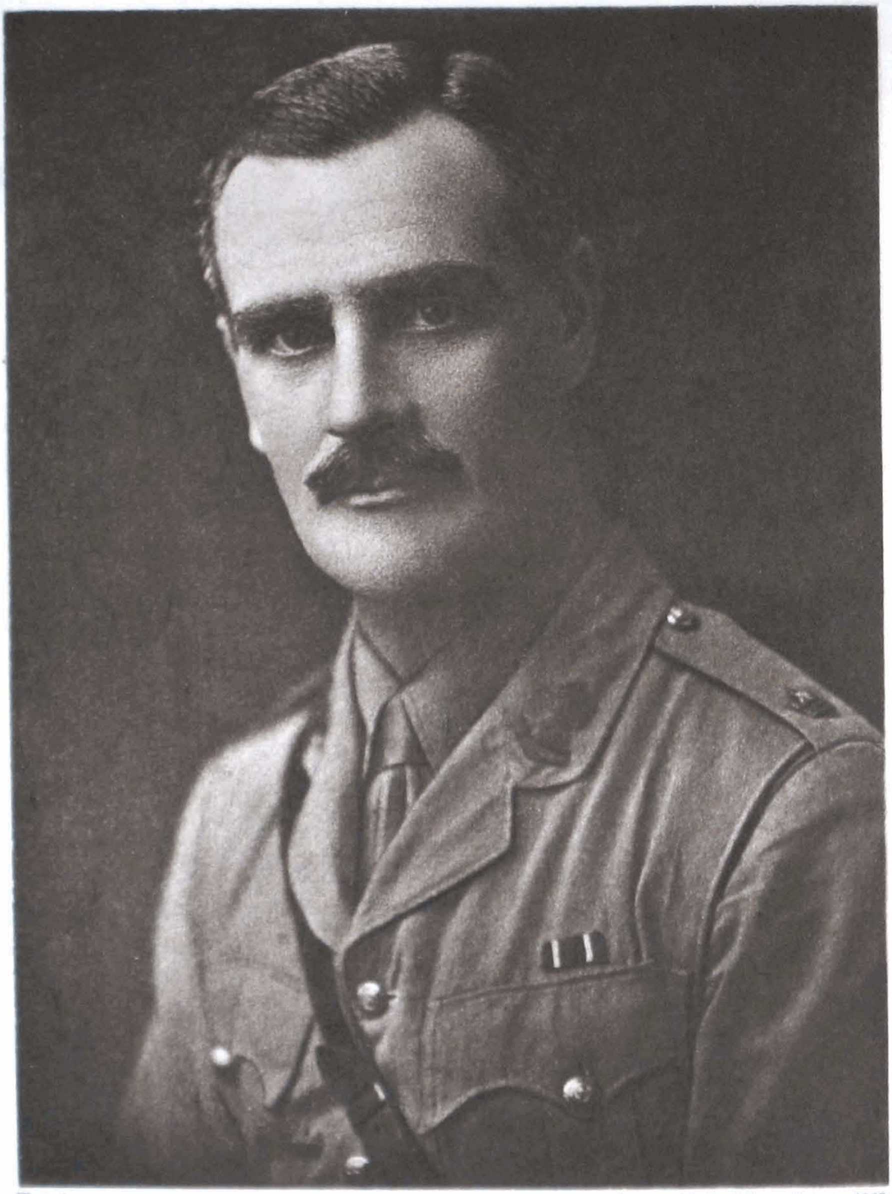

Photogravure

Survey of India Offices, Calcutta, 1928.

COLONEL H. M^c C. COWIE, R. E.,

DIRECTOR OF THE GEODETIC BRANCH, SURVEY OF INDIA, 1923-1925.

1893. 1925.

Lt.-Colonel Herbert McCally Cowie, R.E.

Lt.-Colonel Cowie, whose portrait faces this page, was commissioned in the Royal Engineers in 1893, and after serving in the Military Works and Railway Departments, joined the Survey of India in 1898.

Most of his service was passed in the Geodetic Branch, and for many years he held charge first of the latitude party and later of the pendulum party. While on furlough in 1911-12 he was deputed to test and report on the base-line apparatus—comparators and standards of length—which had been designed for India by Sir David Gill. This work was carried out at Lambeth; his report which was printed in "Engineering" will be a valuable guide, when funds permit of further development. Colonel Cowie was a particularly careful and accurate observer, eminently suited to work of this nature.

In 1904 he was one of the survey officers attached to Sir F. Younghusband's Tibet Mission for which he received the medal and clasp: and later in 1913-14 he was a member of the Turco-Persian Boundary Commission, for which he executed the necessary triangulation from Fāo to Ararat with untiring energy and skill, in face of very considerable difficulties. Recalled therefrom at the outbreak of the great war, he was at the outset, with other senior officers of the Department, not permitted to proceed on active service, being posted to the charge of the Photo. Litho. Office at Calcutta, where he threw himself with characteristic energy and zeal into the heavy task of meeting the unprecedented demands for maps arising from the war.

His opportunity came later when early in 1917 he proceeded to Baghdād to form the West Persia Survey Party; unfortunately a breakdown in health necessitated his return to India about a month later. In 1919 however he had recovered and was in charge of the Survey operations in the Afghān war, being twice mentioned in despatches and receiving the medal and clasp.

Soon afterwards he became Superintendent of the Trigonometrical Survey—the post now known as Director of the Geodetic Branch. His work in this capacity was curtailed by ill health, for he was suffering from very high blood-pressure. This forced him to take leave in 1924. On his return journey, apparently much improved in health, he died suddenly on the 25th September 1925 on board the P.&O.S.S. Rawalpindi at Marseilles. His death was a great loss to the service and to his many friends in all ranks of the Department.

Col. Cowie was author of the following publications :—

Method of measuring geodetic bases by Colby's compensated bars. Survey of India, Professional Paper No. 3, 1900.

Bar comparisons of 1907-08. Survey of India, Departmental Paper No. 7, 1915.

Comparators for the Indian Government. Three articles in "Engineering" 1915.

A criticism of Mr. R. D. Oldham's memoir "The Structure of the Himālayas and of the Gangetic Plain". Survey of India, Professional Paper No. 18, 1921.

A note on the stage reached by the Geodetic Operations of the Survey of India in 1920. Survey of India, Unclassified Paper, 1922.

Besides the above were some useful translations of foreign publications and numerous records of work published in the Annual Reports and Records of the Survey of India.

SURVEY OF INDIA

GEODETIC REPORT

VOL. III

From 1st October 1926
To 30th September 1927

PUBLISHED BY ORDER OF
BRIGADIER R. H. THOMAS, D.S.O.
SURVEYOR GENERAL OF INDIA

PRINTED AT THE GEODETIC BRANCH OFFICE,
SURVEY OF INDIA, DEHRA DŪN, 1929.

Price Three Rupees or Five Shillings and Three Pence

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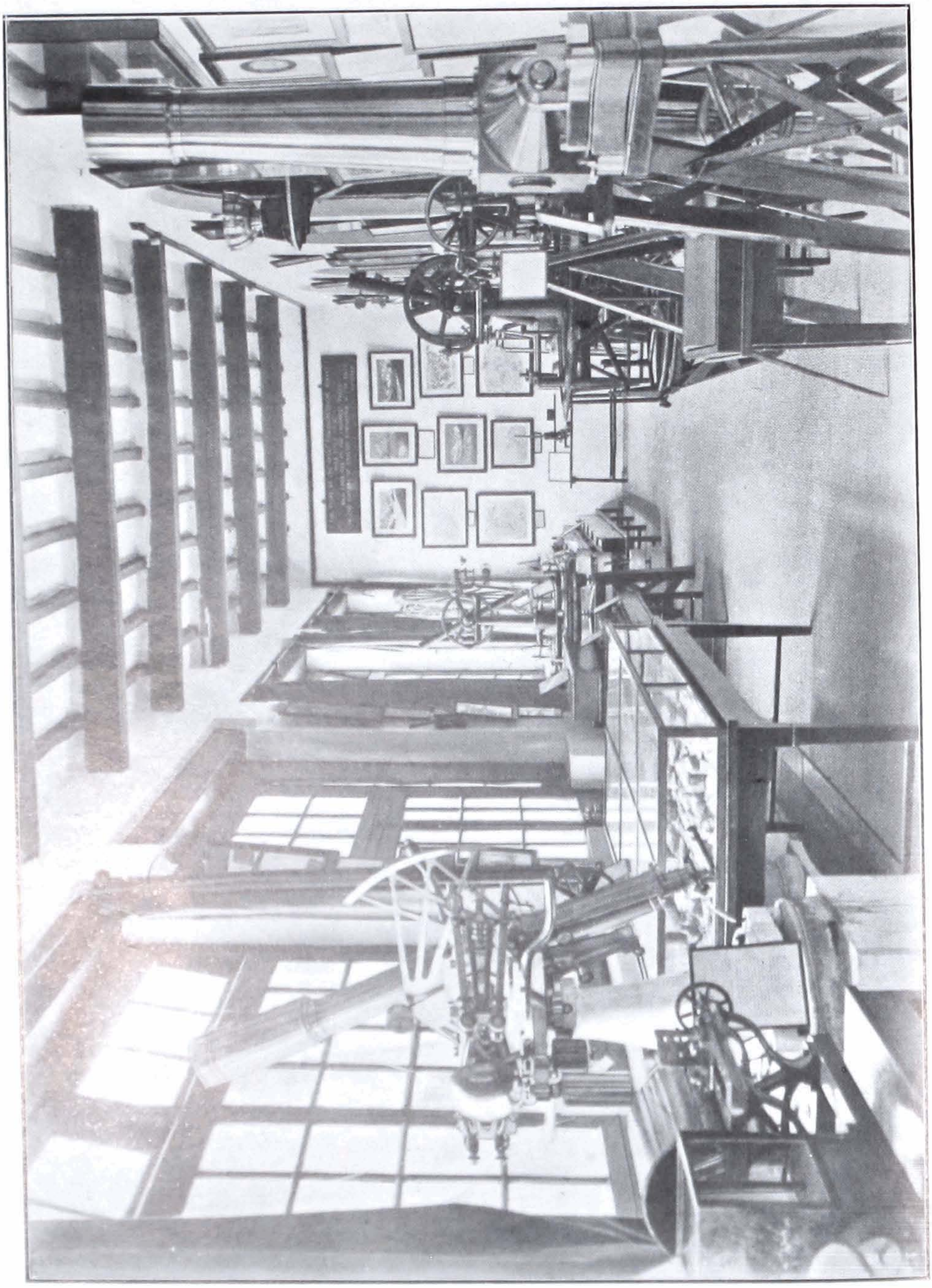
CHAPTER II

Computations and Publication of data

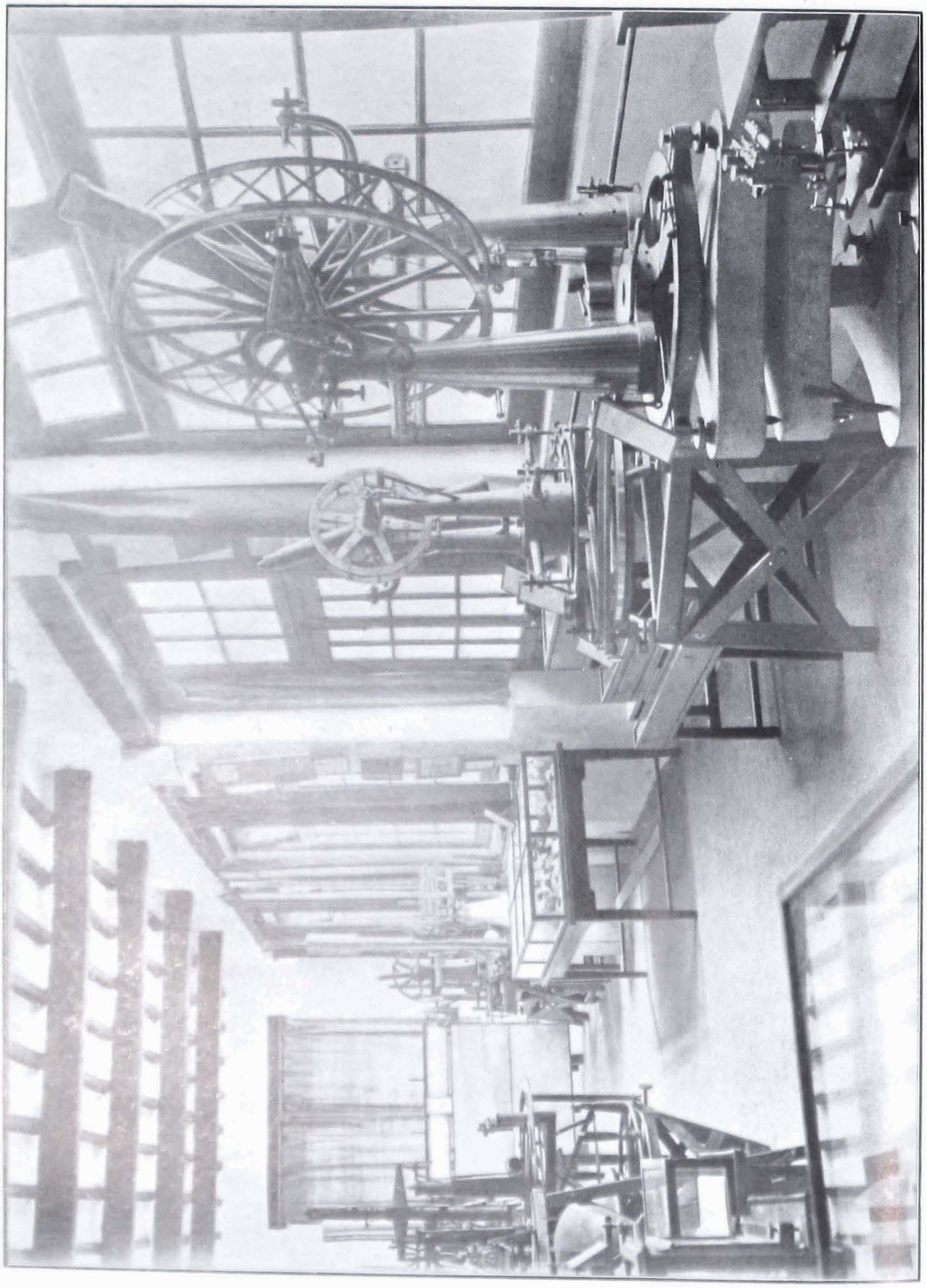
(i) Computations



THE MUSEUM, GEODETIC BRANCH OFFICE (facing north).

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

PLATE II.



THE MUSEUM, GEODETIC BRANCH OFFICE (facing south).

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INTRODUCTION AND SUMMARY

1. The important International Longitude Scheme referred to in last report, which had been arranged for by the joint commission of the International Unions of Astronomy and of Geodesy and Geophysics was duly carried out during October and November 1926. Fifty observatories throughout the world including that at Dehra Dūn participated in the observations. For purposes of the scheme wireless signals were emitted from Bordeaux, Annapolis, Honolulu and Saigon. At Dehra Dūn time observations were made by six observers using two small transit instruments and a geodetic astrolabe. The clock was by Riefler.

Dr. Hunter was in charge of the operations and six observers were employed. The Bordeaux 8^h 01^m and 20^h 01^m and Saigon 11^h 30^m and $19^h 00^m$ Greenwich mean time signals were regularly received but those of Annapolis and Honolulu were never heard. Four different values of longitude for Dehra Dūn were derived; two from Bordeaux signals and two from Saigon. The mean is 5^h 12^m $11^s{\cdot}79_4$ which agrees well with 5^h 12^m $11^s{\cdot}77$ the old value from Indo-European arcs of 1894-96 (*vide* Chap. 1).

2. The Computing Section have been investigating the reliability of triangulated as compared with spirit-levelled heights and have prepared a table giving the mean square error and measure of accuracy of heights for each series of triangulation (*vide* table I, Chap. II § 1).

3. As a result of an enquiry from Professor Wegener the variation of astronomical latitudes at stations where repeat observations had been taken were investigated to see if they afforded any evidence of continental drift. The conclusion was that there is no evidence of such drift (*vide* Chap. II § 2).

4. Two geodetic series, Bāgalkot and Madura observed in 1916-17 were adjusted and corrected values are being published. Graphic adjustment of a large amount of minor triangulation was carried out (*vide* Chap. II §§ 3, 4).

5. A comptometer has been found useful for solution of normal equations in connection with the investigation into the Figure of the Earth (*vide* Chap. II § 5).

6. Besides the International Longitude Project, the Observatory Section has carried out (a) regular time and latitude observations, (b) comparisons of length, (c) magnetic observations, and (d) seismograph and meteorological observations (*vide* Chap. III).

7. The Tidal Section continued its work as usual. A new tidal

observatory was opened at Pilakat or Deserter's creek near Elephant Point in order to enable comparisons to be made with the results at Rangoon. Correction tables, based on differences between predicted and actual values, were prepared and applied to 3 riverain ports Chittagong, Rangoon and Basrah (*vide* Chap. IV § 5).

8. The work on gravity and deviation of the vertical was confined to the computation of topographical and Hayford anomalies for Capt. Glennie's Punjab and Kashmīr observations of 1925. (*vide* Chap. V § 1). By means of an average height map for the larger zones, prepared by Major Glennie, and an adaptation of the formulæ, so as to use common zones for estimating deflections from maps for joint gravity and latitude stations, these laborious computations will be somewhat simplified in future (*vide* Chap. V §§ 2-5 and 8).

The results of the computations were used to draw a section of the compensated geoid in Kashmir with a view to determining which spheroid fits it best. Captain Bomford's conclusion is that the Survey of India spheroid No. II, deduced from the rest of India fits the recent extension into Kashmīr better than the International spheroid could (*vide* Chap. V).

9. The geodetic triangulation of the Rangoon series was continued and completed. The use of Dr. Hunter's portable observation tower in combination with 100-foot lattice-masts and special mast signals proved very effective in this enclosed country (*vide* Chap. VI).

10. Four detachments were employed on levelling of high precision and two on secondary levelling in addition to the Commercial levelling group which carried out secondary and tertiary levelling for the Haveli Irrigation Project (*vide* Chap. VII §§ 1-3).

The levelling comprised 1282 miles of high precision, 974 of secondary, and 11, 727 of tertiary levelling.

19 miles of special levelling between Dehra Dūn and Mussoorie (with temperatures observed at staff and instrument) were carried out to assist in investigating refraction effects when levelling up continuous gradients (*vide* Chap. VII § 4). This year's work completed a big chain of new levelling connecting Kidderpore and Karāchi tidal observatories with a discrepancy of – 1·805 feet in 1,663 miles (*vide* Chap. VII § 12.).

A table showing the progress of the new level net is given in Chap. VII § 13.

The policy of the Survey of India, with regard to the maintenance of Primary Protected Bench-Marks only in future, is outlined in Chap. VII § 14.

11. Description of the newly designed personal equation apparatus is given in a note by Capt. Bomford (*vide* Chap. VIII § I).

12. Capt. Bomford discusses the height of Mount Everest, arriving at the value 29,050 as the nearest approximation to the true

geoidal height deducible from existing data. Reasons for using geoidal heights are given. (*vide* Chap. VIII § 11). Even yet the value cannot be regarded as final.

13. Two photographs of the Geodetic Museum, inaugurated by Colonel M. O'C. Tandy in 1926, will be found in the volume, facing page ix.

The personnel of the Geodetic Branch is given on the next page.

Dehra Dūn, Jan. 1929.

J. de Graaff Hunter,
Director of the Geodetic Branch.

PERSONNEL* OF THE GEODETIC BRANCH, 1926-27

Director, Geodetic Branch

LT.-COLONEL M. O'C. TANDY, D.S.O., O.B.E., R.E., from 1st October 1926 to 30th June 1927.
DR. J. DE GRAAFF HUNTER, M.A., SC. D., F. Inst. P., from 1st July 1927 to 30th Sept. 1927.

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 1st October 1926 to 30th June 1927.

Captain G. Bomford, R.E., in charge from 1st July 1927 to 30th September 1927.

Mr. B. L. Gulatee, B.A. (Cantab).

COMPUTING SECTION.

Mr. Mukundananda Acharya, Head Computer and 9 Geodetic Computers.

Lower Subordinate Service.

4 Computers.

TIDAL SECTION.

Class II Officers.

Mr. D. H. Luxa, Tidal assistant.

Lower Subordinate Service.

10 Computers.

OBSERVATORY SECTION.

Class II Officers.

Mr. R. B. Mathur, B.A.

Mr. P. K. Ghosh, B. A. (Cantab), from 15th August 1927.

Upper Subordinate Service.

Mr. H. C. Banerjea, B.A.

Lower Subordinate Service

5 Computers

Magnetic Observatory.

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

1 Computer.

OFFICE AND P.&M. SECTION.

Upper Subordinate Service.

Mr. Baldeo Bihari Lal

Lower Subordinate Service.

4 Computers, etc.

13 PARTY (ASTRONOMICAL)

Class II Officers.

Mr. S. F. Norman, in charge from 9th November 1926 to 30th September 1927.

Lower Subordinate Service.

3 Computers, etc.

14 PARTY (PENDULUMS)

Class I Officers.

Captain G. Bomford, R.E., in charge from 1st October 1926 to 30th June 1927.

Class II Officers.

Mr. C. West in charge from 1st July 1927 to 30th September 1927.

Mr. Abdul Karim, B.A., from 5th May to 30th September 1927.

Lower Subordinate Service.

4 Computers, etc.

15 PARTY (TRIANGULATION)

Class I Officers.

Captain G. H. Osmaston, M.C., R.E., in charge from 1st October 1926 to 30th September 1927.

Lower Subordinate Service.

3 Computers, etc.

17 PARTY (LEVELLING)

Class I Officers.

Lt.-Colonel V. R. Cotter, I.A., in charge from 1st October 1926 to 1st May 1927.

Class II Officers.

Mr. N. R. Mazumdar. in charge from 2nd May 1927 to 30th September 1927.

Upper Subordinate Service.

Mr. K. K. Das., B.A.
Mr. S. C. Mukerjee.
Mr. L. D. Joshi.
Mr. P. B. Roy.
Mr. A. A. S. Matlub Ahmad.
Mr. J. N. Kohli.
Mr. I. K. Ponnappa.
Mr. B. P. Rundev.

Lower Subordinate Service.

21 Computers, etc.
57 Purely temporary levellers, etc.

19 PARTY (BASE-LINE)

Lt.-Colonel M. O'C Tandy, D.S.O., O.B.E. R.E., in charge from 1st October to 25th November 1926.

TRAINING

Class I Officers under instruction.

Lieut. H. W. Wright, R.E., from 1st October to 8th December 1926.

Lieut. I. M. Cadell, R.E., from 1st October to 6th December 1926.

Lieut. D. McK. Burn, R.E., from 17th December 1926 to 7th July 1927.

Lieut. I. H. R. Wilson, R.E., from 18th December 1926 to 7th July 1927.

TRAINING SCHOOL

Mr. S. F. Norman, Instructor.

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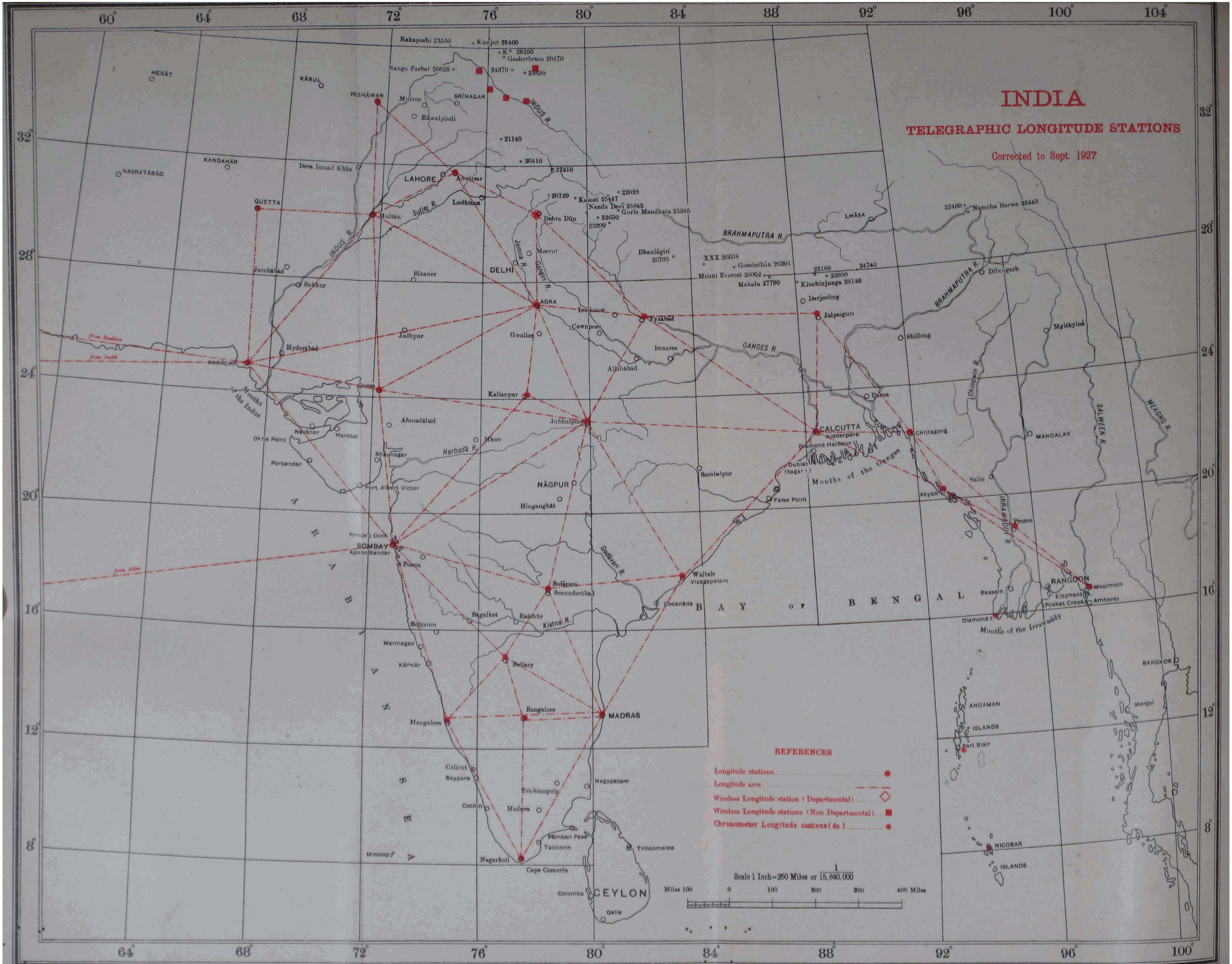
* Excluding No. 2 D.O., Publication and Stores, F.M.O., and 20 Party.



Rec. No. 1753 D.D.D. 1929 (C.O.) S. Ir. 500 — Published under the direction of Brigadier R. H. Thomas, D.S.O., Surveyor General of India. — HELIO. S.I.O. DEHRA DŪN

Chapter I

THE INTERNATIONAL LONGITUDE PROJECT

BY CAPTAIN G. BOMFORD, R.E.

1. Object of the observations.—At the meeting of the International Astronomical Union in 1925 at Cambridge it was decided to undertake a combined determination of the longitudes of a number of observatories in all parts of the world. For this purpose special wireless signals were emitted from four stations, (Bordeaux, Annapolis, Honolulu and Saigon), which were received at about 50 observatories co-operating in the project, one of which was at Dehra Dūn. It was decided to carry out operations in October and November 1926, and all the observatories attempted to take nightly observations for time, and to receive all possible wireless signals during this period.

It was arranged that the observatories at Algiers, Zi-ka-wei (Shanghai), and San Diego (California), should constitute the principal stations, and that they would make independent determinations of their difference of longitude by pairs, the sum being finally adjusted to 360°. There was also some intention of other stations forming subsidiary circuits in the same manner. If the closure of circuits is to give an indication of the probable error of their component arcs, it is necessary that each station in the circuit should utilise different wireless signals and different series of star observations for the determination of each of the separate arcs, with which it is concerned. At Dehra Dūn the stars were grouped into two series, so as to enable this to be done, but the advantage of forming subsidiary circuits is doubtful, and the results of the other observatories, that have been received, are not arranged in such a manner as to admit of their formation. The question is further discussed in § 16.

In addition to the precise determination of longitude, it was hoped to acquire some knowledge of the rate of propagation of wireless signals and of the regularity of the speed of the earth's rotation. The former will arise from a consideration of the closure of the main polygon. The latter is being investigated by M. Bigourdan, Director of the Bureau International de l'Heure, who has asked all participants to send him the uncorrected clock times of the reception of the Bordeaux signal at 20^h 01^m between 15th October and 16th November, 1926. Less intensive observations are being continued at many observatories, including Dehra Dūn, with a view to discovering possible long period or secular changes of longitude.*

2. Summary of work at Dehra Dun.—Observations were

* The results of the 1926-27 observations will be found in Chapter III, Observatories, of this Geodetic Report.

made nightly except on Sundays and on three nights which were cloudy. Three instruments were used, two transit instruments and one astrolabe, and the programme lasted four or five hours nightly. Six observers were employed. The following four signals were regularly received:—

(*a*) Bordeaux	08^h 01^m	G.M.T.
(*b*) ,,	20 01	,,
(*c*) Saigon	11 30	,,
(*d*) ,,	19 00	,,

The value of longitude obtained from the observations at Dehra Dūn is 5^h 12^m $11^s \cdot 79_4 \pm 0 \cdot 020$. The old value, derived from the Indo-European telegraphic arcs of 1894-96, was 5^h 12^m $11^s \cdot 770$.

3. The transit instruments.—Both transit instruments were mounted in the Hunter Observatory, 9 feet apart, on the same meridian as the old longitude station in the Haig Observatory. That known as the North Transit (or T_n) is Transit No. 2 made by Messrs Troughton and Simms in 1894, a reversible instrument of $3\frac{7}{16}$ inches aperture and 36 inches focal length. It has been fitted with a self-registering moving wire micrometer. The field is electrically illuminated. Nadir observations for level and collimation can be made with a Bohnenberger eye-piece, but such observations were not taken into account when reducing the results. One division of the level is 1/20 of an inch long and is equivalent to $0^s \cdot 147$.

The second instrument, known as the South Transit (or T_s), is of the bent transit type, reversible, of $2\frac{1}{2}$ inches aperture and 20 inches focal length. It was made by Messrs Troughton and Simms in 1907. It also has an impersonal eye-piece and electric illumination, and nadir observations can be made. One division of the level is 1/10 of an inch long and is equivalent to $0^s \cdot 155$. The magnification, however, is less than that of T_n, and the latter is probably rather the better instrument.

