	G.T.S. ○ B.M. on bridge No. 7 ...	1·6	,,	−14·133	−14·140	−0·007
416	,,	B.○M. on culvert No. 17...	1·1	,,	−30·202	−30·163	+0·039
417	,,	B.○M. on water column ...	1·3	,,	−30·548	−30·511	+0·037
418	,,	B.○M. ,, ,, *piāo* ...	2·0	,,	−31·957	−31·928	+0·029
419	,,	B.M. ⊕ on boundary pillar	3·0	,,	+31·209	+31·276	+0·067
152	,,	(Type C) at Ganjo Takkar hill ...	3·1	,,	+32·164	+32·246	+0·082

TABLE 2.—*Check-levelling—(contd.)*.

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

Bench-marks of the original levelling that were connected for check-levelling			Distance from starting bench-mark	Observed height above (+) or below (−) starting bench-mark, as determined by			Difference (check − original). The sign + denotes that the height was greater and the sign −, less in 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1927-28	
			miles		*feet*	*feet*	*feet*
		Line 101A (Sukkur to Hyderābād) at Nawābshāh					
231	40 B	B.○M. on culvert ...	0·0	1924-25	0·000	0·000	0·000
232	,,	G.T.S. ○ B.M. at inspection bungalow ...	0·3	,,	− 0·041	− 0·035	+0·006
233	,,	,, ,, ,, ,, ...	0·3	,,	+ 0·930	+ 0·934	+0·004
236	,,	G.T.S. □ B.M. A.D. 1924 ,, ,, ,, ...	0·4	,,	− 1·855	− 1·854	+0·001
235	,,	B.○M. ,, ,, ,, ...	0·4	,,	− 0·724	− 0·726	−0·002
234	,,	G.T.S. ○ B.M. ,, ,, ,, ...	0·4	,,	− 1·540	− 1·541	−0·001
237	,,	B.○M. on ash-pit ...	0·6	,,	+ 0·244	+ 0·233	−0·011
238	,,	G.T.S □ B.M 1904 at railway station ...	0·7	,,	+ 3·071	+ 3·057	−0·014
240	,,	B.○M on culvert No. 201	2·2	,,	− 0·055	− 0·046	+0·009
127	,,	Iron pipe ...	25·6	1921-22	− 3·335	− 3·443	−0·108
		Line 52 C (Shāhpur to Mahrābpur) at Khadro					
105	40 B	81·72 B.○M. on verandah .. 94·76	0·0	1921-22	0·000	0·000	0·000
170	,,	B.○M. on bridge ...	0·1	1922-23	+ 12·998	+ 13·010	+0·012
107	,,	G.T.S. ○ B.M. ,, ,, ...	1·2	1921-22	+ 4·920	+ 4·899	−0·021
108	,,	B.○M. on mile-stone ...	2·7	,,	− 1·666	− 1·739	−0·073

TABLE 2.—*Check-levelling—(contd.).*

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

Bench-marks of the original levelling that were connected for check-levelling			Distance from starting bench-mark	Observed height above (+) or below (−) starting bench-mark, as determined by			Difference (check − original). The sign + denotes that the height was greater and the sign −, less in 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1927-28	
			miles		*feet*	*feet*	*feet*
Line 101 A (Sukkur to Hyderābād) at Kandiāro Road R.S.							
1	40 A	G.T.S. ○ B.M. on culvert No. 41 ...	0·0	1927-28	0·000	0·000	0·000
305	,,	G.T.S. ○ B.M. on culvert No. 37	1·5	,,	− 0·986	− 0·992	−0·006
179	40 B	G.T.S. ○ B.M. at Kandiāro Road R.S ...	2·4	,,	+ 5·253	+ 5 228	−0·025
180 (50)	,,	G.T.S. ○ B.M. on bridge No. 33 ...	4·3	,,	− 0·353	− 0·389	−0·036
181	,,	G.T.S. ○ B.M. on culvert No. 29 ...	5·4	,,	− 5·224	− 5·284	−0·060
182 (49)	,,	G.T.S. ○ B.M. on masonry pillar ...	6·0	,,	− 5·502	− 5·572	−0·070
183	,,	G.T.S. ○ B.M. on culvert No. 28 ...	8·2	,,	− 6·398	− 6·505	−0·107
184	,,	G.T.S. ○ B.M. ,, ,, 23 ...	8·8	,,	− 7·730	− 7·842	−0·112
185	,,	G.T.S. ○ B.M. at Bhiria Rd. R.S. ..	10·5	,,	− 4·919	− 5·048	−0·129
Line 52 L (Daur to Bāndhi) at Moro							
42*	40 B	L.B. ▭ B. ↑ M. at Moro ...	0·0	1925-26	0·000	0·000	0·000
41*	,,	B.○M. at I.B. Moro	0·0	,,	+ 1·066	+ 1·067	+0·001
37*	35 N	B.○M. on M.S. Moro 1 ...	0·6	,,	+ 1·081	+ 1·001	−0·080
136	40 B	G.T.S ○ B.M. at District bungalow, Moro ...	1·6	,,	− 1·353	− 1·334	+0·019
44*	,,	G.T.S. ○ B.M. at Post Office, Moro	1·7	,,	− 0·601	− 0·578	+0·023

* Serial Nos. in Line 52 L (Daur to Bāndhi)

TABLE 2.—*Check-levelling—(contd.)*.

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

Bench-marks of the original levelling that were connected for check-levelling			Distance from starting bench-mark	Observed height above (+) or below (−) starting bench-mark, as determined by			Difference (check—original). The sign + denotes that the height was greater and the sign −, less in 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1927-28	
			miles		*feet*	*feet*	*feet*
Line 52 L (Daur to Bāndhi) at Moro—(contd.)							
45*	35 N	G.T.S. ○ B.M. at hospital, Moro ..	1·9	1925-26	− 1·345	− 1·343	+0·002
137	40 B	G.T.S. ○ B.M. in Police Lines, Moro ...	2·0	1921-22	+ 0·361	+ 0·390	+0·029
46*	,,	G.T.S. ○ B.M. at Barrage Bw., Moro	2·1	1925-26	+ 0·964	+ 0·984	+0 020
138	,,	G.T.S. □ B.M. at P.W.D. bungalow, Moro	2·2	1921-22	− 0·571	− 0·565	+0·006
Line 101 A (Sukkur to Hyderābād) at Daur							
216	40 B	○ B.M. on bridge No. 203 ...	0·0	1924-25	0·000	0·000	0·000
217	,,	G.T.S. B.M. at P.W.D., I.B., □ Daur ... A.D. 1924	0·7	,,	−2·117	− 2·113	+0·004
218	,,	E ○ M. at P.W.D. I.B., Daur G.T.S	0·8	,,	+1·399	+ 1·412	+0·013
219	,,	○ B M. at P.W.D. I.B., Daur G.T.S.	0·9	,,	−1·009	− 0·999	+0·010
220	,,	○ B.M. at Daur R.S. ... G.T.S.	1·1	,,	+4·715	+ 4·678	−0·037
Line 101 A (Sukkur to Hyderābād) at Mahrābpur							
217	40 A	G.T.S. ○ B.M. at P. W. D. I.B., Mahrābpur ... G.T.S.	0·00	1921-22	0·000	0·000	0·000
4	,,	○ B.M. on bridge No. 60 ... G.T.S.	0·24	1924-25	+ 5·124	+ 5·131	+0·007
312	,,	○ B.M. ,, ,, ,, 54 ... G.T.S.	1·81	,,	+11·845	+11·865	+0·020
218	,,	○ B.M. ,, ,, ,, 62 ... G.T.S.	1·69	1921-22	+ 6·091	+ 6·069	−0·022
8	,,	○ B.M. ,, ,, ,, 68 ...	3·71	1924-25	+ 7·693	+ 7·695	+0·002

* Serial Nos. in Line 52 L (Daur to Bāndhi).

TABLE 2.—*Check-levelling—(contd.)*.

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

Bench-marks of the original levelling that were connected for check-levelling			Distance from starting bench-mark	Observed height above (+) or below (−) starting bench-mark, as determined by			Difference (check − original). The sign + denotes that the height was greater and the sign −, less in 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1927-28	
			miles		*feet*	*feet*	*feet*
Line 52 C (Shāhpur to Mahrābpur) at Mahrābpur							
217	40 A	G.T.S. ○ B.M. at P.W.D. I.B., Mahrābpur ...	0·00	1921-22	0·000	0·000	0·000
216	,,	B.○M. on culvert ...	4·48	,,	+ 8·509	+ 8.502	−0·007
215	,,	B.○M. ,, ,, ...	5·43	,,	+ 9 677	+ 9·693	+0·016
214	,,	B.○M. ,, ,, ...	6·79	,,	+ 6·169	+ 6·230	+0·061
213	,,	Top of iron pipe ...	7·25	,,	+ 8·000	- 8·057	+0·057
212	,,	B.○M. on culvert ...	10·38	,,	+ 5·230	+ 5·293	+0·063
Line 101 (Karāchi to Khānpur) at Mehar							
59	35 M	G.T.S. ○ B.M. A.D.1921 Musto's type at Mehar ...	0·00	1920-21	0·000	0·000	0·000
57	,,	G.T.S. ○ B.M. on zinc plate ...	0·83	,,	− 7·408	− 7·405	+0·003
60	,,	G.T.S. ○ B.M. at *mukhtiārkār's* office ...	0·46	,,	− 0·373	− 0·377	−0·004
61	,,	G.T.S. ○ B.M. on bridge ...	0·55	,,	+ 8·089	+ 8·077	−0·012
62	,,	G.T.S. ○ B.M. ,, culvert ...	1·83	,,	− 0·969	− 1·042	−0·073
65	,,	G.T.S. ○ B.M. ,, bridge ...	5·03	,,	− 15·228	+ 15·220	−0·008
66	,,	G.T.S. ○ B.M. A.D.1921 Musto's type at Kolāchi village	5·11	,,	− 0·316	− 0·344	−0·028
Line 101 (Karāchi to Khānpur) at Kākar							
23	35 N	G.T.S. ○ B.M. at I. B. Kākar ...	0·00	1920-21	0·000	0·000	0·000
22	,,	B.○M. on bridge ...	0·17	,,	+ 9·427	+ 9·440	+0·013
21	,,	G.T.S. ○ B.M. on wheel guard stone ...	0·47	,,	− 3·309	− 3·304	+0·005
19	,,	G.T.S. ○ B.M. on culvert ...	2·48	,,	− 4·834	− 4·830	+0·004

TABLE 2.—*Check-levelling—(concld.).*

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

Benoh-marks of the original levelling that were connected for check-levelling			Distance from starting bench-mark	Observed height above (+) or below (−) starting bench-mark, as determined by			Difference (check − original). The sign + denotes that the height was greater and the sign − less in 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1927-28	
			miles		*feet*	*feet*	*feet*
Line 101 (Karāchi to Khānpur) at Kākar—(contd.)							
80	35 M	G.T.S. ○ B.M. on culvert ...	3·67	1920-21	− 2·569	− 2·550	+0·019
Line 52 A (Ruk to Sehwān) at Dādū							
116	35 N	B.○M. on culvert No. 680	0·00	1921-22	0·000	0·000	0·000
115	„	Top of iron pipe ...	1·16	„	− 2·459	− 2·470	−0·011
114	„	G.T.S. ○ B.M. on culvert No. 1 ...	1·51	„	+ 2·117	+ 2·112	−0·005
113	„	G.T.S. ○ B.M. „ 7 ...	2·41	„	+ 1·939	+ 1·953	+0·014
112	„	G.T.S. ○ B.M. „ 13 ...	3·41	„	+ 0·616	+ 0·651	+0·035
111	„	G.T.S. ○ B.M „ 22 ...	4·49	„	+ 2·446	+ 2·549	+0·103
117	„	B.○M. „ 671 ..	1·41	„	+ 3·148	+ 3·138	−0·010
118	„	B.○M. „ 667 ...	2·09	„	− 0·417	− 0·437	−0·020
Line 52 A (Ruk to Sehwān) at Bubak Road R.S.							
129	35 N	B.○M. on culvert No. 602	0·00	1921-22	0·000	0·000	0·000
130	„	Top of iron pipe ...	1·38	„	− 5·358	− 5·366	−0·008
131	„	B.○M. on platform of Bubak R.S.	1·94	„	+ 0·990	+ 0·979	−0·011
132	„	B.○M. on culvert No. 588	2·48	„	+ 2·709	+ 2·718	+0·009
Line 101 (Karāchi to Khānpur) at Johi							
48	35 N	G.T.S. ○ B.M. Musto's type, Johi ... A.D. 1921	0·00	1920-21	0·000	0·000	0·000
47	„	G.T.S. ○ B.M. at police office, Johi	0·06	„	− 0·582	− 0·580	+0·002
49	„	G.T.S. ○ B.M. at *mukhtiārkār's* office, Johi ...	0·18	„	+ 0·973	+ 0·971	−0·002
51	„	B.○M. in temple, Johi ...	0·34	„	+ 2·559	+ 3·456	+0·897
50	„	B.○M. in hospital ...	0·49	„	+ 0·959	+ 0·878	−0·081