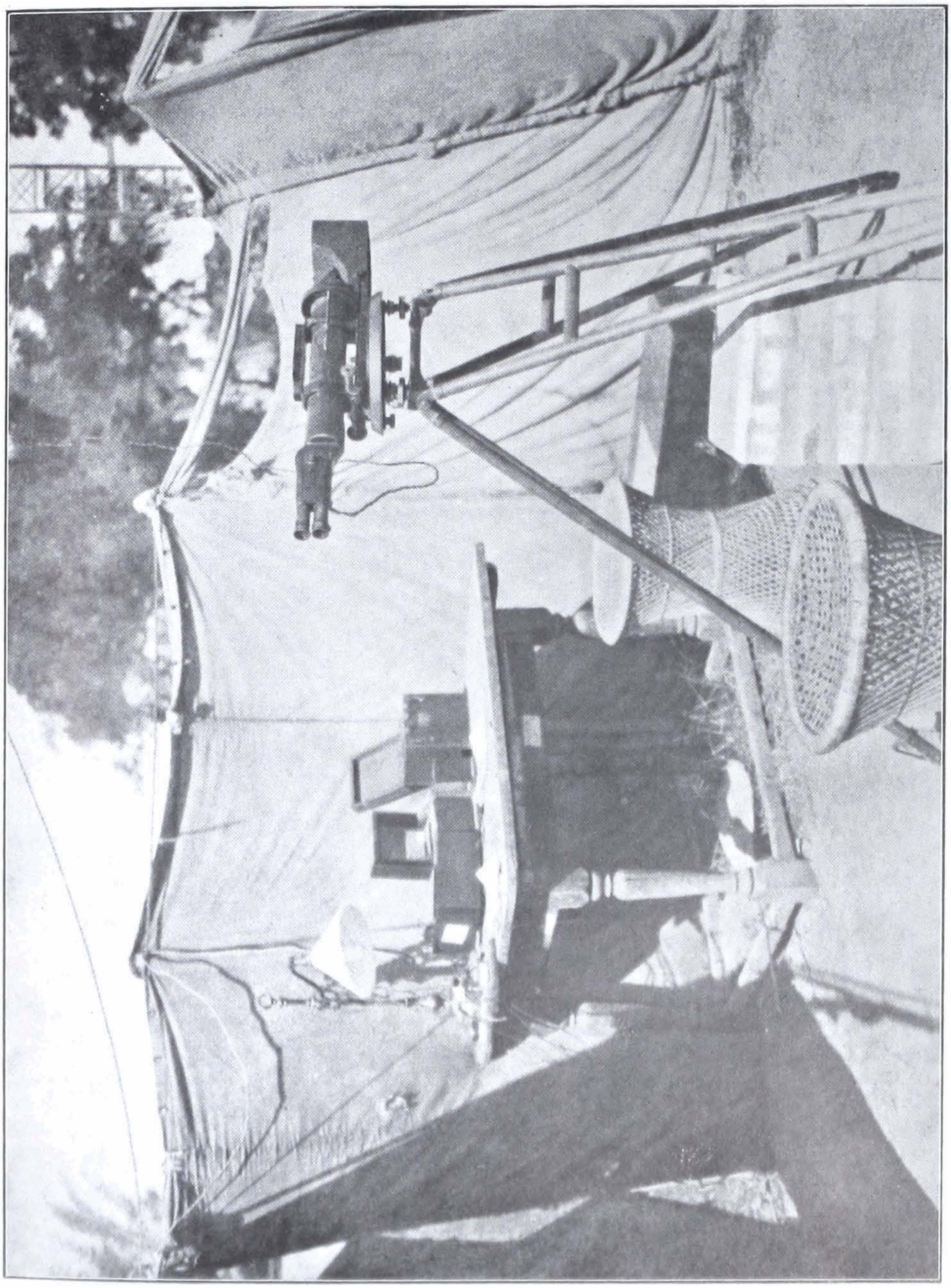
The Hunter Observatory has been symmetrically designed to avoid lateral refraction, and stands well clear of all other buildings.

Two collimators were employed as a check on the constancy of the deviation. Only one collimator was visible from each transit instrument.

4. The astrolabe.—The astrolabe is of the Claude and Driencourt pattern (geodetic model) by S.O.M., of 2 inches aperture and $15\frac{1}{2}$ inches focal length. It was used in the open on its usual tripod, and was protected by a canvas screen. It was at first placed on the same meridian as the transit instruments, but was afterwards moved to another site 70 feet east. All its results have been reduced to the meridian of the former station. The personal equations were determined directly by an instrument, made locally for the purpose, which is described in Chapter VIII. Judged by comparison with the mean of the transit instruments' results, it worked satisfactorily with one observer and unsatisfactorily with another.

5. Chronographs.—The chronographs used were:—

(*a*) A two-pen drum chronograph, by Warner & Swasay, speed ·71 of an inch per second. This was used for the two transit instruments. T_n was connected with



THE PRISMATIC ASTROLABE
GEODETIC MODEL.

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

the pen on which seconds were recorded, and T_8 with the other.

(*b*) A single-pen drum chronograph, by Warner & Swasay, speed ·36 of an inch per second, used for the astrolabe.

(*c*) A tape-chronograph, by Adam Hilger, speed ·42 of an inch per second, used for the personal equation apparatus.

The wireless time signals were received by ear and recorded by tappets on (*a*) and (*b*) (*vide* § 7).

6. Clocks.—The observatory clock used was Riefler clock No. 450. The pressure and temperature, under which the clock works, are both controlled. In addition there are two clocks by Frodsham, about 50 years old, known as clock A and clock B. Neither of the latter are provided with any pressure control. Clock A was placed in the temperature controlled clock-cell with the Riefler clock, and clock B was placed in a room where the diurnal temperature range did not exceed 1° C.

The Riefler is an excellent clock, and the old clocks A and B cannot compare in accuracy with it. However, clock A was useful in connection with the reception of wireless signals (*vide* § 7). Clock B was rated to mean time.

7. Wireless receiving set.—The wireless receiving set was manufactured by Siemens. It has three valves (high frequency, detector and low frequency) with tuned anode. The closed circuit is loosely coupled to the aerial circuit. A heterodyne wave-meter is employed as a local oscillator. Three aerials were available—a vertical aerial of 100 feet and two inverted L's—each of total length about 600 feet, and of height 100 feet.

The Bordeaux and Saigon signals were generally clear and strong, but those of Annapolis and Honolulu were never heard.

The method of reception was that the clock, working through a relay, cut out the heterodyne every second for a period slightly longer than the lengths of the beats of the signals, thus procuring the extinction of a few beats about once every minute. Two or three observers listened for the first beat to emerge, and recorded it on the chronographs. For satisfactory reception by this method it is essential that the clock shall beat very regular seconds, and that the length of its break shall be adjustable to that of the signals. The break of the Riefler clock did not satisfy either of these conditions, and as a substitute a special device working on the pendulum, was designed by Dr Hunter (*vide* Bulletin Géodésique No. 14 of 1927). It was not immediately possible to fit the latter to the Riefler clock, and so clock A was utilised for the reception of signals, and a comparison between it and the Riefler clock made immediately afterwards on the two-pen chronograph.

8. Personnel.—Dr. Hunter was in charge of the operations. Six observers were employed, divided into two groups as follows, each group working alternate weeks :—

(*a*) Capt. G. H. Osmaston, Lieut. H. W. Wright and Lieut. I. M. Cadell.

(*b*) Capt. G. Bomford, Mr. B. L. Gulatee and Mr. R. B. Mathur.

Capt. Osmaston and Mr. Mathur used the South Transit instrument, Lieut. Cadell and Mr. Gulatee the North Transit instrument, and Capt. Bomford and Lieut. Wright the astrolabe. During the last week of November Lieut. Wright was unable to observe and Capt. Osmaston used the astrolabe.

Two recorders, working alternate weeks, were employed booking level readings, etc., for the two transit instruments. The reading of chronograph sheets, and computation of clock errors were as far as possible undertaken by the three off-duty observers assisted by Mr Banerjea and 10 computers.

Arrears accumulated, however, and the work was afterwards brought up to date by the Observatory Section, under Mr. Mathur.

9. Nightly programme.—The star observations were made in two series. The first from $21^h\ 30^m$ to midnight, and the second from $01^h\ 30^m$ to $04^h\ 00^m$. The Bordeaux $20^h\ 01^m$ G.M.T. and the Saigon $19^h\ 00^m$ G.M.T. signals were received between the two series.

The observers on the two transit instruments generally used the same stars. Each series consisted of 10 to 12 time-stars within 15° of the zenith and fairly equally divided between north and south, and of 3 or 4 azimuth-stars at least 30° from the zenith. Generally there were rather more of the latter above the pole than below it. South stars of large zenith distance were also sometimes employed, and gave accordant results.

The levels were read before and after each time-star. The collimators were intersected before each azimuth-star, generally on one face only. Nadir mercury observations were made at the beginning and end of each series, but were not utilised in the computations. All time-stars were observed in both positions of the instrument, as were also all azimuth-stars after 19th October.

About 30 stars in each series were observed with the astrolabe of which 8 to 12 were P.V. stars (*i.e.* within 23° of the prime vertical), and the remainder were fairly equally divided between the four quadrants No stars were observed within 23° of the meridian. Efforts were made to have at least four stars in each quadrant, but unexpected failures occasionally reduced this number to three. 30 to 35 measures of personal equation were also made.

10. Pen-equation and relay lags.—The pen-equation of the two-pen chronograph was obtained by running both pens on the Riefler clock for a few minutes on each sheet. The two pens were actuated by two relays of identical pattern, whose "lags" were shown to be identical (within less than $0^s\cdot003$) by vernier comparisons with the mean time clock, heard in a microphone.

The lag of the single-pen chronograph was compared with that of the standard pen of the two-pen chronograph by making the single pen itself break the circuit of one of the pens of the latter. The wireless reception relay was similarly tested. These two comparisons were carried out only from 17th to 30th November. For this period the mean correction to the single-pen chronograph was $0^s \cdot 002$, which is not greater than the probable error of its determination, and so it has been neglected. The correction for the lag of the wireless relay was found to average $0^s \cdot 013$, and did not vary greatly so long as the instrument was in good adjustment. The correction has been applied when available, and on all other days its mean value has been accepted.

11. Computation of transit observations.—Star places were taken from the American Ephemeris, the corrections given on pages 750-764 of the 1926 edition were included, and also the short period nutation corrections. For level, the spirit-level values were accepted in preference to those of the nadir observations, as the latter were less frequent. At the beginning of the operations the difference between the nadir mercury and spirit-level was considerable and showed some persistence of sign, averaging $0^s \cdot 10$ in each instrument during the first fortnight. During the remaining 6 weeks the mean difference was only $+0^s \cdot 005$ in the North Transit and $-0^s \cdot 004$ in the South Transit instruments respectively. On 1st and 2nd October the results of the observations by both transit instruments, as computed with the bubble reading, were clearly greatly in error, and the observations have been rejected. Had the nadir readings been employed, these two days would have been in fair agreement with the others.

As mentioned above, collimation was eliminated by observing in both positions of the instrument, except for the azimuth-stars before 19th October. For these stars the nadir observations were at first used. These gave a result involving the effect of both collimation and any inequality of the transit pivots, and, as some inequality was apparently present, there resulted a value of the deviation which was clearly incorrect, as shown by a persistent disagreement between time-stars respectively north and south of the zenith. The azimuth-stars were therefore entirely neglected, and the deviation was obtained from the time-stars themselves. The programme was arranged for a close equality in the numbers of north and south stars, and this procedure has been considered satisfactory. After 19th October the azimuth-stars were also observed in both positions, and the deviation obtained from them in usual way.

The results are given in Tables 1 and 2.

12. The astrolabe computations.—The stars were divided into two classes, *viz*. P. V. stars (*i.e.* those observed within 23° of the prime vertical) and quadrant stars, constituting the remainder. Time and latitude* were derived from the quadrant stars by a method of computation less rigorous than that of minimum squares, but which in practice gives substantially the same results. The graphical construction was not employed. For the P. V. stars no such computation is necessary. Their computed times are insensitive to an error in the assumed latitude and, provided the latter is well known, each star gives a value of the clock error which is influenced only by errors in the assumed altitude and casual errors of observation. If the mean values obtained from

* Latitude results will be found in Chapter V of this Geodetic Report.

east and west stars be taken out separately, the mean of the two groups gives a result which is unaffected by errors of latitude or altitude. The arithmetical difference between the times given by the quadrant and P. V. stars averaged about $0^s \cdot 05$, and the simple mean of the two was generally accepted.

The results are given in Tables 1 and 2.

13. Reduction of wireless signals.—The time of coincidence between clock and signal was recorded on the chronograph (*vide* § 7). To obtain the time of the first signal it is necessary to know the number of the signal at which coincidence took place, and the interval between signals. The latter is immediately obtainable if more than one coincidence has been observed, but, if it is otherwise known, its value may be utilised to make a comparison of subsequent coincidences with the first, and thus obtain increased accuracy. This has been done, using for Bordeaux the reputed interval of $\frac{60}{61}$ of a mean second, and for Saigon the value 0·9853 sidereal seconds published by the San Diego observatory. The number of the signal at which coincidence took place is also immediately found, if the approximate time of the first signal is known. During November this was always recorded, but during October reliance was placed on the reputed time of the emission of the first signal. In the case of Bordeaux this time was strictly adhered to and no difficulty arose; in the case of Saigon it was not. For the Saigon signals the necessary information has since been obtained from the published results of the other observatories.

14. Local sidereal time of reception of signals.—The deduced times of reception, corrected for clock error, are given in Tables 3 to 8. They are based on the star observations of the nights immediately preceding and following the reception of each signal, as given in Tables 1 and 2. Individual nights' results have not been smoothed to give a more uniform clock rate. They are true sidereal times, the short period terms of nutation having been taken into account.

The actual time of reception is given, no allowance having been made for the rate of propagation of the signals. The estimated time of transmission from Bordeaux to Dehra Dūn is 0·023 seconds, and from Saigon to Dehra Dūn is 0·013 seconds.

The times of the first and last signals are given for convenience, but they have not been independently reduced. The interval between consecutive signals has been assumed to be 0·9863 sidereal seconds in the case of the Bordeaux signals, and 0·9853 for Saigon. The Saigon signals were irregular in this respect, and to enable the times of first and last signals to be recomputed with a revised value if desired, a column is added giving the particular number of the signals, at which the mean coincidences occurred: *e. g.* if coincidences were recorded at the 80th, 147th and 213th signals, the mean coincidence was at the 147th, and if the interval between signals is thought to be 0·9852 instead of 0·9853 the correction to the time of first signal will be $+0^s \cdot 0001 \times 146$.

Owing to the great irregularity in the times of emission of the

Saigon signals, there have, on some days, been doubts regarding the approximate times of the first signal. The Dehra Dūn results have been compared with those published by other observatories, and have been accepted only when an agreement exists with at least two others. In Tables 5 to 8, A signifies agreement, D disagreement, and a blank indicates that the signal was not received.

15. Performance of the instruments.—The value of the Dehra Dūn clock error, which will make the daily value of any arc, as given in Tables 10 to 13, equal to its mean value, is the clock error according to the star observations of the observatory at the other end of the arc, affected only by the comparatively small errors of wireless reception, and of the value of longitude as determined by the whole two months' work. By this means the error of the Dehra Dūn clock has been obtained in terms of the observations at Greenwich, Paris, Washington, San Diego, Algiers and Tokyo, in addition to those at Dehra Dūn itself. The mean value derived from these seven observatories is given in the last column of Tables 1 and 2 and this is presumably very nearly the true clock error. It is thus possible to find the actual error of each instrument on each day. Table 9 gives the fortnightly mean error of observers on each instrument.

The table reveals very considerable differences between the observers. Although the entries in Table 9 are described as errors, they are really only differences from the mean instrument, and it is not possible to say which is correct. The wide range of variation is most unfortunate, and in consequence of it the probable error of the longitude determination cannot be considered to be less than $\pm 0^s \cdot 020$. It was expected that the transit instruments with their impersonal micrometers would have given better results than this. It may be remarked that the Dehra Dūn observers had very little previous experience of their instruments.

16. Deduction of longitude.—As soon as the results of all stations are published in some such form as in Tables 3 to 8 it will be at once possible to deduce the value of any arc of longitude. The formation of a net work for simultaneous reduction is at first sight an attractive proposition, but closer inspection casts doubt upon its utility, as will appear from the following :—

Denote the observatories by A, B, C, etc.

„ „ wireless stations by α, β, γ, etc.

„ „ different signals by α_1, α_2, α_3, etc.

„ „ L.S.T. of reception of α_1 at A by $T_{A\alpha_1}$, etc.

„ „ longitude of A by L_A, etc.

„ „ difference of longitude between A and B, as deduced from all α_1 signals received by both, by $(L_A - L_B)\alpha_1$.

Denote the correction for the rate of propagation of wireless by $K_{A\alpha B}$, *i.e.*,

$$K_{A\alpha B} = \frac{A\alpha - B\alpha}{v}$$ where $A\alpha$ and $B\alpha$ represent distances, and v is the velocity of propagation.

Then $(L_A - L_B)a_1 = \text{Mean value of}(T_{Aa_1} - T_{Ba_1}) - K_{AaB} + e_{Aa_1B}$,
where e_{Aa_1B} is an error, which is made up of :—

(1) error in star observations.

(2) error on account of clock's irregularity between time of star observations and time of signals.

(3) error on account of any irregularity in the earth's rotation. This is indistinguishable from (2).

(4) error in wireless reception.

(5) error in assumed rate of propagation.

That is to say,

e_{Aa_1B} = the sum of 4 terms (a), (b), (c) and (d),

of which (a) depends on date only,
(b) ,, ,, signal and date,
(c) ,, ,, ,, ,, ,, ,
(d) ,, ,, position of A, a_1 and B, also possibly on date, if v is not constant.

or, e_{Aa_1B} = (a) [error in star observations at A *minus* that at B]
+ (b) [error due to clock and earth's rotation at A at the time of a_1 *minus* that at B]
+ (c) [error in reception of a_1 at A *minus* that at B]
+ (d) [distance $Aa - Ba$] × (error in $\frac{1}{v}$) ....(1)

Let $e_{AB} = e_{Aa_1B} + e_{Aa_2B} + \ldots\ldots$etc, comprising all the signals utilised for the arc AB

Then if n_1, n_2 etc., be the closing errors of different circuits,

$$\left.\begin{array}{l} e_{AB} + e_{BC} + \ldots\ldots\ldots + e_{NA} = n_1 \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots = n_2 \ldots\ldots\text{etc.} \end{array}\right\} \ldots\ldots\ldots\ldots\ldots (2)$$

The equations (2) are to be exactly satisfied, subject to the condition that $(e_{AB})^2 + (e_{BC})^2 + \ldots\ldots$etc., is a minimum.

Now, if at any station the same star observations be used in connection with any two arcs emanating from it, equations (2), in so far as they are concerned with that station, will be identically satisfied with regard to the first term of equations (1). Again, if the same signals are utilised for more than one arc at a station, equation (2) will be identically satisfied as regards the second and third terms of equations (1). And again, if even signals from the same wireless station are used, identity will result as regards the fourth term of equation (1). In consequence, only one half or one third of the stars and signals available can be used for the determination of each arc, and if errors be considered as truly accidental, the weight of the determination of each arc is proportionally reduced: the small increase of weight resulting from adjustment is insufficient compensation for this. Systematic errors are no doubt present, but it is obvious that as regards the first three terms of equation (1), no adjustment will eliminate them.

As regards the term involving the rate of propagation, the situation is a little different. There is reason to suppose that this rate does not differ from the velocity of light, but if it should do so, or if the length of the path followed should differ materially from that of the shortest arc, two cases arise. Firstly, it may be variable with the assumed rate as a mean value: in this case, as above, it is best to use all possible signals in each arc, and to forego adjustment. Secondly, it may tend to some other velocity as its mean value: in this case adjustment is called for. The closure of the circuit Algiers—Zi-ka-wei—San Diego—Algiers (preferably freed from error of star observations by the use of the same determination of local time in connection with the arcs on each side of each station) will show whether this complication is going to arise. If it does, it will become desirable to form further circuits in order that values of the velocity may be found which may be appropriate to each arc.

The condition mentioned above, namely, that no adjacent arcs may be based on signals emitted from the same wireless station, places severe limitations on the nature of the network selected.

17. Utilisation of all signals.—In one respect, however, the results of outside observatories can usefully be employed in the determination of an arc. It may happen that the difference in longitude of two stations is required, which have received no signals, or few signals, in common. The arc Dehra Dūn—Greenwich is such a case. At Dehra Dūn four different signals have been received, only one of which (Bordeaux $20^h\ 01^m$) has been received at Greenwich. If now the arcs Dehra Dūn-Paris and Paris-Greenwich be separately determined by independent signals, a second measure of the arc Dehra Dūn-Greenwich is obtained. If the regularity of performance of the Paris clocks and the accuracy of the Paris reception be considered perfect, it may be assumed that the Paris results were errorless in comparison with those obtained at Dehra Dūn. Hence a value of the Dehra Dūn-Greenwich arc, obtained indirectly through Paris, may be considered of equal weight to one obtained from a direct determination.

18. Longitude of Dehra Dun.—Daily values of the arcs Dehra Dūn-Greenwich (by Bordeaux $20^h\ 01^m$), Dehra Dūn-Paris (by Bordeaux $08^h\ 01^m$), Dehra Dūn-Paris (by Saigon $19^h\ 00^m$) and Dehra Dūn-San Diego (by Saigon $11^h 30^m$) are given in Tables 10 to 13, and summarized in Table 14. The times of reception at Paris have been taken from the "demi-définitif" values given in the Bulletin Horaire No. 32 of 20th February 1927, and those of Greenwich, San Diego and Washington, from their published results. Using data from the same sources, (and it is immaterial whether the times of the intermediate stations Paris and San Diego be based on the best possible star observations or not), the arc Paris-Greenwich, by two Annapolis and two Eiffel Tower rhythmic signals, is found to be $0^h\ 9^m\ 20^s{\cdot}912$*; and the arc San Diego-Greenwich, by two Annapolis rhythmic signals, is found to be $7^h\ 48^m\ 48^s{\cdot}375$*. Combining these arcs with the figures given in Table 14, we have the following values for the arc Dehra Dūn-Greenwich :—

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* These figures are not likely to agree with the final values of the longitudes of Paris and San Diego: this is immaterial. Any change will be due to a more complete computation of their clock errors, and the two component arcs will be affected by changes of opposite sign, leaving the deduced longitude of Dehra Dūn unchanged.

(1)	Direct by Bordeaux $20^h 01^m$	$5^h\ 12^m\ 11^s{\cdot}793$
(2)	Through Paris by Bordeaux $08^h 01^m$	5 12 11 ·801
(3)	Through Paris by Saigon $19^h 00^m$	5 12 11 ·791
(4)	Through San Diego by Saigon $11^h 30^m$	5 12 11 ·790

The mean of these gives the final value of the arc Dehra Dūn-Greenwich to be $\mathbf{5^h\ 12^m\ 11^s{\cdot}79_4}$. The good agreement of the four different arcs is no measure of the accuracy of the result. All may be equally affected by any errors in the star observations, and, as stated in § 15, the differences between different observers have been so great that the probable error of the above result is as much as $\pm\ 0^s{\cdot}020$ This is a disappointingly large probable error of the result of such an extended series of observations, but in the past the repetition of the measurement of various arcs has shown discrepancies greater than were to be expected from their apparent probable errors, and it is to be hoped that the large number of observers and the variety of instruments employed in this arc, will have resulted not only in a fair determination of the longitude, but in one which is as good as its probable error indicates.

The above figure may be compared with the old value of $5^h\ 12^m\ 11^s{\cdot}770$, derived from the Indo-European telegraphic arc of 1894-96. It is noteworthy that the inclusion of the more recent (1903) value of the component arc Greenwich-Potsdam, increasing Indian longitudes by $0^s{\cdot}098$, would apparently have impaired the accuracy of the 1894-96 results.

Fuller details of these operations will eventually be published in a separate volume.

TABLE 1.—*Clock error by each instrument at midnight, Indian Standard Time, October 1926.*

Date	North Transit			South Transit			Astrolabe			Mean Instrument			Clock error derived from mean of 7 observatories
	Observer	Series I	Series II	Observer	Series I	Series II	Observer	Series I	Series II	Series I	Series II	Mean of both series	
Oct.		Slow 2m.	Slow 2m.		Slow 2m.	Slow 2m.		Slow 2m.	Slow 2m.	Slow 2m.	Slow 2m.	Slow 2m.	Slow 2m.
1— 2	I.M.C.	s 58·896*	s 58·582*	G.H.O.	s 58·726*	s 58·692*	H.W.W.	s 58·273*	s 58·224*	s *	s *	s *	s 58·389
2— 3	...	...	...	,,	·539*	·447*	,,	58·165*	·195*	*	*	*	·243
3— 4	...	...	...	...	...	...	...	...	...	...	...	...	·141†
4— 5	B.L.G.	·045*	·301*	R.B.M.	·135	·161	G.B.	57·934	58·008	58·035	58·085	58·060	58·047
5— 6	,,	58·121*	58·239*	,,	58·151	58·019	,,	·860	57·943	58·006	57·981	57·994	57·942
6— 7	,,	57·971*	57·981*	,,	57·891	57·841	,,	57·755	57·783	57·823	57·812	57·818	57·824
7— 8	,,	59·912*	59·940*	,,	59·792	59·790	,,	59·671	59·728	59·732	59·759	59·746	59·709
8— 9	,,	·593	·530	,,	·593	·650	,,	·577	·607	·583	·596	·592	·572
9—10	,,	·393	·350	,,	·383	·430	,,	59·465	·528	·414	·436	·425	·422
10—11	...	...	...	...	...	...	...	...	...	...	...	...	·278†
11—12	I.M.C.	59·115	59·179	G.H.O.	·295	·229	H.W.W.	58·983	59·078	59·131	59·162	59·147	59·133
12—13	,,	58·944	58·929	,,	59·034	59·069	,,	·775	58·725	58·918	58·908	58·913	58·946
13—14	,,	·713	·729	,,	58·963	58·939	,,	·759	·745	·812	·804	·808	·817
14—15	,,	·524	·629	,,	·874	·819	,,	·485	·442	·628	·630	·629	·659
15—16	,,	·556	·518	R.B.M.	·616	·628	,,	·281	·442	·484	·529	·507	·527
16—17	,,	58·415	58·378	,,	58·465	58·448	,,	58·440	58·424	58·440	58·417	58·429	58·418

* Rejected.

† The value of Dehra Dūn included in this mean is interpolated and not observed.

TABLE 1.—*Clock error by each instrument at midnight, Indian Standard Time, October 1926.—(contd.)*

Date	North Transit			South Transit			Astrolabe			Mean Instrument			Clock error derived from mean of 7 observatories
	Observer	Series I	Series II	Observer	Series I	Series II	Observer	Series I	Series II	Series I	Series II	Mean of both series	
Oct.		Slow 2m. s	Slow 2m. s		Slow 2m. s	Slow 2m. s		Slow 2m. s	Slow 2m. s	Slow 2m. s	Slow 2m. s	Slow 2m. s	Slow 2m. s
17—18	...	...	...	...	...	...	...	...	...	...	...	...	58·314*
18—19	B.L.G.	58·153	58·181	G.H.O.	58·313	58·281	G.B.	58·210	58·206	58·225	58·223	58·224	·203
19—20	,,	58·064	58·070	,,	58·254	58·180	,,	58·016	58·019	58·111	58·090	58·101	58·082
20—21	,,	57·944	57·910	R.B.M.	57·944	57·910	,,	57·896	57·955	57·928	57·925	57·927	57·942
21—22	,,	·813	·818	,,	·783	·808	,,	·722	·740	·773	·789	·781	·807
22—23	,,	·603	·638	,,	·623	·668	,,	·645	·675	·624	·660	·642	·667
23—24	,,	·572	·388	,,	·522	·538	,,	·595	·565	·563	·497	·530	·533
24—25	...	...	...	...	...	...	...	...	...	...	...	...	·399*
25—26	I.M.C.	·254	·297	G.H.O	·324	·377	H.W.W.	·157	·201	·245	·292	·269	·270
26—27	,,	57·093	57·126	,,	·213	·286	,,	57·009	57·052	57·105	·155	57·130	·148
27—28	,,	56·932	56·949	,,	·112	·169	,,	56·911	56·895	56·985	57·004	56·995	57·015
28—29	,,	·912	·886	,,	57·002	57·076	,,	·789	·820	·901	56·927	·914	56·908
29—30	,,	·822	·816	,,	56·852	56·916	G.B.	·921	·874	·865	·869	·867	·823
30—31	,,	56·713	56·698	R.B.M.	56·703	56·748	,,	56·631	56·644	56·682	56·697	56·690	·697
31-Nov.1	...	...	...	...	...	...	...	...	...	...	...	...	56·572*

* The value of Dehra Dūn included in this mean is interpolated and not observed.

TABLE 2.—*Clock error by each instrument at midnight, Indian Standard Time, November 1926.*

Date	North Transit			South Transit			Astrolabe			Mean Instrument			Clock error derived from mean of 7 observatories
	Observer	Series I	Series II	Observer	Series I	Series II	Observer	Series I	Series II	Series I	Series II	Mean of both series	
Nov.		Slow 2^m.	Slow 2^m.		Slow 2^m.	Slow 2^m.		Slow 2^m.	Slow 2^m.	Slow 2^m.	Slow 2^m.	Slow 2^m.	Slow 2^m.
1— 2	B.L.G.	$56^s·392$	$56^s·377$	R.B.M.	$56^s·462$	$56^s·407$	G.B.	$56^s·475$	$56^s·432$	$56^s·443$	$56^s·405$	$56^s·424$	$56^s·436$
2— 3	„	·232	·206	„	·312	·316	„	·165	·250	·236	·257	·247	·285
3— 4	„	56·063	56·178	„	·143	·188	„	56·160	56·065	56·122	56·144	56·133	·149
4— 5	„	55·962	55·927	„	56·012	·047	„	55·984	55·910	55·986	55·961	55·974	56·019
5— 6	„	·852	·823	G.H.O.	55·912	56·103	H.W.W.	·740	·740	·835	·889	·899	55·888
6— 7	„	·772	·706	„	·812	55·836	„	·622	·571	·735	·704	·720	·753
7— 8	...	...	...	...	...	...	...	...	...	...	...	...	·601*
8— 9	I.M.C.	·432	·447	„	·542	·557	„	·393	·372	·456	·459	·458	·454
9—10	„	55·243	55·337	R.B.M.	55·313	55·327	„	55·166	55·223	55·241	55·296	55·269	·306
10—11	...	...	...	...	...	...	...	...	...	...	...	...	·176*
11—12	...	...	...	...	...	...	...	...	...	...	...	...	55·063*
12—13	...	...	...	...	...	...	...	...	...	...	...	...	54·930*
13—14	I.M.C.	54·653	54·796	R.B.M.	54·873	54·966	H.W.W.	54·680	54·680	54·735	54·814	54·808	·806
14—15	...	...	...	...	...	...	...	...	...	...	...	...	·689*
15—16	B.L.G.	·503	·555	„	·613	·625	G.B.	·644	·650	·587	·610	·599	·576
16—17	„	54·383	54·376	„	54·463	54·466	„	54·493	54·504	54·446	54·449	54·448	54·432

* The value of Dehra Dūn included in this mean is interpolated and not observed.

TABLE 2.—*Clock error by each instrument at midnight, Indian Standard Time, November 1926.—(contd.)*

Date	North Transit			South Transit			Astrolabe			Mean Instrument			Clock error derived from mean of 7 observatories
	Observer	Series I	Series II	Observer	Series I	Series II	Observer	Series I	Series II	Series I	Series II	Mean of both series	
Nov.		Slow 2m.	Slow 2m.		Slow 2m.	Slow 2m.		Slow 2m.	Slow 2m.	Slow 2m.	Slow 2m.	Slow 2m.	Slow 2m.
17—18	B.L.G	54·272	54·246	G.H.O.	54·332	54·156	G.B.	54·334	54·229	54·313	54·210	54·262	54·277
18—19	,,	·104	54·086	R.B.M.	·144	·196	,,	·113	·149	·120	54·144	·132	54·140
19—20	,,	54·174	53·836	,,	54·034	54·066	,,	54·028	54·019	54·079	53·974	54·027	53·989
20—21	,,	53·661	·665	...	...	...	,,	53·832	53·829	53·747	·747	53·747	·782
21—22	...	...	...	...	...	...	...	...	...	...	...	...	·605*
22—23	I.M.C.	·425	·428	...	...	...	G.H.O.	·418	·514	·437	·471	·454	·438
23—24	...	...	...	...	...	...	...	...	...	...	...	...	·307*
24—25	,,	53·113	·087	...	...	...	,,	·217	·343	·165	·215	·190	·188
25—26	,,	52·972	53·006	...	...	...	,,	53·062	53·148	53·017	53·077	53·047	53·042
26—27	,,	·795	52·905	R.B.M	52·995	52·985	,,	...	...	52·895	52·945	52·920	52·873
27—28	,,	·746	·704	...	...	...	,,	52·756	52·782	·751	·743	·747	·732
28—29	...	...	...	...	...	...	...	...	...	...	...	...	·607*
29—30	,,	·435	·605	,,	·545	·505	G.B.	·535	·461	·505	·524	·515	·477
30-Dec.1	,,	52·395	52·385	,,	52·445	52·445	,,	52·324	52·346	52·388	52·392	52·390	52·333

* The value of Dehra Dūn included in this mean is interpolated and not observed

TABLE 3.—*Local sidereal time of reception at Dehra Dūn India, of BORDEAUX wireless time signals at $8^h\ 01^m$ and $20^h\ 01^m$ G.M.T. in October 1926*

Greenwich Date	8ʰ 01ᵐ G.M.T.				20ʰ 01ᵐ G.M.T.			
	By Series II		By Series $\frac{I+II}{2}$		By Series II		By Series $\frac{I+II}{2}$	
	1st signal	306th signal	1st signal	306th signal	1st signal	306th signal	1st signal	306th signal
	h m s	h m s	h m s	h m s	h m s	h m s	h m s	h m s
1	...	...	...	...	...	...	...	...
2	...	...	...	...	...	...	...	...
3	...	...	...	...	...	...	...	...
4	...	...	...	...	2 04 11·22	2 09 12·04	2 04 11·19	2 09 12·01
5	...	...	...	...	...	...	...	...
6	14 10 06·03	14 15 06 85	14 10 06·04	14 15 06·86	...	...	...	...
7	...	...	...	...	16 00·93	21 01·75	16 00·92	21 01·74
8	17 59·19	23 00·01	17 59·18	23 00·00	19 57·43	24 58·25	19 57·42	24 58·24
9	...	...	...	...	23 53·97	28 54·79	23 53·96	28 54·78
10	...	...	...	...	...	...	...	...
11	29 48·75	34 49·57	29 48·73	34 49·55	31 47·02	36 47·84	31 47·01	36 47·83
12	33 45·25	38 46·08	33 45·25	38 46·07	35 43·53	40 44·35	35 43·54	40 44·36
13	37 41·80	42 42·62	37 41·81	42 42·63	39 40·07	44 40·89	39 40·07	44 40·89
14	41 38·35	46 39·17	41 38·35	46 39·17	...	...	...	...
15	45 34·87	50 35·69	45 34·86	50 35·68	47 33·16	52 33·98	47 33·14	52 33·96
16	49 31·49	54 32·31	49 31·49	54 32·31	2 51 29·75	2 56 30·57	2 51 29 76	2 56 30·58
17	53 28·01	14 58 28·83	53 28·02	14 58 28·84	...	...	...	...
18	14 57 24·62	15 02 25·44	14 57 24·63	15 02 25·45	...	...	...	...
19	15 01 21·20	06 22·02	15 01 21·20	06 22·02	3 03 19·48	3 08 20·30	3 03 19·49	3 08 20·31
20	05 17·78	10 18·60	05 17·79	10 18·61	07 15·99	12 16·81	07 15·99	12 16·81
21	09 14·31	14 15·13	09 14·31	14 15·13	11 12·59	16 13·42	11 12·59	16 13·41
22	...	...	...	...	15 09·22	20 10·04	15 09·21	20 10·03
23	17 07·46	22 08·28	17 07·47	22 08·29	19 05·73	24 06·55	19 05·76	24 06·58
24	21 03·99	26 04·81	21 04·01	26 04·83	...	...	...	...
25	25 00·60	30 01·42	25 00·59	30 01·41	26 58·95	31 59·77	26 58·93	31 59·75
26	28 57·19	33 58·01	28 57·17	33 57·99	30 55·47	35 56·29	30 55·45	35 56·27
27	32 53·75	37 54·57	32 53·74	37 54·56	...	...	...	...
28	36 50·29	41 51·12	36 50·28	41 51·10	38 48·52	43 49·34	38 48·51	43 49·33
29	40 46·85	45 47·67	40 46·85	45 47·67	42 45·12	47 45·94	42 45·12	47 45·94
30	44 43·37	49 44·19	44 43·37	49 44·19	3 46 41·65	3 51 42·47	3 46 41·64	3 51 42·46
31	15 48 39·91	15 53 40·73	15 48 39·91	15 53 40·73	...	...	...	...

TABLE 4.—*Local sidereal time of reception at Dehra Dūn India, of BORDEAUX wireless time signals at* $8^h\ 01^m$ *and* $20^h\ 01^m$ *G.M.T. in November 1926*

Greenwich Date	8h 01m G.M.T.				20h 01m G.M.T.			
	By Series II		By Series $\frac{I+II}{2}$		By Series II		By Series $\frac{I+II}{2}$	
	1st signal	306th signal	1st signal	306th signal	1st signal	306th signal	1st signal	306th signal
	h m s	h m s	h m s	h m s	h m s	h m s	h m s	h m s
1	15 52 36·44	15 57 37·26	15 52 36·45	15 57 37·27	3 54 34·70	3 59 35·52	3 54 34·71	3 59 35·53
2	...	...	...	...	3 58 31·25	4 03 32·07	3 58 31·24	4 03 32·06
3	...	...	...	...	4 02 27·83	07 28·65	4 02 27·82	07 28·64
4	16 04 26·07	16 09 26·89	16 04 26·08	16 09 26·90	06 24·33	11 25·15	06 24·34	11 25·16
5	08 22·64	13 23·46	08 22·65	13 23·47	10 20·95	15 21·77	10 20·96	15 21·78
6	12 19·15	17 19·97	12 19·16	17 19·98	14 17·37	19 18·19	14 17·39	19 18·21
7	...	...	...	...	...	...	...	...
8	20 12·28	25 13·10	20 12·28	25 13·11	22 10·50	27 11·33	22 10·50	27 11·32
9	24 08·80	29 09·62	24 08·79	29 09·61	...	...	...	...
10	28 05·28	33 06·11	28 05·25	33 06·07	30 03·63	35 04·45	30 03·59	35 04·41
11	32 01·90	37 02·73	32 01·85	37 02·67	34 00·20	39 01·02	34 00·13	39 00·95
12	35 58·46	40 59·28	35 58·40	40 59·23	37 56·74	42 57·56	37 56·69	42 57·51
13	39 55·02	44 55·84	39 54·99	44 55·81	41 53·27	46 54·09	41 53·26	46 54·08
14	43 51·55	48 52·37	43 51·53	48 52·35	...	...	...	...
15	47 48·11	52 48·93	47 48·08	52 48·90	49 46·41	54 47·23	49 46·40	54 47·22
16	51 44·65	16 56 45·47	51 44·64	16 56 45·46	53 42·95	4 58 43·77	53 42·95	4 58 43·77
17	55 41·20	17 00 42·02	55 41·23	17 00 42·05	4 57 39·46	5 02 40·28	4 57 39·51	5 02 40·33
18	16 59 37·74	04 38·56	16 59 37·76	04 38·58	5 01 36·08	06 36·90	5 01 36·07	06 36·90
19	...	...	...	...	05 32·66	10 33·48	05 32·71	10 33·53
20	17 07 30·98	12 31·80	17 07 31·00	12 31·82	09 29·20	14 30·03	09 29·20	14 30·03
21	...	...	...	...	...	...	...	...
22	15 24·21	20 25·03	15 24·20	20 25·02	17 22·46	22 23·28	17 22·44	22 23·26
23	...	...	...	...	21 19·01	26 19·83	21 18·98	26 19·80
24	23 17·31	28 18·13	23 17·28	28 18·10	25 15·53	30 16·35	25 15·51	30 16·33
25	27 13·78	32 14·60	27 13·75	32 14·57	29 12·09	34 12·91	29 12·06	34 12·88
26	31 10·39	36 11·21	31 10·36	36 11·18	33 08·67	38 09·49	33 08·64	38 09·47
27	...	...	...	...	37 05·14	42 05·96	37 05·14	42 05·96
28	39 03·41	44 04·23	39 03·41	44 04·23	...	...	...	...
29	42 59·98	48 00·80	42 59·98	48 00·80	44 58·27	49 59·09	44 58·26	49 59·08
30	17 46 56·56	17 51 57·38	17 46 56·56	17 51 57·38	5 48 54·84	5 53 55·66	5 48 54·84	5 53 55·66

TABLE 5.—*Local sidereal time of reception at Dehra Dūn India, of SAIGON wireless time signals at 11ʰ 30ᵐ G.M.T. in October 1926*

11ʰ 30ᵐ G. M. T.				Number of signal corresponding to mean coincidence	Comparison with other observatories.		
By Series I		By Series (I+II)/2			Tokyo	Zi-ka-wei	San Diego
1st signal	300th signal	1st signal	300th signal				
h m s	h m s	h m s	h m s				
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
17 37 14·97	17 42 09·57	17 37 14·96	17 42 09·56	128	D	A	A
40 30·14	45 24·74	40 30·15	45 24·75	137	D	A	A
49 13·75	54 08·36	49 13·76	54 08·37	171	A	D	A
48 54·39	17 53 49·00	48 54·40	17 53 49·01	172	A	A	A
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
17 59 56·59	18 04 51·20	17 59 56·60	18 04 51·20	131	A	A	A
18 03 34·64	08 29·24	18 03 34·65	08 29·24	136	A	A	A
07 35·82	12 30·43	07 35·82	12 30·43	178	A	A	D
11 00·54	15 55·14	11 00·55	15 55·16	164	A	A	D
15 00·44	19 55·05	15 00·44	19 55·04	128	A	A	A
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
33 50·12	38 44·73	33 50·12	38 44·72	184	A	A	A
...	...	...	...	...	...	...	...
39 11·37	44 05·98	39 11·38	44 05·98	262	A	A	A
42 54·18	47 48·78	42 54·19	47 48·80	182	A	A	A
47 03·94	51 58·55	47 03·93	51 58·53	164	A	A	A
49 44·21	54 38·81	49 44·19	54 38.80	159	A	A	A
53 21·04	18 58 15·65	53 21·06	18 58 15·66	156	A	A	A
18 58 15·32	19 03 09·93	18 58 15 35	19 03 09·95	142	A	A	A
19 00 35·82	05 30·42	19 00 35·83	05 30·44	146	A	A*	...
06 11·45	11 06·05	06 11·46	11 06·07	134	...	A	A
09 28·10	14 22·71	09 28·11	14 22·71	175	A	A	A
19 12 25·80	19 17 20·41	19 12 25·81	19 17 20·41	175	A	A	A
...	...	...	...	...	...	...	...

* Minute not given.

TABLE 6.—*Local sidereal time of reception at Dehra Dūn India, of Sai wireless time signals at 19^h 00^m G.M.T. in October 1926*

Greenwich Date	19h 00m G.M.T. By Series I 1st signal	By Series I 300th signal	By Series (I+II)/2 1st signal	By Series (I+II)/2 300th signal	Number of signal corresponding to mean coincidence	Comparison with other observ. Tokyo	Zi-ka-wei	P
	h m s	h m s	h m s	h m s				
1	...	...	...	...	...	...	...	
2	...	...	...	...	...	...	...	
3	...	...	...	...	...	...	...	
4	1 00 33·43	1 05 28·04	1 00 33·46	1 05 28·06	164	A	A	
5	...	...	...	...	...	...	...	
6	...	...	...	...	...	...	...	
7	...	...	...	...	...	...	...	
8	21 31·70	26 26·30	21 31·70	26 26·30	153	A	A	
9	18 25·24	23 19·85	18 25·26	23 19·86	195	A	A	
10	...	...	...	...	...	...	...	
11	28 36·89	33 31·50	28 36·91	33 31·51	138	A	A	
12	32 14·91	37 09·52	32 14·91	37 09·51	117	A	A	
13	34 16·98	39 11·58	34 16·97	39 11·58	190	A	A	
14	38 42·17	43 36·77	38 42·17	43 36·78	152	A	...	
15	43 02·34	47 56·94	43 02·36	47 56·96	156	A	A	
16	46 19·06	1 51 13·66	46 19·05	1 51 13·65	122	A	A	
17	...	...	...	...	...	...	...	
18	1 59 34·25	2 04 28·86	1 59 34·25	2 04 28·85	193	A	D	
19	2 03 10·65	08 05·26	2 03 10·64	08 05·25	158	A	A	
20	07 05·91	12 00·51	07 05·91	12 00·51	189	A	A	
21	09 35·99	14 30·60	09 36·00	14 30·60	150	A	A	
22	14 13·25	19 07·85	14 13·26	19 07·87	151	A	D	
23	17 54·81	22 48·91	17 54·28	22 48·88	171	A	A	
24	...	...	...	...	...	...	...	
25	25 35·24	30 30·84	25 36·26	30 30·87	148	A	A	
26	29 04·88	33 59·47	29 04·89	33 59·49	126	A	A	
27	31 02·23	35 56·83	31 02·24	35 56·84	166	A	A	
28	36 28·67	41 23·28	36 28·68	41 23·29	153	A	A	
29	40 32·25	45 26·85	40 32·25	45 26·86	176	A	A	
30	2 42 55·19	2 47 49·80	2 42 55·20	2 47 49·80	165	A	D	
31	...	...	...	...	...	...	...	

BLE 7.—*Local sidereal time of reception at Dehra Dūn India, of SAIGON wireless time signals at 11^h 30^m G.M.T. in November 1926*

11^h 30^m G.M.T.				Number of signal corresponding to mean coincidence	Comparison with other observatories.		
By Series I		By Series $\frac{I+II}{2}$			Tokyo	Zi-ka-wei	San Diego
1st signal	300th signal	1st signal	300th signal				
h m s	h m s	h m s	h m s				
19 20 15·52	19 25 10·13	19 20 15·51	19 25 10·11	110	A	A	A
23 31·04	28 25·65	23 31·05	28 25·65	144	A	A	D
27 12·72	32 07·32	27 12·73	32 07·33	182	A	A	A
31 41·15	36 35·75	31 41·14	36 35·75	159	...	A	A
33 56·52	38 51·12	33 56·56	38 51·16	188	A	A	A
42 03·11	46 57 72	42 03 12	46 57·73	193	A	A	A
...	...	...	...	...		...	...
45 32·71	50 27·31	45 32·71	50 27·31	197	A	A	A
51 10·56	56 05·16	51 10 58	56 05·19	139	D	A	A
19 54 26·22	19 59 20·83	19 54 26·27	19 59 20·87	88	A	A	A
...	...	.	...	...	..	...	...
20 01 47·28	20 06 41·89	20 01 47·34	20 06 41·94	169	A	A	A
.	.	...	.	...	...	...	...
08 28·68	13 23·29	08 28·72	13 23 33	194	A	A	A
17 14·05	22 08 66	17 14·06	22 08·66	145	A	...	A
20 55·78	25 50·39	20 55·79	25 50·39	123	A	A	A
23 14·44	28 09·04	23 14·40	28 09·01	112	A	A	A
27 53.43	32 48·04	27 53·42	32 48·03	159	A	A	A
32 21·24	37 15·85	32 21·21	37 15 81	156	A	A	A
35 38.98	40 33·58	35 38 96	40 33·57	137	A	A	A
40 14·88	45 09·48	40 14·88	45 09·49	142	A	A	A
44 16·86	49 11·47	44 16·88	49 11 48	177	A	A	A
47 22·81	52 17 42	47 22·84	52 17·45	157	A	A	A
52 02·36	20 56 56·97	52 02·39	20 56 57·00	141	A	A	A
55 48·21	21 00 42 81	55 48·24	21 00 42·84	105	A	A	A
20 58 35·72	21 03 30·32	20 58 35·74	21 03 30·35	147	A	A	A
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...

TABLE 8.—*Local sidereal time of reception at Dehra Dūn India, of SAIG wireless time signals at 19ʰ 00ᵐ G.M.T. in November 1926*

Greenwich Date	19ʰ 00ᵐ G.M.T. By Series I 1st signal	By Series I 300th signal	By Series $\frac{I+II}{2}$ 1st signal	By Series $\frac{I+II}{2}$ 300th signal	Number of signal corresponding to mean coincidence	Comparison with other obser… Tokyo	Zi-ka-wei	P
	h m s	h m s	h m s	h m s				
1	2 51 31·70	2 56 26·30	2 51 31·68	2 56 26·28	146	A	A	
2	54 00·81	2 58 55·42	54 00·83	2 58 55·43	135	A	A	
3	2 58 29·14	3 03 23·75	2 58 29·15	3 03 23·76	135	A	A	
4	3 02 42·73	07 37·34	3 02 42·72	07 37·33	156	A	A	
5	05 53·95	10 48·56	05 54·01	10 48·62	173	A	D	
6	09 22·95	14 17·56	09 22·94	14 17·54	162	A	D	
7	...	...	...			...	...	
8	16 01·42	20 56·02	16 01·42	20 56·02	194	A	..	
9	21 27·17	26 21·77	21 27·19	26 21·80	162	A	A	
10	25 25·24	30 19·84	25 25·29	30 19·89	171	A	A	
11	...	...	...	...	...	...	.	
12	34 02·11	38 56·71	34 02·16	38 56·76	142	A	A	
13	...	..	...	...	...	...	..	
14	...	...		..	...		...	
15	48 30·13	53 24·71	8 30·15	53 24·75	150	A	A	
16	52 11·63	3 57 06·24	52 11·63	3 57 06·24	169	A	...	
17	55 41·45	4 00 36·06	55 41·40	4 00 36·01	137	A	A	
18	3 59 09·90	04 04·51	3 59 09·91	04 04·52	163	A	A	
19	4 03 13·22	08 07·83	4 03 13·17	08 07·78	132	A	A	
20	...	...	...	..	...	...	...	
21	.	...	...	...	...	...		
22	15 32·82	20 27·43	15 32·84	20 27·45	119	A	D	
23	17 53·10	22 47·70	17 53·13	22 47·73	160	A	A	
24	22 19·21	27 13·84	22 19·26	27 13·87	119	A	A	
25	28 03·06	32 57·67	28 03·09	32 57·70	135	A	A	
26	4 29 08·88	4 34 03·49	4 29 08·91	4 34 03·51	141	A	A	
27	...	...	...	...	...	...	...	
28	...	...	...	..	...	...	...	
29	...	...	...	...	...	...	...	
30	...	...	...	...	...	...	...	

TABLE 9.—*Mean error of observers on each instrument**

Instrument	Observer	1st fortnight		2nd fortnight		3rd fortnight		4th fortnight		TOTAL	
		No. of days	Error	No. of days	Error	No. of days	Error	No. of days	Error	No. of days	Mean Error
North Transit	I. M. C.	6	+ ·031	6	+ ·018	3	+ ·037	7	+ ·012	22	+ ·022
do.	B. L. G.	2	+ ·030	6	+ ·026	6	+ ·047	6	+ ·044	20	+ ·038
South Transit	G. H. O.	4	− ·139	7	− ·104	3	− ·096	1	+ ·033	15	− ·103
do.	R. B. M.	8	− ·067	5	+ ·004	6	− ·031	7	− ·063	26	− ·044
Astrolabe	G. B.	6	+ ·014	8	+ ·012	4	+ ·042	8	− ·030	26	+ ·004
do.	H. W. W.	6	+ ·118	4	+ ·106	5	+ ·122	...	...	15	+ ·116
do.	G. H. O.	...	...	...		...	...	4	− ·059	4	− ·059

* The mean error of each instrument in this table is the observed error of clock by each instrument *minus* the error of clock by the mean instrument or (O − M).

The sign of (O − M) is $\frac{+}{-}$ according as the clock error is fast and $O \gtreqless M$

" " $\frac{+}{-}$ " " slow and $O \lesseqgtr M$.

TABLE 10.—*Daily values of the arc Dehra Dūn—Greenwich, determined by BORDEAUX wireless time signals at 20^h 01^m G.M.T.*

Greenwich Date	Arc	Daily value − Mean value	Greenwich Date	Arc	Daily value − Mean value
Oct.	h m s	s	Nov.	h m s	s
1	..	...	1	5 12 11·793	−·020
2	.	...	2	·761	−·052
3	...	...	3	·818	+·005
4	5 12 11·834	+·022	4	·770	−·043
5	...	...	5	·869	+·056
6	...	...	6	·770	−·043
7	·874	+·062	7	...	...
8	·865	+·053	8	·813	·000
9	·845	+·033	9	...	...
10	...	...	10	·770	−·043
11	·831	+·019	11	·753	−·060
12	·792	−·020	12	·779	−·034
13	·791	−·021	13	·792	−·021
14	...	...	14	...	...
15	783	−·029	15	·839	+·026
16	·828	+·016	16	·838	+·025
17	..	...	17	·786	−·027
18	..	...	18	·806	−·007
19	·835	+·023	19	·843	+·030
20	·773	−·039	20	·748	−·065
21	·749	−·063	21	...	...
22	...	...	22	·841	+·028
23	.	...	23	·817	+·004
24	...	...	24	·813	·000
25	·829	+·017	25	·851	+·038
26	·802	−·010	26	·883	+·070
27	..	...	27	·837	+·024
28	·764	−·048	28	...	...
29	·829	+·017	29	·863	+·050
30	·786	−·026	30	·878	+·065
31	...	...			

Summary

	h m s
October mean	= 5 12 11·812
November ,,	= 5 12 11·813
General mean	= 5 12 11·813
Correction for time of propagation	= −·020
Final Arc	= 5 12 11·793

TABLE 11.—*Daily values of the arc Dehra Dūn—Paris, determined by BORDEAUX wireless time signals at* 8^h 01^m *G.M.T.*

Greenwich Date	Arc	Daily value − Mean value	Greenwich Date	Arc	Daily value − Mean value
Oct.	h m s	s	Nov.	h m s	s
1	...	...	1	5 2 50·912	+ ·011
2	...	...	2	...	...
3	...	...	3	...	...
4	...	...	4	·836	− ·065
5	...	...	5	·887	− ·014
6	5 2 50·921	·000	6	·858	− ·043
7	...	...	7	...	...
8	·948	+ ·027	8	·894	− ·007
9	...	...	9	·855	− ·046
10	...	...	10	·826	− ·075
11	·913	− ·008	11	·867	− ·034
12	·891	− ·030	12	·884	− ·017
13	·905	− ·016	13	·920	+ ·019
14	·897	− ·024	14	·909	+ ·008
15	·879	− ·042	15	·902	+ ·001
16	·925	+ ·004	16	·881	− ·020
17	·892	− ·029	17	·876	− ·025
18	·916	− ·005	18	·825	− ·076
19	·942	+ ·021	19	...	...
20	·907	− ·014	20	·908	+ ·007
21	·897	− ·024	21	...	...
22	...	...	22	·965	+ ·064
23	·887	− ·034	23	...	...
24	·928	+ ·007	24	·959	+ ·058
25	·921	·000	25	·911	+ ·010
26	·935	+ ·014	26	·980	+ ·079
27	·955	+ ·034	27	...	...
28	·972	+ ·051	28	·938	+ ·037
29	·965	+ ·044	29	·955	+ ·054
30	·935	+ ·014	30	·977	+ ·076
31	·925	+ ·004			

Summary

	h m s
October mean =	5 2 50·921
November ,, =	5 2 50·901
General mean =	5 2 50·911
Correction for time of propagation =	−·022
Final Arc =	5 2 50·889

TABLE 12.—*Daily values of the arc Dehra Dūn—Paris, determined by SAIGON wireless time signals at 19^h 00^m G.M.T.*

Greenwich Date	Arc	Daily value − Mean value	Greenwich Date	Arc	Daily value − Mean value
Oct.	h m s	s	Nov.	h m s	s
1	...	...	1		...
2	...	...	2	...	...
3	...	...	3	5 2 50·922	+ ·074
4	5 2 50·904	+ ·036	4	·843	− ·005
5	...	...	5	...	...
6	...	...	6	...	...
7	...	...	7	..	...
8	...	...	8	·778	− ·070
9	·866	− ·002	9	·715	− ·133
10	...	...	10	...	...
11	·865	− ·003	11	...	...
12	·786	− ·082	12	...	..
13	·822	− ·046	13	...	...
14	·765	− ·103	14	...	...
15	·775	− ·093	15	...	...
16	·820	− ·048	16	·783	− ·065
17	...	...	17	·764	− ·084
18	·850	− ·018	18	·816	− ·032
19	·878	+ ·010	19	·913	+ ·065
20	...	...	20	...	...
21	·903	+ ·035	21	..	...
22	·930	+ ·062	22	·952	+ ·104
23	...	...	23	·925	+ ·077
24	...	...	24	·912	+ ·064
25	·893	+ ·025	25	...	...
26	·902	+ ·034	26	...	.
27	·886	+ ·018	27	...	...
28	·916	+ ·048	28	...	...
29	·926	+ ·058	29	..	...
30	·931	+ ·063	30	...	...
31	...	...			

Summary

		h	m	s
October mean	=	5	2	50·868
November ,,	=	5	2	50·848
General mean	=	5	2	50·858
Correction for time of propagation	=			+ ·021
Final Arc	=	5	2	50·879

TABLE 13.—*Daily values of the arc Dehra Dūn—San Diego, determined by SAIGON wireless time signals at 11^h 30^m G.M.T.*

Greenwich Date	Arc	Daily value − Mean value	Greenwich Date	Arc	Daily value − Mean value
Oct.	h m s	s	Nov.	h m s	s
1	...	...	1	13 1 0·130	+·012
2	...	...	2	...	...
3	...	...	3	·092	−·026
4	...	...	4	·079	−·039
5	...	...	5	·141	+·023
6	13 1 0·136	−·014	6	·061	−·057
7	·204	+·054	7	...	...
8	·236	+·086	8	·076	−·042
9	·198	+·048	9	·129	+·011
10	...	...	10	·076	−·042
11	...	...	11	...	...
12	...	...	12	·128	+·010
13	·147	−·003	13	...	...
14	...	...	14	·111	−·007
15	...	...	15	·143	+·025
16	·162	+·012	16	·123	+·005
17	...	...	17	·125	+·007
18	...	...	18	·090	−·028
19	·158	+·008	19	·135	+·017
20	...	...	20	·127	+·009
21	·146	−·004	21	·150	+·032
22	·144	−·006	22	·139	+·021
23	·118	−·032	23	·160	+·042
24	·104	−·046	24	...	...
25	·069	−·081	25	·124	+·006
26	·156	+·006	26	·141	+·023
27	...	...	27	...	...
28	·087	−·063	28	...	...
29	·161	+·011	29	...	...
30	·178	+·028	30	...	...
31	...	...			

Summary

	h m s
October mean	= 13 1 0·150
November „	= 13 1 0·118
General mean	= 13 1 0·134
Correction for time of propagation	= +·031
Final Arc	= 13 1 0·165

TABLE 14.—*Abstract of longitude differences, corrected for speed of propagation.*

Arc	October	November	Mean
	h m s	h m s	h m s
Dehra Dūn—Greenwich, *via* Bordeaux signals at 20h 01m G.M.T. ...	5 12 11·792	5 12 11·793	5 12 11·793
Dehra Dūn—Paris, *via* Bordeaux signals at 8h 01m G.M.T. ...	5 2 50·899	5 2 50·879	5 2 50·889
Dehra Dūn—Paris, *via* Saigon signals at 19h 00m G.M.T. ...	5 2 50·889	5 2 50·869	5 2 50·879
Dehra Dūn—San Diego, *via* Saigon signals at 11h 30m G.M.T. ...	13 1 0·181	13 1 0·149	13 1 0·165

Chapter II

COMPUTATIONS AND PUBLICATION OF DATA

BY CAPTAIN G. BOMFORD, R.E.

(i) Computations

1. Accuracy of triangulated heights.—An investigation was made by Dr. J. de Graaff Hunter into the reliability of triangulated heights. As mentioned in the Geodetic Report Vol. II., Chap. I § 7, an attempt to construct a chart, showing the errors of the triangulated heights in each part of the country, as revealed by spirit-levelled connections, had failed on account of the comparatively small number of connections and of the irregularity of the errors found. It consequently became necessary to be satisfied with a knowledge of the probable error of the triangulated heights at any place. This was determined as follows:—

If h_1, h_2, and h_3 be the observed differences of height in the three sides of any triangle, reckoned in one direction, it is clear that the sum $(h_1 + h_2 + h_3)$ should be zero: let it actually be equal to ∇. The quantity $p = \sqrt{\frac{\Sigma \nabla^2}{3n}}$ has been computed for each geodetic series, n being the number of triangles in each series.

0.6745 p is then the probable error of the observed height difference of each side, and the probable error after triangular adjustment will be $\sqrt{\frac{2}{3}} \times \cdot 6745\, p$, i. e. $\cdot 55p$.

p is analogous to the quantity m, used to express the quality of the horizontal angles of each series. A second quantity P, analogous to M, has also been computed, defined by the relation $P = p\sqrt{\frac{18}{l}}$ where l is the average length (in miles) of the sides of triangles forming the series, 18 miles being the average for the whole of India.

Then the probable error of height in a pendent series, at a point distant 100 S miles from the nearest spirit-levelled connection, is, $1 \cdot 3\, P\sqrt{S}$ feet, and $4\, P\sqrt{S}$ may be considered exceptional. When a series, or part of a series, has been closed on spirit-levelled heights at both ends, the probable error will be $1 \cdot 3\, P\sqrt{S}\sqrt{\frac{K}{K+1}}$, where 100 S and 100 KS are the distances in miles from the connections. If K be greater than unity, (i. e. if 100 S always be the distance to the nearest connection), the value of the fraction $\sqrt{\frac{K}{K+1}}$ varies between 0·7 and 1·0, and allowance for it is easily made. A chart is being prepared showing the greatest error in height likely to occur in any part of the Indian triangulation.

The values of p and P are given in Table 1.