TABLE 3.—*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 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1927-28 (unadjusted)	
			miles		*feet*	*feet*	*feet*
		Part of Line 140 (Muttra to Hāthras)					
25	54 E	Standard, Muttra ...	0·0	1905-06	0·000	0·000	0·000
40	,,	at *Kachahri* ...	0·0	,,	+ 2·035	+ 2·032	− 0·003
21	,,	on culvert ...	0·9	,,	+ 5·680	+ 5·682	+ 0·002
20	,,	at Muttra R.S. ...	1·4	,,	+ 13·527	+ 13·529	+ 0·002
161 (19)	,,	(Type B) at Muttra ...	1·5	1925-27	+ 13·703	+ 13·692	− 0·011
18	,,	on bridge ...	2·1	1905-06	+ 1·857	+ 1·835	− 0·022
39	,,	,, ,, ...	2·4	,,	+ 1·609	+ 1·610	+ 0·001
17	,,	,, ,, ...	2·4	,,	+ 1·619	+ 1·631	+ 0·012
16	,,	on pillar ...	4·1	,,	+ 4·005	+ 4·019	+ 0·014
15	,,	on culvert ...	5·9	,,	+ 9·521	+ 9·530	+ 0·009
14	,,	on bridge ...	7·5	,,	+ 30·038	+ 30·046	+ 0·008
13	,,	(Type B) at Raya R.S. ...	9·4	,,	+ 24·853	+ 24·876	+ 0·023
12	,,	on stone ...	10·1	,,	+ 22·645	+ 22·673	+ 0·028
11	,,	on bridge ...	11·6	,,	+ 23·455	+ 23·428	− 0·027
10	,,	,, ,, ...	13·4	,,	+ 24·382	+ 24·361	− 0·021
9	,,	on stone pillar ...	14·8	,,	+ 21·630	+ 21·554	− 0·076
8	,,	on bridge ...	16·3	,,	+ 24·763	+ 24·703	− 0·060
7	,,	on drain ...	17·4	,,	+ 17·874	+ 17·822	− 0·052
5	,,	(Type B) at Mursān R.S.	19·0	,,	+ 12·247	+ 12·177	− 0·070
1	,,	on well ...	24·0	,,	+ 21·802	+ 21·723	− 0·079
89	54 I	Telegraph office ...	26·2	,,	+ 24·920	+ 24·945	+ 0·025
22	,,	(Type B) at Hāthras R.S.	26·7	,,	+ 24·327	+ 24·238	− 0·089
		Part of Line 121 (Howrah to Balasore)					
455	79 B	at civil court, Howrah ...	0·0	1913-14	0·000	0·000	0·000
267	,,	on platform ...	0·4	,,	− 3·792	− 3·820	− 0·028
456	,,	on lever ...	1·0	,,	− 4·160	− 4·161	− 0·001
458	,,	on sluice ...	3·6	,,	− 2·560	− 2·581	− 0·021
265	,,	on memorial vase ...	4·8	1881-83	− 1·466	− 1·357	+ 0·109
264	,,	at Supdt's house, Sibpur...	5·1	1913-14	− 5·024	− 5·030	− 0·006
847 (464)	,,	at lamp-post ...	0·2	1924-25	− 0·712	− 0·689	+ 0·023
453	,,	at P. & T. O. ...	0·3	1913-14	− 0·821	− 0·829	− 0·008
821	,,	on seat ...	0·5	1924-25	+ 0·859	+ 0·861	+ 0·002
828	,,	on plinth ..	1·2	,,	− 4·649	− 4·611	+ 0·038
827	,,	on step ...	1·3	,,	− 1·552	− 1·546	+ 0·006
825	,,	at Supdt's quarters ...	1·5	,,	− 1·352	− 1·372	− 0·020
824	,,	at waiting hall ...	1·5	,,	− 0·983	− 0·999	− 0·016

TABLE 3.—*Revision levelling—(contd.)*.

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 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1927-28 (unadjusted)	
			miles		*feet*	*feet*	*feet*
		Part of Line 121 (Howrah to Balasore)—(contd.)					
823	79 B	at parcel office ...	1·6	1924-25	− 1·082	− 1·086	− 0·004
831	,,	at *chāndmāri* bridge ...	0·9	,,	− 4·507	− 4·526	− 0·019
832	,,	on plinth ...	1·3	,,	− 0·777	− 0·763	+ 0·014
246	,,	on lock ...	20·4	1881-83	3·488	− 3·354	+ 0·134
245	,,	at I.B. Ulubāria ...	20·5	,,	− 7·910	− 7·986	− 0·076
29	73 O	at I.B. Jaleswar ...	119·4	,,	+ 22·098	+ 21·479	− 0·619
28	,,	on culvert ...	120·5	,,	+ 21·864	+ 21·661	− 0·203
27	,,	,, ,, ...	121·3	,,	+ 24·919	+ 24·749	− 0·170
26	,,	at Patna T. S. ...	122·3	,,	+ 59·967	+ 59·719	− 0·248
25	,,	on culvert ...	123·4	,,	+ 22·913	+ 22·944	+ 0·031
20	,,	on bridge ...	128·7	,,	+ 7·033	+ 7·063	+ 0·030
17	,,	,, ,, ...	132·3	,,	+ 9·210	+ 9·250	+ 0·040
14	,,	(Type B) at Basta ...	134·5	,,	+ 0·840	+ 0·287	− 0·553
5	,,	,, at Nayāpāra ...	141·8	,,	+ 1·789	+ 1·552	− 0·237
66	73 K	on bridge ...	151·1	,,	+ 11·951	+ 11·952	+ 0·001
76	,,	at D.B. Balasore ...	152·0	,,	+ 24·066	+ 24·078	+ 0·012
78	,,	Standard ,, ...	153·0	,,	+ 24·339	+ 24·210	− 0·129
		Part of branch line 61 A (Sahāranpur to Dehra Dūn)					
41	53 G	Standard, Sahāranpur ...	0·0	1905-07	0·000	0·000	0·000
79	,,	G.T.S. ○ B.M. on step of well ...	1·2	,,	− 1·501	− 1·545	− 0·044
49	,,	○ on top of tower of Nojli T. S. ..	9·7	,,	+ 35·187	+ 35·173	− 0·014
42	,,	G.T.S. ⊕ B.M. on step ...	0·0	,,	+ 0·155	+ 0·176	+ 0·021
44	,,	B.○M. on bridge ...	6·8	,,	+ 27·081	+ 27·049	− 0·032
9	53 F	G.T.S. ○ B.M. at Fatehpur *dāk* bungalow ..	14·9	,,	+ 83·188	+ 83·157	− 0·031
11	,,	B.M. ○ on bridge No. $\frac{1}{85}$ ...	19·3	,,	+ 102·279	+ 102·274	− 0·005
13	,,	B.M. ○ ,, ,, ,, $\frac{1}{87}$ ...	21·1	,,	+ 150·179	+ 150·167	− 0·012

TABLE 3.—*Revision levelling*—(*contd.*).

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 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1927-28 (unadjusted)	
			miles		*feet*	*feet*	*feet*
Part of branch line 61 A (Sahāranpur to Dehra Dūn)—(contd.)							
15	53F	B.⊙M. on bridge No. 1/88 ...	22·5	1905-07	+ 206·915	+ 206·895	− 0·020
17	,,	Stone B.M. at Mohan ...	27·2	,,	+ 586·955	+ 586·994	+ 0·039
18	,,	↑ R.B. on boundary stone	28·0	,,	+ 689·011	+ 689·019	+ 0·008
19	,,	G.T.S. ⊙ B.M. on bridge No. 2/94 ...	28·2	,,	+ 706·197	+ 706·246	+ 0·049
20	,,	G.T.S. ⊙ B.M. ,, ,, ,, 10 ...	28·6	,,	+ 742·332	+ 742·402	+ 0·070
21	,,	G.T.S. ⊙ B.M. on iron bridge ...	29·8	,,	+ 824·400	+ 824·494	+ 0·094
22	,,	G.T.S. ⊙ B.M. on bridge No. 4/96 ...	30·3	,,	+ 876·561	+ 876·651	+ 0·090
23	,,	G.T.S. ⊙ B.M. ,, ,, ,, 50 ...	30·8	,,	+ 933·976	+ 934·071	+ 0·095
24	,,	G.T.S. ⊙ B.M. ,, ,, ,, 14/98 ...	32·9	,,	+ 1289·911	+ 1290·037	+ 0·126
25	,,	↑ on boundary stone...	33·2	,,	+ 1316·589	+ 1316·710	+ 0·121
26	,,	G.T.S ⊙ B.M. on bridge No. 6/99 ...	33·4	,,	+ 1367·943	+ 1368·058	+ 0·115
27	,,	G.T.S. ⊙ B.M. ,, ,, ,, 11/99 ...	33·9	,,	+ 1462·713	+ 1462·863	+ 0·150
28	,,	G.T.S. ⊙ B.M. ,, ,, ,, 5/100 ...	34·2	,,	+ 1542·086	+ 1542·240	+ 0·154
30	,,	↑ on boundary stone...	34·6	,,	+ 1631·207	+ 1631·371	+ 0·164
31	,,	B.⊙M. on astronomical pillar ...	35·0	,,	+ 1566·261	+ 1566·459	+ 0·198
33	,,	G.T.S. ⊙ B.M. on bridge No. 3/101 ...	35·3	,,	+ 1491·779	+ 1491·941	+ 0·162
35	,,	G.T.S. ⊙ B.M. Embedded at Asārori	36·0	,,	+ 1408·537	+ 1408·651	+ 0·114

TABLE 3.—*Revision levelling—(contd.)*.

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 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1927-28 (unadjusted)	
			miles		*feet*	*feet*	*feet*
Part of branch line 61A (Sahāranpur to Dehra Dūn) —(concld.)							
37	53 F	Stone B.M. at Mohabāwāla	37·1	1905-07	+ 1194·121	+ 1194·225	+0·104
39	,,	○ on plinth level ...	39·6	,,	+ 1057·156	+ 1057·263	+0·107
40	,,	Colonel Everest's upper mark of Dehra Dūn Base-Line E. end T.S. ...	39·6	,,	+ 1056·661	+ 1056·741	+0·080
43	,,	G.T.S. B.M ○ on well ...	39·4	,,	+ 1084·794	+ 1084·912	+0·118
1	53 J	on culvert ...	40·0	,,	+ 1100 661	+ 1100·775	+0·114
110	,,	B.○M. on culvert ...	40·6	,,	+ 1134·446	+ 1134·576	+0·130
2	,,	G.T.S. B.○M. on bridge ...	41·0	,,	+ 1140·097	+ 1140·240	+0·143
108	,,	↑ on boundary pillar ...	41·8	,,	+ 1193·496	+ 1193·643	+0·147
107	,,	 Wheel guard rail	42·4	,,	+ 1232·834	+ 1232·987	+0·153
5	,,	G.T.S. B.M. ○ in *tahsīl*, Dehra Dūn	43·1	,,	+ 1280·122	+ 1280·237	+0·115
106	,,	B.○M. on sluices ...	43·5	,,	+ 1307·484	+ 1307·643	+0·159
6	,,	G.T.S. Bench-mark at Dehra Dūn 1904	44·0	,,	+ 1329·756	+ 1329·919	+0·163
12	,,	Iron Plug in D.G.B'S office, Dehra Dūn ...	44·0	,,	+ 1326·754	+ 1326·903	+0·149
8	,,	Cole's Satellite Station, Dehra Dūn 1869 ...	44·1	,,	+ 1334·974	+ 1335·139	+0·165
9	,,	Standard B.M. Dehra Dūn	44·2	,,	+ 1334·110	+ 1334·259	+0·149
10	,,	⊙ ,,	44·2	,,	+ 1332·523	+ 1332·670	+0·147
11	,,	Standard B. M. at Dalanwāla, Dehra Dūn ...	44·5	,,	+ 1328·362	+ 1328·515	+0·153

TABLE 3.—*Revision levelling—(contd.).*

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 1926-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1926-28 (unadjusted)	
			miles		*feet*	*feet*	*feet*
		Part of Line 104 (Buhar to Tatta)					
4	40 D	(Type B) at Buhar ... G.T.S.	0·0	1889-90	0·000	0·000	0·000
5	,,	○ at bridge ... B.M. G.T.S.	7·6	,,	+ 14·096	+ 13·704	−0 392
12	,,	○ on M.S. Mughalbīn 6 B.M. G.T.S.	16·4	,,	+ 11·662	+ 11·675	+0·013
16	,,	□ at Chāh Hātho B.M. Wāh bridge ... A. D. 1890 G.T.S.	19·9	,,	+ 13·369	+ 13·407	+0·038
20	,,	○ on M.S. Sujāwal 10 B.M. G.T.S.	22·3	,,	+ 14·191	+ 13·893	−0·298
21	,,	○ ,, ,, ,, 8 B.M. G.T.S.	24·4	,,	+ 17·501	+ 17·486	−0·015
23	,,	○ on bridge ... B.M. G.T.S.	26·5	,,	+ 22·609	+ 22·518	−0·091
24	,,	○ ,, M.S. Sujāwal 5 B.M. G.T.S.	27·8	,,	+ 19·439	+ 19·822	+0·383
28	,,	○ ,, ,, ,, 1 B.M.	31·0	,,	+ 17·608	+ 18·970	+1·362
29	,,	E.B.M. at Sujāwal ...	32·5	,,	+ 20·519	+ 20·493	−0·026
33	,,	B.○M. on M. S. Sujāwal 2 G.T.S.	34·2	,,	+ 20·477	+ 20·399	−0·078
34	,,	○ on bridge ... B.M. 2 G.T.S.	35·4	,,	+ 28·064	+ 28·049	−0·015
84	35 P	○ on block of stone ... B.M. G.T.S.	49·7	,,	+ 23·033	+ 23·058	+0·025
64	,,	□ on M. S. Tatta 2 ... B.M.	53·7	,,	+ 63·111	+ 63·147	+0·036
67	,,	⊙ G. L. Mark-stone of Domāni H. S. .. G.T.S.	60·3	,,	+182·685	+182·763	+0·078
190	,,	○ at hospital, Tatta ,, B.M.	51·1	1924-26	+ 30·363	+ 30·432	+0·069

TABLE 3.—*Revision levelling—(contd.)*.