TABLE 1.—*Values of "p" and "P" for all Geodetic Series of the Indian Triangulation.*

No.	Name of Series	Season	$\pm p$	$\pm$ P	No.	Name of Series	Season	$\pm p$	$\pm$ P
1	South Pārasnāth Meridional	1831-39	9·98	8·64	28	Kāthiāwār Mer....	1852-56	2·01	2·04
2	Budhon Meridional	1833-43	7·47	7·23	29	Gujarāt Lon. ...	1852-62	1·37	1·55
3	Amūa Meridional	1834-38	4·71	4·59	30	Kāthiāwār Lon.	1853	1·66	1·47
4	Rangīr Meridional	1834-64	7·52	7·03	31	Sābarmati ...	1853-54	0·91	1·68
5	Calcutta Lon. ...	1834-69	2·23	1·83	32	Great Indus ...	1853-61	1·74	2·07
6	Great Arc Mer. Section 24°-30°	1835-66	4·26	3·84	33	Rāhon Mer. ...	1853-63	1·24	1·40
7	Bombay Lon. ...	1837-63	2·19	1·77	34	Assam Lon. ...	1854-60	1·52	1·82
8	Great Arc Mer. Section 18°-24°	1838-41	1·26	1·16	35	Cutch Coast ...	1855-58	1·80	2·16
9	Great Arc Mer. Section 8°-18°...	1840-74	1·80	1·56	36	Kashmīr Principal	1855-60	2·48	2·40
10	Singi Meridional	1842-62	1·26	1·07	37	Jogī-Tīla Mer. ...	1855-63	1·67	2·02
11	South Konkan Coast ...	1842-67	1·62	1·26	38	Sambalpur Lon.	1856-57	1·48	1·43
12	Karāra Meridional	1843-46	3·46	3·62	39	(Cutch) Coast Line ...	1856 60	1·44	1·85
13	North Malūncha Meridional ...	1844-46	3·69	3·65	40	Kāthiāwār Mer. No. 1 ..	1858-59	0·87	1·22
14	Chendwār Mer.	1844-69	1·51	1·65	41	Kāthiāwār Mer. No. 2 .	1859-60	1·39	1·70
15	Gora Meridional	1845-47	3·09	3·32	42	Kāthiāwār Mer. No. 3 ...	1859-60	3·36	4·51
16	Calcutta Mer.	1845-48	1·52	2·21	43	Bīdar Lon. ...	1859-72	1·21	1·09
17	South Malūncha Meridional ...	1845-53	1·49	1·60	44	Eastern Frontier or Shillong Mer.	1860-64	1·24	1·45
18	Khānpisura Mer.	8415-62	2·11	1·72	45	Sutlej Meridional	1861-63	1·74	2·27
19	Gurwāni Mer. ..	1846-47	2·57	2·94	46	Madras Mer. and Coast ...	1861-68	1·28	1·17
20	North-East Lon.	1846-55	1·36	1·73	47	Kāthiāwār Mer. No. 4 ...	1863-64	...	...
21	Harilāong Mer.	1848-52	2·42	2·72	48	East Calcutta Longitudinal ...	1863-69	0·96	1·25
22	North-West Himālaya ...	1848-53	2·15	1·81	49	Mangalore Mer.	1863-73	1·14	1·00
23	Gurhāgarh Mer.	1848-62	1·44	1·66	50	Kumaun&Garhwāl	1864-65	1·81	1·48
24	East Coast ...	1848-63	1·58	1·63	51	Nāsik ...	1864-65	0·78	1·01
25	Karāchi Lon. ...	1849-53	1·88	2·01	52	Burma Coast ...	1864-82	1·27	1·21
26	Abu Meridional ..	1851-52	1·53	1·63	53	Jubbulpore Mer.	1865-67	1·04	0·93
27	North Pārasnāth Meridional ...	1851-52	2·10	2·61	54	Madras Lon. ...	1865-80	1·23	1·13

(continued)

TABLE 1.—*Values of "p" and "P" for all Geodetic Series of the Indian Triangulation.—(contd.)*

No.	Name of Series	Season	±p	±P
55	Assam Valley Triangulation ...	1867-78	1·60	2·21
56	Brahmaputra Mer.	1868-74	1·02	1·25
57	Coimbatore No. 1	1869-71	2·50	2·87
58	Bilāspur Mer. ...	1869-73	0·98	1·06
59	Cuddapah ...	1871-72	1·32	1·34
60	Hyderābād ...	1871-72	0·78	0·74
61	Malabar Coast ...	1871, 74, 80	1·17	1·19
62	Jodhpur Mer. ...	1873-76	1·11	1·19
63	South East Coast	1875-79	1·33	1·65
64	Eastern Sindh Meridional ...	1876-81	1·25	1·45
65	Siam Branch Triangulation ...	1878-81	2·55	2·70
66	Mandalay Mer.	1889-95	1·46	1·19
67	Mong Hsat ...	1891-93	2·71	2·35
68	Manipur Lon. ...	1894-99	1·45	1·15
69	Makrān Lon. ..	1895-97	0·92	0·60
70	Mandalay Lon. .	1899-1909	1·00	1·03
71	Manipur Mer.	1899-1902 } 1915-1916 }	2·22	2·07
72	Great Salween ...	1900-11	4·28	3·18
73	Kidarkanta ...	1902-03	2·17	2·36
74	Kalāt Lon. ...	1904-08	3·15	2·12
75	Baluchistān Triangulation ..	1908-09	2·97	2·18

No.	Name of Series	Season	±p	±P
76	North Baluchistān	1908-10	1·82	1·35
77	Gilgit ...	1909-11	2·62	1·96
78	Khāsi Hills ...	1909-11	0·76	0·99
79	Mawkmai ...	1909-11	1·56	2·00
80	Upper Irrawaddy	1909-11	3·14	2·41
81	Jaintiā Hills ..	1910-11	0·49	0·79
82	Bhīr ..	1911-12	2·49	2·53
83	Rānchi ..	1911-12	0·61	0·66
84	Villupuram ..	1911-12	0·46	0·59
85	Sambalpur Mer.	1911-14	1·28	1·07
86	Indo-Russian Connection ...	1912-13	2·17	2·79
87	Khandwā ...	1912-13	1·71	1·86
88	Ashta ...	1913-15	1·33	1·44
89	Buldāna ...	1913-14	0·98	1·18
90	Naldrug ...	1913-14	1·91	2·08
91	Nāga Hills ...	1913-14	2·17	2·00
92	Middle Godāvari	1914 15	0·72	0·74
93	Kohīma ...	1914-15	1·48	1·62
94	Cāchār ...	1914-15	1·17	1·53
95	Bombay Island ...	1911-14	...	...
96	Madura ...	1916-17	1·49	1·71
97	Bāgalkot ...	1916-17	1·15	1·18
98	Sind Sāgar Triangulation ..	1917-18	1·05	1·64

2. Latitude variation.—As a result of an enquiry from Professor Wegener, the values of astronomical latitudes, found at stations in India at which observations had been taken at more than one time, separated by considerable periods, were scrutinised to see whether they afforded any evidence of earth movement. The results are given in Table 2. They have not been cleared of polar variation.

TABLE 2.—*Latitude Variation*

Station	Epoch of observation	Longitude	Latitude	Variation of latitude from the latest value	Instrument used	Method of observation	Star catalogue used in reduction
Dŏddagunta	1805·502	77° 38′	12° 59′ 50″·51	−1″·56	Z. S. R.	Z. D.	Hennessey (1)
	1806·477		51·71	−0·36	Z. S. No. 2	,,	,,
	1870·034		52·07		,, ,,	Sector	,,
Pachapālaiyam	1806·305	77 37	10 59 40·68	−0·21	Z. S. R.	Z. D.	,,
	1870·183		40·89		Z. S. No. 2	Sector	,,
Punnæ ...	1809·316	77 38	8 9 30·18	+0·52	Z. S. R.	Z. D.	,,
	1871·103		29·66		Z. S. No. 2	Sector	,,
Dāmargīda	1815·129	77 40	18 3 14·56	−0·60	Z. S. R.	Z. D.	,,
	1840·967		15·16		A. C. No. 1	,,	,,
Kaliānpur	1825·022	77 39	24 7 10·69	+0·22	Z. S. R.	,,	(2)
	1839·988		10·85	+0·38	A. C. No. 1	,,	(2)
	1840·966		11·11	+0·64	,, No. 2	,,	(2)
	1865·148		11·37	+0·90	,, No. 1	,,	Hennessey (1)
	1865·901		10·83	+0·36	,, No. 1	,,	,,
	1899·034		10·47		Z. S. No. 1	Talcott	Greenwich 1880
Gogīpatri ...	1860·411	74 41	33 51 46·56	−0·34	T. S. 14 No. 5		
	1922·387		46·90		Z. T.	,,	Newcomb
Poshkar ...	1860·393	74 30	34 2 3·38	+0·60	T. S. 14 No. 5		
	1922·409		2·78		Z. T.	,,	,,
Mussoorie	1866·823	78 01	30 27 4·13	+0·18	A. C. No. 1	Z. D.	Hennessey (1)
	1867·739		3·03	−0·92	,, No. 1	,,	,,
	1867·809		3·95		,, No. 2	,,	,,
Sangalpur	1867·098	75 02	31 17 35·42	+0·09	A. C. No. 1	Z. D.	Hennessey (1)
	1868·024		35·33		,, No. 2	,,	,,
Harnāsa ...	1869·251	75 33	22 47 26·50	−0·27	,, No. 2	,,	,,
	1869·862		26·77		,, No. 2	,,	,,
Khānpisura	1870·259	74 47	18 45 22·63	+0·15	,, No. 2	,,	,,
	1893·040		22·48		Z. T.	Talcott	Greenwich 1880, 1872, 1t64
Kundgol ..	1871·987	75 15	15 15 14·28	−0·24	Z. S. No. 1	Sector	Hennessey (1)
	1872·182		14·52		,, No. 1	,,	,,
Agra (Long. Stn.)	1893·831	78 01	27 9 34·49	−0·17	,, No. 1	Talcott	Gr. 1872, 1880, 1864. 1880
	1898·189		34·62		Z. T.	,,	,,
Dehra Dūn	1905·051	78 03	30 18 51·80	−0·23	,,	,,	Greenwich 1880&Newcomb
	1926·827		52·03		Astrolabe		American Ephemeris

Z. S. R. = Ramsden's Zenith Sector. Z. S. = Strange's Zenith Sector. A. C. = Astronomical Circle.

T. S. 14 = Troughton and Simms' 14-inch theodolite. Z.T. = Zenith telescope.

(1) A star catalogue, reduced to 1st January 1850, was compiled by Mr. Hennessey of the Survey of India from various catalogues including 6 adopted ones, namely, Greenwich 12-year 1840 and 1845, Madler 1850, Greenwich 7-year 1860, Greenwich 7-year 1864 and Greenwich 9-year 1872, and from 15 others of epochs varying from 1835 to 1878. This was used for all observations prior to 1886.

(2) The first 3 values of latitude at Kaliānpur were deduced in 1880 the star places being taken from a modern star catalogue, author unknown.

Five sets of observations, at Mussoorie, Sangatpur, Harnāsa and Kundgol, cover intervals of less than a year each, in spite of which they show changes not much smaller than those of the others. Of the remaining stations, four out of five show increases in latitude between 1800 and 1870, and three out of six show increases between 1870 and 1927. The changes at Gogīpatri and Poshkar, which are situated 15 miles apart, are directly contradictory. It can only be concluded that all the changes may be attributed to errors of observation or of star place, and that there is no evidence of continental drift. Nor, on the other hand, is there any disproof of the existence of a drift of the order of fifty feet per century.

3. Adjustment of Geodetic triangulation.—The adjustment of the Bāgalkot and Madura primary series was carried out. These two series were observed in 1916-17. Table 3 gives details of the series, values of M, and the closing errors which had to be distributed.

TABLE 3.—*Values of M, closing errors &c. of Bāgalkot and Madura Series.*

	Bāgalkot series	Madura series
Length (miles) ...	102	68
M ...	±0·83	±1·53
No. of figures ...	10 triangles and 1 quadrilateral	10 triangles
Closing error in latitude ...	−0″·06	−0″·01
Closing error in longitude ...	−0″·09	−0″·09
Closing error in azimuth ...	−1″·14	+3″·17
Closing error in log side ...	−0·0000068	−0·0000205
Closing error in height ...	−0·6 feet	Not available

4. Adjustment of minor triangulation.—A large amount of work has been done towards the adjustment of minor triangulation in the North-West Frontier area, where the work of many different observers has for a long time been allowed to remain in different terms, and with unadjusted discrepancies at points of contact. No rigorous method of adjustment is either practicable or necessary, and all that has been attempted is to bring neighbouring pieces of work into mutual agreement. The procedure followed was to compile a list of the discrepancies at points common to adjoining pieces of work, and then, by considering first the larger pieces, and those most closely connected to primary triangulation, to decide on the correction applicable to common stations. The common stations were then plotted on blank charts and the corrections entered against them. "Lines of equal correction" for both latitude and longitude were roughly drawn on the charts, intermediate lines being interpolated. The correction applicable to a station or intersected point in any part of the chart can then at once be read off. The azimuths and lengths of sides have not been adjusted, nor will their values be published. When required, they will be computed directly from the adjusted co-ordinates of the stations concerned.

The compilation of the list of discrepancies, involving reference to old records, was extremely tedious. Data for 1/M sheets 38 and 43 were compiled in two months by a computer, sent to the Frontier Circle Office at Simla for this purpose, and the adjustment in these sheets has proceeded satisfactorily. The compilation for sheets 34 and 39 has not yet been commenced.

5. Figure of the Earth.—Computations have been carried out in connection with the investigation into the Figure of the Earth. These mostly involve the formation and solution of normal equations, in which a comptometer manufactured by Felt and Tarrant has proved very useful.

(ii) Publication of data

6. Levelling handbook.—A new edition of the levelling handbook has been printed. The principal changes are:—

(1) The inclusion of a description of the Zeiss level.
(2) A fuller description of standard types of bench-marks.
(3) A new method of crossing wide rivers.
(4) A fuller description of the connection of triangulation stations situated on steep hills.
(5) The omission of Appendix A. (Comparison of standard tapes).
(6) A new appendix dealing with the procedure to be followed when a new line of levelling closes badly, and a general change of ground level is suspected.

7. Geodetic Report.—The Geodetic Report Volume I (1922-25) and Volume II (1925-26), the first two volumes of a new series, have been edited. The various geodetic parties and offices prepare their own reports, but the editing of these first two volumes for press has thrown a great deal of work on to the Computing Office.

8. Triangulation pamphlets.—Triangulation data of 32 Indian, 18 'Irāq and 9 Aden degree sheets have been compiled. 10 pamphlets, comprising 20 degree sheets, have been printed off. 66 existing pamphlets have been photozincographed, to replace shortage of stock.

9. Professional forms and tables.—Traverse forms 1, 11, 15, 16, 24, 25 and 26, and levelling form 9 have been reduced to foolscap size.

The following new forms have been devised and printed:—

(a) 9 and 10 Ast. Two forms constituting an alternative to the graphical method of computing time and latitude from a series of observations with the prismatic astrolabe. The formula used is less rigorous than reduction by least squares, but gives sensibly the same results.

(b) 28 Topo. Computation of the rectangular co-ordinates of cutting points for theodolite resection by the semi-graphic method.

(c) 29 Topo. Approximate determination of position by observation of horizontal and vertical angles to two known points.

Tables.—A table (42 Sur.) has been compiled, giving the astronomical refraction for various zenith distances at a pressure of 29 inches and temperature of 75°F. It is intended for use with rough sun azimuths in traverse work, for which a precise computation of refraction is not necessary.

10. Levelling pamphlets.—The editing of levelling pamphlets has also been transferred to the Preservation and Maintenance section, the levelling party being, as before, responsible for their preparation. A new series of pamphlets, giving the results of levelling of secondary precision, carried out for commercial purposes, has been introduced. The first two pamphlets of this series have been published.

11. Miscellaneous.—Triangulation data have been compiled for the War Office, London, in connection with the production of a map of part of the Aden Protectorate, also for the Turco-'Irâq boundary commission, and for the Anglo Persian oil company.

400 miscellaneous requisitions for data and publications were complied with.

CHAPTER III

OBSERVATORIES

BY CAPTAIN G. BOMFORD, R.E.

1. Summary.—The principal work of the observatories has been :—

(1) Regular time and latitude observations.
(2) Comparison of standards of length.
(3) Magnetic observations.
(4) Seismograph and meteorological observations.

2. Time observations.—During October and November 1926 the intensive programme of the International Longitude Project was carried out. In common with many other observatories, Dehra Dūn has undertaken to carry out a regular but less intensive programme for an indefinite subsequent period, and for this purpose observations were made twice a week with one transit instrument and one astrolabe. The Bordeaux wireless signal at 8^h 01^m G. M. T. was also received daily. In June, July, August and early September clouds make regular star observations impossible at Dehra Dūn and atmospherics make the reception of wireless signals difficult. Consequently there will always be unavoidable gaps in the continuity of observations during these months. This year the wireless set was dismantled for alterations and adjustments, and the break was complete.

The instruments used are described in Chapter I. Table 2 gives the values of the clock error according to each instrument. On a few days discrepancies are rather greater than would normally be expected. As soon as the times of reception of signals at some other observatories are published, it will be possible to discriminate between the two instruments, and to decide whether any results are to be rejected. Pending this decision, the results of the two instruments have been kept separate in Table 5 which shows the corrected times of reception of each wireless signal. The deduced values of the longitude will be published in a subsequent Geodetic Report.

3. Latitude observations.—The use of the astrolabe for time has resulted in a regular series of latitude observations being obtained. Table 3 gives the daily results for October and November 1926, and Table 4 gives a summary for this period, and the bi-weekly results up to the end of May, when astrolabe observations had to be discontinued. The following are the monthly mean values of $\Delta\lambda$ the observed value *minus* the previously accepted value, which is based on the old value of 30° 18′ 51″·80 for the Haig Observatory.

October 1926	+0″·22
November ,,	+0·24
December ,,	+0·26
January 1927	+0·12
February ,,	+0·57
March ,,	−0·53
April ,,	+0·06
May ,,	−0·26

If the present programme can be continued for an extended period, it may possibly contribute something to the problem of latitude variation, although the astrolabe may prove to be an insufficiently precise instrument for this purpose. Combined with a similar series of observations in the distant future, it should at any rate serve to test Wegener's theory of continental drift, for which purpose a long series of observations of lower precision are likely to be more useful than a single observation of the highest apparent accuracy.

4. Standards of length.—The equipment of the observatory includes a comparator and a set of standard bars for the standardisation of base-line apparatus and other work requiring the highest possible accuracy. It was received in 1914, but has never yet been employed on the work for which it was designed. The apparatus has been overhauled and made use of for comparing the field tapes used by the levelling party for measuring the lengths of staves. It is intended that this should in future form part of the routine work of the Observatory Section.

A 100-foot sub-base which is correct to 1 : 20,000 has been laid down on the floor of the base-line alley to facilitate the rough standardisation of tapes required for bases in exploration or other topographical work. There are intermediate marks every 10 feet, and also at 66 feet.

5. Graduation of levelling staves.—A batch of 14 staves recently graduated by the Mathematical Instrument Office was tested for regularity of graduation at every foot. Table 7 gives the values of actual length *minus* reputed length, and Table 8 shows the errors in the regularity of the graduations, viz. :—

(actual length) *minus* $\left(\text{reputed length} \times \dfrac{\text{actual total length}}{10 \text{ feet}}\right)$. This latter expression is of course the true criterion of the staff's worth.

A similar test was made of four staves, which had been in use for some years, but which were still considered fit for high precision geodetic work. Tables 9 and 10 give the results. As regards their actual lengths the old staves are better than the new ones, which are all about 0·0035 too long. As regards uniformity, the old and the new ones are of similar quality.

It is noteworthy that, especially in the old staves, these departures from uniformity show considerable persistence of sign in any one staff, and that the signs of the errors in Table 10 are opposite to those in Table 9, indicating that the top end of a staff undergoes greater expansion and contraction than does the bottom end, as can be immediately seen in Table 9, where the errors at 5 feet are very much less than half of those at 10 feet. This persistence of sign might, under certain circumstances, produce considerable error. When levelling up a steady gradient, the back readings on the staff are always at 8 or 9 feet, and the fore readings at 1 or 2 feet. If two staves such as No. 20 A were being used, the back readings would have an average error of about 0·0003, while the fore readings would be correct. In such a line as that from Rājpur to Mussoorie, rising 3,200 feet in 13 miles and involving 600 stations the error introduced would be about 0·15. This is a very extreme case as the line is an exceptional one, and staff No. 20 A is not typical. In the other three staves the error at two feet is about equal to that at 8 feet, and the error would be much less. But it might not be quite negligible.

6. Magnetic observations.—The usual programme of magnetic observations was carried out, comprising a continuous magnetographic record of declination, horizontal and vertical force, daily observations of dip, and bi-weekly observations of declination and horizontal force. Three exceptionally severe magnetic storms occurred on January 26th to 28th, February 23rd to 25th and October 13th to 16th. The horizontal force magnetograms of these days are reproduced in Plate V.

Sub-soil water percolated into the observatory between August 4th and 9th.

Declination and horizontal force constants.—Table 11 gives the mean monthly values of the magnetic collimation, the distribution constants $P_{1\cdot2}$ and $P_{2\cdot3}$, and the accepted value of log $\left(1 + \frac{P}{r^2} + \frac{Q}{r^4}\right)^{-1}$ for Magnet No. 17.

Base-line values.—Table 12 gives the mean monthly observed values of the declination and horizontal force base-lines which have been used to compute the values of these elements for 1926. The moment of inertia of the magnet was assumed to be the same as determined in 1919.

Scale values and temperature range.—The mean scale values for 1926 for an ordinate of 1/25 inch were :—

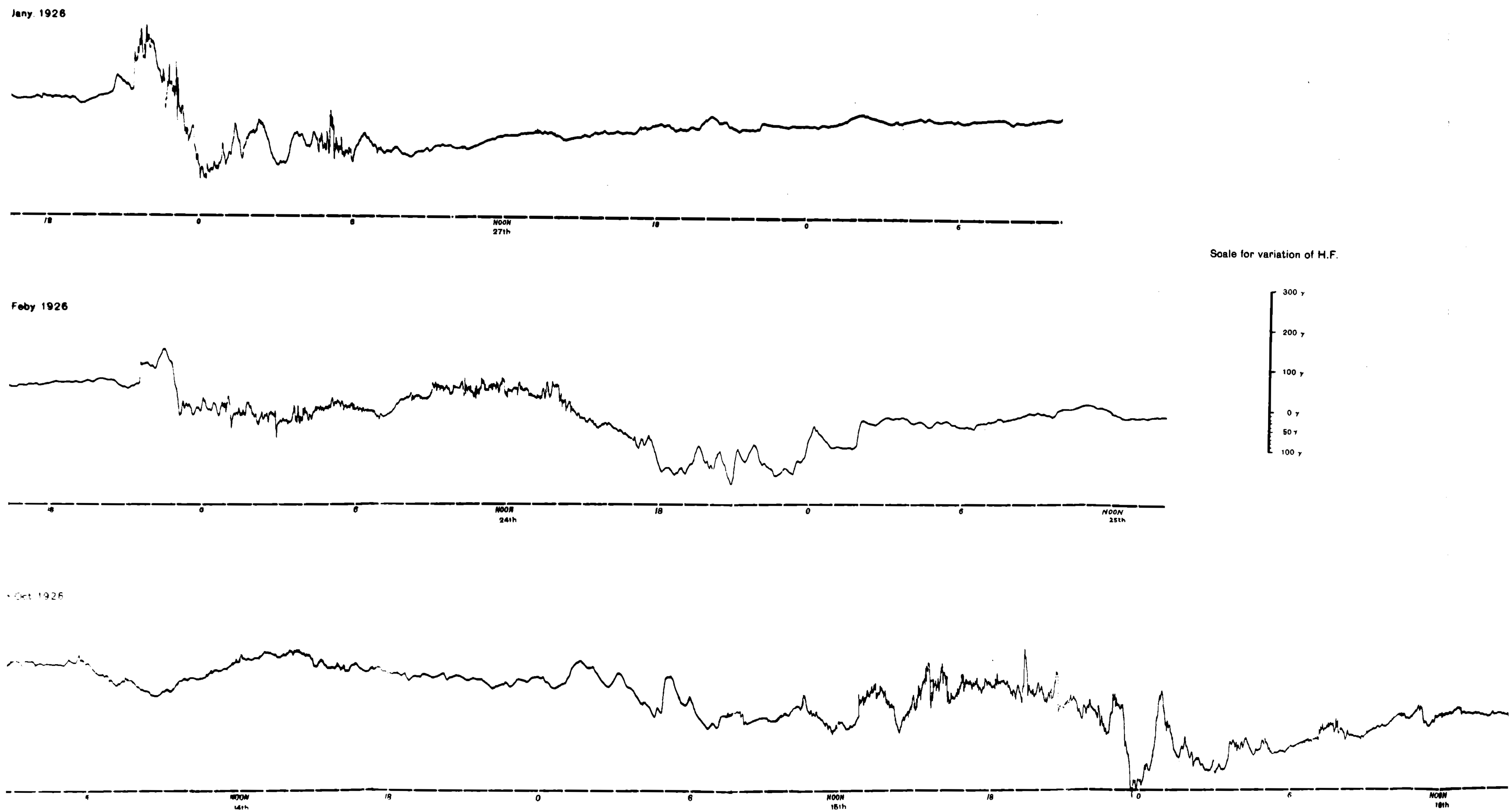
Horizontal force	4·32 gammas
Declination	1·03 minutes
Vertical force	9·86 to 11·59 gammas

The mean temperature of the year was 26°·5 C with maximum and minimum monthly values of 27°·3 and 26°·3 C. The temperature of reduction was 27°·0 C.

Monthly values and annual changes—Table 13 shows the monthly mean values of the magnetic elements for 1925 and 1926, and the annual changes for that period. The mean values of the magnetic elements at the Dehra Dūn observatory in 1926 are given below :—

Plate No V.

Chart shewing Horizontal Force during three
Magnetic Storms recorded at Dehra Dun in 1926



Dip	Declination	Horizontal force	Vertical force
° ′	° ′	C. G. S.	C. G. S.
N 45 26·1	E 1 26·3	·32933	·33436

Hourly values of the elements.—The monthly mean values of the magnetic elements and the hourly deviations from these means are given in Tables 15 to 18. These have been deduced from five selected quiet days. A classification of the magnetic character of all days during the year 1926 is given in Table 14.

7. Seismograph and meteorological observations.—The Omori seismograph was in operation throughout the year except during October, November and December 1926, when repeated stoppages of the clock necessitated a general overhaul. Table 6 gives a list of the earthquakes recorded at Dehra Dūn during 1926-27. The usual daily meteorological observations were made throughout the year and rainfall telegrams sent to the Director General of Observatories at Simla. The standard barometer, which had hitherto been kept in the verandah of the main block of the office buildings adjoining the clock tower, was removed in January 1927 to the eastern verandah of the Hennessey observatory. The height of the cistern containing the mercury is 6 feet higher in its new place than in the old, the new height being 2,239 feet.

TABLE 1.—*Temperature and pressure of Riefler clock No. 450 and its rate, by transit instruments, 1926-27*

Date	Cell temperature	Clock			Remarks
		Rate during preceding period per day	Pressure	Temperature	
	F	s	m m	C	
1926	°			°	
Dec. 25	80·6	+0·07	641	26·8	
29	79·7	+0·17	640	26·6	
1927					
Jan. 1	78·0	+0·21	610	26·1	
4	79·8	+0·05	639	26·4	
8	79·6	+0·16	640	26·4	
12	78·9	+0·17	641	26·6	
15	79·9	+0·18	641	27·0	
18	79·9	+0·11	641	27·1	
21	80·1	+0·13	642	27·0	
26	79·3	+0·20	641	26·7	
Feb. 3	78·5	+0·16	639	25·8	
5	80·1	+0·12	640	26·9	
10	79·1	+0·19	639	26·1	
18	79·6	+0·18	640	26·7	
24	80·0	+0·20	640	26·8	

NOTE— +ve rate = gaining
−ve rate = losing

TABLE 1.—*Temperature and pressure of Riefler clock No. 450 and its rate, by transit instruments, 1926-27—(contd.)*

Date		Cell temperature	Clock			Remarks
			Rate during preceding period per day	Pressure	Temperature	
1927		F	s	m m	C	
Feb.	28	80°·0	+0·19	640	26°·8	
Mar.	4	80·0	+0·21	640	26·9	
	11	79·9	+0·20	640	26·7	
	15	80·0	+0·24	640	26·8	
	19	80·0	+0·26	640	26·7	
	26	79·8	+0·17	640	26·8	
	31	80·0	+0·04	640	26·8	
April	5	80·0	+0·12	640	26·7	
	11	80·2	+0·09	640	26·7	
	18	80·3	+0·13	641	26·8	
	22	80·0	+0·09	641	26·5	
	29	79·9	+0·13	640	26·6	
May.	4	79·9	+0·15	640	26·5	
	10	80·0	+0·08	640	26·6	
	15	80·1	...	640	26·6	On 15th clock stopped, & was restarted on 17th.
	17	82·0	...	...	...	Pressure was unsteady from 17th to 22nd.
	20	81·4	−1·61	...	27·3	On 23rd pressure was adjusted to 642mm.
	26	83·2	−1·32	643	28·3	
	31	85·0	−1·18	645	29·3	On 2nd June pressure rose to 695 mm.
June	10	84·8	−1·91	699	29·2	Pressure was unsteady from 11th to 17th.
	18	87·0	−1·40	...	30·4	On 18th pressure was adjusted to 602 mm.
	20	87·9	−0·18	602	30·7	
	22	86·8	−0·16	602	30·4	Pressure was unsteady on 23rd and 24th.
	24	86·6	−0·40	...	30·2	On 25th pressure was adjusted to 598 mm.
July	1	86·7	−0·28	598	30·2	
	11	86·7	−0·22	596	30·2	
	15	85·1	−0·24	594	29·3	
	23	84·2	−0·29	593	28·8	
Aug.	6	83·1	−0·24	592	28·3	
	8	81·0	−0·28	588	27·1	
	13	80·8	−0·28	588	27·0	
	18	80·4	−0·03	587	26·8	On 19th pressure was reduced to 561mm.
	26	81·1	+0·10	560	27·2	
Sept.	13	81·0	+0·17	560	27·1	
	16	80·5	+0·21	560	26·8	
	21	80·8	+0·12	560	26·9	
	23	81·2	+0·19	560	27·4	
	29	81·5	+0·17	560	27·4	

NOTE— + ve rate = gaining
− ve rate = losing

TABLE 2.—*Error of Riefler clock No. 450, at 20 hours, Indian Standard Time, by transit instruments and astrolabe, 1926-27*

Date	South Transit	North Transit	Astrolabe	Date	South Transit	North Transit	Astrolabe
1926	m s	m s	m s	1927	m s	m s	m s
Dec. 3	-2 52·00	...	...	April 11	-2 31·35	...	-2 31·40
7	51·23	...	-2 51·24	18	30·43	...	...
10	50·77	...	50·83	22	30·08	...	30·11
15	...	-2 50·22	50·25	29	29·19	...	29·37
18	49·93	...	49·85	May 4	28·43	...	28·39
22	...	49·27	49·39	10	27·97	...	27·83
25	49·05	...	49·05	17	+0 19·57	...	...
29	48·39		48·43	20	14·73	...	+0 14·75
1927							
Jan. 1	...	47·75*	47·87	26	6·81	...	6·64
4	...	47·60	47·58	31	0·90	...	0·67
8	46·95	46·89*	46·82	June 10	-0 18·21	...	...
12	46·28	...	46·25	18	...	-0 29·39†	...
15	...	45·74*	45·89	20	29·75	...	...
18	45·40	...	45·52	22	30·06	30·05†	...
21	...	45·02*	44·95	24	...	30·86†	...
26	44·00	...	44·10	July 1	...	32·80†	...
Feb. 3	42·73	...	42·89	11	...	35·04†	...
5	42·49	...	42·44	15	35·99*	35·99†	...
10	41·53	...	41·50	23	...	38·34†	...
18	40·07	...	40·11	Aug. 6	...	41·68†	...
24	38·88	...	...	8	...	42·23†	...
28	38·13	...	38·26	13	...	43·61†	...
Mar. 4	37·28	...	37·47	18	43·78*†	...	...
11	35·85	...	35·91	26	43·00*†	...	...
15	34·80	..	35·13	Sept. 13	..	39·87†	...
19	33·87	...	34·07	16	39·23§	39·23†	...
26	32·67	...	...	21	38·63†	...	...
31	32·48	...	32·58	23	38·26§	...	...
April 5	31·88	...	31·91	29	37·23†	...	...

NOTE—1. The transit observer was Mr. Mathur, except for items marked* for which the observer was Mr. B. B. Lall, items marked † for which the observer was Mr. H. C. Banerjea, and items marked§ for which the observer was Mr. P. K. Ghosh. The astrolabe observer was Mr. H. C. Banerjea.

2. The clock stopped on 15th May, and was restarted on 17th May 1927.

3. For October and November 1926, *vide* Chapter I, Tables 1 and 2.

TABLE 3.—*Latitude by astrolabe. October and November 1926*
($\Delta\lambda$ = Observed latitude—accepted latitude, in seconds of arc)

Date	Observer	Δλ Series I	Δλ Series II	Mean Δλ	Date	Observer	Δλ Series I	Δλ Series II	Mean Δλ
1926		"	"	"	1926		"	"	"
Sept. 21-22	G.B.	+1·13	...	+1·13	Oct. 26-27	H.W.W.	+1·67	−0·38	+0·65
„ 23-24	G.B.	−0·06	.	−0·06	„ 27-28	H.W.W.	+0·24	−0·23	+0·01
„ 25-26	G.B.	+0·29	...	+0·29	„ 28-29	H.W.W.	+0·19	−0·39	−0·10
Sept. 28-29	G.B.	+0·41	...	+0·41	Oct. 29-30	G.B.	+0·62	−0·68	−0·03
„ 29-30	H.W.W.	+1·06	...	+1·06	„ 30-31	G.B.	+0·48	−0·23	+0·13
„ 30-Oct. 1	G.B.	−0·41	...	−0·41	Nov. 1- 2	G.B.	+0·25	+0·02	+0·14
Oct. 1- 2	H.W.W.	+0·40	+0·14	+0·27	Nov. 2- 3	G.B.	−0·32	−0·32	−0·32
„ 2- 3	H.W.W.	+0·08	−0·18	−0·05	„ 3- 4	G.B.	+0·80	−0·32	+0·24
„ 4- 5	G.B.	+0·32	+0·99	+0·66	„ 4- 5	G.B.	+0·12	−0·36	−0·12
Oct. 5- 6	G.B.	−0·31	−0·20	−0·26	Nov. 5- 6	H.W.W.	+2·81*	...	+2·81*
„ 6- 7	G.B.	+0·33	+0·88	+0·61	„ 6- 7	H.W.W.	+1·43	+0·23	+0·83
„ 7- 8	G.B.	+0·19	+0·96	+0·58	„ 8- 9	H.W.W.	+0·95	−0·47	+0·24
Oct. 8- 9	G.B.	+0·43	+0·21	+0·32	Nov. 9-10	H.W.W.	+1·17	−0·57	+0·30
„ 9-10	G.B.	+0·12	+0·70	+0·41	„ 13-14	H.W.W.	+1·20	...	+1·20
„ 11-12	H.W.W.	−0·30	+0·00	−0·15	„ 15-16	G.B.	−1·01	−0·54	−0·78
Oct. 12-13	H.W.W.	+0·34	−0·09	+0·13	Nov. 16-17	G.B.	+0·33	+0·48	+0·41
„ 13-14	H.W.W.	−0·86	+0·83	−0·01	„ 17-18	G.B.	−0·49	+0·64	+0·08
„ 14-15	H.W.W.	+0·40	−0·11	+0·15	„ 18-19	G.B.	+0·40	+0·78	+0·59
Oct. 15-16	H.W.W.	+0·02	+0·00	+0·01	Nov. 19-20	G.B.	+0·45	+0·26	+0·36
„ 16-17	H.W.W.	+0·72	+0·01	+0·37	„ 20-21	G.B.	+0·40	+0·51	+0·46
„ 18-19	G.B.	−0·89	+1·19	+0·15	„ 22-23	G.H.O.	+0·35	+0·43	+0·39
Oct. 19-20	G.B.	+0·07	+1·51	+0·79	Nov. 23-24	G.H.O.	+0·61	...	+0·61
„ 20-21	G.B.	−0·83	−0·77	−0·80	„ 24-25	G.H.O.	+0·40	+0·04	+0·22
„ 21-22	G.B.	+0·36	−0·22	+0·07	„ 25-26	G.H.O.	+0·60	−0·13	+0·27
Oct. 22-23	G.B.	+0·64	+0·15	+0·40	Nov. 27-28	G.H.O.	+0·50	+0·14	+0·32
„ 23-24	G.B.	+0·55	−0·02	+0·27	„ 29-30	G.B.	−0·05	+0·48	+0·22
„ 25-26	H.W.W.	+0·59	−0·14	+0·23	„ 30-Dec. 1	G.B.	+0·09	+0·96	+0·53

* Cloudy. Incomplete programme.

NOTE—1. The accepted latitude is based on the old value of 30° 18′ 51″·80 for the Haig observatory.

2. Series I was from about $21^h 30^m$ to $24^h 00^m$, Series II from $1^h 30^m$ to $4^h 00^m$. Each series consisted of about 5 stars in each quadrant. The average probable error of each series is about 0″·3.

TABLE 4.—*Latitude by astrolabe 1926-27*

(Δλ = Observed latitude—accepted latitude, in seconds of arc)

Date	Δλ	Date	Δλ	Date	Δλ	Date	Δλ
1926	″	1926	″	1927	″	1927	″
Sept. 21	+1·13	Nov. 13	+0·32	Jan. 1	+0·26	March 15	−0·23
25	+0·12	16	−0·41	4	+0·92	19	−1·15
28	+0·41	19	+0·38	8	−1·75	31	+0·83
Oct. 1	+0·35	23	+0·43	12	+0·38	April 5	−1·21
5	+0·17	26	+0·37	15	−0·79	11	−0·75
8	+0·43	30	+0·17	18	+1·88	22	+0·62
12	+0·18	Dec. 3	+1·14	21	−0·19	29	+1·58
15	+0·03	7	−0·61	26	+0·24	May 4	−1·28
19	+0·18	10	−0·55	Feb. 3	+0·46	10	+0·67
22	+0·11	15	+0·60	5	−0·04	20	−0·20
26	+0·47	18	+1·08	10	+1·40	26	−1·03
29	+0·01	22	−0·27	18	+0·39	31	+0·52
Nov. 2	+0·08	25	−0·16	28	+0·65		
5	+0·46	29	+0·88	March 4	−0·97		
9	+0·66			11	−1·14		

NOTE—1. The accepted latitude is based on the old value of 30° 18′ 51 ·80 for the Haig observatory.

2. The results of October and November 1926, are summarised from Table 3. The remaining entries are each based on one series containing about 4 stars in each quadrant. Observer was Mr. H. C. Banerjea.

TABLE 5.—*Local sidereal time of reception of 1st wireless signal of Bordeaux at 8^h 01^m G.M.T.*

Date	L. S. T. according to transit instrument	L. S. T. according to astrolabe	Date	L. S. T. according to transit instrument	L. S. T. according to astrolabe
1926	h m s	h m s	1927	h m s	h m s
Dec. 1	17 50 53·124	17 50 53·059	Jan. 1	19 53 06·187	19 53 06·301
2	54 49·642	54 49·532	2	19 57 02·840	19 57 02·926
3	17 58 46·217	17 58 46·062	3	20 00 59·480	20 00 59·521
4	18 02 42·715	18 02 42·545	4	04 56·139	04 56·135
5	...	...	5	08 52·694	08 52·657
6	10 35·783	10 35·603	6	12 49·174	12 49·110
7	14 32·439	14 32·254	7	16 45·709	16 45·618
8	18 28·987	18 29·008	8	20 42·277	20 42·159
9	22 25·531	22 25·568	9	24 38·832	24 38·724
10	26 22·152	26 22·205	10	28 35·454	28 35·371
11	30 18·746	30 18·801	11	32 31·940	32 31·882
12	...	...	12	36 28·470	36 28·437
13	38 11·787	38 11·830	13	40 25·015	40 25·031
14	42 08·306	42 08·343	14	44 21·543	44 21·619
15	46 04·849	46 04·880	15	48 18·103	48 18·239
16	50 01·403	50 01·406	16	52 14·681	52 14·825
17	53 57·818	53 57·786	17	20 56 11·278	20 56 11·410
18	18 57 54·577	18 57 54·510	18	21 00 07·872	21 00 07·992
19	19 01 51·172	19 01 51·133	19	04 04·478	04 04·552
20	05 47·719	05 47·730	20	08 01·087	08 01·100
21	09 44·203	09 44·264	21	11 57·628	11 57·580
22	13 40·736	13 40·847	22	...	...
23	17 37·281	17 37·374	23	...	...
24	21 33·906	21 33·957	24	23 47·015	23 47·041
25	25 30·625	25 30·634	25	27 43·727	27 43·787
26	29 27·041	29 27·049	26	31 40·236	31 40·330
27	33 23·587	33 23·605	27	35 36·795	35 36·903
28	37 20·218	37 20·246	28	39 33·447	39 33·562
29	41 16·746	41 16·784	29	43 29·993	43 30·115
30	...	...	30	47 26·516	47 26·645
31	19 49 09·704	19 49 09·792	31	2 51 23·067	21 51 23·203

TABLE 5.—*Local sidereal time of reception of 1st wireless signal of Bordeaux at 8^h 01^m G.M.T.*—(*contd*).

Date	L. S. T. according to transit instrument	L. S. T. according to astrolabe	Date	L. S. T. according to transit instrument	L. S. T. according to astrolabe
1927	h m s	h m s	1927	h m s	h m s
Feb. 1	21 55 19·593	21 55 19·736	Mar. 1	23 45 43·226	23 45 43·366
2	21 59 16·192	21 59 16·342	2	49 39·716	49 39·871
3	...	...	3	53 36·251	53 36·421
4	...	...	4	23 57 32·788	23 57 32·973
5	22 11 06·002	22 11 05·983	5	...	...
6	15 02·602	15 02·458	6	0 05 25·926	0 05 26·084
7	18 59·118	18 59·078	7	09 22·465	09 22·605
8	...	...	8	...	...
9	26 52·256	26 52·224	9	...	...
10	30 48·763	30 48·735	10	...	...
11	34 45·316	34 45·295	11	25 08·613	25 08·681
12	38 41·839	38 41·827	12	29 05·175	29 05·271
13	42 38·400	42 38·397	13	33 01·683	33 01·823
14	46 34·992	46 34·998	14	36 58·274	36 58·458
15	50 31·481	50 31·496	15	40 54·826	40 55·054
16	54 28·013	54 28·037	16	44 51·390	44 51·621
17	22 58 24·590	22 58 24·623	17	48 47·955	48 48·175
18	23 02 21·085	23 02 21·127	18	52 44·537	52 44·746
19	06 17·677	06 17·729	19	0 56 41·090	0 56 41·288
20	10 14·282	10 14·347	20	1 00 37·695	1 00 37·925
21	...	...	21	04 34·309	04 34·587
22	...	...	22	08 30·885	08 31·211
23	22 03·886	22 03·990	23	12 27·374	12 27·748
24	26 00·455	26 00·572	24	16 23·921	16 24·343
25	29 57·004	29 57·129	25	20 20·490	20 20·960
26	33 53·526	33 53·654	26	..	...
27	...	...	27	28 13·549	28 14·021
28	23 41 46·716	23 41 46·850	28	...	...
			29	36 06·736	36 07·038
			30	40 03·302	40 03·519
			31	1 43 59·895	1 44 00·027

TABLE 5.—*Local sidereal time of reception of 1st wireless signal of Bordeaux at 8ʰ 01ᵐ G.M.T.—(concld.)*

Date	L. S. T. according to transit instrument	L. S. T. according to astrolabe	Date	L. S. T. according to transit instrument	L. S. T. according to astrolabe
1927	h m s	h m s	1927	h m s	h m s
April 1	1 47 56·451	1 47 56·544	May 1	...	...
2	51 52·983	51 53·061	2	...	...
3	...	...	3	...	...
4	1 59 46·054	1 59 46·102	4	...	...
5	2 03 42·564	2 03 42·597	5	...	...
6	07 39·087	07 39·119	6	4 05 55·861	4 05 55·794
7	11 35·692	11 35·728	7	09 52·452	09 52·368
8	15 32·234	15 32·274	8	13 49·033	13 48·932
9	...	...	9	17 45·606	17 45·488
10	...	...	10	21 42·134	21 41·999
11	...	...	11	25 38·706	25 38·557
12	31 18·419	31 18·483	12	...	...
13	35 14·949	35 15·026	13	33 31·800	33 31·617
14	39 11·495	39 11·585	14	37 28·346	4 37 28·146
15	..	...	15	...	...
16	47 04·614	47 04·730	16	...	...
17	51 01·119	51 01·248	17	4 49 17·953	...
18	...	...	18	...	...
19	2 58 54·182	2 58 54·308	19	...	...
20	3 02 50·743	3 02 50·839	20	5 01 07·721	...
21	06 47·291	06 47·357	21	...	...
22	10 43·900	10 43·936	22	...	...
23	14 40·472	14 40·515	23	12 57·004	5 12 57·073
24	...	...	24	...	...
25	22 33·635	22 33·720	25	20 50·191	20 50·324
26	26 30·205	26 30·311	26	24 46·810	24 46·975
27	...	...	27	5 28 43·374	5 28 43·530
28	3 34 23·283	3 34 23·431	28	...	.
29	..	...	29	...	...
30	...	...	30	...	...
			31	...	...

NOTE—1. These times are based on the star observations of the nights closest preceding and following the reception of each signal. Individual nights' results have not been smoothed to give a more uniform clock rate.

2. These times are true sidereal times, the short period terms of nutation having been taken account of.
3. No account has been taken of the rate of propagation of radio signals.
4. For October and November 1926, *vide* Chapter I, Tables 3 and 4.
5. From 28th May 1927, reception of wireless signals was discontinued.
6. Wireless reception by Messrs R. B. Mathur and H. C. Banerjea.
7. Throughout this period the Astrolabe Observer was Mr. H. C. Banerjea.

TABLE 6.—*Earthquakes recorded at Dehra Dūn during 1926-27*

Date	Time of beginning. Indian standard time				Duration	Distance of epicentre		Intensity	Remarks
	Dehra Dūn		Simla*			Dehra Dūn	Simla*		
	h	*m*	*h*	*m*	*m*	*miles*	*miles*		
16-2-27	7	16	7	16	148	4,400	4,800	slight	
28-2-27	20	59	...		30	2,000	...	slight	
7-3-27	15	07	15	07	90	3,400	3,500	great	
16-3-27	3	23	3	23	9	1,300	1,300	slight	
16-3-27	22	31	22	31	10	700	700	slight	
18-4-27	20	35	20	34	uncertain	300	300	slight	
19-4-27	23	08	23	08	uncertain	2,100	2,900	slight	
28-4-27	1	05	...		26	4,000	...	slight	
9-5-27	16	07	16	06	19	2,000	1,300	slight	
21-5-27	13	39	13	38	5	500	500	slight	
23-5-27	4	08	4	08	147	2,000	1,800	severe	Kansu, China
2-6-27	22	11	22	10	18	400	600	moderate	
3-6-27	12	53	12	53	68	3,500	4,400	moderate	
8-7-27	1	42	1	40	9	700	800	slight	
11-7-27	18	46	18	47	17	2,000	1,900	slight	Palestine
22-7-27	9	29	9	30	29	1,500	1,400	moderate	
24-7-27	1	52	1	53	22	1,500	1,500	slight	
24-7-27	4	18	4	15	12	1,600	1,500	slight	
29-7-27	5	39	5	38	20	900	1,300	slight	
6-8-27	2	52	2	52	42	4,000	3,700	moderate	
10-8-27	17	16	17	16	41	2,000	4,200	slight	
12-8-27	15	58	15	56	5	300	600	slight	
12-8-27	21	55	...		2	...	...	slight	
19-8-27	1	16	1	07	43	2,500	3,700	slight	
24-8-27	23	46	23	47	25	3,000	2,800	slight	Tokyo
12-9-27	3	53	3	53	57	3,000	2,400	slight	Black sea.

* From Daily Weather Report.

N B.—The seismograph was not in working order from 1st October 1926 to 9th January 1927.

TABLE 7.—*Graduation of new levelling staves*
(Actual length—Reputed length).

Reputed length	No. 013A	No. 013B	No. 011B	No. 011A	No. 012A	No. 012B	No. 014B	No. 014A	No. 08B	No. 08A	No. 010A	No. 09B	No. 09A	No. 010B
feet	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*
1	+0·0004	+0·0001	+0·0002	+0·0000	−0·0001	+0·0005	+0·0004	+0·0003	+0·0004	+0·0001	+0·0002	+0·0001	+0·0004	−0·0004
2	+0·0016	+0·0012	+0·0009	+0·0008	+0·0008	+0·0011	+0·0006	+0·0009	+0·0017	+0·0005	+0·0010	+0·0009	+0·0012	+0·0006
3	+0·0017	+0·0013	+0·0012	+0·0009	+0·0008	+0·0015	+0·0008	+0·0005	+0·0014	+0·0007	+0·0009	+0·0008	+0·0011	+0·0005
4	+0·0024	+0·0020	+0·0016	+0·0016	+0·0009	+0·0017	+0·0011	+0·0011	+0·0022	+0·0016	+0·0020	+0·0015	+0·0020	+0·0008
5	+0·0026	+0·0022	+0·0014	+0·0016	+0·0009	+0·0016	+0·0012	+0·0008	+0·0020	+0·0018	+0·0021	+0·0020	+0·0022	+0·0008
6	+0·0025	+0·0021	+0·0022	+0·0020	+0·0014	+0·0015	+0·0011	+0·0009	+0·0022	+0·0021	+0·0025	+0·0017	+0·0024	+0·0013
7	+0·0031	+0·0021	+0·0027	+0·0024	+0·0015	+0·0018	+0·0008	+0·0013	+0·0028	+0·0021	+0·0026	+0·0017	+0·0025	+0·0015
8	+0·0030	+0·0026	+0·0032	+0·0028	+0·0022	+0·0023	+0·0013	+0·0014	+0·0030	+0·0028	+0·0031	+0·0027	+0·0029	+0·0022
9	+0·0032	+0·0028	+0·0037	+0·0027	+0·0028	+0·0025	+0·0014	+0·0011	+0·0031	+0·0027	+0·0033	+0·0030	+0·0033	+0·0025
10	+0·0039	+0·0033	+0·0041	+0·0030	+0·0033	+0·0028	+0·0019	+0·0014	+0·0033	+0·0032	+0·0038	+0·0035	+0·0036	+0·0030

TABLE 8.—*Graduation of new levelling staves*

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

Reputed length	No. 013A	No. 013B	No. 011B	No. 011A	No. 012A	No. 012B	No. 014B	No. 014A	No. 08B	No. 08A	No. 010A	No. 09B	No. 09A	No. 010B
feet	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*
1	−0·0000	+0·0000	−0·0002	−0·0003	−0·0004	+0·0002	+0·0002	+0·0002	+0·0001	−0·0002	−0·0002	−0·0002	+0·0000	−0·0007
2	+0·0008	+0·0006	+0·0001	+0·0002	+0·0001	+0·0005	+0·0003	+0·0006	+0·0011	−0·0001	+0·0002	+0·0002	+0·0004	−0·0001
3	+0·0005	+0·0003	−0·0000	+0·0000	−0·0002	+0·0006	+0·0003	+0·0001	+0·0004	−0·0003	−0·0003	−0·0003	+0·0000	−0·0004
4	+0·0008	+0·0007	−0·0001	+0·0004	−0·0004	+0·0005	+0·0003	+0·0005	+0·0009	+0·0003	+0·0005	+0·0000	+0·0006	−0·0004
5	+0·0006	+0·0006	−0·0006	+0·0001	−0·0007	+0·0002	+0·0003	+0·0001	+0·0004	+0·0002	+0·0002	+0·0003	+0·0004	−0·0007
6	+0·0001	+0·0001	−0·0003	+0·0002	−0·0006	−0·0002	−0·0000	+0·0000	+0·0003	+0·0002	+0·0002	−0·0005	+0·0003	−0·0005
7	+0·0004	−0·0002	−0·0002	+0·0003	−0·0008	−0·0002	−0·0005	+0·0003	+0·0005	−0·0002	−0·0000	−0·0008	+0·0000	−0·0006
8	−0·0002	+0·0000	−0·0001	+0·0004	−0·0004	−0·0000	−0·0002	+0·0002	+0·0004	+0·0002	+0·0001	−0·0001	+0·0001	−0·0002
9	−0·0004	−0·0001	+0·0000	−0·0000	−0·0002	−0·0001	−0·0003	−0·0002	+0·0002	−0·0003	−0·0001	−0·0002	+0·0001	−0·0001
10	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000

TABLE 9.—*Graduation of old levelling staves*
(Actual length—Reputed length)

Reputed length	No. E_1	No. O_1	No. 16A	No. 20A
feet	*feet*	*feet*	*feet*	*feet*
1	−0·0001	−0·0000	+0·0000	+0·0001
2	+0·0002	−0·0003	+0·0002	+0·0002
3	+0·0002	+0·0001	−0·0002	+0·0003
4	−0·0002	+0·0003	−0·0005	+0·0003
5	+0·0002	+0·0001	−0·0007	−0·0001
6	+0·0004	+0·0001	−0·0006	−0·0001
7	+0·0008	−0·0003	−0·0010	+0·0001
8	+0·0008	+0·0002	−0·0014	+0·0003
9	+0·0012	+0·0002	−0·0018	+0·0006
10	+0·0014	+0·0006	−0·0024	+0·0007

TABLE 10.—*Graduation of old levelling staves*

$$\left(\text{Actual length—Reputed length} \times \frac{\text{Actual total length}}{10 \text{ feet}}\right)$$

Reputed length	No. E_1	No. O_1	No. 16A	No. 20A
feet	*feet*	*feet*	*feet*	*feet*
1	−0·0002	−0·0001	+0·0003	+0·0001
2	−0·0001	−0·0004	+0·0007	0·0000
3	−0·0002	0·0000	+0·0006	0·0000
4	−0·0007	+0·0001	+0·0005	0·0000
5	−0·0005	−0·0002	+0·0005	−0·0004
6	−0·0004	−0·0003	+0·0009	−0·0005
7	−0·0001	−0·0007	+0·0006	−0·0004
8	−0·0003	−0·0002	+0·0006	−0·0003
9	−0·0001	−0·0003	+0·0004	0·0000
10	0·0000	0·0000	0·0000	0·0000

TABLE 11.—*Mean values of the constants of Magnet No. 17 at Dehra Dūn in 1926*

Months	Declination constants: Mean magnetic collimation	H. F. Constants: Distribution factors $P_{1\cdot2}$	$P_{2\cdot3}$	$\log\left(1+\frac{P}{r^2}+\frac{Q}{r^4}\right)^{-1}$	Mean values of m: Monthly means	Accepted m
	′ ″	cm²	cm²		C. G. S.	C. G. S.
January ...	− 6 23	5·80	6·74	$\bar{1}$·99404 accepted throughout	806·66	806·18 throughout
February ...	− 6 26	5·93	6·78		806·64	
March ...	− 6 18	5·96	6·73		806·60	
April ...	− 6 20	5·82	6·90		806·62	
May ...	− 6 21	5·77	6·96		806·54	
June ...	− 6 20	5·88	6·87		806·53	
July ...	− 6 20	5·68	6·85		806·39	
August ...	− 6 23	5·60	6·88		806·49	
September	− 6 25	5·76	7·01		806·58	
October ...	− 6 22	5·66	6·88		806·61	
November ...	− 6 24	5·62	6·86		806·67	
December ...	− 6 26	5·64	6·93		806·81	

TABLE 12.—*Base-line values of magnetographs at Dehra Dūn in 1926*

Months	Declination: Mean value of base-line	Horizontal force: Mean value of base-line
	° ′	C.G.S.
January ...	0 45·4	·32628
February ...	0 45·6	·32628
March ...	0 45·9	·32630
April ...	0 45·8	·32624
May ...	0 45·9	·32636
June ...	0 45·9	·32641
July ...	0 45·9	·32645
August ...	0 45·9	·32647
September ...	0 45·8	·32640
October ...	0 46·0	·32637
November ...	0 46·0	·32628
December ...	0 46·1	·32625

TABLE 13.—*Monthly mean values of the magnetic elements and annual changes at Dehra Dūn in 1925-26*

Months	Horizontal force ·32000 C.G.S. +			Declination E. 1° +			Dip N. 45° +			Vertical force ·33000 C.G.S. +		
	1925	1926	Annual change	1925	1926	Annual change	1925	1926	Annual change	1925	1926	Annual change
	γ*	γ*	γ*	′	′		′	′	′	γ*	γ*	γ*
January ...	945	925	−20	32·7	28·2	−4·5	18·8	24·4	+5·6	308	397	+89
February ...	945	918	−27	32·4	28·1	−4·3	19·2	24·7	+5·5	315	395	+80
March	951	921	−30	32·1	28·1	−4·0	19·3	25·6	+6·3	322	414	+92
April ...	959	927	−32	31·7	27·4	−4·3	20·1	25·3	+5·2	346	415	+69
May ...	961	941	−20	30·8	26·9	−3·9	20·5	25·7	+5·2	357	437	+80
June ...	953	941	−12	30·6	26·3	−4·3	20·7	26·2	+5·5	351	446	+95
July ...	950	948	−02	30·0	25·9	−4·1	21·3	26·0	+4·7	361	450	+89
August .	949	949	00	29·6	25·3	−4·3	21·8	26·2	+4·4	370	455	+85
September ..	939	941	+02	29·4	25·0	−4·4	22·7	27·0	+4·3	377	462	+85
October ...	941	924	−17	29·3	25·0	−4·3	21·9	27·6	+5·7	364	457	+93
November ...	940	931	−09	29·1	24·5	−4·6	22·9	27·0	+4·1	382	453	+71
December ...	940	932	−08	28·7	24·4	−4·3	23·0	27·0	+4·0	384	452	+68
Means .	948	933	−15	30·5	26·3	−4·2	21·0	26·1	+5·1	353	436	+83

* γ = ·00001 C.G.S.

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

C = Calm. S = Slight. M = Moderate. G = Great. VG = Very great. — = Trace lost. * = Trace partly lost.

TABLE 15 —*Declination at Dehra Dūn in 1926,* (determined from 5 selected quiet days in each month)

Months	Mean hourly value †	Hourly deviation from the mean																							
		0	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	0
	E 1° + ′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	28·2	+0·3	+0·5	+0·4	−0·1	−0·1	−0·1	−0·5	−0·3	+0·3	**+1·6**	+1·3	+0·2	−0·9	**−1·1**	−0·8	−0·5	−0·3	−0·2	−0·3	0	−0·1	−0·1	0	0	0
Feb.	28·1	−0·1	−0·1	−0·2	−0·3	−0·3	−0·4	−0·5	−0·2	+1·0	+2·5	**+2·8**	+1·6	0	−1·0	**−1·6**	−1·4	−0·7	0·2	−0·4	−0·1	+0·1	−0·2	0	−0·2	0
Mar.	28·1	+0·4	+0·2	+0·2	+0·1	0	−0·3	−0·2	+0·6	+2·0	**+3·0**	+2·4	+0·8	−1·0	−2·3	**−2·4**	−1·8	−0·7	−0·3	−0·4	−0·3	0	+0·1	−0·4	−0·5	−0·3
Oct.	25·0	+0·5	+0·5	+0·4	+0·4	+0·4	+0·3	+0·4	+1·5	**+2·0**	+1·4	+0·3	−1·1	**−2·4**	−2·3	−1·4	−0·5	+0·3	0	−0·3	−0·2	+0·1	+0·2	+0·2	+0·3	+0·2
Nov.	24·5	+0·1	+0·2	+0·1	0	−0·2	−0·3	−0·2	+0·4	+1·3	**+1·6**	+1·1	−0·1	**−1·2**	−1·0	−0·7	−0·4	−0·2	−0·1	−0·2	−0·1	−0·2	−0·2	−0·1	+0·2	+0·3
Dec.	24·4	+0·2	+0·2	+0·1	+0·2	−0·1	−0·5	−0·4	**−0·6**	−0·2	+0·6	**+1·0**	+0·9	+0·3	−0·2	−0·4	−0·2	0	−0·3	−0·2	−0·1	−0·1	−0·2	−0·1	−0·1	−0·1
Winter Means*	23·4	+0·2	+0·2	+0·2	0	−0·1	−0·2	−0·2	+0·2	+1·1	**+1·8**	+1·5	+0·4	−0·9	**−1·3**	−1·2	−0·8	−0·3	−0·2	−0·3	−0·1	0	−0·1	−0·1	−0·1	0
April	27·4	−0·1	+0·2	+0·1	+0·1	−0·2	−0·1	+0·5	+2·2	+3·6	**+3·9**	+2·4	−0·1	−2·2	**−3·4**	−3·3	−2·3	−1·0	−0·3	−0·3	−0·7	−0·5	+0·1	+0·2	+0·2	+0·1
May	26·9	0	+0·1	+0·1	+0·2	+0·2	+0·5	+2·1	+3·5	**+3·6**	+2·8	+1·0	−1·3	−2·9	**−3·3**	−3·0	−3·2	−1·2	−0·4	0	−0·4	−0·5	−0·2	0	+0·2	+0·3
June	26·3	+0·6	+0·8	+0·7	+0·8	+0·8	+1·3	+2·7	+3·8	**+3·9**	+3·0	+1·1	−0·9	−2·5	−3·6	**−3·7**	−3·2	−2·3	−1·2	−0·2	−0·2	−0·5	−0·4	0	+0·1	+0·4
July	25·9	+0·3	+0·5	+0·4	+0·4	+0·6	+1·0	+2·4	+4·0	**+4·1**	+3·3	+1·5	−1·1	−2·4	−3·7	**−4·0**	−3·3	−2·2	−0·9	0	−0·3	−0·6	−0·4	−0·2	−0·1	+0·1
Aug.	25·3	+0·1	+0·5	+0·4	+0·7	+0·9	+1·1	+2·1	+3·1	**+3·3**	+2·7	+1·3	−0·4	−1·7	−2·7	**−2·8**	−2·4	−1·8	−1·1	−0·3	−0·4	−0·5	−0·4	−0·3	−0·1	+0·2
Sept.	25·0	+0·2	+0·3	+0·4	+0·2	+0·3	+0·5	+1·1	+2·5	**+3·1**	+2·4	+0·7	−1·5	−2·8	**−3·1**	−2·4	−1·4	−0·4	+0·4	0	−0·4	−0·4	−0·3	−0·2	−0·1	+0·1
Summer Means*	26·1	+0·2	+0·4	+0·4	+0·4	+0·5	+0·8	+1·9	+3·2	**+3·6**	+3·1	+1·4	−0·8	−2·4	**−3·3**	−3·2	−2·4	−1·4	−0·5	−0·1	−0·4	−0·5	−0·2	0	+0·1	+0·2

* Derived from the actual difference between the mean value for any hour and the general mean for all hours of the 5 selected quiet days of the six months.

† Obtained from the mean of all hours for the 5 selected quiet days in each month.