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 1926-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1926-28 (unadjusted)	
			miles		*feet*	*feet*	*feet*
Part of Line 104 (Buhar to Tatta)—(contd.)							
191	35 P	B◯M G.T.S. on cattle trough ...	51·6	1924-26	+ 24·113	+ 24·179	+0·066
189 (70)	,, ,,	◯ B.M. G.T.S. at Municipal office, Tatta ...	51·3	,,	+ 32·083	+ 32·155	+0·072
188	,,	◯ B.M. G.T.S. on bridge ...	51·9	,,	+ 24·836	+ 24·908	+0·072
187 (69)	,, ,,	◯ B.M. G.T.S. ,, ,, ...	52·8	,,	+ 29·343	+ 29·432	+0·089
181 (72)	,, ,,	◯ B.M. G.T.S. at Makli Hills bungalow, Tatta ...	53·0	,,	+ 55·815	+ 55·901	+0·086
186 (68)	,, ,,	▢ B.M. G.T.S. at Makli Hills bungalow, Tatta ...	53·0	,,	+ 57·493	+ 57·585	+0·092
183	,	Iron bolt (of S. B. M.), Tatta ...	53·2	,,	+ 49·340	+ 49·414	+0·074
184	,,	S. stone prism, Tatta ...	53·2	,,	+ 48·472	+ 48·568	+0·096
185	,,	N. ,, ,, ,, ...	53·2	,,	+ 48·430	+ 48·525	+0·095
182	,,	S.B.M. at Tatta ...	53·2	,	+ 49·221	+ 49·317	+0·096
Part of Line 101 A (Sukkur to Bāndhi)							
100	40 A	(Type C) G.T.S. at Sukkur ...	0·0	1921-23	0·000	0·000	0·000
252 (52)	,,	◯ B.M. G.T.S. on verandah .	0·5	,,	− 56·445	− 56·456	−0·011
253 (99)	,,	◯ B.M. G.T.S. ,, wheel guard ...	0·5	,,	− 56·718	− 56·725	−0·007
46	,,	◯ B.M. G.T.S. ,, Ry. bridge ...	1·5	,,	− 34·962	− 34·972	−0·010
254	,,	◯ B.M. G.T.S. ,, bridge No. 354 ...	1·7	,,	− 28·068	− 28·073	−0·005
255	,,	◯ B.M. G.T.S. ,, Lansdowne bridge	1·9	,,	− 19·447	− 19·447	0·000
256	,,	◯ B.M. G.T.S. ,, ,,	2·4	,	− 14·778	− 14·771	+0·007

TABLE 3.—*Revision levelling—(contd.).*

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 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1927-28 (unadjusted)	
			miles		*feet*	*feet*	*feet*
Part of Line 101 A (Sukkur to Bāndhi)—(contd.)							
257	40 A	G.T.S. ⊙ B.M. on platform ...	3·3	1921-23	−29·276	−29·287	−0·011
43	,,	G.T.S. ○ B.M. ,, bridge No. 180	4·9	1904-06	−54·789	−54·834	−0·045
41	,,	○ B.M. ,, ,, ,, 166	8·9	,,	−64·106	−64·172	−0·066
40	,,	G.T.S. ○ ,, masonry pillar ...	10·8	,,	−63·831	−64·125	−0·294
36	,,	G.T.S. ○ B.M. ,, ,, ,, ...	14·9	,,	−63·896	−64·198	−0·302
34	,,	G.T.S. ○ B.M. ,, culvert No. 143	19·0	,,	−70·468	−70·534	−0·066
30	,,	G.T.S. ○ B.M. ,, ,, ,, 127	23·1	,,	−78·185	−78·239	−0·054
29	,,	G.T.S. ○ B.M. ,, masonry pillar ...	24·9	,,	−74·996	−75·172	−0·176
28	,,	G.T.S. ○ B.M. ,, ,, ,, ...	26·9	,,	−76·076	−76·171	−0·095
23	,,	G.T.S. ○ B.M. ,, culvert No. 113	33·8	,,	−83·440	−83·520	−0·080
22	,,	G.T.S. ○ B.M. ,, bridge No. 111	35·0	,,	−80·142	−80·172	−0·030
14	,,	G.T.S. ○ B.M. ,, culvert No. 97	43·3	,,	−92·527	−92·716	−0·189
10	,,	G.T.S. ○ B.M. ,, ,, ,, 82	47·7	,,	−95·280	−95·449	−0·169
9	,,	G.T.S. ○ B.M. ,, bridge No. 75	49·5	,,	−95·788	−95·997	−0·209
8	,,	G.T.S. ○ B.M. ,, culvert ,, 68	51·8	,,	−99·200	−99·404	−0·144

TABLE 3.—*Revision levelling—(contd.)*.

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 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1927-28 (unadjusted)	
			miles		*feet*	*feet*	*feet*
Part of Line 101 A (Sukkur to Bāndhi)—(concld.)							
7	40 A	G.T.S. ○ B.M. on culvert No. 62	53·8	1904-06	−100·768	−101·003	−0·235
4	,,	G.T.S. ○ B.M. ,, ,, ,, 60	55·7	,,	−101·829	−101·952	−0·123
2	,,	G.T.S. ○ B.M. ,, ,, ,, 47	59·5	,,	−101·210	−101·352	−0·142
1	,,	G.T.S ○ B.M. ,, ,, ,, 41	61·9	,,	−105·157	−105·298	−0·141
50	40 B	G.T.S. ○ B.M. ,, bridge No. 33	66·9	,,	−105·494	−105·663	−0·169
49	,,	○ B.M. ,, masonry pillar ...	68·6	,,	−110·567	−110·816	−0·249
45	,,	G.T.S. ○ B.M. ,, culvert No. 17	75·2	,,	−118·828	−119·235	−0·407
43	,,	G.T.S. ○ B.M. ,, bridge No. 7	79·5	,,	−115·712	−115·892	−0·180
34	,,	G.T.S. ○ B.M. ,, culvert No. 204	93·9	,,	−130·880	−131·158	−0·278
Part of Line 52 C (Shāhpur to Mahrābpur)							
1	40 G	G.T.S. ○ B.M. on Tangan sluice ...	0·0	1921-22	0·000	0.000	0·000
7	40 F	B.○M. on mile-stone ...	5·8	,,	− 0·217	− 0·187	+0·030
6	,,	B.○M. on culvert ...	10·0	,,	+ 2·411	+ 2·416	+0·005
4	,,	G.T.S. ○ B.M. on bridge ...	13·1	,,	+ 3·893	+ 3·909	+0·016
3	,,	G.T.S. ○ B.M. on culvert ...	16·4	,,	+ 7·084	+ 7·085	+0·001

TABLE 3.—*Revision levelling—(contd.)*.

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 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1927-28 (unadjusted)	
			miles		*feet*	*feet*	*feet*
		Part of Line 52 C (Shāhpur to Mahrābpur)—(contd.)					
2	40 F	G.T.S. ○ on bridge B.M. ...	18·6	1921-22	+13·100	+13.146	+0·046
1	,,	G.T.S. B.□M. on H.F.L. stone	18·8	,,	+12·510	+12·551	+0·041
116	40 B	G.T.S. □ on verandah B.M. ...	23·2	,,	+ 4·288	+ 4·320	+0 032
113	,,	⊙ on culvert ...	30·9	,,	+ 7·017	+ 7·026	+0·009
		Parts of Lines 52C (Shāhpur to Mahrābpur), 52B (Daur to Lundo) and 101A (Sukkur to Hyderābād)					
113	40 B	○ on culvert ...	0·0	1921-22	0·000	0·000	0·000
110	,,	B.○M. on culvert ...	10·2	,,	+ 3·525	+ 3·477	−0·048
101	,,	B.○M. ,, ,, ...	32·8	,,	+18·182	+18·134	−0·048
257 (5)	,,	G.T.S. ○ ,, ,, No. 180 B.M. ...	47·2	,,	+17·001	+16·825	−0·176
94	,,	G.T.S. ○ ,, step B.M. ...	79·4	,,	+17·716	+17·587	−0·129
93	,,	G.T.S. ○ ,, pillar B M. ...	79·5	,,	+17·598	+17·464	−0·134
95	,,	Top of iron pipe ...	85·5	,,	+17·717	+17·509	−0·208
96	,,	G.T.S. ○ on stone block B.M. ...	89·3	,,	+16·972	+16·712	−0·260
97	,,	Top of iron pipe ...	90 9	,,	+17·103	+16·816	−0·287
99	,,	G.T.S. ○ on verandah B.M. ...	96·4	,,	+13·259	+12·894	−0·365
100	,,	90·54 ○ on stone block ...	96·5	,,	+19·794	+19·454	−0·340
98	,,	↑ B.○M. on bridge ...	96·9	,,	+22·244	+21·884	−0·360

TABLE 3.—*Revision levelling—(contd.)*.

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 height, above (+) or below (−) the starting bench-mark			Difference (revision − original). The sign + denotes that the height was greater and the sign −, less in 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1927-28 (unadjusted)	
			miles		*feet*	*feet*	*feet*
Parts of Lines 101 A (Sukkur to Hyderābād), 52 L (Daur to Bāndhi) and 52 C (Shāhpur to Mahrābpur)							
182 (49)	40 B	G.T.S. ○ B.M. on masonry pillar ...	0·0	1927-28	0·000	0·000	0·000
185	,,	G.T.S. ○ B.M. at Bhiria R.S. ...	8·5	,,	+ 0·583	+ 0·535	−0·048
187	,,	G.T.S. ○ B.M. at Karya minor ...	9·9	,,	− 0·765	− 0·803	−0·038
186	,,	G.T.S. 151 ○ 84 B.M. at bridge	10·1	,,	+ 6·102	+ 6·058	−0·044
57*	,,	B.○M. at outhouses Phul	29·4	1925-26	− 7·509	− 7·675	−0·166
58*	,,	B.○M. at S. D. O's office Phul ...	29·5	,,	− 7·363	− 7·533	−0·170
56*	,,	G.T.S. ○ B.M. at B. bungalow ...	29·6	,,	− 6·954	− 7·118	−0·164
55*	,,	L.B. □ B↑M in compound of B. Phul ...	29·7	,,	− 8·393	− 8·558	−0·165
55A*	,,	J.B. ○ 27 M on Dr. Summer's stone ...	30·1	,,	− 8·117	− 8·289	−0·172
144	,,	G.T.S. ○ B.M. on culvert ...	35·3	1921-22	−13·642	−13·745	−0·103
146	,,	G.T.S. ○ B.M. at bridge ...	40·4	,,	− 5·390	− 5·474	−0·084
147	,,	□ at P. W. D., I. B. ...	41·9	,,	− 6·382	− 6·435	−0·053
148	,,	G.T.S B.○M. at P.W.D's office ...	41·9	,,	− 6·299	−6 ·378	−0·079
149	,,	G.T.S. ○ B.M. at *mukhtiārkār's* office ...	42·2	,,	− 6·917	− 6·995	−0·078
152	,,	G.T S.○B.M. at Tharushāh	71·3	,,	− 4·584	− 4·649	−0·065

* Serial numbers in Line 52L (Daur to Bāndhi).

TABLE 3.—*Revision levelling—(contd.).*

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 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1927-28 (unadjusted)	
			miles		*feet*	*feet*	*feet*
Parts of Lines 52 L (Daur to Bāndhi) and 101 A (Sukkur to Hyderābād)							
42*	40 B	L.B. □ at Moro B. ↑ M.	0·0	1925-26	0·000	0·000	0·000
47*	,,	G.T.S. ○ on stone pillar B M.	1·5	,,	+ 2·182	+ 2·206	+ 0·024
208† (35)	,,	G.T.S. ○ at culvert No. 206... B.M.	41·4	1924-25	− 1·737	− 1·891	− 0·154
34	,,	G.T.S. ○ ,, ,, ,, 204... B.M.	43·3	1927-28	− 4·361	− 4·503	− 0·142
201	,,	G.T.S. ○ at verandah ... B.M.	43·6	,,	− 2·153	− 2·297	− 0·144
202	,,	B.○M. on well ... G.T.S.	43·8	,,	− 0·325	− 0·474	− 0·149
203	,,	B.M. at P. W. D., I. B., □ Bāndhi ... A.D. 1924	43·8	,,	− 4·577	− 4·718	− 0·141
212†	,,	G.T.S. ○ at Bāndhi R.S. ... B.M.	44·0	1924-25	+ 0·329	+ 0·184	− 0·145
Parts of Lines 101 A (Sukkur to Hyderābād) and 52 L (Daur to Bāndhi)							
216†	40 B	○ B.M. at bridge No. 203 ...	0·0	1924-25	0·000	0·000	0·000
10*	,,	B.○M. at M.S. Daulatpur 4 / Thul Rukan 4	70·4	1925-26	− 1·028	− 0·939	+ 0·089
11*	,,	G.T.S. ○ at bridge ... B.M. 126·14	77·7	,,	+ 10·767	+ 10·886	+ 0·119
12*	,,	B.○M. □ at bridge ... ↑	77·7	,,	+ 10·622	+ 10·741	+ 0·119
13*	,,	G.T.S. ○ at I. B. Thul ... B.M.	77·8	,,	+ 0·281	+ 0·399	+ 0·118

* Serial numbers in Line 52 L (Daur to Bāndhi).
† Proisvional numbers in Line 101 A (Sukkur to Hyderābād).

TABLE 3.—*Revision levelling—(contd.).*

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 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1927-28 (unadjusted)	
			miles		*feet*	*feet*	*feet*
Parts of Lines 101 A (Sukkur to Hyderābād) and 52 L (Daur to Bāndhi)—(contd.)							
14*	40 B	G.T.S. ○ B.M. at P.W.D., I.B., Thul ...	77·8	1925-26	+ 1·214	+ 1·330	+0·116
15*	„	L.B. □ B. ↑ M. at Thul ...	77·9	„	+ 0·573	+ 0·691	+0·118
Part of Line 52 C (Shāhpur to Mahrābpur)							
217	40 A	G.T.S. ○ B.M. at I.B. Mahrābpur ...	0·0	1921-22	0·000	0·000	0·000
209	„	B. ○ M. on bridge ...	21·0	„	+ 9·271	+ 9·482	+0·211
208	„	165·76 B. □ M. „ „ ↑	22·4	„	+15·970	+16·198	+0·228
205	„	G.T.S. ○ B.M. „ „ ...	27·1	„	+13·084	+13·245	+0·161
206	„	G.T.S. ○ B.M. at school ...	29·3	„	+ 2·804	+ 3·030	+0·226
207	„	B. ○ M. on culvert ...	29·6	„	+ 5·560	+ 5·807	+0·247
203	„	G.T.S. ○ B.M. at I. B. Kandiāro ...	39·5	„	+ 1·594	+ 1·719	+0·125
204	„	G.T.S. ○ B.M. at *mukhtiārkār's* office Kandiāro ...	39·7	„	− 0·536	− 0·400	+0·136
201	„	Top of iron pipe ...	45·7	„	− 9·345	− 9·178	+0·167
179	40 B	G.T.S. ○ B.M. at Kandiāro Rd. R.S	58·2	1924-25	+ 7·053	+ 7·183	+0·130
177	„	G.T.S. ○ B.M. „ I.B. „ „ ...	58·8	„	+ 0·265	+ 0·401	+0·136
178	„	G.T.S. □ B.M. A. D. 1924 „ „ „ „ ...	58·9	„	− 0·178	− 0·044	+0·134

* Serial numbers in Line 52 L (Daur to Bāndhi).

TABLE 3.—*Revision levelling—(contd.)*.