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 16.—*Horizontal force at Dehra Dūn in 1926*, (determined from 5 selected quiet days in each month)

Months	Mean hourly value †	Hourly deviation from the mean 0	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	0
	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.	32925	− 4	− **5**	− 4	+ 1	− 2	− 3	− 1	+ 1	+ 4	+ 5	+ 3	0	+ 3	+ **7**	+ 4	− 1	0	− 1	0	+ 3	− 2	− 2	− 1	0	+ 2
Feb.	918	+ 1	0	− 2	− 2	− 3	− 2	0	+ 2	+ 5	+ 8	+ 9	+ 8	+ **12**	+ 10	+ 7	+ 4	− 2	− 5	− 6	− 12	− **13**	− 8	0	+ 1	+ 1
Mar.	921	− 10	− **11**	− 8	− **7**	− 8	− 5	− 5	− 2	+ 1	+ 5	+ **15**	+ 13	+ 11	+ 10	+ 8	+ 4	− 1	− 1	− 2	− 2	− 1	− 1	− 1	+ 3	+ 2
Oct.	924	− 6	− 4	− 2	0	0	+ 2	+ 1	− 1	− 2	− 3	+ 3	+ 7	+ 11	+ **12**	+ 11	+ 6	− 1	− 5	− 5	− 5	− **7**	− **8**	− 6	− 3	+ 2
Nov.	931	− 4	− 5	− **6**	− 5	− 4	− 3	− 2	+ 1	+ 4	+ 5	+ 7	+ 10	+ **13**	+ 8	+ 3	− 2	− 1	− 3	− 2	− 2	− 3	− 4	− 1	− 2	0
Dec.	932	− **10**	− 8	− 4	− 8	− 7	− 5	− 3	+ 3	+ 8	+ 11	+ 15	+ **15**	+ 9	+ 1	− 1	− 5	− **6**	− 5	− 3	− 1	− 1	− 1	− 2	− 1	0
Winter Means*	925	− **5**	− 5	− 4	− 3	− 4	− 2	− 1	+ 1	+ 4	+ 5	+ 9	+ 9	+ **10**	+ 8	+ 6	+ 1	− 2	− 3	− 3	− 3	− **4**	− 4	− 2	0	+ 1
April	32927	− 4	− [illegible]	− 8	− 6	− 4	− 3	0	− 1	− 1	+ 2	+ 7	+ 8	+ 17	+ **18**	+ 16	+ 12	+ 5	− 2	− 6	− **5**	− 7	− **9**	− 8	− 3	− 2
May	941	− 7	− 9	− 8	− 8	− 8	− 7	− 6	− 11	− **13**	− 11	− 1	+ 13	+ 21	+ **24**	+ 22	+ 19	+ 11	+ 1	− 5	− **6**	− 3	− 4	− 6	− 5	− 6
June	941	− 10	− 9	− **10**	− 10	− 7	− 5	− 5	− 7	− 10	− 9	− 3	+ 5	+ 12	+ **19**	+ 18	+ 16	+ 10	+ 5	0	− 2	− 1	− 1	+ 1	+ 1	+ 2
July	948	− 7	− 6	− 5	− 5	− 3	− 2	+ 3	− 3	− 5	− **7**	− 7	+ 2	+ 11	+ **16**	+ 15	+ 13	+ 7	− 1	− 3	− 3	− 3	− 2	− 4	0	+ 3
Aug.	949	− 4	− 6	− 4	− 3	− 4	− 4	− 5	− **3**	− **7**	− **8**	− 6	+ 3	+ 10	+ **11**	+ 10	+ 10	+ 10	+ 3	+ 1	+ 1	+ 2	+ 2	+ 1	+ 3	+ 3
Sept.	941	− 4	− 4	− 4	0	− 1	− 2	− 3	− **7**	− 11	− **12**	− 9	− **3**	+ 7	+ 11	+ **16**	+ 14	+ 9	+ 2	− 1	− 2	0	+ 1	+ 3	+ 2	0
Summer Means*	941	− 6	− 6	− 6	− 5	− 4	− 4	− 2	− 5	− **8**	− 7	− 3	+ 5	+ 13	+ **17**	+ 16	+ 14	+ 9	+ 2	− 2	− 3	− 2	− 2	− 2	0	0

* Derived from the actual difference between the mean value for any hour and the general mean for all hours of the 5 selected quiet days of the six months.
† Obtained from the mean of all hours for the 5 selected quiet days in each month.

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 17.—*Vertical force at Dehra Dūn in 1926,* (determined from 5 selected quiet days in each month)

Months	Mean hourly value †	Hourly deviation from the mean 0	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	0
	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.	33397	+ 5	+ 4	+ 4	+ 5	+ 2	+ 2	+ 3	+ 2	+ 4	+ 1	− 2	− 9	− 9	− 9	− 6	− 5	− 3	− 1	− 1	− 1	− 1	0	+ 1	+ 1	+ 2
Feb.	395	+ 3	+ 2	+ 2	+ 2	+ 2	+ 3	+ 3	+ 5	+ 6	+ 5	+ 1	− 6	− 9	−12	− 9	− 5	− 2	0	+ 2	+ 2	+ 3	+ 4	+ 5	+ 5	+ 5
Mar.	414	+ 2	+ 3	+ 4	+ 4	+ 3	+ 4	+ 4	+ 6	+ 7	+ 1	− 4	−13	−15	−14	− 6	− 2	+ 2	+ 3	+ 2	+ 2	+ 4	+ 4	+ 5	+ 6	+ 6
Oct.	457	+ 2	+ 2	+ 2	+ 3	+ 2	+ 2	+ 2	+ 4	+ 3	− 2	− 6	− 5	− 7	− 5	− 2	+ 2	+ 2	+ 1	0	+ 2	+ 1	+ 1	+ 1	+ 2	+ 2
Nov.	452	+ 2	+ 2	+ 2	+ 2	+ 2	+ 2	+ 2	+ 3	+ 3	− 3	−10	− 7	− 7	− 4	− 3	0	+ 2	+ 2	+ 3	+ 2	+ 2	+ 2	+ 3	+ 2	+ 2
Dec.	452	− 8	− 6	− 6	− 7	− 7	− 7	− 7	− 7	− 5	− 3	− 4	+ 4	0	+ 1	+ 2	+ 4	+ 7	+ 6	+ 9	+ 8	+ 8	+ 8	+ 8	+ 8	+ 8
Winter Means *	428	+ 1	+ 1	+ 1	+ 2	+ 1	+ 1	+ 1	+ 2	+ 3	0	− 4	− 6	− 8	− 7	− 4	− 1	+ 1	+ 2	+ 3	+ 3	+ 3	+ 3	+ 4	+ 4	+ 4
April	415	+ 1	0	0	+ 2	+ 3	+ 4	+ 7	+10	+ 7	+ 3	− 5	−17	−16	−12	− 5	− 2	+ 1	+ 3	+ 1	+ 2	+ 2	+ 3	+ 4	+ 5	+ 6
May	437	+ 3	+ 4	+ 4	+ 4	+ 4	+ 5	+ 8	+ 4	0	− 8	−16	−21	−17	− 9	− 3	+ 1	+ 5	+ 5	+ 4	+ 5	+ 5	+ 7	+ 8	+ 8	+ 8
June	446	+ 4	+ 4	+ 5	+ 5	+ 6	+ 8	+11	+ 7	+ 2	− 8	−13	−18	−19	−17	−12	− 4	+ 2	+ 5	+ 4	+ 3	+ 4	+ 5	+ 6	+ 6	+ 6
July	450	+ 6	+ 6	+ 6	+ 7	+ 7	+ 8	+11	+10	+ 8	+ 1	− 7	−20	−21	−16	−12	− 6	− 2	+ 1	+ 3	+ 2	+ 3	+ 4	+ 5	+ 7	+ 9
Aug.	455	+ 3	+ 4	+ 4	+ 4	+ 3	+ 5	+ 5	+ 3	0	− 3	− 8	− 6	− 8	− 8	− 8	− 4	− 2	+ 1	+ 2	+ 2	+ 3	+ 3	+ 4	+ 5	+ 4
Sept.	462	+ 1	+ 2	+ 2	+ 3	+ 2	+ 3	+ 4	+ 6	+ 5	0	− 4	− 7	− 9	−10	− 5	− 1	+ 2	+ 2	0	0	+ 2	+ 3	+ 4	+ 4	+ 4
Summer Means *	444	+ 3	+ 4	+ 4	+ 4	+ 4	+ 5	+ 8	+ 7	+ 4	− 2	− 9	−15	−15	−12	− 7	− 2	+ 1	+ 3	+ 3	+ 3	+ 3	+ 4	+ 5	+ 6	+ 6

* Derived from the actual difference between the mean value for any hour and the general mean for all hours of the 5 selected quiet days of the six months.

† Obtained from the mean of all hours for the 5 selected quiet days in each month.

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 18.—*Dip at Dehra Dūn in 1926,* (determined from 5 selected quiet days in each month)

Months	Mean hourly value †	Hourly deviation from the mean																								
		0	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	0
	N4 5°+ ′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	24·4	**+0·5**	+0·5	+0·5	+0·3	+0·3	+0·3	+0·3	+0·1	+0·1	−0·1	−0·2	−0·4	−0·5	**−0·8**	−0·4	−0·1	**−0·1**	+0·1	0	−0·1	+0·1	+0·2	+0·2	+0·1	+0·1
Feb.	24·7	+0·1	+0·1	+0·2	+0·2	+0·3	+0·3	+0·2	+0·2	+0·1	−0·1	−0·4	**−0·7**	−1·1	**−1·1**	−0·8	−0·4	0	+0·3	+0·5	+0·8	**+0·9**	+0·7	+0·3	+0·2	+0·2
Mar.	23·6	+0·6	**+0·7**	+0·6	+0·5	+0·5	+0·4	+0·4	+0·4	+0·3	−0·3	−1·0	**−1·4**	−1·4	−1·3	−0·8	−0·4	+0·1	+0·2	+0·2	+0·2	+0·2	+0·2	+0·3	+0·1	+0·2
Oct.	27·6	+0·4	+0·3	+0·2	+0·2	+0·1	0	+0·1	+0·3	+0·3	+0·1	−0·5	−0·6	**−0·9**	−0·9	−0·7	−0·2	+0·2	+0·3	+0·3	+0·4	+0·4	**+0·5**	+0·4	+0·3	0
Nov.	27·0	+0·4	+0·4	**+0·5**	+0·4	+0·4	+0·3	+0·2	+0·1	0	−0·4	−0·8	−0·8	**−1·0**	−0·6	−0·3	+0·1	+0·2	+0·3	+0·3	+0·2	+0·3	+0·4	+0·2	+0·2	+0·1
Dec.	27·0	0	0	−0·2	0	−0·1	−0·2	−0·3	−0·6	−0·7	−0·8	**−1·1**	−0·6	−0·5	−0·1	+0·1	+0·4	**+0·6**	+0·5	+0·6	+0·4	+0·4	+0·4	+0·5	+0·4	+0·3
Winter Means*	26·1	+0·3	+0·3	+0·3	+0·2	+0·2	+0·1	+0·1	0	0	−0·3	−0·7	−0·8	**−0·9**	−0·8	−0·5	−0·1	+0·1	+0·2	+0·3	+0·3	+0·3	**+0·4**	+0·3	+0·2	+0·1
April	25·3	+0·3	+0·3	+0·4	+0·4	+0·4	+0·4	+0·4	+0·6	+0·4	0	−0·6	−1·3	**−1·7**	−1·6	−1·1	−0·7	−0·2	+0·3	+0·4	+0·4	+0·5	**+0·6**	+0·6	+0·4	+0·4
May	25·7	+0·5	+0·7	+0·6	+0·6	+0·6	+0·6	+0·7	**+0·8**	+0·7	+0·2	−0·6	−1·8	**−2·0**	−1·7	−1·3	−0·9	−0·3	+0·2	+0·5	+0·6	+0·4	+0·6	+0·7	+0·7	+0·7
June	26·2	+0·7	+0·6	+0·7	+0·7	+0·6	+0·6	**+0·8**	+0·7	+0·6	0	−0·6	−1·2	−1·6	**−1·9**	−1·6	−1·1	−0·5	0	+0·2	+0·2	+0·2	+0·3	+0·2	+0·2	+0·2
July	26·0	**+0·7**	+0·6	+0·6	+0·6	+0·5	+0·5	+0·4	+0·7	+0·7	+0·4	0	−1·1	**−1·7**	−1·7	−1·4	−1·0	−0·5	+0·1	+0·3	+0·3	+0·3	+0·3	+0·5	+0·4	+0·3
Aug.	26·2	+0·4	**+0·5**	+0·4	+0·4	+0·4	+0·4	+0·5	+0·3	+0·4	+0·3	−0·1	−0·5	−0·9	**−1·0**	−0·9	−0·7	−0·6	−0·1	+0·1	+0·1	+0·1	+0·1	+0·2	+0·1	+0·1
Sept.	27·0	+0·2	+0·3	+0·3	+0·1	+0·1	+0·2	+0·3	+0·7	**+0·8**	+0·6	+0·2	−0·2	−0·6	**−1·3**	−1·1	−0·8	−0·4	0	0	+0·1	+0·1	+0·1	0	+0·1	+0·2
Summer Means*	26·1	+0·4	+0·5	+0·5	+0·4	+0·4	+0·4	+0·5	**+0·6**	+0·6	+0·2	−0·3	−1·0	−1·5	**−1·6**	−1·3	−0·9	−0·4	+0·1	+0·2	+0·3	+0·2	+0·3	+0·3	+0·3	+0·3

* Derived from the actual difference between the mean value for any hour and the general mean for all hours of the 5 selected quiet days of the six months.
† Obtained from the mean of all hours for the 5 selected quiet days in each month.

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 IV

TIDES

BY CAPTAIN G. BOMFORD, R.E.

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 and Basrah. These operations were conducted under the direction of this department, the immediate control of each observatory being entrusted to the local officers of the port concerned. In addition to the above, the actual times and heights of high- and low-water were observed on tide-poles during daylight only, under the supervision of the local port officials, at Bhāvnagar, Chittagong and Akyab. These observations were compared against the predicted values, with a view to testing whether the predictions, which were based on tidal observations taken many years ago, still maintained a sufficient degree of accuracy. Table 1 is a complete list of stations at which tidal registrations have been carried out since 1874, the year in which tidal operations were commenced in India. The stations at which automatic tide-gauges are still working are shown in italics. Minor stations were closed after a few years on the completion of the requisite registrations.

TABLE 1.—*List of tidal stations*

Serial No.	Station	Automatic or personal observations	Date of commencement of observations	Date of closing of observations	Number of years of observations	Remarks
1	Suez ...	automatic	1897	1903	7	
2	Perim ...	,,	1898	1902	5	
3	*Aden* ...	,,	1879	still working	48	
4	Maskat ...	,,	1893	1898	5	
5	Bushire ...	,,	1892	1901	8	
6	*Karāchi* ...	,,	{ 1868 1881	1880 still working	*13 } 59 46 }	* Small tide-gauge working

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 ...	automatic	1874	1875	1	Tide-tables not published
8	Navānar ...	,,	1874	1875	1	
9	Okha Point ...	,,	1874 re-started 1904	1875 1906	1 } 2 1	Year 1904-05 is excluded
10	Porbandar ...	personal	1893	1894	2	
10A	Porbandar ...	automatic	1898	1902	2	Years 1898, 1899 & 1902 are excluded
11	Port Albert Victor (Kāthiāwār)	personal	1881	1882	1	
11A	Port Albert Victor (Kāthiāwār)	automatic	1900	1903	4	
12	Bhāvnagar ...	,,	1889	1894	5	
13	*Bombay (Apollo Bandar)*	,,	1878	still working	49	
14	Bombay (Prince's Dock)	,,	1888	1924	37	Dismantled in May 1924
15	Marmagao (Goa) ...	,,	1884	1889	5	
16	Kārwār ...	,,	1878	1883	5	
17	Beypore ...	,,	1878	1884	6	
18	Cochin ...	,,	1886	1892	6	
19	Tuticorin ...	,,	1888	1893	5	
20	Minicoy ...	,,	1891	1896	5	
21	Galle ...	,,	1884	1890	6	
22	Colombo ...	,,	1884	1890	6	
23	Trincomalee ...	,,	1890	1896	6	
24	Pāmban Pass ...	,,	1878	1882	4	
25	Negapatam ...	,,	1881	1888	5	Years 1883 to 1885 are excluded
26	*Madras* ...	,,	1880 re-started 1895	1890 still working	10 } 42 32	
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	46	
33	Chittagong ...	,,	1886	1891	5	
34	Akyab ...	,,	1887	1892	5	

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 } 6 4	Registrations re-started at new observatory in November 1923
37	Elephant Point ...	"	1880 re-started 1884	1881 1888	1 } 5 4	Year 1880-81 is excluded
37A	*Pilakat or Deserter's Creek*	"	re-started 1927	still working	...	Observations resumed at new observatory in March 1927
38	*Rangoon* ...	"	1880	still working	47	
39	Amherst ...	"	1880	1886	6	
40	Moulmein ...	"	1880 re-started 1909	1886 1924	6 } 22 16	Tide-gauge dismantled in November 1924
41	Mergui ...	"	1889	1894	5	
42	Port Blair ...	"	1880	1925	45	Tide-gauge dismantled in April 1925
43	Basrah ...	personal	1916	1922	7 } 12	Observations taken on a tide-pole until 31-3-22: after which date an automatic tide recorder was installed
43A	*Basrah* ...	automatic	1922	still working	5	

2. Inspections.—The tidal observatories at Bassein and Rangoon were inspected by Mr. D. H. Luxa, the tidal assistant, between February and March 1927. The Port trust surveyor, Bombay, carried out an inspection of the tidal observatory at Apollo Bandar between the 11th and 15th May 1926, and again between the 20th and 22nd April 1927. The Kidderpore tidal observatory was inspected by the Assistant Chart Superintendent Port Commissioners', Calcutta, in October 1926 and again in January 1927.

No reports have been received from the port authorities at Aden, Karāchi, Madras, or Basrah 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 as follows:—

Aden:—In October 1924 by Lt.-Colonel S. W. S. Hamilton, D.S.O., R.E.

Karāchi:—In December 1924 by Mr. D. H. Luxa, tidal assistant.
Madras:— In November 1924 by Mr. D. H. Luxa, tidal assistant.

Except for minor stoppages, all the tide-gauges worked satisfactorily except that at Madras, where there was a break of 10 days in July 1926, while the cylinder was being renewed. Between January and April 1927 the registrations at Madras were also extremely faulty, on account of an undetected stoppage of the inlet hole.

3. Resumption of tidal observations at the mouth of the Rangoon river.—A tidal observatory has been opened in the Pilakat or Deserter's Creek near Elephant Point at the mouth of the Rangoon river. During 1922 to 1925 comparison of the predicted times of high- and low-water at Rangoon with those actually recorded had revealed regular errors which were repeated from year to year. The port engineer made some rough tidal observations at Elephant Point in 1924 and 1925, which showed the predictions there to be similarly in error. It was consequently decided to make fresh tidal observations at the latter place with an automatic gauge for a few years. Mr. D. H. Luxa installed the gauge in March 1927, and registrations were begun on March 16th. Observations were made at Elephant Point in 1880-81, but owing to rapid erosion the gauge had to be removed to Pilakat Creek about two miles up the river, where observations were made from 1884 to 1888. Since that date the river bank is said to have been eroded about 2,000 feet, and the site of the old observatory has disappeared. The new site is a short distance up the creek about 800 feet from the former site.

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

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

Tide symbol	1924*				Tide symbol	1925†			
	$A_0 = 8 \cdot 330$					$A_0 = 8 \cdot 162$			
	R	ζ	H	κ		R	ζ	H	κ
Short period	*feet*		*feet*		Short period	*feet*		*feet*	
S_1	0·078	149°·29	0·078	149°·20	S_1	0·060	160°·50	0·060	160°·50
S_2	0·696	92·20	0·696	92·29	S_2	0·743	91·99	0·743	91·99
S_4	0·009	93·86	0·009	93·86	S_4	0·016	80·84	0·016	80·84
S_6	0·002	242·10	0·002	242·10	S_6	0·002	120·96	0·002	120·98
S_8	0·040	92·03	0·040	92·03	S_8	0·003	111·80	0·003	111·80
M_1	0·030	244·65	0·028	267·11	M_1	0·034	87·13	0·036	12·81
M_2	2·242	274·64	2·175	50·14	M_2	2·271	200·36	2·222	51·71
M_3	0·022	213·76	0·021	57·01	M_3	0·006	101·69	0·006	238·72
M_4	0·252	61·04	0·237	332·03	M_4	0·251	274·83	0·241	337·53

* 1924 was worked as an open coast station.

† 1925 was worked as a riverain station.

TABLE 2.—*Values of the tidal constants for Bassein 1924 and 1925.—(contd.)*

Tide symbol	1924*				Tide symbol	1925†			
	$A_0 = 8\ 330$					$A_0 = 8{\cdot}162$			
	R	ζ	H	κ		R	ζ	H	κ
Short period	*feet*	°	*feet*	°	Short period	*feet*	°	*feet*	°
M_6	0·092	198·15	0·084	244·65	M_6	0·092	338·66	0·086	252·72
M_8	0·022	340·87	0·020	162·87	M_8	0·020	67·03	0·018	192·44
O_1	0·142	90·81	0·167	45·52	O_1	0·148	1·55	0·164	34·33
K_1	0·335	222·95	0·369	46·81	K_1	0·344	222·70	0·366	45·22
K_2	0·147	279·05	0·185	107·62	K_2				
P_1	0·120	252·03	0·120	62·42	P_1	0·135	243·55	0·135	53·19
J_1	0·022	292·24	0·025	93·42	J_1	0·009	267·43	0·010	168·19
Q_1	0·021	106·83	0·024	81·15	Q_1	0·012	89·50	0·013	40·10
L_2	0·212	109·99	0·187	38·57	L_2				
N_2	0·384	256·35	0·372	51·46	N_2				
ν_2	0·143	107·36	0·139	359·96	ν_2				
μ_2	0·254	261·40	0·239	172·39	μ_2				
T_2	0·065	46·01	0·065	48·03	T_2				
$(MS)_4$	0·183	240·97	0·178	16·47	$(MS)_4$				
$(2SM)_2$	0·086	83·75	0·081	308·25	$(2SM)_2$				
$2N_2$	0·138	143·87	0·134	318·59	$2N_2$				
$(M_2N)_4$	0·093	32·35	0·088	322·95	$(M_2N)_4$				
$(M_2K_1)_3$	0·052	317·39	0·056	276·74	$(M_2K_1)_3$	0·093	260·80	0·096	294·67
$(2M_2K_1)_3$	0·057	187·38	0·059	274·52	$(2M_2K_1)_3$	0·061	26·57	0·062	266·75
Long period Mm	0·191	53·39	0·172	33·77	Long period Mm				
Mf	0·091	351·41	0·130	37·49	M				
MSf	0·226	196·00	0·219	60·51	ΣSf				
Sa	2·304	233·48	2·304	153·10	Sa				
Ssa	0·426	88·12	0·426	287·34	Ssa				

* 1924 was worked as an open coast station.

† 1925 was worked as a riverain station.

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

Chittagong.—Based on comparisons in 1922 to 1926.

TABLE 3.—*Corrections to Chittagong predictions*

	Time	Height
	minutes	*feet*
High-water	+ 12	+ 0·1
Low-water	+ 13	+ 0·7

Basrah.—Based on comparisons in 1923 to 26. No correction to heights.

TABLE 4.—*Corrections to Basrah predictions.*

Month	Tide	Dates					
		1st-5th	6th-10th	11th-15th	16th-20th	21st-25th	26th-31st
		minutes	*minutes*	*minutes*	*minutes*	*minutes*	*minutes*
January ...	High	+ 20	+ 18	+ 15	+ 13	+ 11	+ 10
	Low	+ 30	+ 27	+ 24	+ 22	+ 21	+ 20
February ...	High	+ 9	+ 8	+ 8	+ 8	+ 9	+ 10
	Low	+ 18	+ 17	+ 17	+ 17	+ 18	+ 18
March ...	High	+ 11	+ 12	+ 14	+ 15	+ 16	+ 18
	Low	+ 19	+ 20	+ 22	+ 23	+ 24	+ 25
April ...	High	+ 20	+ 22	+ 24	+ 26	+ 27	+ 28
	Low	+ 26	+ 28	+ 29	+ 31	+ 32	+ 33
May ...	High	+ 29	+ 29	+ 29	+ 29	+ 28	+ 27
	Low	+ 34	+ 34	+ 34	+ 34	+ 33	+ 32
June ...	High	+ 26	+ 25	+ 24	+ 24	+ 24	+ 25
	Low	+ 32	+ 31	+ 30	+ 29	+ 28	+ 28
July ...	High	+ 26	+ 27	+ 28	+ 30	+ 32	+ 34
	Low	+ 27	+ 27	+ 27	+ 27	+ 28	+ 28
August ...	High	+ 37	+ 39	+ 41	+ 43	+ 45	+ 47
	Low	+ 30	+ 31	+ 32	+ 34	+ 36	+ 39
September	High	+ 49	+ 50	+ 52	+ 53	+ 54	+ 55
	Low	+ 42	+ 44	+ 46	+ 48	+ 50	+ 52
October ...	High	+ 56	+ 57	+ 58	+ 58	+ 58	+ 57
	Low	+ 56	+ 58	+ 59	+ 60	+ 61	+ 62
November...	High	+ 56	+ 56	+ 54	+ 53	+ 50	+ 48
	Low	+ 62	+ 63	+ 63	+ 62	+ 61	+ 59
December .	High	+ 45	+ 41	+ 36	+ 32	+ 28	+ 24
	Low	+ 56	+ 52	+ 48	+ 44	+ 40	+ 35

Rangoon.—Based on comparisons in 1923 to 26. No correction to heights.

TABLE 5.—*Corrections to Rangoon predictions.*

Month	Tide	Dates					
		1st-5th	6th-10th	11th-15th	16th-20th	21st-25th	26th-31st
		minutes	*minutes*	*minutes*	*minutes*	*minutes*	*minutes*
January ...	High	− 14	− 17	− 19	− 21	− 23	− 24
	Low	− 8	− 11	− 14	− 15	− 17	− 18
February ...	High	− 25	− 26	− 27	− 27	− 27	− 27
	Low	− 19	− 20	− 19	− 19	− 18	− 18
March ...	High	− 27	− 26	− 24	− 22	− 20	− 18
	Low	− 17	− 16	− 14	− 12	− 10	− 9
April ...	High	− 17	− 15	− 14	− 13	− 12	− 10
	Low	− 7	− 6	− 5	− 3	− 2	− 2
May ...	High	− 9	− 8	− 8	− 8	− 8	− 9
	Low	− 2	− 2	− 2	− 4	− 5	− 6
June ..	High	− 10	− 11	− 12	− 14	− 16	− 17
	Low	− 6	− 6	− 6	− 8	− 9	− 10
July ...	High	− 16	− 16	− 17	− 19	− 22	− 25
	Low	− 12	− 12	− 13	− 13	− 13	− 13
August ...	High	− 28	− 30	− 30	− 29	− 27	− 23
	Low	− 13	− 13	− 12	− 11	− 9	− 7
September...	High	− 19	− 16	− 12	− 9	− 6	− 3
	Low	− 5	− 3	− 2	0	+ 2	+ 3
October ...	High	− 1	0	+ 2	+ 3	+ 5	+ 6
	Low	+ 4	+ 6	+ 7	+ 8	+ 9	+ 10
November...	High	+ 7	+ 7	+ 8	+ 8	+ 7	+ 6
	Low	+ 10	+ 10	+ 10	+ 10	+ 9	+ 8
December...	High	+ 3	+ 1	− 2	− 5	− 8	− 11
	Low	+ 6	+ 4	+ 2	0	− 2	− 5

6 Tide-tables.—The tide-tables for 1928 for Basrah and the Indian ports were prepared and published. Distribution was completed by October 1927. Advance copies for the 1928 tide-tables, for Suez, Aden, Bushire, Karāchi, Bhāvnagar, Bombay, Marmagao, Colombo, Trincomalee, Madras, Dublat (Sāgar Island), Chittagong, Elephant Point and Mergui, were prepared and despatched by the end of March 1927 to the Hydrographer to the Admiralty for incorporation in the Admiralty tide-tables for 1928. The amount realized by the sale of tide-tables during the year ending 30th September 1927 amounted to Rs. 5997/7/-, excluding commission charged for by agents and the cost of copies issued gratis.

7. Comparisons between actual & predicted values.—From comparisons made between the actual and predicted times and heights of high- and low-water, the predictions for 1926 were found to be as accurate as those for the preceding year, except at Bhāvnagar, where a great deterioration had taken place. At Bhāvnagar observations were made with a tide-pole, with which it is not easy to judge the times of high- and low-water. In spite of this, previous years' comparisons had indicated extremely small average errors, much smaller than at stations where automatic gauges are installed. It is believed that the change is due to stricter supervision by the port authorities and that the previous excellent agreement was fictitious. The port is situated up a creek and the range of height is large: although the predictions are bad, they are not much worse than might reasonably be expected. At Basrah, on the other hand, there has been a considerable improvement, especially in the heights.

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

Kidderpore.—Predicted	*minus*	actual		+2·2 feet on 18th July and 22nd & 23rd October 1926.
Rangoon.—	,,	,,	,,	−3·4 feet on 25th & 26th August 1926.
Bassein.—	,,	,,	,,	−4·1 feet on 25th August 1926.
Basrah.—	,,	,,	,,	−3·0 feet on 28th December 1926.

Tables 6 to 16 give the fortnightly mean errors of the predictions for all stations at which comparisons were made.

TABLE 6.—*Mean errors E_1 and E_2 for 1926*

ADEN

PERIOD 1926	MEAN ERRORS (Predicted—actual) E₁* H. W. Time (minutes) +		H. W. Height (feet) +		L. W. Time (minutes) +		L. W. Height (feet) +		E₂* H. W. Time (minutes)	H. W. Ht. (feet)	L. W. Time (minutes)	L. W. Ht. (feet)	Number of errors exce[eding] 30 minutes of time H. W.	30 minutes of time L. W.	[cut off] H. W.
	+	−	+	−	+	−	+	−							
Jan. 1-15	4·0		0·0		6·1			0·0	6·5	0·1	9·6	0·1	0	0	0
16-31	5·9		0·0		3·0		0·0		8·8	0·1	6·7	0·1	0	0	0
Feb. 1-15	0·4		0·1		4·8		0·1		5·9	0·1	8·1	0·1	0	0	[illegible]
16-28	7·3		0·1		7·3		0·1		13·1	0·1	14·0	0·1	3	1	0
Mar. 1-15	2·3		0·0		8·1		0·0		8·8	0·1	12·0	0·1	2	2	0
16-31	5·1			0·0	10·3		0·1		13·2	0·1	14·5	0·2	2	3	0
April 1-15	1·0			0·1	4·9			0·1	11·6	0·2	12·1	0·1	2	1	[illegible]
16-30	3·7			0·1		0·7	0·0		8·1	0·1	7·2	0·1	1	1	0
May 1-15	2·4			0·2	0·1			0·2	7·3	0·2	10·1	0·2	0	1	0
16-31	0·5			0·1	4·3			0·0	7·2	0·1	9·3	0·1	1	0	0
June 1-15	4·4			0·2	4·3			0·1	7·6	0·2	7·7	0·1	0	0	0
16-30	4·2			0·3	6·8			0·3	5·6	0·3	8·7	0·3	1	0	1
July 1-15	7·0			0·3	2·2			0·2	10·1	0·3	6·6	0·2	2	0	[illegible]
16-31	7·5			0·1	8·2			0·1	7·9	0·1	10·7	0·1	0	2	0
Aug. 1-15	6·6		0·0		11·0		0·1		10·1	0·2	12·0	0·2	1	2	0
16-31		4·2	0·1		6·7		0·1		18·9	0·1	11·0	0·1	5	2	[illegible]
Sept. 1-15	7·8			0·0	16·4		0·0		8·9	0·1	18·0	0·1	0	1	[illegible]
16-30		1·8		0·1	6·0			0·1	11·3	0·2	14·6	0·1	2	3	[illegible]
Oct. 1-15	9·2			0·1	9·8			0·1	12·2	0·1	13·5	0·1	2	0	
16-31	2·6		0·1		2·2			0·0	9·2	0·1	6·4	0·1	2	0	
Nov. 1-15	3·1		0·1		8·9		0·1		7·0	0·2	9·5	0·1	0	0	
16-30	2·3			0·0		0·1		0·1	10·6	0·2	10·3	0·1	1	0	
Dec. 1-15	5·0		0·3		2·1		0·2		7·7	0·3	11·1	0·3	1	0	
16-31		8·8	0·3		4·8		0·2		14·1	0·3	12·7	0·2	3	2	
TOTALS...	92·3	14·8	1·1	1·6	133·3	0·8	1·0	1·3	231·7	3·9	256·4	3·3	31	21	
MEANS ...	+ 3·2		− 0·0		+ 5·5		− 0·0		9·7	0·2	10·7	0·1	...	...	