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 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1927-28 (unadjusted)	
			miles		*feet*	*feet*	*feet*
Part of Line 52 A (Ruk to Sehwān)							
69	35 M	G.T.S. ○ (Musto's type) B.M. Mehar A. D. 1921	0·0	1920-21	0·000	0·000	0·000
132	,,	G.T.S. ○ at Sita Rd. R. S. ... B.M.	38·6	1921-22	+ 2·112	+ 2·013	−0·099
131	,,	G.T.S. ○ on culvert No. 84 ... B.M.	39·5	,,	+ 3·630	+ 3·548	−0·082
130	,,	G.T.S. ○ ,, ,, ,, 85 ... B.M	40·7	,,	+ 3·710	+ 3·661	−0·049
129	,,	G.T.S. ○ ,, ,, ,, 88 ... B.M.	41·7	,,	+ 2·830	+ 2·802	−0·028
128	,,	G.T.S. ○ ,, ,, ,, 95 ... B.M.	42·7	,,	+ 1·148	+ 1·099	−0·049
127	,,	G.T.S. ○ ,, ,, ,, 100 ... B.M.	43·9	,,	+ 1·908	+ 1·837	−0·071
126	,,	G.T.S. ○ ,, ,, ,, 102 ... B.M.	44·9	,,	+ 4·115	+ 4·066	−0·049
125	,,	G.T.S. ○ ,, ,, ,, 105 ... B.M.	46·6	,,	+ 4·063	+ 4·020	−0·043
124	,,	G.T.S. ○ ,, ,, ,, 106 ... B.M.	48·1	,,	+ 7·105	+ 6·989	−0·116
123	,,	G.T.S. ○ ,, bridge ... B.M.	48·7	,,	+ 7·093	+ 6·955	−0·138
122	,,	G.T.S. ○ at Rādhan R.S. ... B.M.	50·2	,,	+ 9·901	+ 9·909	+ 0·008
121	,,	G.T.S. ○ on bridge ... B.M.	51·2	,,	+17·778	+17·625	−0·153
120	,,	G.T.S. ○ ,, ,, No. 111 ... B.M.	52·2	,,	+10·063	+ 9·928	−0·135

TABLE 3.—*Revision levelling —(concld.)*.

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 1927-28 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1927-28 (unadjusted)	
			miles		*feet*	*feet*	*feet*
Part of Line 52 A (Ruk to Sehwān)—(contd.)							
119	35 M	G.T.S. ○ B.M. on culvert No. 116...	53·2	1921-22	+14·057	+13·927	−0·130
118	„	G.T.S. ○ B.M. „ bridge „ 124 ...	54·2	„	+11·446	+11·336	−0·110
58	„	G.T.S. ○ B.M. at I.B. Mehar ...	58·7	1920-21	+ 0·965	+ 0·807	−0·158

TABLE 4.—*List of triangulation stations connected by spirit-levelling, season 1927-28.*

Name of station	Height above mean sea-level		Difference (Trian.—Levelling)	Remarks
	Spirit-levelling	Triangulation		
	feet	*feet*	*feet*	
Calcutta Longitudinal Series				
Nibria T.S. Lat. 22° 35′ 33″·92 Long. 88 14 42·43	12·280	14	+2	Ground level mark-stone
South Malūncha Meridional and East Coast Series				
Dāntūn T.S. Lat. 21° 56′ 10″·27 Long. 87 16 42·89	115·512	116	0	Top mark-stone
East Coast Series				
Patna T.S. Lat. 21° 47′ 20″·83 Long. 87 11 45·53	80·212	80	0	Top mark-stone
Great Arc Meridional Series				
Nojli (Naujli) T.S. Lat. 29° 53′ 27″·76 Long. 77 40 24·59	886·829	879	−8	Ground level mark-stone
Cutch Coast Series				
Moghul Bhin T.S. Lat. 24° 21′ 7″·66 Long. 68 17 7·49	24·064	24·65	+1	Lower mark
Gada T.S. Lat. 24° 26′ 21″·25 Long. 68 10 55·48	19·601	20·25	+1	Lower mark
Vikia T.S. Lat. 24° 41′ 52″·60 Long. 68 3 39·48	26·779	27·09	0	Lower mark

TABLE 5.—*Results of comparison of staves with standard steel tape No. 3, Lines 55 P & 136, season 1927-28.*

Place of comparison	Date	Length of staff–10 feet No. of staff		Remarks
		20 A	20 B	
		feet	*feet*	
Jabboāna ...	23-10-27	− 0·0012	− 0·0003	Clear
,, ...	1-11-27	− 0·0012	− 0·0005	,,
,, ...	1-11-27	− 0·0011	− 0·0004	,,
Thatta Māhla ...	9-11-27	− 0·0015	− 0·0010	Light scattered clouds and high wind
Shāh Jewāna R.S. ...	17-11-27	− 0·0020	− 0·0012	Clear
Sillanwāli ...	24-11-27	− 0·0035	− 0·0026	,,
Hundiewāli ...	1-12-27	− 0·0028	− 0·0022	,,
Sargodha ...	10-12-27	− 0·0022	− 0·0017	Scattered clouds
Bhalwal ...	20-12-27	− 0·0013	− 0·0005	,, ,,
Chak Raib ...	30-12-27	− 0·0020	− 0·0012	Cloudy & drizzling
Chilliānwāla ...	10-1-28	− 0·0007	+ 0·0002	Very high wind
Lāla Mūsa ...	18-1-28	− 0·0017	− 0·0005	Cloudy & drizzling
Gujrāt ...	26-1-28	− 0·0009	+ 0·0001	Scattered clouds
Phullarwān ...	7-2-28	+ 0·0002	− 0·0002	,, ,,

TABLE 5.—*Results of comparison of staves with standard steel tape No. 7, Lines 140, 106, 153, & 121, season 1927-28—(contd.).*

Place of comparison	Date	Length of staff–10 feet No. of staff		Remarks
		O 1	E 1	
		feet	*feet*	
Hāthras ...	11-10-27	+ 0·0008	− 0·0006	Clear
Muttra ...	19-10-27	− 0·0012	− 0·0028	,,
Semri ...	26-10-27	− 0·0011	− 0·0026	,,
Palwal ...	3-11-27	− 0·0027	− 0·0035	Cloudy
Okhla ...	11-11-27	− 0·0025	− 0·0034	Clear
Jumna bridge ...	20-11-27	− 0·0030	− 0·0037	,,
Sikrikalān ...	28-11-27	− 0·0031	− 0·0039	,,
Meerut ...	5-12-27	− 0·0028	− 0·0046	,,
Muttra ...	9-12-27	− 0·0022	− 0·0035	,,
Hāthras ...	17-12-27	− 0·0019	− 0·0030	,,
Balasore ...	30-12-27	− 0·0019	− 0·0027	,,
Jaleswar ...	10-1-28	− 0·0010	− 0·0032	,,
Rampurā ...	19-1-28	− 0·0012	− 0·0026	,,
Debrā ...	27-1-28	− 0·0014	− 0·0034	,,
Tamultala ...	5-2-28	− 0·0005	− 0·0018	,,
Ulubaria ...	15-2-28	− 0·0015	− 0·0031	,,
Rāmrājatala ...	24-2-28	− 0·0009	− 0·0027	,,
,, ...	3-3-28	− 0·0012	− 0·0035	,,
Kharakpur ...	10-3-28	− 0·0033	− 0·0036	,,
Balasore ...	17-3-28	− 0·0026	− 0·0044	,,
,, ...	22-3-28	− 0·0025	− 0·0043	Light clouds

TABLE 5.—*Results of comparison of staves with standard steel tape No. 7, Line 61 A, season 1927-28—(contd.).*

Place of comparison	Date	Length of staff–10 feet		Remarks
		No. of staff		
		015A	015B	
		feet	*feet*	
Sahāranpur	31-3-28	0·0000	+ 0·0003	Clear
,,	2-4-28	+ 0·0008	+ 0·0010	Hazy and cool breeze
Behārigarh	6 4-28	+ 0·0010	+ 0·0014	Clear
Mohan	10-4-28	+ 0·0006	+ 0·0009	,,
,,	14-4-28	+ 0·0006	+ 0·0009	Clear and cool breeze
,,	17-4-28	+ 0·0002	+ 0·0006	,, ,, ,,
Asārori	24-4-28	− 0·0001	+ 0·0003	Clear
Dehra Dūn	25-4-28	− 0·0008	+ 0·0003	,,

TABLE 5.—*Results of comparison of staves with standard steel tape No. 4, Lines 61A, 139, 137, and 104, season 1927-28—(contd.).*

Place of comparison	Date	Length of staff–10 feet		Remarks
		No. of staff		
		O 2	O 5	
		feet	*feet*	
Dehra Dūn ...	6-10-27	+ 0·0030	+ 0·0002	Light clouds
,, ,, ...	11-10-27	+ 0·0036	+ 0·0006	Clear
Mohan Pass ...	17-10-27	+ 0·0040	+ 0·0007	,,
Amānatgarh ...	23-10-27	+ 0·0033	+ 0·0004	,,
Sahāranpur ...	31-10-27	+ 0·0038	+ 0·0009	,,
,, ...	5-11-27	+ 0·0032	+ 0·0007	,,
Jagādhri ...	15-11-27	+ 0·0028	+ 0·0005	,,
Brahman Mazra ...	21-11-27	+ 0·0027	+ 0·0007	,,
Ambāla City ...	30-11-27	+ 0·0021	+ 0·0004	Clear and high breeze
Sādhugarh ...	7-11-27	+ 0·0022	0·0000	,, ,, ,,
Bahu Mazra ...	15-12-27	+ 0·0016	− 0·0004	Cloudy
Ludhiāna ...	23-12-27	+ 0·0003	+ 0·0001	Clear
Bhūj (Cutch) ...	8- 1-28	+ 0·0028	+ 0·0005	,,
Ratnāl (,,) ...	15- 1-28	+ 0·0022	− 0·0004	Clear and high breeze
Mamuāra ...	23- 1-28	+ 0·0016	− 0·0010	,, ,, ,,
Nakhtarāna Motā (Cutch) ...	25- 1-28	+ 0·0013	− 0·0001	Clear
Vigori (Cutch) ...	31- 1-28	− 0·0003	− 0·0005	Clear and cool breeze
,, ,, ...	4- 2-28	− 0·0002	− 0·0013	,,
Mātānomadh (Cutch)	11- 2-28	− 0·0005	− 0·0020	Clear
Lakhpat ,, ...	23- 2-28	− 0·0003	− 0·0014	,,
Ali Muhammad Māchi (Sind) ...	1- 3-28	0·0000	− 0·0022	Clear and high breeze
Jāti ...	8- 3-28	− 0·0002	− 0·0020	Clear
Khalifa ...	16- 3-28	− 0·0009	− 0·0026	,,
Sujāwal ...	24- 3-28	+ 0·0005	− 0·0019	,,
Domania ...	1- 4-28	− 0·0002	− 0·0020	,,
Tatta ...	5- 4-28	− 0·0006	− 0·0021	Clear and high breeze
Saidpur Ferry *Ghāt*	14- 4-28	+ 0·0003	− 0·0018	,, ,, ,, wind
Tanka-ki-miān ...	18- 4-28	+ 0·0004	− 0.0011	,, ,, ,, breeze

TABLE 5.—*Results of comparison of staves with standard steel tape Nos. 2 & 6, Line 101 A and Blocks M', H', L', and K', season 1927-28—(contd.).*

	Place of comparison	Date	Length of staff—10 feet				Remarks
			No. of staff				
			08A	08B	09A	09B	
			feet	*feet*	*feet*	*feet*	
Tape No. 6	Sukkur ...	4-11-27	+0·0022	+0·0021			Clear
	Khairpur Mīrs	13-11-27	+0·0025	+0·0025			,,
	Gambat ...	26-11-27	+0·0019	+0·0017			,,
	Mahrābpur ...	3-12-27	+0·0011	+0·0010			Clear and cool breeze
	Pad Idan ...	12-12-27	+0·0004	+0·0004			,, ,, ,,
	Daur ...	18-12-27	+0·0004	+0·0009			Clear
Tape No. 2	Hyderābād ...	13-11-27			+0·0024	+0·0025	,,
	Alahdino Sand	21-11-27			+0·0021	+0·0014	,,
	Tando Adam...	30-11-27			+0·0014	+0·0005	,,
	Lundo ...	8-12-27			+0·0014	−0·0007	,,
	Bucheri ...	17-12-27			+0·0008	−0·0013	,,
	Daur ...	20-12-27			+0·0013	0·0000	Clear and cool breeze
Tape No. 6	Chotiāri ...	25-12-27	+0·0003	+0·0007	+0·0002	−0·0004	Clear
	Relu-ki-hāt ...	7- 1-28	+0·0007	+0·0010	+0·0007	+0·0002	Clear and cool breeze
	Sānghar ...	18- 1-28	−0·0005	−0·0003	−0·0003	−0·0009	,, ,, ,,
	Khair Muhammad Magsi ...	2- 2-28	−0·0012	−0·0002	−0·0007	−0·0015	,, ,, ,,
	Khadro ...	12- 2-28	−0·0019	−0·0010	−0·0018	−0·0029	Scattered clouds
	Gole-ka-goth	26- 2-28	−0·0027	−0·0014	−0·0017	−0·0034	Clear
	Nawāb Shāh ...	13- 3-28	−0·0033	−0·0020	−0·0027	−0·0040	Cloudy

TABLE 5.—*Results of comparison of staves with standard steel tape No 10, Blocks Y, Z, C', D', G', H' and F', season 1927-28—(contd.).*

Place of comparison	Date	Length of staff – 10 feet				Remarks
		No. of staff				
		O10 A	O10 B	O14 A	O14 B	
		feet	*feet*	*feet*	*feet*	
Mahrābpur ...	4-11-27	+0·0013	+0·0017	+0·0003	−0·0009	Clear
Mubarka ...	11-11-27	−0·0002	+0·0002	−0·0015	−0·0004	Clear and cool breeze
Chihu ...	18-11-27	−0·0006	−0·0006	−0·0016	−0·0017	,, ,,
Gurmukh Singh ...	26-11-27	−0·0004	−0·0006	−0·0019	−0·0020	,, ,,
Rajokirio ...	4-12-27	−0·0011	−0·0015	−0·0022	−0·0016	,, ,,
Naushahro ...	13-12-27	−0·0019	−0·0024	−0·0036	−0·0025	,, ,,
Moro ...	20-12-27	−0·0027	−0·0022	−0·0038	−0·0032	,, ,,
Kathri ...	28-12-27	−0·0023	−0·0024	−0·0031	−0·0031	,, ,,
Sherkhān ...	5- 1-28	−0·0016	−0·0020	−0·0031	−0·0018	,, ,,
Sabkui ...	12- 1-28	−0·0020	−0·0021	−0·0031	−0·0025	Light scattered clouds
Āmurji ...	20- 1-28	−0·0023	−0·0027	−0·0026	−0·0025	Light scattered clouds & cool breeze
Zardari ...	27- 1-28	−0·0034	−0·0030	−0·0035	−0·0034	Clear & strong breeze
Fazal Lakho Jo-goth	4- 2-28	−0·0041	−0·0034	−0·0040	−0·0035	Clear & breeze
Jiwan Khān Jo-goth	11- 2-28	−0·0042	−0·0036	−0·0039	−0·0030	Light scattered clouds
Imāmuddin Jo-goth	18- 2-28	−0·0036	−0·0042	−0·0036	−0·0032	Scattered clouds & cool breeze
(Dād) D. B. ...	25- 2-28	−0·0048	−0·0040	−0·0016	−0·0032	Clear
Lashari ...	5- 3-28	−0·0072	−0·0058	−0·0058	−0·0048	Dusty and cool breeze
Shāhdād Zardan ..	12- 3-28	−0·0065	−0·0047	−0·0051	−0·0035	Cloudy & breeze
Kazi Ahmad ...	16- 3-28	−0·0065	−0·0054	−0·0056	−0·0037	Clear and cool breeze

TABLE 5.—*Results of comparison of staves with standard steel tape No. 5, Blocks V,U,T,Y,C,'F,'B' and X, season 1927-28—(concld.).*

Place of comparison	Date	Length of staff—10 feet				Remarks
		No. of staff.				
		012A	012 B	013A	013B	
		feet	*feet*	*feet*	*feet*	
Mahrābpur ...	4-11-27	+0·0020	+0·0017	+0·0018	+0·0019	Clear
Gul Shāh ...	14-11-27	+0·0007	+0·0006	+0·0006	+0·0006	,,
Kandiāro ...	23-11-27	+0·0011	+0·0010	+0·0014	+0·0009	,,
Mayo Sial ...	1-12-27	+0·0011	+0·0007	+0·0007	+0·0007	,,
Bahlani ...	9-12-27	−0·0015	−0·0018	−0·0011	−0·0013	,,
Mahrābpur ...	13-12-27	+0·0006	−0·0003	−0·0005	−0·0004	Light scattered clouds
Radhan ...	21-12-27	+0·0007	−0·0007	−0·0006	−0·0004	Clear
Ghulām Mohd...	29-12-27	+0·0005	+0·0001	+0·0002	+0·0002	,,
Khātia ...	7- 1-28	−0·0025	−0·0003	−0·0002	−0·0002	,,
Sita Road ...	15- 1-28	−0·0002	−0·0005	−0·0001	−0·0003	,,
Dillu ...	23- 1-28	−0·0004	−0·0008	−0·0004	−0·0002	Clear & cool breeze
Dādu ...	13- 3-28	−0·0020	−0·0037	−0·0040	−0·0039	Light scattered clouds and cool breeze
Radhan ...	28- 3-28	−0·0018	−0·0032	−0·0032	−0·0027	Clear and wind
Dillu ...	23- 1-28	−0·0003	−0·0008	−0·0004	−0·0002	Clear & cool breeze
Khera ...	26- 1-28	−0·0008	−0·0011	−0·0013	−0·0013	Light scattered clouds and very cool breeze
Gul ...	31- 1-28	−0·0015	−0·0027	−0·0028	−0·0002	Light scattered clouds and cool breeze
Dādu ...	8- 2-28	−0·0007	−0·0014	−0·0014	−0·0012	Clear
Khudābād R.S....	15- 2-28	−0·0012	−0·0025	−0·0016	−0·0014	,,
Bubak R.S. ..	23- 2-28	−0·0003	−0·0012	−0·0020	−0·0015	,,
Sainkur ...	10- 3-28	−0·0018	−0·0032	−0·0030	−0·0024	,,
Mīr Mohd. ...	2- 3-28	−0·0018	−0·0030	−0·0029	−0·0026	Light scattered clouds

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Price in Indian money		English equivalent	
Rupees	Annas	Shilling	Pence
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0	4	0	5
0	8	0	10
0	12	1	3
1	0	1	9
1	2	1	11
1	8	2	6
1	12	3	0
2	0	3	6
2	8	4	6
3	0	5	3
3	8	6	0
4	0	6	9
4	4	7	3
4	8	7	6
5	0	8	3
5	8	9	0
6	0	9	9
6	8	10	6
7	0	11	6
7	8	12	0
8	0	13	6
8	8	14	6
9	0	15	0
9	8	16	0
10	0	16	6
10	8	17	6
12	0	19	6

PART I.—NUMERICAL DATA

Triangulation Pamphlets—each covering one square degree, giving descriptions, positions, (latitude and longitude) and heights of triangulated points and other data with chart. The chart shows the plan of triangulation with the position of stations and points. Triangulation data falling in 1/M sheet are printed in a series of sixteen pamphlets A to P. In the last pamphlet of every series, a coloured map on scale 1 inch = 16 miles approximately is given in addition to the chart, to illustrate the topographical features of the area covered by the 1/M sheet. Pamphlets having this map are charged Rs. 1-8 extra.

Index charts of the published triangulation pamphlets are given at the end.

Price Re. 1 per pamphlet. Published at Dehra Dūn.

Levelling Pamphlets—

(i) **Levelling of Precision**—giving heights and descriptions of all *Benchmarks*, fixed by Levelling of Precision. Each pamphlet embraces an area of 4° × 4° and the numbering is the same as that of the corresponding sheets of the 1/M map of India. Each is illustrated by a map of the area. Published at Dehra Dūn.

(a) **Levelling of Precision in India and Burma—**

Pamphlet		Latitude	Longitude	Published in	Price
Sheet	Distinctive name of sheet				
34	(Quetta) ...	28°–32°	64°–68°	1916	Rs. 2-0-0
35	(Karāchi) ..	24–28	64–68	1911	Rs. 2-0-0
38	(Kābul) ..	32–36	68–72	1912	Rs. 2-0-0
39	(Multān) ...	28–32	68–72	1913	Rs. 2-0-0
	Addendum to 39 ...	...	...	1916	Rs. 2-0-0
40	(Hyderābād, Sind) ...	24–28	68–72	1911	Rs. 2-0-0
41	(Rājkot) ...	20–24	68–72	1913	Rs. 2-0-0
43	(Srīnagar) ...	32–36	72–76	1913	Rs. 2-0-0
	Addendum to 43 ...	...	...	1915	Rs. 2-0-0
44	(Lahore) ...	28–32	72–76	1926	Rs. 3-0-0
45	(Ajmer) ...	24–28	72–76	1911	Rs. 2-0-0
46	(Baroda) ...	20–24	72–76	1912	Rs. 2-0-0
47	(Bombay) ...	16–20	72–76	1912	Rs. 2-0-0
	Addendum to 47, Island of Bombay ...	...	...	1915	Re. 1-0-0
48	(Goa) ...	12–16	72–76	1912	Rs. 2-0-0
49	(Calicut) ...	8–12	72–76	1911	Re. 1-0-0
52	(Leh) ...	32–36	76–80	1912	Re. 1-0-0
53	(Delhi) ...	28–32	76–80	1920 (reprinted 1929)	Rs. 3-0-0
54	(Agra) ...	24–28	76–80	1921	Rs. 2-0-0

Levelling Pamphlets—(*Continued*).

Sheet	Pamphlet: Distinctive name of sheet	Latitude	Longitude	Published in	Price
55	(Nāgpur) ...	20°-24°	76°-80°	1912	Rs. 2-0-0
56	(Hyderābād, Deccan) ...	16-20	76-80	1912	Rs. 2-0-0
	Addendum to 56 ...	...	..	1919	Re. 1-0-0
57	(Mysore) ...	12-16	76-80	1919	Rs. 2-0-0
58	(Ootacamund) ..	8-12	76-80	1914	Rs. 2-0-0
62	(Mānasarowar) ...	28-32	80-84	1922	Re. 1-0-0
63	(Allahābād) ...	24-28	80-84	1923	Rs. 2-0-0
64	(Raipur) ..	20-24	80-84	1912	Rs. 2-0-0
65	(Vizagapatam) ...	16-20	80-84	1913	Rs. 2-0-0
66	(Madras) ..	12-16	80-84	1912	Rs. 2-0-0
72	(Kātmāndu) ...	24-28	84-88	1912	Rs. 2-0-0
	Addendum to 72 ...	...	...	1919	Rs. 2-0-0
73	(Cuttack) ...	20-24	84-88	1913	Rs. 2-0-0
	Addendum to 73 ...	...	...	1920	Rs. 2-0-0
74	(Purī) ..	16-20	84-88	1913	Rs 2-0-0
78	(Darjeeling) ...	24-28	88-92	1923	Rs. 2-0-0
79	(Calcutta) ...	20-24	88-92	1924	Rs. 2-0-0
83	(Dibrugarh) ...	24-28	92-96	1912	Rs. 2-0-0
84	(Akyab) ...	20-24	92-96	1918	Rs. 2-0-0
85	(Prome) ...	16-20	92-96	1917	Rs. 2-0-0
92	(Bhamo) ...	24-28	96-100	1918	Rs. 2-0-0
93	(Mandalay) ...	20-24	96-100	1917	Rs. 2-0-0
94	(Rangoon)) ...	16-20	96-100	1916	Rs. 2-0-0
95	(Mergui))	12-16	96-100		

(b) Levelling of Precision in Mesopotamia—

Descriptions and heights of bench-marks in Mesopotamia in one pamphlet, published at Dehra Dūn, 1923. *Price Rs. 3.*

(ii) Levelling of Secondary Precision -

Descriptions and heights of bench-marks by lines generally produced by Gestetner at Dehra Dūn.

Serial No.	Line number	Situated in degree sheets	Published in	Price
1	52A (Ruk to Sehwān) ...	35 M & N and 40 A	1928	As. 6
2	52B (Daur to Lundo) ...	40 B & C	,,	,,
3	52C (Shāhpur to Mahrābpur) ...	35 N and 40 A, B, C, F & G	,,	,,
4	52D (Tando Alāhyār to Hyderābād)	40 C & D	,,	,,

Levelling Pamphlets—(*Continued*).

Serial No.	Line number	Situated in degree sheets	Published in	Price
5	52E (Rohri to Jām Sahib) ...	40 A, B & E	1928	As. 6
6	52F (Shāhpur to Mīrpur Purāna) ...	40 B, C & G	„	„
7	52G (Lāndhi canal bungalow (39th mile) to Khipro) ..	40 C & G	„	„
8	52H (Khipro to Ghulām Bhurgari)	40 G	„	„
9	52 I (Mīrpur Khās to Tando Ghulām Alī via Umarkot and Dādāh) ...	40 C, D, G & H	„	„
10	52J (Mīrpur Khās to Tando Ghulām Alī via Dīgrī) ...	40 G	„	„
11	52K (Dīgrī to Dādāh) ...	40 G & H	„	„
12	70J (Barākar to Hazāribāgh Road)	73 I and 72 H & L	„	As. 12
13	74C (Howrah to Uttarpāra) 74D (Baidyabāti to Sheorāphūli) 74E (Bāndel Church to Bāndel Ry. Stn.) 74F (B.M. 251(*118*)/79A to Pandua Ry. Stn.)	79 A & B	„	As. 8
14	74G (B.M. 126/73M to Saktigarh Ry. Stn.) 74H (B.M. 116/73M to Burdwān Ry. Stn.) 70E (B.M. 85/73M to Mānkar Ry. Stn.) 70F (B.M. 76/73M to Pānagar Ry. Stn.) 70G (B.M. 58/73M to Durgāpur Ry. Stn.) 70H (B.M. 28/73M to Rānīganj Ry. Stn.) 70 I (B.M. 15/73M to Asansol, Kālīpāhari & Churulia) 70M (Khāna Ry. Stn. to Galsi Ry. Stn.)	73 I & M	„	As. 12
15	77Q (Calcutta to Nārāyanpur) 77R (Nārāyanpur to Nārāyanpur)	79 B	„	Re. 1
16	87A (Moulmein to Paan) 87B (Moulmein to Wekali) 87C (Babukon to Kawmyatkyi) 87D (Nyaungbinzeik to Natchaung)	94 H & L and 95 E & I	„	As. 12

Levelling Pamphlets—(*Continued*).

Serial No.	Line number	Situated in degree sheets	Published in	Price
17	88B (Kyauktaga to Myitkyo) 88C (Dalanun to Pazunmyaung) 88D (Pegu to Zenyaungbin) 88E (Myitkyo to Okpo) 88F (E. B. M. at R. D. 25 of the Yenwe Embankment to Uaw) 90A (Nyaungzaye to Kandin) 90B (Ma-ubin to Bassein) 90C (Sagamya to Pantanaw) 90E (Thonze to Rangoon)	85 L,N,O & P and 94 B,C & D	1928	Rs. 2
18	89A (Kyaukse to Minzu) 89B (Ywakainggyi to Amarapura) 89C (Kyaukse to Mandalay) 89D (Tangôn to Shwebo) 89E (Kabo to Myittaw) 89F (Okshitkan to Paukkan) 90D (Meiktila to Yewe)	93 B & C. and 84 M, N, O & P	,,	Rs. 1-8
19	29C (Nīra to Batgarh) ...	47 F & J	1929	As. 6
20	53A (Madad Chāndia to Mehar)	35 M	,,	,,
21	54B (Shikārpur to Kambar) ...	40 A	,,	,,
22	54C (Wāriāso to Rato-dero) ...	34 P, 35 M, 39 D & 40 A.	,,	,,
23	55I (Garh Mahārāja to Damāmia)	39 N, 44 A&B	,,	,,
24	55K (Aherbela to Multān) 55L (Rangpur to Muzaffargarh) 55M (Muzaffargarh to Basti Maluk)	39 N & O	,,	As. 10
25	55O (Sujābād to Sabuwāli) ...	39 O	,,	As. 6
26	55P (Jabboāna to Kot Māldeo) ...	44 A	,,	,,
27	56H (Kasūr to Basirpur) ...	44 F, I & J	,,	,,
28	57D (Lodhrāu to Bahāwalpur) ...	39 O	,,	,,
29	57H (Basirpur to Lodhrān) ...	39 O, 44 B,C & F	,,	,,
30	57J (Kutabpur to Adamwāhān) ...	39 O	,,	,,
31	57L (Dīngarh to Khānpur) ...	39 L,O & P	,,	,,
32	57M (Mithra to Khānpur) ...	39 H & L and 40 E & I.	,,	,,
33	57N (Chachran to Khānbela) ...	39 K,L & O	,,	,,
34	74B (Kidderpore to Dublat) ...	79 B	,,	,,
35	77V (Hastings Bridge to Dakhinesar) ...	79 B	,,	,,

Levelling Pamphlets.—(*Concluded*).