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

TABLE 7.—*Mean errors E_1 and E_2 for 1926*

BASRAH

PERIOD 1926	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		17·1	0·4			12·7	0·3		30·2	0·4	53·0	0·6	13	21	9	11
16-31	42·2			0·1	37·5		0·2		62·5	0·4	78·5	0·8	12	20	6	12
Feb. 1-15	2·4			0·3		9·8		0·5	28·3	0·4	45·9	0·8	10	17	6	11
16-28		19·0		0·5		28·7		1·0	39·9	0·7	57·1	1·2	10	19	15	19
Mar. 1-15	10·8			0·2		13·2		1·1	37·5	0·6	40·1	1·2	14	18	13	23
16-31		5·5		0·5		38·6		1·3	51·5	0·6	59·8	1·3	17	20	15	24
April 1-15	1·0			0·7		11·3		1·5	41·3	0·7	25·1	1·5	16	10	19	28
16-30		25·7		0·5		30·4		1·0	57·0	0·5	30·8	1·0	23	15	13	25
May 1-15		19·4		0·6		35·9		1·0	51·2	0·6	36·1	1·0	18	13	15	26
16-31		31·6		0·5		26·5		0·6	62·0	0·6	44·6	0·6	24	20	14	17
June 1-15		24·2		0·4		29·9		0·6	47·1	0·6	49·6	0·7	19	19	16	20
16-30		5·4		0·2		3·8		0·6	47·9	0·3	44·5	0·6	21	17	7	13
July 1-15		45·6		0·1		53·8		0·5	57·6	0·4	73·5	0·7	15	21	4	19
16-31		15·2	0·3			15·0		0·1	32·2	0·3	42·9	0·4	14	19	3	7
Aug. 1-15		33·7	0·0			31·5	0·1		36·0	0·4	52·0	0·5	16	18	8	13
16-31		15·3	0·3			12·3	0·1		33·3	0·4	46·3	0·5	13	18	8	11
Sept. 1-15		41·5	0·3			32·9	0·6		51·8	0·4	51·8	0·6	22	21	9	16
16-30		40·9	0·5			53·0	0·5		60·8	0·6	62·8	0·8	20	21	10	20
Oct. 1-15		55·2	0·3			49·0	0·3		58·6	0·5	49·3	0·6	18	16	16	17
16-31		55·4	0·4			53·1	0·1		61·8	0·4	54·6	0·5	20	21	10	10
Nov. 1-15		72·3	0·4			64·6		0·0	74·9	0·6	68·6	0·5	20	19	16	8
16-30		41·0		0·5		48·9		0·8	47·9	0·7	53·5	1·1	13	13	13	21
Dec. 1-15		9·6	0·3			30·0		0·0	43·1	0·6	51·3	0·5	16	19	10	9
16-31		41·5	0·3			61·8		0·1	49·9	0·5	68·9	0·5	23	22	9	14
TOTALS ...	56·4	624·1	3·5	5·1	37·5	746·7	2·2	10·7	1164·3	12·2	1240·6	18·5	407	437	264	39[illegible]
MEANS ...	− 23·7		− 0·1		− 29·6		− 0·4		48·5	0·5	51·7	0·8	...	...	...	

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

TABLE 8.—*Mean errors E_1 and E_2 for 1926*

KARĀCHI

PERIOD 1926	MEAN ERRORS (Predicted—actual)												Number of errors exce…		
	E_1*								E_2*				30 minutes of time		ft …
	H. W. Time (minutes)		H. W. Height (feet)		L. W. Time (minutes)		L. W. Height (feet)		H. W. Time (minutes)	H. W. Ht. (feet)	L. W. Time (minutes)	L. W. Ht. (feet)	H. W.	L. W.	H. W.
	+	−	+	−	+	−	+	−							
Jan. 1-15		0·1		0·1	9·6		0·1		7·8	0·2	16·9	0·1	0	2	0
16-31	5·2			0·2	7·0		0·1		10·4	0·2	11·8	0·2	0	1	0
Feb. 1-15		0·1		0·3	9·9		0·0		7·3	0·3	17·5	0·2	0	4	0
16-28		0·7		0·4	1·1			0·2	12·0	0·4	7·5	0·2	1	0	0
Mar. 1-15		7·8		0·5	2·8			0·1	11·8	0·5	13·3	0·2	0	4	0
16-31		5·6		0·1	0·7		0·1		10·7	0·2	7·9	0·1	2	1	0
April 1-15		10·5		0·4	5·0			0·1	15·2	0·4	9·2	0·2	2	1	0
16-30		5·6	0·0			1·1	0·2		9·4	0·2	11·2	0·3	1	2	[illegible]
May 1-15		8·3		0·1	6·6		0·2		10·2	0·2	10·1	0·3	1	1	0
16-31		7·4		0·2		0·1		0·0	9·1	0·2	10·5	0·2	1	1	0
June 1-15		4·4		0·0		0·9	0·2		7·6	0·1	10·3	0·3	0	0	0
16-30		0·0		0·4	4·1			0·3	7·4	0·4	10·1	0·3	1	2	0
July 1-15		0·6		0·5	2·6			0·3	9·5	0·5	7·1	0·3	1	0	0
16-31		2·8		0·2	10·9			0·1	7·5	0·3	14·5	0·2	0	2	0
Aug. 1-15	2·2			0·3	1·1			0·1	6·9	0·3	11·3	0·2	0	0	0
16-31	0·8			0·4	8·5			0·2	5·9	0·4	10·7	0·2	0	1	[illegible]
Sept. 1-15		0·7		0·5	3·1			0·3	6·3	0·5	10·3	0·4	0	1	1
16-30		1·8		0·6	2·6			0·4	8·9	0·6	11·3	0·4	1	2	5
Oct. 1-15	2·5			0·3	1·5			0·1	8·3	0·4	11·7	0·2	1	0	0
16-31	0·7			0·1	4·3		0·0		8·6	0·2	10·1	0·2	1	0	0
Nov. 1-15		0·2		0·4	7·0			0·2	8·6	0·4	10·3	0·2	1	2	0
16-30		0·7		0·2	5·9			0·1	6·9	0·3	11·4	0·2	0	2	[illegible]
Dec. 1-15		0·9		0·2		3·0		0·1	4·7	0·3	9·2	0·2	0	0	0
16-31	0·7			0·1	4·4			0·1	6·8	0·2	12·1	0·1	0	2	[illegible]
TOTALS ...	12·1	58·2	0·0	6·5	98·7	5·1	0·9	2·7	207·8	7·7	66·3	5·4	14	31	6
MEANS ...	− 1·9		− 0·3		+ 3·9		− 0·1		8·7	0·3	11·1	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 1926*

BHĀVNAGAR

PERIOD 1926	MEAN ERRORS (Predicted — actual) E_1* H. W. Time (minutes) +	E_1 H. W. Time (minutes) −	E_1 H. W. Height (feet) +	E_1 H. W. Height (feet) −	E_1 L. W. Time (minutes) +	E_1 L. W. Time (minutes) −	E_1 L. W. Height (feet) +	E_1 L. W. Height (feet) −	E_2* H. W. Time (minutes)	E_2 H. W. Ht. (feet)	E_2 L. W. Time (minutes)	E_2 L. W. Ht. (feet)	Number of errors exceeding 30 minutes of time H. W.	30 minutes of time L. W.	1·0 feet of height H. W.	1·0 feet of height L. W.
Jan. 1-15	0·7		0·8			2·7	0·3		5·0	0·8	4·9	0·7	0	0	6	2
16-31	13·0		1·5			11·4	0·8		18·6	1·5	12·7	0·9	2	3	10	7
Feb. 1-15	20·6		1·8			5·4	1·6		23·4	1·8	21·4	1·9	7	4	14	11
16-28	19·5		1·2			5·3	0·9		21·9	1·2	17·6	1·1	3	2	9	7
Mar. 1-15	20·9			0·1		4·4	0·0		20·9	0·3	17·6	1·0	4	2	0	6
16-31	16·8		0·2			7·4		0·3	16·8	0·5	14·3	0·8	1	3	0	4
April 1-15	20·3			0·4		6·9		0·4	20·6	0·5	22·1	1·1	3	5	2	6
16-30	15·6		0·4			4·1	0·4		5·6	0·8	12·5	0·5	0	0	4	0
May 1-15	11·3			0·4		18·8	0·0		13·5	0·7	20·5	0·8	0	6	5	5
16-31	11·6		0·3			2·9	0·3		17·2	0·7	12·8	0·5	2	0	2	2
June 1-15	17·0			0·3		5·6	0·3		17·5	0·8	12·0	0·4	2	1	4	0
16-30	18·4			0·1		7·2	0·3		20·7	0·3	15·6	0·6	3	3	0	3
July 1-15	20·3			0·5	0·9			0·1	20·3	0·6	9·5	0·5	2	0	2	3
16-31	18·9			0·1		16·9		0·3	26·5	0·6	26·1	0·9	6	6	2	6
Aug. 1-15	18·1			0·4		7·1	0·8		18·1	0·5	11·2	0·8	2	0	1	3
16-31	12·4			0·6		15·8		0·4	13·5	0·6	21·8	1·4	1	7	3	8
Sept. 1-15	11·3			0·8		5·9	0·4		11·5	0·8	9·9	0·8	0	0	6	4
16-30	10·9			0·8		18·2		1·4	12·7	0·9	31·0	1·6	1	8	5	8
Oct. 1-15	16·6			0·3		4·3	0·9		17·1	0·4	13·7	1·0	2	0	0	6
16-31	12·3		0·1			22·1		0·6	14·4	0·3	29·9	1·2	2	6	1	7
Nov. 1-15	6·5			0·3		5·6	0·3		14·8	0·4	12·8	0·5	0	1	1	2
16-30	10·5		0·2			23·9		0·6	14·1	0·5	24·1	0·9	0	6	1	5
Dec. 1-15		3·9		0·1		19·6		0·2	19·5	0·6	19·6	0·4	3	2	1	0
16-31	4·4		0·2			13·1		0·6	18·8	0·4	19·5	0·8	1	6	0	6
TOTALS	327·9	3·9	6·7	5·2	0·9	234·6	7·3	4·9	413·0	16·4	413·1	21·1	47	71	79	111
MEANS	+13·5		+0·1		−9·7		+0·1		17·2	0·7	17·2	0·9	...	...	...	...

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

TABLE 10—*Mean errors E_1 and E_2 for 1926*

BOMBAY (APOLLO BANDAR)

PERIOD 1926	MEAN ERRORS (Predicted—actual) E_1* H. W. Time (minutes) +		H. W. Height (feet) +	−	L. W. Time (minutes) +	−	L. W. Height (feet) +	−	E_2* H. W. Time (minutes)	H. W. Ht. (feet)	L. W. Time (minutes)	L. W. Ht. (feet)	Number of errors exceeding 30 minutes of time H. W.	30 minutes of time L. W.	1·0 feet of height H. W.
	+	−	+	−	+	−	+	−							
Jan. 1-15		7·7	0·2			4·4	0·4		9·2	0·3	6·2	0·4	1	1	0
16-31		6·1	0·0			9·4	0·2		6·1	0·2	11·0	0·2	0	0	0
Feb. 1-15		8·0		0·1		4·6	0·2		8·6	0·2	6·7	0·3	0	0	0
16-28	4·5		0·0		6·6		0·1		6·6	0·2	8·2	0·2	0	0	0
Mar. 1-15	1·2			0·2		1·0	0·2		6·1	0·3	5·8	0·3	0	0	0
16-31		3·4	0·0			7·7	0·3		4·5	0·3	8·6	0·3	0	0	0
April 1-15	0·6			0·4		2·2	0·0		7·4	0·5	7·7	0·2	1	0	0
16-30		2·3	0·0			7·6	0·3		10·2	0·3	10·7	0·3	1	1	0
May 1-15		0·8		0·2		4·2	0·2		4·7	0·4	6·6	0·3	0	0	1
16-31		4·8		0·1	0·1		0·0		6·1	0·3	5·3	0·2	1	1	0
June -15		1·0	0·0			2·8	0·2		5·1	0·3	5·9	0·3	0	0	0
16-30		1·6		0·3	2·2			0·2	3·4	0·3	3·6	0·2	0	0	0
July 1-15		0·5		0·6	6·1			0·6	5·7	0·6	7·5	0·6	0	0	2
16-31		1·9		0·2	2·2			0·3	4·8	0·3	6·0	0·3	0	0	0
Aug. 1-15	5·3			0·4	7·1			0·4	8·6	0·4	7·6	0·4	0	0	1
16-31		0·6		0·3	0·2			0·5	6·0	0·3	7·0	0·5	0	0	0
Sept. 1-15		4·4		0·1	1·4			0·4	9·6	0·3	5·2	0·4	1	0	0
16-30	0·7			0·2	3·5			0·2	6·2	0·2	5·7	0·3	0	0	0
Oct. 1-15	2·9		0·3		2·2		0·1		3·6	0·3	5·8	0·3	0	1	0
16-31		7·1	0·2			4·2	0·2		8·6	0·3	8·4	0·3	0	0	0
Nov. 1-15		2·0		0·0		0·5		0·1	2·7	0·1	3·1	0·2	0	0	0
16-30		5·4	0·2			7·5	0·2		6·4	0·4	9·8	0·3	0	2	1
Dec. 1-15		0·8	0·0			1·9		0·0	5·7	0·2	5·2	0·2	0	0	0
16-31		6·7		0·1		6·0	0·1		10·2	0·2	8·1	0·2	2	1	0
TOTALS	15·2	65·1	0·9	3·2	31·6	64·0	2·7	2·7	156·1	7·2	165·7	7·2	7	7	5
MEANS ..	− 2·1		− 0·1		− 1·4		+ 0·0		6·5	0·3	6·9	0·3			

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

TABLE 11.—*Mean errors E_1 and E_2 for 1926*

MADRAS

PERIOD 1926	MEAN ERRORS (Predicted—actual)												Number of errors exceeding			
	E_1*								E_2*				30 minutes of time		0·4 feet of height	
	H. W. Time (minutes)		H. W. Height (feet)		L. W. Time (minutes)		L. W. Height (feet)		H. W. Time (minutes)	H. W. Ht (feet)	L. W. Time (minutes)	L. W. Ht. (feet)	H. W.	L. W.	H. W.	L. W.
	+	−	+	−	+	−	+	−								
Jan. 1-15	11·3		0·1		12·4		0·2		11·4	0·1	12·4	0·2	0	0	0	0
16-31	11·0			0·0	12·7		0·1		11·1	0·1	12·7	0·1	0	1	0	0
Feb. 1-15	8·8			0 0	6·9		0·2		9·6	0·1	8·6	0·2	0	0	0	0
16-28	7·0		0 2		7·5		0·3		7·7	0·2	7·9	0·3	1	0	1	6
Mar. 1-15	4 6		0·1		4·4		0 3		5·5	0·1	7·0	0·3	0	0	0	0
16-31	4·0		0·1		6·1		0·2		6·0	0·1	7·4	0·2	0	0	0	0
April 1-15	6·1			0·0	5·1		0·1		6·3	0·1	5·8	0·2	0	0	1	0
16-30	4·0		0·4		6·2		0·6		6·1	0·4	8·3	0·6	0	0	16	26
May 1-15	4·3		0·1		5·6		0·4		5·4	0·2	6·3	0·4	0	0	4	11
16-31	3·1			0·1	6·5		0·1		6 1	0·2	7·1	0·2	0	0	1	0
June 1-15	6·1			0·1	5·8		0·1		7 9	0·2	6·9	0·1	0	0	1	0
16-30	6·5			0·0	9·3		0·2		6·5	0·2	9·3	0·2	0	0	0	1
July 1-15	3·5		0·5		11·7		0·5		4·1	0·5	11·7	0·5	0	0	6	7
16-31	6·0		0·3		5·6		0·4		7·1	0·3	6·0	0·4	0	0	3	12
Aug. 1-15	4·7		0·0		7·9		0·2		5·3	0·1	8·2	0·2	0	0	0	0
16-31	7·1		0·2		6·7		0·4		7·4	0·2	6·9	0·4	0	0	2	8
Sept. 1-15	2·1		0·2		2·7		0·3		4·1	0·2	4·0	0·3	0	0	0	4
16-30		2·0	0·2		1·6		0·3		3·6	0·2	4·0	0·3	0	1	2	6
Oct. 1-15	0·2		0·1		1·4		0·2		3·2	0·1	4·8	0·2	0	0	0	4
16-31		2·5	0·0		0·4			0·1	5·9	0·1	5·1	0·1	0	0	0	0
Nov. 1-15		3·6		0·1		1·9	0·0		7·1	0·1	11·9	0·1	0	1	0	0
16-30		7·9	0·0			9·0	0 1		10·0	0·1	10·9	0·2	0	1	0	2
Dec. 1-15		1·8	0·0			0·5	0·0		7·1	0·2	6·2	0 2	1	0	1	2
16-31		0·1		0·1	3·2			0·1	8·4	0·1	10·2	0 1	1	2	0	0
TOTALS	100·4	17·9	2·5	0·4	129·7	11·4	5·2	0·2	162·9	4·2	189·6	6 0	3	6	38	89
MEANS	+ 3 4		+ 0 1		+ 4·9		+ 0·2		6·8	0·2	7·9	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 1926*

KIDDERPORE

PERIOD 1926	MEAN ERRORS (Predicted—actual)												Number of errors exceeding			
	E_1*								E_2*				30 minutes of time		[illegible] 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	16·6			0·0	9·4		0·2		18·3	0·2	11·1	0·4	3	3	0	[illegible]
16-31	14·9		0·2		11·7		0·2		15·5	0·3	17·5	0·6	0	0	0	[illegible]
Feb 1-15	19·1		0·3		7·8		0·3		19·1	0·3	10·7	0·5	5	0	0	[illegible]
16-28	20·1		0·2		15·0		0·3		20·2	0·4	17·5	0·5	2	2	0	[illegible]
Mar. 1-15	13·9		0·1		6·4		0·2		16·6	0·4	12·3	0·4	3	1	0	[illegible]
16-31	2·7		0·4		7·8		0·5		8·7	0·5	10·5	0·5	0	1	2	[illegible]
April 1-15	7·6		0·3			5·7	0·5		12·5	0·4	8·0	0·5	2	0	0	[illegible]
16-30	7·4		0·4		8·4		0·7		9·9	0·4	13·4	0·7	1	3	0	[illegible]
May 1-15	0·7		0·4			13·0	0·4		9·7	0·5	14·0	0·4	0	1	3	[illegible]
16-31	9·2		0·3		9·5		0·4		13·5	0·3	13·2	0·5	1	4	0	[illegible]
June 1-15	7·0		0·3		4·1		0·1		8·1	0·3	11·4	0·3	0	1	1	[illegible]
16-30	8·6		0·8		10·9		0·6		15·1	0·8	12·1	0·6	3	3	7	[illegible]
July 1-15		0·5	1·7		14·2		1·3		11·6	1·7	19·8	1·3	0	8	27	[illegible]
16-31		2·0	1·1			1·8	1·2		10·2	1·1	11·2	1·2	0	2	15	[illegible]
Aug. 1-15	7·3		0·2		18·2		0·9		11·4	0·6	24·5	0·9	1	6	3	[illegible]
16-31	10·3		0·1		1·5			0·9	12·1	0·7	9·5	0·9	1	2	8	[illegible]
Sept. 1-15	2·0			0·2	4·7		0·5		7·4	0·4	8·0	0·5	0	2	1	[illegible]
16-30	1·7			0·1		3·2	0·4		6·4	0·5	10·6	0·5	1	2	2	[illegible]
Oct. 1-15		5·6	0·2			3·9	0·9		7·7	0·6	7·9	1·0	0	0	5	[illegible]
16-31		12·6	0·6			8·7	1·5		14·8	0·7	17·7	1·5	2	1	6	[illegible]
Nov. 1-15		18·0	0·5			11·8	1·3		18·1	0·5	14·8	1·3	3	1	0	[illegible]
16-30		6·2	0·1			4·7	0·7		13·6	0·7	19·7	0·7	0	6	6	[illegible]
Dec. 1-15		1·6		0·1		7·0	0·4		7·8	0·2	9·9	0·4	0	1	0	[illegible]
16-31	5·9			0·1	8·4		0·3		17·5	0·5	13·5	0·4	3	6	2	[illegible]
TOTALS...	155·0	46·5	8·2	0·5	138·0	62·8	13·8	0·9	305·8	13·0	318·8	16·5	31	56	88	[illegible]
MEANS...	+ 1·5		+ 0·3		+ 3·1		+ 0·5		12·7	0·5	13·3	0·7	...	...	...	[illegible]

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

TABLE 13.—*Mean errors E_1 and E_2 for 1926*

CHITTAGONG

PERIOD 1926	MEAN ERRORS (Predicted — actual) E_1 * H. W. Time minutes +	−	H. W. Height feet +	−	L. W. Time minutes +	−	L. W. Height feet +	−	E_2 * H. W. Time minutes	H. W. Ht. feet	L. W. Time minutes	L. W. Ht. feet	Number of errors exceeding 30 minutes of time H. W.	30 minutes of time L. W.	1·0 feet of height H. W.	1·0 feet of height L. W.
Jan. 1-15		12·1		0·1		8 0		0·6	14·0	0·2	8·0	0·6	2	0	0	0
16-31		11·6	0·2			11·1		0·4	11·6	0·4	11·1	0·5	1	0	0	2
Feb. 1-15		7·3	0·3			8·7		0·3	8·1	0·3	8·7	0·5	0	0	0	0
16-28		20·0		0·4		5·9		0·9	20·0	0·6	10·5	0·9	3	0	4	6
Mar. 1-15		14·6		0·5		5·4		0·7	21·0	0·6	11·5	0·7	5	0	0	3
16-31		6·1	0·4			2·4		0·2	8·8	0·5	5·4	0·4	0	0	0	0
April 1-15		10·4	0·2			12·2		0·4	11·2	0·2	12·7	0·6	0	0	0	4
16-30		15·8	0·4			12·4	0·2		15·8	0·5	12·4	0·3	1	1	2	0
May 1-15		9·7	0·6			16·6	0·2		9·7	0·8	16·6	0·5	0	0	6	0
16-31		12·9	0·4			12·3		0·4	12·9	0·5	12·3	0·7	0	0	0	1
June 1-15		13·4	0·1			11·9		0·2	13 4	0·6	11·9	0·4	0	0	1	1
16-30		8·0		0·0		9·0		0·6	8·0	0·5	9·0	0·6	0	0	0	1
July 1-15		10·5	0·6			7·9	0·4		10·5	0·6	10 1	0·5	0	1	4	1
16-31		10·5	0·1			13·6		0·8	10·5	0·5	13·6	0·8	0	0	0	5
Aug. 1-15		2·9		0·8		5·6		1·4	7·4	0·8	8·7	1·4	0	1	4	8
16-31		13·7		0·2		10·1		0·5	13·7	0·9	10·1	0·5	2	1	6	2
Sept. 1-15		15·9	0·1			22·8		0·4	16·0	0·6	22·8	0·5	0	3	0	2
16-30		21·3	0·2			23·5		0·8	21·3	0·7	23·5	0·8	3	5	1	5
Oct. 1-15		32·1		0·3		43·7		1·3	32·1	0·4	43·7	1·3	8	13	0	9
16-31		46·5		0·1		41·9		1·1	46·5	0·4	41·9	1·1	15	14	2	10
Nov. 1-15		33·5	0·2			33·8		0·5	33·5	0·4	33·8	0·5	10	9	0	1
16-30		29·0		0·1		25·5		0·8	29·0	0·9	26·1	0·8	4	5	5	5
Dec. 1-15		25·6		0·1		21·7		0·7	25·5	0·4	21·7	0·7	3	1	1	0
16-31		17·9		0·6		16·5		0·8	18·0	0·6	16·5	0·8	1	0	4	3
TOTALS ...		401·2	3·8	3·2		382·4	0·8	13·8	418·5	12·9	402·6	16·4	58	54	40	69
MEANS ...	− 16·7		+ 0·0		− 15·9		− 0·5		17·4	0·5	16·8	0·7	...	...	...	...

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

TABLE 14.—*Mean errors E_1 and E_2 for 1926*

AKYAB

PERIOD 1926	MEAN ERRORS (Predicted—actual)												Number of errors exceeding			
	E_1*								E_2*				30 minutes of time		0·8 feet of height	
	H. W. Time (minutes)		H. W. Height (feet)		L. W. Time (minutes)		L. W. Height (feet)		H. W. Time (minutes)	H. W. Ht. (feet)	L. W. Time (minutes)	L. W. Ht. (feet)	H. W.	L. W.	H. W.	L. W.
	+	−	+	−	+	−	+	−								
Jan. 1-15	5·9			0·2	6·4		0·2		5·9	0·2	6·4	0·3	0	0	0	0
16-31	7·1			0·0	6·9		0·0		7·1	0·1	6·9	0 2	0	0	0	0
Feb. 1-15	5·9			0·3	6·9		0·2		5·9	0·3	6 9	0·3	0	0	1	2
16-28	7·0			0·2	6·3		0·2		7·0	0·3	6 3	0·2	0	0	1	0
Mar. 1-15	7·2			0·2	6·7			0·2	7·2	0·3	6·7	0·4	0	0	0	3
16-31	6·3			0·2	7 0			0·2	6·3	0·3	7·0	0·4	0	0	0	3
April 1-15	7·0			0·2	6·6		0·1		7·0	0·3	6 6	0·3	0	0	0	0
16-30	5·9			0·2	6·8		0 3		5·9	0·3	6·8	0 3	0	0	0	1
May 1-15	6·5			0·3	6·7		0·6		6·5	0·5	6·7	0·7	0	0	2	5
16-31	7 1			0·1	6·6			0·0	7·1	0·2	6·6	0·4	0	0	0	0
June 1-15	6·4			0·1	6·2		0·3		6·4	0·4	6 2	0·4	0	0	2	0
16-30	6·2			0·0	7·1			0·2	6·2	0·2	7 1	0·2	0	0	0	0
July 1-15	6·9			0·3	6·5			0·1	6·9	0·3	6·5	0 1	0	0	0	0
16-31	6·8			0·2	6·3			0·0	6 8	0·2	6·3	0·1	0	0	0	0
Aug. 1-15	5·9			0·2	7·1		0·0		5·9	0·2	7·1	0·1	0	0	1	0
16-31	6·5			0·2	6·9			0·1	6 5	0·3	6·9	0·2	0	0	1	0
Sept. 1-15	6·5			0·2	6·2		0·1		6·5	0·3	6·2	0·2	0	0	1	0
16-30	6·8			0 0	6·6			0·0	6·8	0·4	6·6	0·1	0	0	1	0
Oct. 1-15	8·5			0·1	6·8		0·1		8·5	0·2	6·8	0·2	1	0	0	0
16-31	6 3			0·3	6·2			0·0	6·3	0·2	6 2	0·2	0	0	0	0
Nov. 1-15	6·7			0·2	6·9		0·2		6·7	0·4	6 9	0·3	0	0	1	0
16-30	6·9			0·2	5·9			0·0	6·9	0·2	5·9	0·2	0	0	0	0
Dec. 1-15	6·9			0·1	7·0		0·1		6·9	0·1	7·0	0·2	0	0	0	0
16-31	8·9			0·2	6·0		0 0		8·9	0·2	6·0	0·1	0	0	0	0
TOTALS ...	162·1			4·1	158·6		2·4	0·8	162·1	6·4	158·6	6·1	1	0	11	14
MEANS ...	+ 6·8		− 0·2		+ 6·6		+ 0·1		6·8	0·3	6·6	0·3	...	...	...	...

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

TABLE 15.—*Mean errors E_1 and E_2 for 1926*

RANGOON

PERIOD 1926	MEAN ERRORS (Predicted—actual) E_1* H. W. Time minutes +	−	H. W. Height feet +	−	L. W. Time minutes +	−	L. W. Height feet +	−	E_2* H. W. Time minutes	H. W. Ht. feet	L. W. Time minutes	L. W. Ht. feet	Number of errors exceeding 30 minutes of time H. W.	L. W.	1·0 feet of height H. W.	L. W.
Jan. 1-15	14·9		0·1		14·3		0·3		14·9	0·3	16·7	0·5	1	5	0	2
16-31	17·3		0·2		14·0		0·2		17·3	0·3	17·0	0·5	0	6	0	7
Feb. 1-15	23·7		0·4		17·0		0·4		23·7	0·5	18·8	0·7	7	7	1	4
16-28	20·8		0·1		16·9		0·2		21·8	0·4	16·9	0·4	2	5	0	2
Mar. 1-15	25·1		0·0		13·2		0·3		25·1	0·3	14·1	0·6	6	1	0	3
16-31	14·7		0·2		13·3		0·1		16·8	0·3	13·6	0·4	1	3	0	0
April 1-15	12·1		0·2			0·6	0·2		13·3	0·4	9·1	0·5	0	0	0	1
16-30	6·9		0·3		6·7		0·4		10·1	0·4	10·4	0·5	2	2	0	3
May 1-15	5·0		0·1			4·7	0·2		6·8	0·3	10·0	0·5	0	0	0	1
16-31	7·9		0·1		11·5			0·1	8·8	0·3	14·6	0·6	0	4	1	6
June 1-15	4·1		0·3		4·3			0·0	5·9	0·4	11·7	0·4	0	2	0	2
16-30	13·9		0·3		14·6			0·2	14·4	0·4	16·7	0·5	1	5	2	2
July 1-15	12·8		0·5		10·9		0·6		13·2	0·5	15·7	0·7	0	6	1	8
16-31	19·1		0·5		13·0		0·2		19·1	0·7	16·2	0·6	4	7	4	1
Aug. 1-15	17·7			0·3	17·7		0·1		17·7	0·4	17·8	0·4	1	5	2	1
16-31	35·6			0·4	7·0			1·5	35·6	0·6	12·1	1·5	24	2	6	22
Sept. 1-15	10·8			0·0	6·0		0·3		11·6	0·3	9·7	0·5	0	0	0	0
16-30	·5		0·2			0·5		0·2	11·9	0·7	11·6	0·4	3	1	7	0
Oct. 1-15		8·1	0·2			1·0	1·0		9·1	0·4	7·9	1·0	1	1	1	18
16-31		1·7		0·2		9·7		0·6	9·4	0·4	14·1	0·7	0	1	1	5
Nov. 1-15		10·6	0·1			12·3	0·3		11·0	0·2	12·3	0·4	3	1	0	1
16-30		8·9	0·3			8·2	0·0		11·2	0·8	18·1	0·6	0	5	11	4
Dec. 1-15		1·2	0·0			8·6	0·6		4·1	0·3	10·8	0·6	0	0	0	1
16-31	10·5		0·2		7·1		0·2		11·5	0·4	15·3	0·5	3	2	0	4
TOTALS	281·4	30·5	4·3	0·9	187·5	45·6	5·6	2·6	341·3	10·0	331·2	14·0	59	71	37	98
MEANS	+ 10·5		+ 0·1		+ 5·9		+ 0·1		14·3	0·4	13·8	0·6	...	...	...	...