Serial No.	Line number	Situated in degree sheets	Published in	Price
36	70K (Allāhābād to Barākar) ...	63 G, K & O, 72 C, G, K&L and 73 I	„	As. 14
37	70L (Mughal Sarai to Hazāribāgh Road) ...	63 O & P and 72 D & H	„	As. 10

Tide-Tables—

Since 1881 Tidal predictions based on the observations of the Survey of India have been published annually by the India Office, London, up till the year 1922. From 1923 onwards the prediction and publication have been undertaken at Dehra Dūn by the Survey of India. The tables give the times and heights of high- and low-water for every day in the year for 37 ports, and are published early in the previous year. They are published as follows :—

(i) A single volume styled **"The Major Series"** comprising Tide-Tables for the following ports :—

Suez, Aden, Bushire, Karāchi, Okha Point & Bet Harbour, Bhāvnagar, Bombay, Cochin, Tuticorin, Pāmban Pass, Colombo, Madras, Vizagapatam, Dublat, Diamond Harbour, Kidderpore, Chittagong, Elephant Point and Rangoon. *Price Rs. 8.*

(ii) **Combined Pamphlets** as below :—

(*a*) Okha Point and Bet Harbour (Mouth of the Gulf of Cutch)
Porbandar
Port Albert Victor (Kāthiāwār)
Bhāvnagar *Price Rs. 1-8.*

(*b*) Marmagao
Kārwār *Price Rs. 1-2.*

(*c*) Dublat (Sāgar Island)
Diamond Harbour
Kidderpore (Calcutta) } Hooghly River *Price Rs. 1-8*

(*d*) Amherst
Moulmein } Moulmein River *Price Rs. 1-2.*

(*e*) Tuticorin
Pāmban Pass (Island of Rāmeswaram) *Price Rs. 1-2.*

(*f*) Colombo
Galle
Trincomalee } Ceylon *Price Rs. 1-8*

(*g*) Diamond Island
Bassein } Bassein River *Price Rs. 1-2.*

(*h*) Elephant Point
Rangoon } Rangoon River *Price Rs. 1-2.*

Tide-Tables—(*Continued*).

(iii) **Separate pamphlets** for each of the following ports:—

Suez, Aden, Basrah, Bushire, Karāchi, Bombay, Beypore, Cochin, Negapatam, Madras, Cocanāda, Vizagapatam, False Point, Chittagong, Akyab, Mergui, and Port Blair. *Price of each pamphlet is As. 12.*

PART II.—GEODETIC WORKS OF REFERENCE

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 Captain George Everest, F.R.S. &c, 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.-Colonel G. Everest, R.F.S. and his assistants, 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.

Vol. I—**The Standards of Measure and the 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 the 10-feet Standards **A** and **B**, and determinations of the Difference of their Expansions.

Appendix No. **3**. Comparisons between the 10-feet Standards I_B, I_S and **A**.

Appendix No. **4**. Comparisons of the 6-inch Brass Scales of the Compensated Microscopes.

Appendix No **5**. Determination of the Length of the Inch [7.8] on Cary's 3-foot Brass Scale.

Appendix No. **6**. Comparisons between the 10-feet Standard Bars *S* and **A** for determining the Expansion of **A**.

Appendix No. **7**. Final determination of the Differences in Length between the 10-feet Standards I_B, I_S and **A**.

Appendix No. **8**. On the Thermometers employed with the Standards of Length.

Appendix No. **9**. Determination of the Lengths of the Sub-divisions of the Inch [*a.b*].

Appendix No. **10**. Report on the Practical Errors of the Measurement of the Cape Comorin Base.

Vol. II—**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.

G.T.S. Volumes—(*Continued*).

Appendix No. **6**. On Tidal Observations at Karāchi 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 NW. 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).

Vol. 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. *Price Rs. 10-8.*

Vol. IVA—**North-West Quadrilateral**—The Principal Triangulation, the Jodhpur and the Eastern Sind Meridional Series with the details of their Reduction and the Final Results. Dehra Dūn, 1886. *Price Rs. 10-8.*

Vol. V—**Pendulum Operations** details of, by Captains J. P. Basevi and W. J. Heaviside, and of their Reduction. Dehra Dūn and Calcutta, 1879. *Price Rs. 10-8*

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 elsewheres

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.

Vol. 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 Bīdar Longitudinal, the Jubbulpore and the Bilāspur Meridionals. Dehra Dūn, 1880. (Out of print.)

Vol. 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. *Price Rs. 10-8.*

G.T.S. Volumes—*(Continued).*

Appendix No. 1. The Details of the Separate Reduction of the Budhon Meridional Series, or Series J of the North-East Quadrilateral.

Appendix No. 2. Reduction of the North-East Quadrilateral. The Non-circuit Triangles and their Final Figural Adjustments.

Appendix No. 3. On the Theoretical Errors generated respectively in Side, Azimuth, Latitude and Longitude in a Chain of Triangles.

Appendix No. 4. On the Dispersion of the Residual Errors of a Simultaneous Reduction of several Chains of Triangles.

Vol. VIII—**North-East Quadrilateral**—Details of the following eleven series:—

Gurwāni Meridional, Gora Meridional, Hurīlāong Meridional, Chendwār Meridional, North Parasnāth Meridional, North Malūncha Meridional, Calcutta Meridional, East Calcutta Longitudinal, Brahmaputra Meridional, Eastern Frontier—Section 23°-26°, and Assam Longitudinal. Dehra Dūn, 1882. *Price Rs. 10-8.*

Vol. IX—**Telegraphic Longitudes**—during the years 1875-77 an 1880-81. Dehra Dūn, 1883. *Price Rs. 10-8.*

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.

Vol. X—**Telegraphic Longitudes**—during the years 1881-82, 1882-83, and 1883-84. Dehra Dūn, 1887. *Price Rs. 10-8.*

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. *Price Rs. 10-8.*

Vol 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. *Price Rs. 10-8.*

Vol. 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. *Price Rs. 10-8.*

G.T.S. Volumes—(*Continued*).

Vol. XIV—**South-West Quadrilateral**—Details of Principal Triangulation and Simultaneous Reduction of its component series. Dehra Dūn, 1890. *Price Rs. 10-8.*

Vol. 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. *Price Rs. 10-8.*

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).

Vol. XVI—**Tidal Observations**— from 1873 to 1892, and the Methods of Reduction. Dehra Dūn, 1901. *Price Rs. 10-8.*

Vol. XVII—**Telegraphic Longitudes**—during the years 1894-95-96. The Indo-European Arcs from Karāchi to Greenwich. Dehra Dūn, 1901. *Price Rs. 10-8.*

Appendix No. **1.** Descriptions of Points used for Longitude Stations.

Appendix No. **2.** The Longitude of Madras.

Vol. XVIII—**Astronomical Latitudes**—from 1885 to 1905 and the deduced values of Plumb-line Deflections. Dehra Dūn, 1906. *Price Rs. 10-8.*

Appendix No. **1.** On Deflections of the Plumb-line in India.

Appendix No. **2.** Determination of the Geodetic Elements of the Latitude Stations of Bajamara, Bahak, Lambatach and Kidarkanta.

Appendix No. **3.** On the (N-S) Difference exhibited by Zenith Sector No. 1.

Appendix No. **4.** On the Value of the Micrometer of the Zenith Telescope.

Appendix No. **5.** On the Azimuth Observations of the Great Trigonometrical Survey of India.

Appendix No. **6.** A Catalogue of the Publications of the Great Trigonometrical Survey of India.

Appendix No. **7.** On the combination weights employed.

Vol. XIX—**Levelling of Precision in India**—from 1858 to 1909. Dehra Dūn, 1910. *Price Rs. 10-8.*

Appendix No. **1.** Experiment to test the changes, due to moisture and temperature, in the Length of a levelling staff.

Appendix No. **2.** On the erection of Standard Bench-marks in India during the years 1904-1910.

Appendix No. **3.** Memorandum on the steps taken in 1905-1910 to enable movements of the Earth's Crust to be detected.

Appendix No. **4.** Dynamic and Orthometric corrections to the Himālayan levelling lines and circuit; and a consideration of the order of magnitude of possible refraction errors.

Appendix No. **5.** The passage of rivers by the levelling operations.

Appendix No. **6.** The errors of the Trigonometrical values of heights of stations of the Principal Triangulation.

G.T.S. Volumes—(*Concluded*).

Appendix No. 7. The effect on the spheroidal correction of employing theoretical instead of observed values of gravity and a discussion of different formulæ giving variation of gravity with latitude and height.

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

Vol. XIXA—**Bench Marks** on the **Southern** Lines of Levelling. Dehra Dūn, 1910. *Price Rs. 5.*

Vol. XIXB—**Bench Marks** on the **Northern** Lines of Levelling. Dehra Dūn, 1910. *Price Rs. 5.*

PART III.—HISTORICAL AND GENERAL REPORTS.

Memoirs.

1. A Memoir on the Indian Surveys, by C. R. Markham, India Office, London, 1871. *Price Rs. 5.*
2. A Memoir on the Indian Surveys. (Second Edition), by C. R. Markham, C.B., F.R.S., India Office, London, 1878. *Price Rs. 5-8.*
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.*

"Notes of the Survey of India" are issued monthly. *Price As. 2.*

Annual and Special Reports.

Reports of the **Revenue Branch**—1851-1877. (1851-67 and 1869-70, out of print). *Price Rs. 3.*

Ditto **Topographical Branch**—1860-1877. (Out of print).

Ditto **Trigonometrical Branch**—1861-1878.—(1861-71, out of print). *Price Rs. 2.*

In 1878 the three branches were amalgamated, and from that date onwards annual reports in single volumes for the whole department, were published as follows:—

General Reports { from 1877-1900 (1877-79, 1887-88, 1895-96 and 1897-98, out of print). *Price Rs. 3 per volume.*
from 1900-1922 (1902-04 and 1906-08, out of print). *Price Rs. 2 per volume.*

From 1900 onwards the Report was issued annually in the form of a condensed statement known as (*a*) the "**General Report**" supplemented by fuller reports, which were called (*b*) "**Extracts from Narrative Reports**" up to 1909, and since then until 1921 have been styled (*c*) "**Records of the Survey of India**".

Annual Reports &c.—(*Continued*).

From 1922 the annual reports are published in three separate volumes of octavo size, *viz.*, (*a*) **General Report** which is confined to reporting the Survey operations of the ordinary field parties and detachments with only brief abstracts of geodetic operations, Map Publication and Office work. Published annually *Price 1922-25 Rs. 2, from 1925 Re. 1.* (*d*) **Map Publication and Office Work** report which contains all the Index Maps showing the Progress of Map Publication on all scales, with reports on publication and issue. Published annually beginning with year 1924. *Price Re. 1.* (*e*) **Geodetic Report** which includes full details of all scientific work of the Geodetic Branch, Survey of India excluding the work of the Dehra Drawing Office and Publication Office. Vol. 1 of this series covers a period of three years 1922-25. *Price Rs. 6.* Subsequent volumes will be published annually. There will be in addition occasional Records volumes.

These fuller reports are available as follows:—

(*b*) **Extracts Volumes.**

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. *Price Rs. 1-8.*

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. *Price Rs. 1-8.*

1904-05—Magnetic Survey. Pendulum Operations. Tidal and Levelling. Triangulation in Baluchistān. Survey Operations with the Somāli-and Field Force. Calcutta, 1907. *Price Rs. 1-8.*

1905-06—Magnetic Survey. Pendulum Operations. Tidal and Levelling. Topography in Shan States. Calcutta, 1908. *Price Rs. 1-8.*

1906-07—Magnetic Survey. Pendulum Operations. Tidal and Levelling. Triangulation in Baluchistān. Astronomical Latitudes. Topography in Shan States. Calcutta, 1909. *Price Rs. 1-8.*

1907-08—Magnetic Survey. Tidal and Levelling. Astronomical Latitudes. Pendulum Operations. Topography in Shan States. Calcutta, 1910. *Price Rs. 1-8.*

1908-09—Magnetic Survey. Tidal and Levelling. Pendulum Operations. Triangulation. Calcutta, 1911. *Price Rs. 1-8.*

Annual Reports &c.—(*Continued*).

(*c*) Records of the Survey of India.

Vol. I—**1909-10**—Topographical Survey. Triangulation. Tidal and Levelling Operations. Geodetic Survey (Astronomical latitudes and pendulum observations). Magnetic Survey. Calcutta, 1912. *Price Rs. 4.*

Vol. II—**1910-11**—Topographical Survey. Triangulation. Tidal and Levelling Operations. Geodetic Survey. Magnetic Survey. Calcutta, 1912. *Price Rs. 4.*

Vol. III—**1911-12**—Topographical Survey. Triangulation. Tidal and Levelling Operations. Geodetic Survey. Magnetic Survey. Calcutta, 1913. *Price Rs. 4.*

Vol. IV—**1911-13**—*Explorations on the North-East Frontier—North Burma, Mishmi, Abor and Mīri Surveys.* Calcutta, 1914. *Price Rs. 4.*

Vol. V—**1912-13**—Topographical Survey. Triangulation. Tidal and Levelling Operations. Geodetic Survey. Magnetic Survey. Note on the relationship of the Himālayas to the Indo-Gangetic Plain. Calcutta, 1914. *Price Rs. 4.*

Vol. VI—**1912-13**—*Link connecting the Triangulations of India and Russia.* Dehra Dūn, 1914. *Price Rs. 4.*

Vol. 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. *Price Rs. 4.*

Vol. VIII—{ **1865-79 Part I** / **1879-92 Part II** } *Explorations in Tibet and neighbouring regions.* Dehra Dūn, 1915. *Price of each part Rs. 4.*

Vol. VIII (A)—**1914**—*Explorations in the Eastern Kara-koram and the Upper Yārkand Valley,* by Lt.-Colonel H. Wood, R.E. Dehra Dūn 1922. *Price Rs. 3.*

Vol. 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 Himālaya Mountains" an address by Colonel S. G. Burrard, F.R.S. Report on Turco-Persian Frontier Commission. Calcutta, 1916. *Price Rs. 4.*

Vol 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. *Price Rs. 4.*

Vol. 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 Morē. Photo-Litho Office—New method of preparing Layer plates—Developments and Improvements in preparing Tint-plates. Dehra Dūn, 1918. *Price Rs. 4.*

Vol. XII—*Notes on Survey of India Maps and the modern development of Indian Cartography,* by Lt.-Colonel W. M. Coldstream, R.E., Superintendent, Map Publication. Calcutta, 1919. *Price Rs. 3.*

Annual Reports &c.—(*Continued*).

Vol. XIII—**1917-18**—Topographical Survey. Tidal and Levelling Operations. Magnetic Survey. Photo-Litho office—the Powder Process. Problem of the Himālayan and Gangetic Trough—Review by Dr. A. Morley Davies. Dehra Dūn, 1919. *Price Rs. 4.*

Vol. XIV—**1918-19**—Topographical Survey. Tidal and Levelling Operations. Levelling in Mesopotamia. Magnetic Survey.
Dehra Dūn, 1920. *Price Rs. 4.*

Vol. XV—**1919-20**—Topographical Survey. Tidal work. Levelling—proposed new level net. Magnetic Survey. The Earth's Axes and Figure, by 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 Ladākh.
Dehra Dūn, 1921. *Price Rs. 4.*

Vol. XVI—**1920-21**—Topographical Survey. Tidal work. Levelling and Magnetic Survey. High Climbs in the Himālaya prior to the Everest Expedition. Mt. Everest Survey Detachment Report, 1921. Traverse Survey of Allahābād city. Settlement of Boundary between Mysore and South Kanara.
Dehra Dūn, 1922. *Price Rs. 4.*

Vol. XVII—**1923**—*Memoir on Maps of Chinese Turkistān and Kansu* from the Surveys made during Sir A. Stein's Exploratoins, 1900-01, 1906-08, 1913-15. Dehra Dūn, 1923. *Price Rs. 12.*

Vol. XVIII—**1921-22**—Topographical Survey. Tidal work. Levelling and Magnetic Survey. Traverse Survey of Allahābād city. Settlement of Boundary between Mysore and South Kanara. Notes on Revision Survey in the neighbourhood of Poona.
Dehra Dūn, 1923. *Price Rs. 4.*

Vol. XIX—**1901-20**—The Magnetic Survey, by Lt.-Colonel R. H. Thomas, D.S.O., R.E., and E. C. J. Bond, V.D.
Dehra Dūn, 1925. *Price Rs. 4.*

Vol. XX—**1914-20**—The War Record. Dehra Dūn, 1925. *Price Rs 3.*

Vol. XXI—**1922-23-24**—I. *Air Survey in the Irrawaddy Delta* 1923-24, by Major C. G. Lewis, R.E., and
II. *Reconnaissance Survey in Bhutan and South Tibet 1922*, by Captain H. R. C. Meade, I.A.
Dehra Dūn, 1925. *Price Rs. 1-8.*

Vol. XXII—**1926**—Exploration of the Shaksgam Valley and Aghil Ranges, 1926, by Major K. Mason, M.C., R.E.
Dehra Dūn, 1928. *Price Rs. 3*

(*c*) **Geodetic Reports.**

Vol. I—**1922-25**—Computations and Research. Tidal work. Time and Magnetic observations. Latitude and Pendulum observations in Bihār, Assam and Kashmīr. Levelling. Lecture on "The height of Mount Everest and other Peaks".
Dehra Dūn, 1928. *Price Rs. 6.*

Vol. II—**1925-26**—Computations and Research. Tidal work. Time and Magnetic observations. Preparations for the International Longitude Project. Triangulation. Levelling. Investigation of the behaviour of tree bench-marks in India.
Dehra Dūn, 1928. *Price Rs. 3.*

Annual Reports &c.—(*Concluded*).

Vol. III—**1926-27**—The International Longitude Project. Computations and Publication of data Observatories. Tides. Gravity and deviation of the vertical. Triangulation. Levelling. Research and Technical Notes regarding Personal Equation Apparatus and the height of Mount Everest.
Dehra Dūn, 1929. *Price Rs. 3.*

Vol. IV—**1927-28**—Computations and Publication of data. Observatories. Tides. Gravity and deviation of the vertical. Triangulation. Levelling. Dehra Dūn, 1929. *Price Rs. 3.*

PART IV.—CATALOGUES AND INSTRUCTIONS

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.** —	834
2.—**Circular Orders (Administrative).** —	420
3.—**Circular Orders (Professional).** —	196

4.—**Departmental Orders.** (appointments, promotions, transfers, etc.)

These are numbered serially and had reached the above numbers by September 1928. *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.
Ditto ditto 1919-1924.—Dehra Dūn, 1926.

Departmental Orders.—(*Concluded*)

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 Class II Service.—Dehra Dūn, 1927 & 1929. *Price Re. 1* per year.

Catalogues and Lists.

1. **Catalogue of Maps** published by the Survey of India. Corrected to 31st March 1928, Calcutta, 1928. *Price Re. 1.*

Lists of new maps published during each month appear in the monthly NOTES OF THE SURVEY OF INDIA. These monthly lists are also issued separately.

2. **Catalogue of Maps** of the Bombay Presidency, Calcutta, 1913. *Price As. 4.*
3. **Catalogue of Maps of Burma.** Calcutta 1925. *Price As. 8.*
4. **Catalogue** of Maps of Cantonments and Military stations. Dehra Dūn, 1927. *Price As. 8.*
5. **Catalogue** of Books in the headquarters Library, Calcutta, 1901. (Out of print).
6. **Catalogue** of Scientific Books and Subjects in the Library of the Trigonometrical Survey Office. Dehra Dūn, 1908. *Price Re. 1.*
7. Classified **Catalogue** of the Trigonometrical Survey Library. Dehra Dūn, 1921. *Gratis.*
8. **Green Lists**—Part I—List of Officers in the Survey of India (annually to date 1st January), Calcutta. *Price Rs. 3-4.*

   Part II—History of Services of Officers in the Survey of India (annually to date 1st July), Calcutta. *Price Rs. 1-8.*
9. **Blue Lists**—Ministerial and Lower Subordinate Establishments of the Survey of India.

   Part I—Headquarters and Dehra Dūn offices (published annually to date 1st April), Calcutta. *Price Rs. 6-12.*

   Part II—Circles and parties (published annually to date 1st January), Calcutta. *Price Rs. 5.*
10. **List of the publications of the Survey of India** (published annually) Dehra Dūn. *Gratis.*
11. **Price List of Mathematical Instrument Office.** Corrected up to 1st September 1927, Calcutta, 1928. *Gratis.*

Tables and Star Charts.

1. **Auxiliary Tables**—to facilitate the calculations of the Survey of India. Fourth Edition, Dehra Dūn, 1906. (Out of print).
2. **Auxiliary Tables**—of the Survey of India. Fifth Edition, (revised and extended), by J. de Graaff Hunter, M.A., SC.D., F. INST. P. In parts—

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* For Departmental use only.

Tables and Star Charts.—(*Continued*).

Part I—Graticules of Maps, (reprinted). Dehra Dūn, 1926. *Price Re. 1.*

Part II—Mathematical Tables, (reprinted with additions). Dehra Dūn, 1924. *Price Rs. 2.*

Part III—Topographical Survey Tables, (reprinted with additions). Dehra Dūn, 1928. *Price Rs. 3.*

3. Tables for Graticules of Maps. Extracts for the use of **Explorers.** Dehra Dūn, 1918. *Price As. 4.*

4. * Metric Weights and Measures and other tables. Photo-Litho Office. Calcutta, 1889. (Out of print).

5. Logarithmic Sines and Cosines to 5 places of decimals. Dehra Dūn, 1886. (Out of print).

6. Logarithmic Sines, Cosines, Tangents and Cotangents to 5 places of decimals. Dehra Dūn, 1915. (Out of print).

7. Common Logarithms to 5 places of decimals, 1885. (Out of print).

8. Table for determining Heights in Traversing. Dehra Dūn, 1898. *Price As. 8.*

9. Tables of distances in Chains and Links corresponding to a subtense of 20 feet. Dehra Dūn, 1889. *Price As. 4.*

10. * Ditto ditto 10 feet. Calcutta, 1915.

11. * Ditto ditto 8 feet. Ditto.

12. Field Traverse Tables. First Edition. Calcutta, 1928. *Price As. 8.*

13. Star Charts for latitude 20° N., by Colonel J. R. Hobday, I.S.C. Calcutta, 1904. *Price Rs. 1-8.*

14. Star Charts for latitude 30° N., by Lt.-Colonel S. G. Burrard, R.E., F.R.S. Dehra Dūn, 1906. *Price Rs. 1-8.*

15. Star Charts for latitude 15° N. Dehra Dūn, 1928. *Price Rs. 2.*

16. Star Charts for latitude 30° N. Dehra Dūn, 1928. *Price Rs. 2.*

17. Catalogue of 249 Stars for epoch 1st Jan. 1892, from observations by the Survey, Dehra Dūn, 1893. *Price Rs. 2.*

18. * Rainfall, maximum and minimum temperatures, from 1868 to 1927, recorded at the Survey Office Observatory, Dehra Dūn, 1928.

Old Manuals.

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 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 Lt.-Colonel R. Smyth. Third Edition, revised and enlarged. Calcutta, 1875. (Out of print).

4. Hand-Book, Revenue Branch. Calcutta, 1893. *Price Rs. 2-8.*

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* For Departmental use only.

Survey of India Hand-Books.

1. * **Hand-Book of General Instructions,** (in 2 vols.) Fifth Edition. 1927.

2. **Hand-Book, Trigonometrical Branch,** Second Edition. Calcutta, 1902. (Out of print).

3. **Hand-Book of Trigonometrical Instructions.**—Third Edition. Parts in pamphlet forms—

Part V—The Tides. Third Edition, revised, Dehra Dūn 1926. *Price Rs. 2.*

Part VI—Levelling. Third Edition, revised, Dehra Dūn, 1928. *Price Re. 1.*

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, 1921. *Price As. 8.*

„ II—Constitution and Organization of a Survey Party. —reprinted with additions, 1923. *Price As. 8.*

„ III—Triangulation and its Computation.—revised 1923. *Price Re. 1.*

„ IV—Theodolite Traversing—Third Edition, 1927. *Price Re. 1.*

„ V—Plane-tabling.—Third Edition, 1926. *Price Re. 1.*

„ VI—Fair Mapping.—reprinted with additions and revised, (Sixth Edition) 1928. *Price Re. 1.*

Chapter VII—Forest Surveys and Rectangulation (old Chapter IX) revised, 1925. *Price As. 8.*

„ VIII—Surveys in war and Trans-frontier Reconnaissance (old Chapters VII and VIII). *Under preparation.*

„ IX—Geographical Maps (old Chapter XI). Second Edition, 1926. *Price As. 8.*

„ X—Map Reproduction. Second Edition, 1919. *Price As. 8.*

6. ***Photo-Litho Office,** Notes on Organization, Methods and Processes, by Major W. C. Hedley, R.E. Third Edition. Calcutta, 1924.

7. **The Reproduction (for the guidance of other Departments), of Maps, Plans, Photographs, Diagrams, and Line Illustrations.** Calcutta, 1914. *Price Rs. 3.*

8. Survey of India Copy Book of Lettering. Calcutta. *Price Rs. 3-8.*

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. (Out of print).

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* For Departmental use only.

Notes and Instructions.—(*Continued*).

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. (Out of print)

4. *Notes on some of the Methods of Map Reproduction suitable for the Field with appendix—Suggested Equipment Tables for the Light Field Litho. Press (experimental), by Lieut. A. A. Chase, R.E. Calcutta, 1911.

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 Lieut. 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 Co-ordinates.**—On a Simplification of the Computations relating to, by J. Eccles, M. A. Dehra Dūn, 1911. *Price Re. 1.*

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

12 *Notes on boundary ribands on maps of the Survey of India, by Major F. Fraser Hunter, D.S.O., I.A. Calcutta, 1922.

13. *Notes on the map of Arabia and the Persian Gulf, with a general index of place names on the map, 1905-08, by Captain F. Fraser Hunter, I.A. Calcutta, 1910.

14. **Accounts Pamphlet.**—Notes on account for field units. Dehra Dūn, 1928. *Price Re. 1.*

PART V.—MISCELLANEOUS PAPERS

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. per part

2 *Report on the Identification and Nomenclature of the Himālayan Peaks as seen from Kātmāndu, Nepāl, by Captain H. Wood, R.E. Calcutta, 1904.

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Unclassified Papers.—(*Continued*).

3. Routes in the Western-Himālaya, Kashmīr, etc., by Lt.-Colonel T. G. Montgomerie, R.E., F.R.S., F.R.G.S. Dehra Dūn, 1909. (Out of print).

4. Routes in the Western-Himālaya, Kashmīr, etc. with which are included Montgomerie's Routes. Volume I. Pūnch, Kashmīr and Ladākh, by Major Mason, M.C., R.E., First Edition, Dehra Dūn, 1923. *Price Rs. 6.*

Exploration.

1. *Account of the Survey Operations in connection with the Mission to Yārkand and Kashgar 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).

3. Report on the Trans-Himālayan Explorations during 1870. Dehra Dūn, 1871. (Out of print).

4. Report on the Trans-Himālayan Explorations during 1878. Calcutta, 1880. (Out of print).

Special Reports.

1. *Report on the Mussoorie and Landour, Kumaun and Garhwāl, Rānīkhet and Kosi Valley Surveys, extended to Peshāwar and Kāghān Triangulation during 1869-70, by Major T. G. Montgomerie, R.E. (Out of print).

2. Report on the Recent Determination of the Longitude of Madras, by Captain S. G. Burrard, R.E. Calcutta, 1897. (Out of print).

3. *Report on the Observations of the Total Solar Eclipse of 6th April, 1875 at Camorta, Nicobar Islands, by Captain J. Waterhouse. Calcutta, 1875. (Out of print).

4. *The Total Solar Eclipse, 22nd January, 1898. Dehra Dūn, 1898.

(1) Report on the observations at Dumraon.
(2) Report on the observations at Pulgaon.
(3) Report on the observations at Sahdol.

5. *Report on Local Attraction in India, 1893-94, by Captain S. G. Burrard, R.E. Calcutta, 1895. (Out of print).

6. *Report on the Trigonometrical Results of the Earthquake in Assam, by Captain S. G. Burrard, R.E. Calcutta, 1898. (Out of print).

7. *Notes on the Topographical Survey of the 1/50,000 Sheets of Algeria by the Topographical Section of the "Service Geographique de l'Armée", by Captain W. M. Coldstream, R.E. Calcutta, 1906.

8. *The Simla Estates Boundary Survey on the scale of 50 feet to 1 inch, by Captain E. A. Tandy, R.E. Calcutta, 1906.

9. *A note on the stage reached by the Geodetic Operations of the Survey of India in 1920, by Lt.-Colonel H. McC. Cowie, R.E. The Magnetic Survey of India, by Major R. H. Thomas, D.S.O., R.E. and a note on the present levelling policy, by Major K. Mason, M.C., R.E. Dehra Dūn, 1922. (Out of print).

Geodesy.

1. Notes on the Theory of Errors of Observation, by J. Eccles, M.A. Dehra Dūn, 1903. *Price As. 8.*

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* For Departmental use only.

Unclassified Papers.—(*Concluded*).

2. *Note on a Change of the Axes of the Terrestrial Spheroid in relation to the Triangulation of the G.T. Survey of India, by J. de Graaff Hunter, M.A. Dehra Dūn. (Out of print), now incorporated in Professional Paper No. 16.

3. Report on the Treatment, and use of Invar in measuring Geodetic Bases. by Captain H. H. Turner, R.E. London, 1907. *Price As. 8.*

Projections.

1. On the projection used for the General Maps of India. Dehra Dūn, 1903. (Out of print).

2. *On the deformation resulting from the method of constructing the International Atlas of the World on the scale of one to one million, by Ch. Lallemand. Translated by J. Eccles, M.A., together with tables for the projection of 1/M Maps on the International system. Dehra Dūn, 1912. (Out of print).

Mapping.

1. *A Note on the different methods by which hills can be represented upon maps, by Colonel S. G. Burrard, C.S.I., R.E., F.R.S., Surveyor General of India. Simla, 1912.

2. *A Note on the representation of hills, by Major C. L. Robertson, C.M.G., R.E. Dehra Dūn, 1912.

3. *A Note on the representation of hills on the Maps of India, by Major F. W. Pirrie, I.A. Dehra Dūn, 1912.

4. *A consideration of the Contour intervals, and Colour Scales, best suited to Indian 1/M maps, by Captain M.O'C. Tandy, R.E. Calcutta, 1913. (Out of print).

Professional Papers.

No. 1—**Projection**—On the Projection for a Map of India, and adjacent Countries, on the scale of 1: 1,000,000, by Colonel St. G. C. Gore, R.E. Second Edition. Dehra Dūn, 1903. *Price Re. 1.*

No. 2 ***Base Lines**—Method of measuring Geodetic Bases by means of Metallic Wires, by M. Jäderin. (Translated from Memoires Prēsentēs par Divers. Savants ā l' Acadēmie des Sciences de l' Institute de France). Dehra Dūn, 1899. (Out of print).

No. 3—**Base Lines**—Method of measuring Geodetic Bases by means of Colby's Compensated Bars, compiled by Lieut. H. McC. Cowie, R.E. Dehra Dūn, 1900. (Out of print).

No. 4—**Spirit levels**—Notes on the Calibration of Levels, by Lieut. E. A. Tandy, R.E. Dehra Dūn, 1900. (Out of print).

No. 5—**Geodesy**—The Attraction of the Himālaya Mountains upon the Plumb-Line in India, considerations of recent data, by Major S. G. Burrard, R.E. Second Edition, Dehra Dūn, 1901. *Price Rs. 2.*

No. 6—**Base Lines**—Account of a Determination of the Coefficients of Expansion of the Wires of the Jäderin Base Line Apparatus, by Captain G. P. Lenox-Conyngham, R.E. Dehra Dūn, 1902. (Out of print).

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* For Departmental use only.

Professional Papers.—*(Continued).*

No. 7—***Miscellaneous.** Calcutta, 1903.

(1) On the values of Longitude employed in maps of the Survey of India.

(2) Levelling across the Ganges at Dāmukdia.

(3) Experiment to test the increase in the length of a levelling staff due to moisture and temperature.

(4) Description of a Sun-dial designed for use with tide-gauges.

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1. *India's Contribution to Geodesy, by General J. T. Walker, R.E., C.B., F.R.S., LL.D. (Philosophical Transactions, Royal Society. Series A, Volume 186, 1895).

2. *On the Intensity and Direction of the Force of Gravity in India, by Lt.-Colonel S. G. Burrard, R.E, F.R.S. (Philosophical Transactions, Royal Society, Series A, Volume 205, pages 289-318, 1905).

3. †A climb on Kolahoi, by Lieut. Kenneth Mason, R.E. (Royal Engineers Journal, November 1910).

4. *On the effect of the Gangetic Alluvium on the Plumb-line in Northern India, by R. D. Oldham, F.R.S (Proceedings of the Royal Society, Series A, Volume 90, pages 32-40, 1914).

5. *On the origin of the Indo-Gangetic trough, commonly called the Himālayan Foredeep, by Colonel Sir S. G. Burrard, K.C.S.I., R.E., F.R.S. (Proceedings of the Royal Society, Series A, Volume 91, pages 220-238, 1915).

6. §Three comprehensive articles on "Comparators for the Indian Government" from a report by Major H. McC. Cowie, R.E. (Engineering, Aug. 20, Aug. 27, Sept. 3, 1915).

7. ||Identification of Peaks in the Himālaya with notes, by Colonel Sir S. G. Burrard, K.C.S.I., R.E., F.R.S. (Geographical Journal, September 1918).

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36. ||Graphical methods of plotting from Air Photographs, by Lt.-Colonel L. N. F. I. King, O.B.E., R.E.

37 †The Demarcation of the Turco-Persian Boundary in 1913-14, by Colonel C. H. D. Ryder, R.E. (Geographical Journal, September 1925).

38. Geodesy, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. (Enc. Brit. 13th Edition, New Vol. ii, 1926).

39. ¶The De Filippi Expedition to the Eastern Kara-koram, by B. B. D. and Colonel Sir G. P. Lenox-Conyngham, Kt., R.E., F.R.S., M.A. (Nature, 13th February 1926).

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46. †The Stereographic Survey of the Shaksgam, by Major K. Mason, M.C., R.E. (Geographical Journal, October 1927).

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50. Figure of the Earth—Presidential address by J. de Graaff Hunter, M.A., SC.D., F. INST. P., at the Section of Mathematics and Physics of the Fifteenth Indian Science Congress, Calcutta 1928 (Published by the Asiatic Society of Bengal, Calcutta).

51. †Note on Sir Francis Younghusband's Urdok Glacier, by Major Kenneth Mason, M.C., R.E. (Geographical Journal, March 1928).

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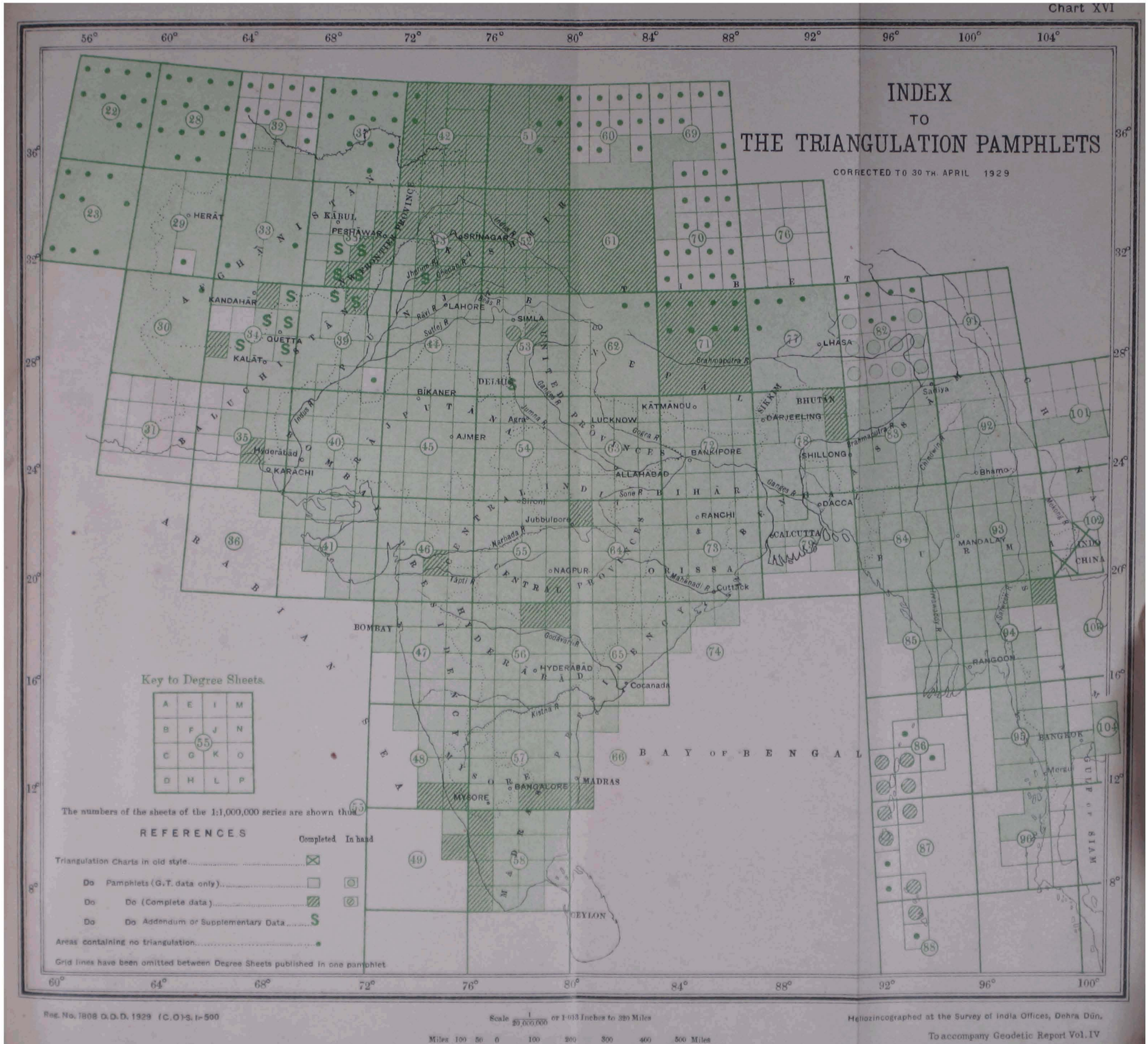

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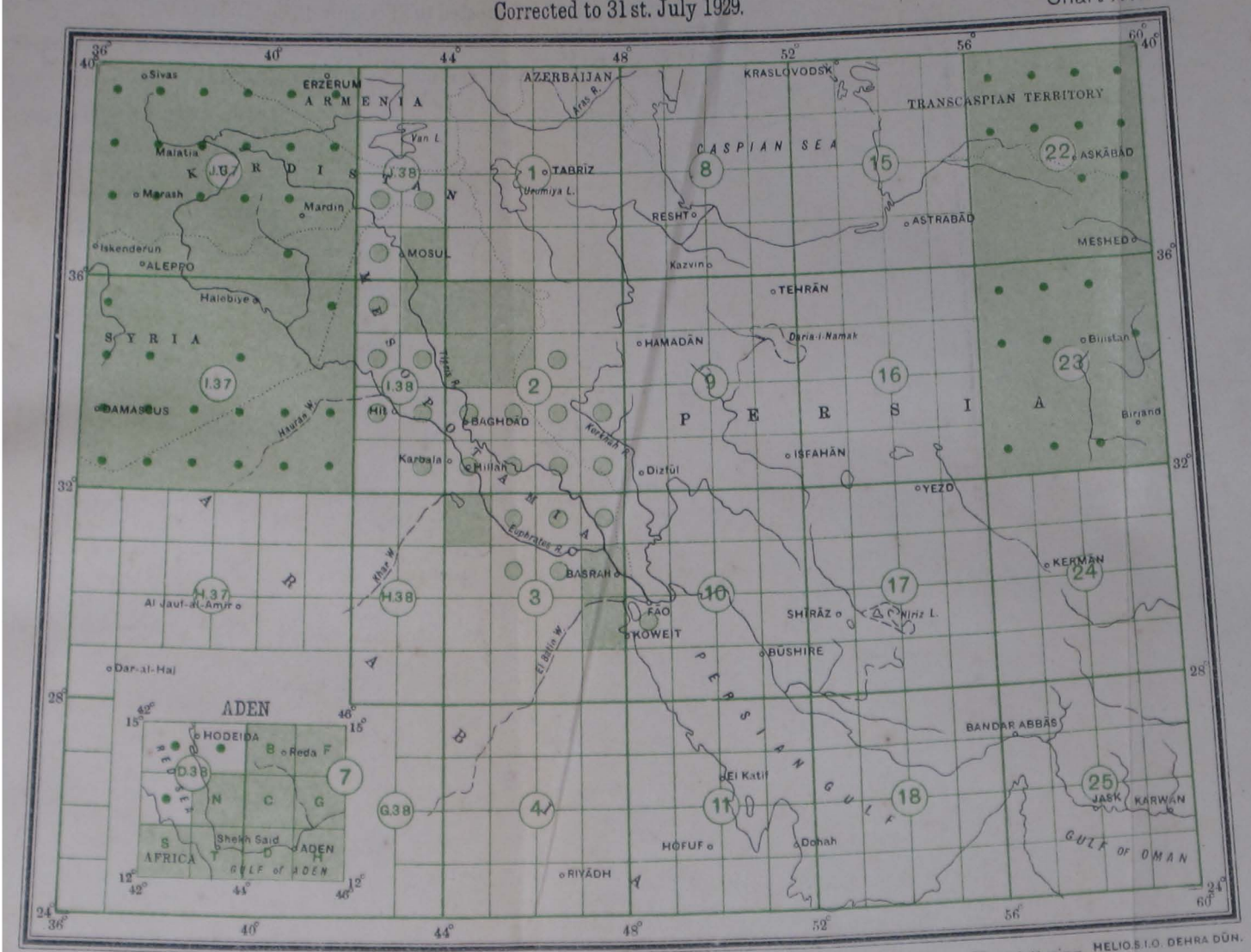
Chart XVII



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