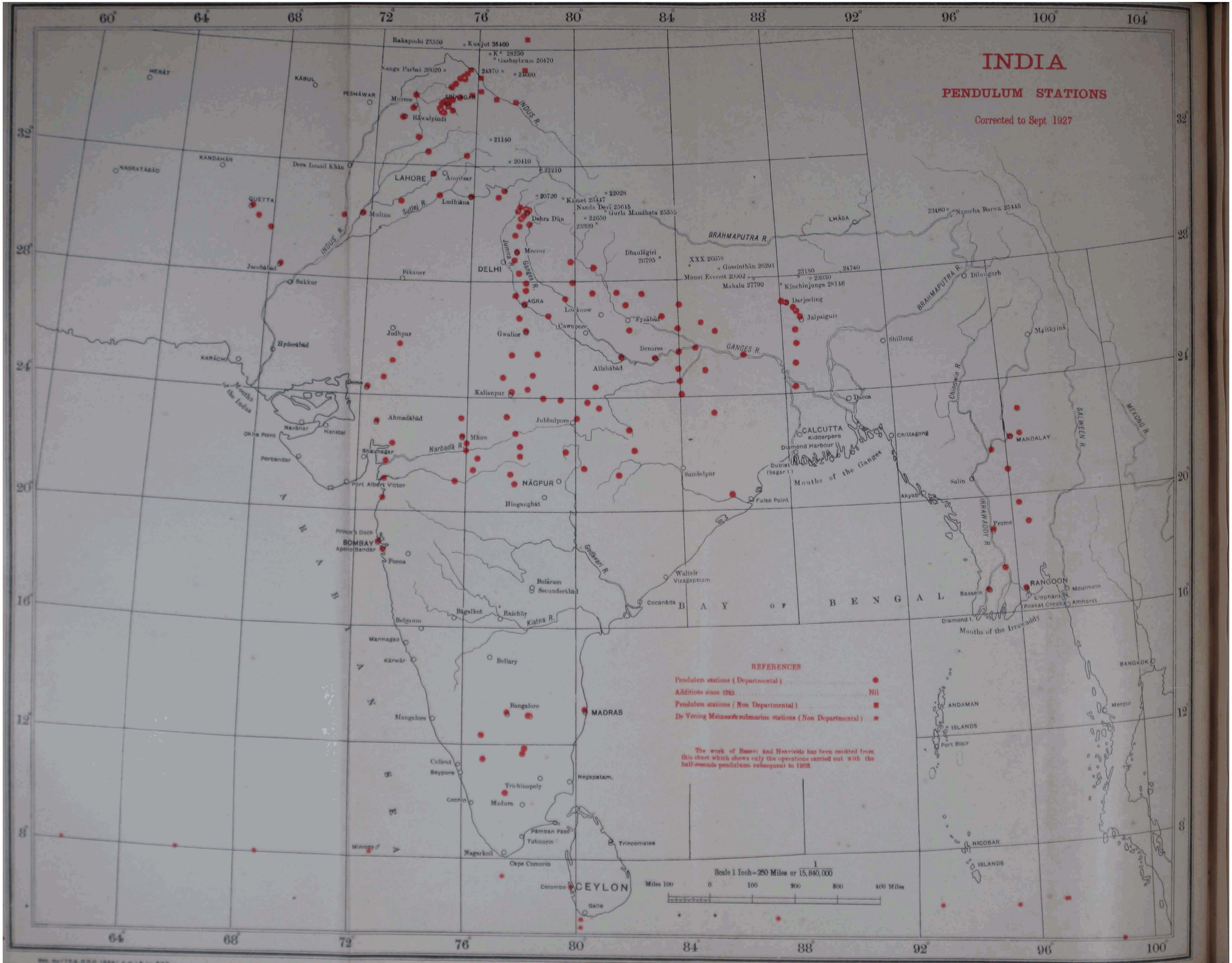
* E_1 is with regard to sign : E_2 is without regard to sign.

TABLE 16.—*Mean errors E_1 and E_2 for 1926*

BASSEIN

PERIOD 1926	MEAN ERRORS (Predicted — actual) E_1* H. W. Time minutes +	−	H. W. Height feet +	−	L. W. Time minutes +	−	L. W. Height feet +	−	E_2* H. W. Time minutes	H. W. Ht. feet	L. W. Time minutes	L. W. Ht. feet	Number of errors exceeding 30 minutes of time H. W.	L. W.	0·6 feet of height H. W.	L. W.
Jan. 1-15	14·2			0·7		9·1	0·0		20·9	0·7	15·7	0·1	9	2	19	0
16-31	8·6			0·5		17·1	0·3		14·6	0·5	17·6	0·3	5	4	13	5
Feb. 1-15	9·1			0·2		9·4	0·8		17·6	0·3	22·2	0·8	6	9	0	21
16-28		0·1		0·2		23·8	0·7		16·9	0·3	28·4	0·7	4	14	2	15
Mar. 1-15	1·1			0·3		14·6	0 8		10·7	0·3	24·8	0·8	2	11	3	19
16-31		1·0		0·2		24·2	0·7		15·7	0·3	28·3	0·7	3	13	4	20
April 1-15	1·4			0·4		21·6	0·5		9·0	0·4	25·8	0·5	1	12	4	11
16-30		4·0		0 0		32·1	0·8		10·3	0·4	32·2	0·8	1	15	4	16
May 1-15		0·9		0·6		33·7	0·4		9·8	0·6	33·7	0·4	1	17	10	6
16-31	0·3			0·5		28·6	0·2		14·8	0·5	28·6	0·3	3	12	9	2
June 1-15		13·1		0·5		23·3	0·1		15·8	0·5	23·3	0·3	5	6	12	1
16-30		10·8		0·2		25·5	0·3		21·8	0·3	25·5	0·4	8	10	2	5
July 1-15	1·9		0·0			26·4	0·4		10·5	0·2	26·4	0·4	2	10	1	8
16-31	6·9		0·5			16·7	0·0		18·2	0·5	24·0	0·7	5	8	9	21
Aug. 1-15		8·6	0·3			22·2		1·1	21·4	0·3	23·3	1·1	8	8	3	21
16-31		21·2		0·3		15·8		3·1	29·8	0·3	21·0	3·1	17	10	5	30
Sept 1-15		13·0	0·5			27·9		1·2	21·4	0·5	28·8	1·2	7	12	6	28
16-30		9·3	0·5			27·0		1·1	15·3	0·5	29·6	1·2	1	16	8	22
Oct. 1-15		23·4	0·5			40·7	0·4		24·7	0·5	40 7	0 4	7	15	10	8
16-31		12·3		0·6		48·2		1·4	14·5	0·6	50·3	1·4	4	28	9	23
Nov. 1-15		11·5		0·9		45·3		0·9	21·7	0·9	45·3	1·0	7	22	24	17
16-30		30·1		0·9		52·3		0·6	30·4	0·9	52·3	0·6	11	26	19	7
Dec. 1-15		18·3		1·1		38·3		0·4	22·0	1·1	38 3	0·4	7	23	28	5
16-31		1·9		0·8		19·5		0·5	17·9	0·8	20·0	0·5	6	7	22	9
TOTALS ..	43·5	179·5	2·3	8·9		643·3	6·4	10·3	425·7	12·2	706·1	18·1	130	310	226	32[illegible]
MEANS ...	− 5·7		− 0·3		− 26·8		− 0·2		17·7	0·5	29·4	0·8	...	...	...	...

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



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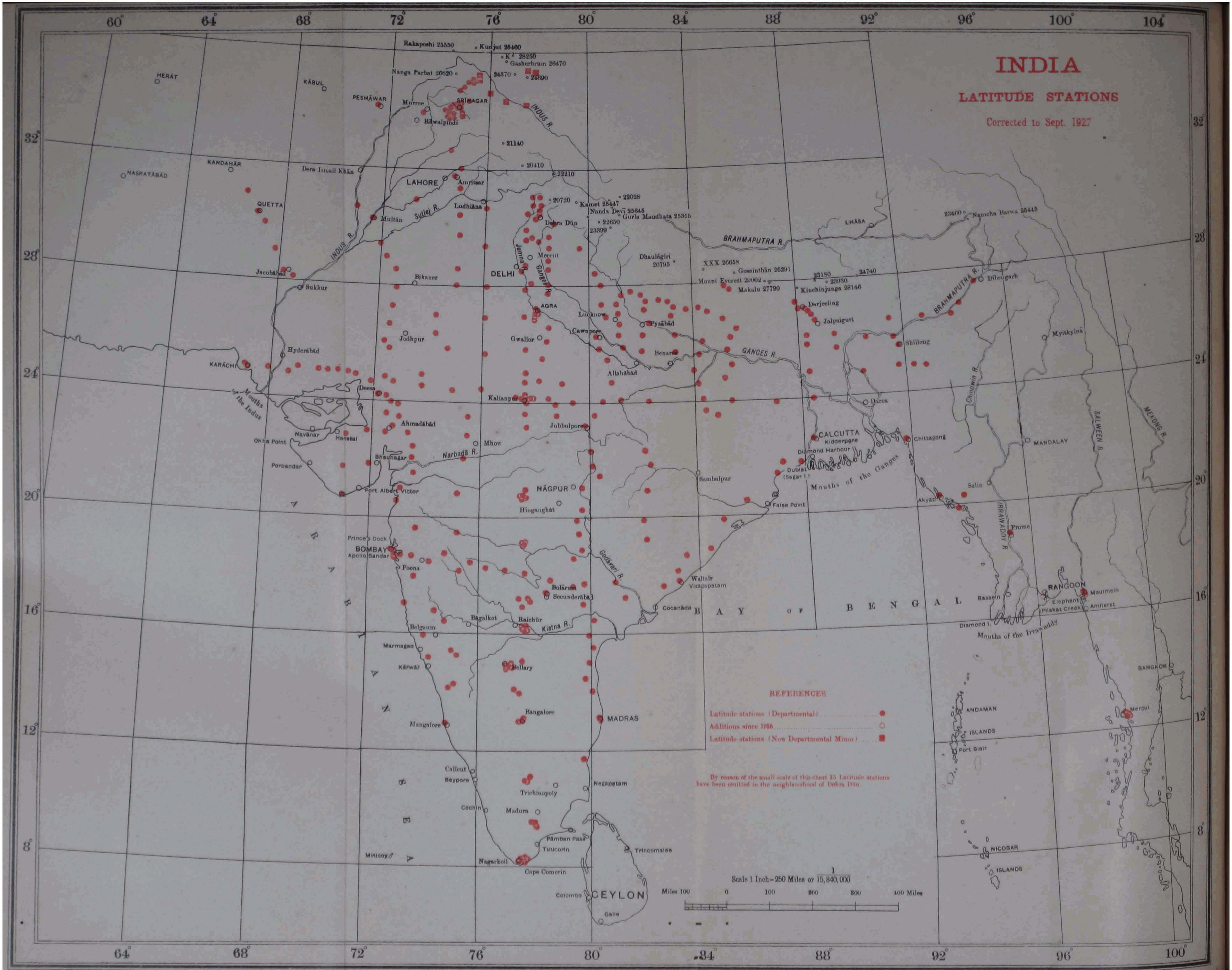

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CHAPTER V

GRAVITY AND DEVIATION OF THE VERTICAL

BY CAPTAIN G. BOMFORD, R.E.

(i) Computation of Hayford anomalies

1. Observations for latitude and gravity at identical stations.—The only gravity work undertaken during 1926-27 was the computation of the topographical and Hayford anomalies for the observations made by Captain E. A. Glennie, D.S.O., R.E., in Kashmīr in 1925.

At the majority of these stations gravity and latitude were observed at practically identical places, a fact which involves some change in the existing system of reduction, if one estimate of height is to serve for both. In the past the zones for latitude stations were so chosen that the ratio of each ring to the next was 1·426, while for gravity stations the zones were bounded by conveniently sized rings measured in round numbers of feet and miles. So long as gravity and latitude stations do not coincide, this system is the most convenient, but when they are coincident, its advantages do not outweigh the disadvantage of having to repeat the height estimates. In view of the complexity of the gravity tables, it was decided to retain the gravity zones and to use them for both reductions.

2. Zone factor.—The northerly deflection in seconds caused by a mass h feet high, bounded by arcs of radii r_1 and r_2, the radii being inclined at angles a_1 and a_2 to the meridian, is given by :—

$$D = 12''\cdot 44 \frac{\delta}{\Delta} h \,(\sin a_2 - \sin a_1)\, \log_e \frac{r_2}{r_1},^{*}$$ where $\frac{\delta}{\Delta}$ is the ratio of the surface density to the mean density of the earth. $\frac{r_2}{r_1}$ has been chosen equal to 1·426, and $\sin a_2 - \sin a_1$ equal to 0·25, resulting in the convenient relation $D = \frac{h}{10{,}000}$; so that $0''\cdot 01$ is recorded for every 100 feet in the average height of the compartment. In the gravity zones $\frac{r_2}{r_1}$ is not equal to 1·426, so that, after computing the effect of all the compartments in each gravity zone by the above rule, it is necessary to multiply the results by a "zone factor" equal to $\log \frac{r_2}{r_1} \Big/ \log 1\cdot 426$. This factor is given in Table 1. No reference is made to zones beyond zone 12, as the Hayford corrections for these zones can be obtained suffi-

* cf. Clarke's Geodesy pages 295-296.

ciently accurately by interpolation from stations which have already been reduced.

3. Height correction.—The formula quoted in § 2 involves three approximations. Firstly the curvature of the earth is neglected—as far as zone 12 no correction on this account is necessary. Secondly, the compartment is assumed to be everywhere of equal height: any departures from this approximation have been neglected in the past, and may continue to be neglected in future. Thirdly, a minor correction has to be applied, when the height of the zone above the station is not negligible in comparison with the radius of the earth. The formation of the new zones necessitates a recomputation of this correction. The formula is * :—

$$C = 12''\cdot 44 \frac{\delta}{\Delta} h (\sin a_2 - \sin a_1) \left[\log_e \frac{r_2 + \sqrt{r_2^2 + h^2}}{r_1 + \sqrt{r_1^2 + h^2}} - \log_e \frac{r_2}{r_1} \right].$$ This

approximates with sufficient accuracy to $C = \cdot 37 \frac{h^3}{r_2^2} \left(\frac{r_2^2}{r_1^2} - 1 \right)$ for one compartment. C is in seconds and h, r_2 and r_1 are in feet.

The correction for the new zones has been calculated by this formula. It should be noted that this correction must be applied after the total for each zone has been multiplied by the zone factor.

4. Hayford factor.—As Hayford has shown, compensation is allowed for by multiplying the effect of each zone by a factor dependent on the radii of the bounding arcs of the zone, and on the assumed depth of compensation. This Hayford factor, which must not be confused with the zone factor, defined above, is given by the formula † :—

$$\text{Hayford factor} = 1 - \frac{\log \dfrac{r_2 + \sqrt{r_2^2 + h_1^2}}{r_1 + \sqrt{r_1^2 + h_1^2}}}{\log \dfrac{r_2}{r_1}},$$ where h_1 is the assumed

depth of compensation. Taking h_1 as 70 miles, this has been computed for the gravity zones, and is given in Table 1.

TABLE 1.—*Zone factor and Hayford factor*

Zone	r_2	r_1	Zone factor	Hayford factor
	miles	*miles*		
12	399·0	298·5	0·816	0·018
13	298·5	210·8	0·979	0·036
14	210·8	177·1	0·490	0·058
15	177·1	151·9	0·433	0 082
16	151·9	132 2	0·389	0·095
17	132 2	116·5	0·354	0·125
18	116·5	103·6	0·332	0·159
P	103·6	60·0	1·538	0·254
O	60 0	32·0	1·771	0·469
N	32·0	20·0	1·324	0·658
M	20 0	12·0	1·440	0·782
L	12·0	8·0	1·142	0·863

* Hayford. Figure of the Earth and Isostasy page 34.
† Hayford. Figure of the Earth and Isostasy page 70.

TABLE 1.—*Zone factor and Hayford factor*—(*contd.*)

Zone	r_2	r_1	Zone factor	Hayford factor
	miles	*miles*		
K	8·0	5·0	1·324	0·908
J	5·0	3·0	1·440	0·945
I	3·0	2·0	1·142	0·963
H	2·0	1·5	0·810	0·976
G	1·5	1·0	1·142	0·983
F	1·0	0·5	1·954	0·990
E	0·5	1400 *feet*	1·788	0·996
D	1400 *feet*	600 ,,	2·388	0·996
C	600 ,,	200 ,,	3·097	0·999
B	200 ,,	10 ,,	8·442	1·000

5. Procedure when longitude is also observed.—In future years, gravity, latitude, and longitude may all be observed at one station, and the simultaneous computation of the meridian and prime vertical deflections will involve a further modification of the system. The simplification $\sin a_2 - \sin a_1 = 0 \cdot 25$ will have to be abandoned and the spacing of the bounding radii altered to 15° apart. Then in addition to the zone factor, there will be a "compartment factor" of $4 (\sin a_2 - \sin a_1)$, by which the effect of each compartment will have to be multiplied before the summation into zones. This factor will not be the same for both meridian and prime vertical deflections. In the former a_1 and a_2 will be measured from the meridian, and in the latter, from the prime vertical.

The present "height correction" (*vide* § 3) will also be different for each compartment, but it is very small and the following approximation will suffice. Use the formula as given above, and for the 12 compartments lying nearest the meridian (or nearest the prime vertical, for prime vertical deflections) take the correction as it stands; for the remaining compartments divide it by 3.

6. Gravity reduction.—For gravity stations the horizontal direction of an attracting mass is immaterial, and nothing more would be required than the mean height of each zone above the station, but for the fact that in the inner zones the effect of a zone or compartment does not vary linearly as this height, but more nearly as its square. Consequently it is only allowable to mean together the heights of compartments which lie at similar heights above the station. Inspection of the reduction tables immediately shows what range of heights may be meaned together in any particular case. The heights of various compartments having been meaned in groups in this way, the reduction tables are entered separately with each mean. The results are multiplied by the fraction of the whole zone which they represent, and are then summed to give the total effect of the zone. The variation of the Compensation tables is more nearly linear with height than that of the Topography tables, and more general means can consequently be taken before entering the tables.

7. Systematic error.—The fact noted above, namely that the effect of an inner zone depends not on its mean height above the station but more nearly on the root mean-square height, introduces a systematic error. Any process of finding the mean height whatsoever whether by estimating the mean height of a compartment or by the meaning of compartments into larger fractions of a zone, reduces the computed effect of the elements so meaned. An estimate has been made of the error likely to be caused by the system outlined above, and it is found that for the most uneven type of country (e.g., Murree) the systematic error is likely to be between ·001 & 003 cm/sec². Such an amount of error does not seriously affect the usefulness of the computation, but any increase over this amount requires to be guarded against.

8. Average height map.—For zones outside No. 12 (about 400 miles), the effect can be obtained by interpolation from stations already computed. To facilitate the computations for the larger zones inside this limit, Major E. A. Glennie is preparing an "average height map of India" showing the average height of each 30-minute square, carefully estimated once and for all from the best available maps. In the zones beyond zone P (103·6 miles) the root mean-square effect (*vide* § 7) is of no consequence, and the simple mean height of the zone is all that is required. With the help of the map, this is very easily obtained.

9. The results for Kashmir and Punjab, 1925.—Tables 2 & 3 show the results for the Kashmīr and Punjab latitude and gravity stations respectively. The heights have been estimated by Mr. Abdul Karim, B.A. The average height map has been used for zones 18 to 12.

TABLE 2.—*Latitude deflections in Kashmīr, 1925*
(referred to Everest's spheroid)

Station	Height	Longitude E	Geodetic latitude N	Seconds of Astronomical latitude N	Plumb-line deflection A − G*	Estimated Topo. deflection †	Estimated Hayford deflection	Hayford residual
	feet	° ′ ″	° ′ ″	″	″	″	″	″
Bāramūla ...	...	74 21 01·12	34 12 25	23·95	− 1	−42	− 2·54	+ 2
Shādipur ...	5193	74 41 00·35	34 11 12·59	56·70	−15·89	−44	−10·16	− 5·73
Gandarbal ...	5200	74 46 08·57	34 12 48·03	39·79	−18·24	−51	−16·46	− 1·78
Hayan ...	6084	74 58 28·94	34 13 54·49	33·68	−20·81	−49	−15·99	− 4·82
Sonāmarg ...	9050	75 16 19	34 18 03	51·15	−12	−38	− 8·29	− 4
Churawan ...	8151	74 54 00·01	34 39 31·69	15·64	−16·05	−42	−12·89	− 3·16
Minmarg ...	9351	75 04 34·57	34 47 30·21	22 67	−07·54	−33	− 8·00	+ 0·46
Deosai I ...	13311	75 14 41·24	34 57 20·76	21·20	+00·44	−26	− 5·10	+ 5·54
Deosai II ...	12805	75 23 46·32	35 02 03·82	11·78	+07·96	−24	− 5·59	+13·55

* A positive value of A − G denotes a southerly deflection of the plumb-line.
† Due to topography within 400 miles of the station only.

(continued)

TABLE 2.—*Latitude deflections in Kashmīr, 1925—(contd.)*

(referred to Everest's spheroid)

Station	Height	Longitude E	Geodetic latitude N	Seconds of Astronomical latitude N	Plumb-line deflection A − G*	Estimated Topo. deflection †	Estimated Hayford deflection	Hayford residual
	feet	° ′ ″	° ′ ″	″	″	″	″	″
Deosai III ...	12391	75 25 38·30	34 55 47·20	65·42	+ 18·22	−23	− 2·72	+ 20·94
Lālpur ...	5633	74 32 11·69	34 05 36·93	40·19	+ 03·26	−32	+ 1·06	+ 2·20
Srinagar ...	5198	74 49 27·27	34 04 36·61	19·42	− 17·19	−43	− 9·92	− 7·27
Pingalan ...	5227	74 55 59·16	33 54 22·49	06·32	− 16·17	−42	− 7·91	− 8·26
Yūs Maidān	7867	74 39 57·26	33 49 56·55	59·08	+ 02·53	−32	+ 2·84	− 0·31
Korag ...	10952	74 33 20·90	33 48 31·37	33·36	+ 01·99	−33	+ 2·25	− 0·26
Tosh Maidān	10315	74 29 58·13	33 55 17·33	19·01	+ 01·68	−27	+ 3·43	− 1·75

* A positive value of A − G denotes a southerly deflection of the plumb-line.

† Due to topography within 400 miles of the station only.

TABLE 3.—*Results of gravity observations in the Punjab and Kashmīr 1925*

Station	Latitude N	Longitude E	Height	γ_0	γ_A	γ_C	g	$g-\gamma_A$	$g-\gamma_C$
	° ′ ″	° ′ ″	feet	cm/sec²	cm/sec²	cm/sec²	cm/sec²	cm/sec²	cm/sec²
Wazīrābād ...	32 26 48	74 06 28	756	979·517	979·446	979·394	$979·39_4$	$-0·05_2$	$0·00_0$
Jhelum ...	32 55 20	73 42 41	764	979·556	979·484	979·418	$979·39_6$	$-0·08_8$	$-0·02_2$
Rāwalpindi	33 36 41	73 01 07	1754	979·613	979·449	979·393	$979·34_6$	$-0·10_3$	$-0·04_7$
Murree ...	33 54 07	73 23 15	6885	979·637	978·992	979·049	$979·02_4$	$+0·03_2$	$-0·02_5$
Domel ...	34 21 08	73 28 07	2239	979·675	979·465	979·346	$979·29_8$	$-0·16_7$	$-0·04_8$
Shādipur ...	34 11 14	74 41 00	5193	979·661	979·174	979·088	$979·05_9$	$-0·11_6$	$-0·03_0$
Gandarbal ...	34 12 48	74 46 09	5200	979·663	979·170	979·072	$979·08_2$	$-0·09_4$	$+0·01_0$
Hayan ...	34 13 54	74 58 29	6084	979·665	979·095	978·973	$978·99_0$	$-0·10_5$	$+0·01_7$
Sonāmarg ...	34 18 02	75 16 19	9050	979·671	978·823	978·765	$978·81_0$	$-0·01_3$	$+0·04_5$
Churawan ...	34 39 32	74 54 01	8151	979·701	978·937	978·849	$978·88_1$	$-0·05_6$	$+0·03_2$
Minmarg ...	34 47 30	75 04 49	9351	979·712	978·836	978·768	$978·80_3$	$-0·03_3$	$+0·03_5$
Deosai I ...	34 57 21	75 14 41	13311	979·726	978·479	978·535	$978·62_5$	$+0·14_6$	$+0·09_0$
Deosai II ...	35 02 04	75 23 47	12805	979·733	978·533	978·565	$978·62_7$	$+0·09_4$	$+0·06_2$
Deosai III ...	34 55 47	75 25 38	12391	979·724	978·563	978·579	$978·67_4$	$+0·11_1$	$+0·09_5$
Lālpur ...	34 05 37	74 32 12	5633	979·653	979·125	979·063	$979·08_0$	$-0·04_5$	$+0·01_7$
Srinagar ...	34 04 36	74 49 27	5198	979·652	979·165	979·074	$979·09_5$	$-0·07_0$	$+0·02_1$
Pingalan ...	33 54 23	74 55 59	5227	979·638	979·148	979·063	$979·07_5$	$-0·07_3$	$+0·01_2$
Yūs Maidān	33 49 57	74 39 57	7867	979·631	978·894	978·910	$978·91_8$	$+0·02_4$	$+0·00_8$
Korag ...	33 48 32	74 33 19	10952	979·629	978·603	978·718	$978·75_2$	$+0·14_9$	$+0·03_4$
Tosh Maidān	33 55 18	74 29 58	10315	979·639	978·673	978·758	$978·80_8$	$+0·13_5$	$+0·05_0$

NOTES.—$\gamma_0 = 978·030\ (1 + 0·005302 \sin^2 \phi - 0·000007 \sin^2 2\phi)$ cm/sec².

γ_A is γ_0 corrected for height (Free air)

γ_C is γ_A corrected for topography & compensation on Hayford's system.

g is the observed value of gravity.

(ii) Gravity in Kashmir

10. Discussion of results.—The following discussion is principally concerned with the gravity and latitude observations made by Major Glennie in 1925. Two of De Filippi's stations and two older stations of the Survey of India are also considered.

The stations are shown on Plate VIII.* The Hayford anomalies are given in Tables 4 & 5. The deflections are given with reference to three different spheroids, (a) the Everest spheroid, (b) the International spheroid, so oriented as regards the assumed deflections at Kaliānpur, as to make the best possible fit with the "compensated geoid"† in India and (c) the Survey of India spheroid No. II, namely that which best fits the Indian "compensated geoid". It will be noticed that, except in the north, the deflections relative to the International spheroid are generally of opposite sign to the Everest deflections. The Everest spheroid is not a satisfactory one, and there can be no doubt that either of the two latter spheroids should be accepted in preference to it.

The Hayford gravity anomalies are given with reference to Helmert's gravity formula of 1901. This also may be imperfect, but a better cannot be suggested‡. It is not possible to affirm that all the gravity results should not be changed, more or less equally, by as much as (say) 0·010 cm./sec^2 in either direction, but any much larger change would probably be inadmissible.

Then, taking the deflections with reference to the International spheroid, and the gravity anomalies with reference to Helmert's formula, we see that practically every deflection anomaly is to the south, and that practically every gravity anomaly (excluding the Punjab) is positive. Here is a fundamental contradiction. The north Punjab is an area of defect, (as is apparent from gravity observations there, and also from charts II & III of Dr. Hunter's address to the Indian Science Congress, 1928), and the southerly deflections in Kashmīr indicate that the "compensated geoid" falls lower and lower as we proceed into Kashmīr. The obvious deduction is that Kashmīr is an area of defect of gravity. But the positive pendulum anomalies deny this.

Plate IX Figure I shows the deflection anomalies generalised along the line of the section AB in Plate VIII. Stations far off the line have been omitted. To allow for the fact that total deflections probably lie at right angles to the line of the hills, the observed latitude deflections have been multiplied by a factor of 1·3 to convert them to deflections in the plane of the section.

Figure II (solid line) shows these deflection anomalies, integrated up to give a section of the compensated geoid. The datum of −20 feet at Ranjītgarh is taken from an unpublished chart, showing the compensated geoid in India, with reference to the International spheroid.

Figure III shows the gravity anomalies.

There is a possible explanation of the above contradictory results which is as follows:—Between Ranjītgarh and Korag there is a large gap which has been filled by assuming the deflection anomalies in the interval to be the same as the almost equal anomalies at the ends. This is an improbable assumption. Analogy with the rest of the outer

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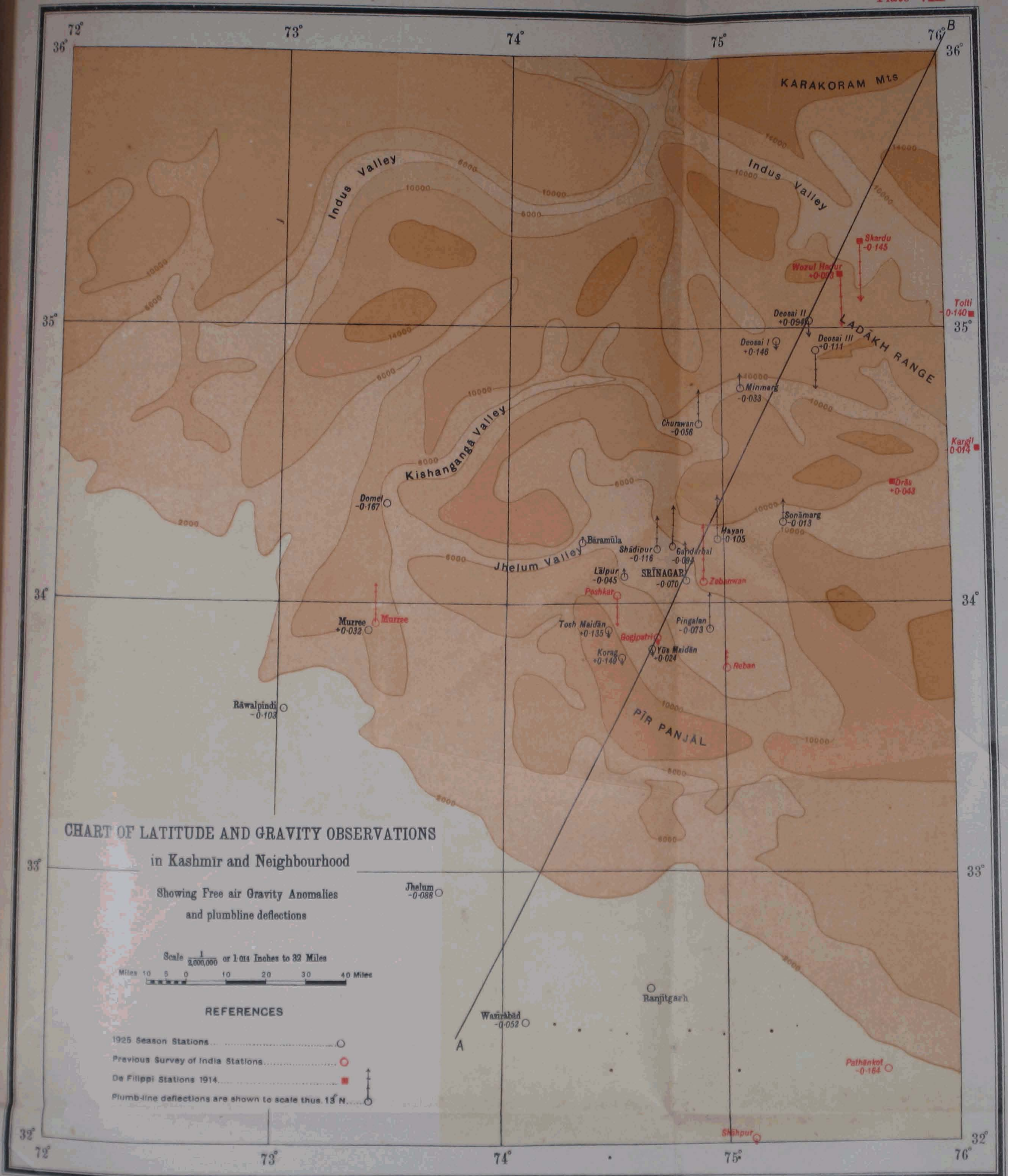
* From Geodetic Report Vol. I. *N. B.* The anomalies there shown are "Free air" and do not come into the present discussion.

† For "Compensated geoid", *vide* § 12.

‡ Introducing a coefficient of $\sin^2 \phi$ conformable with a flattening of 1/297, changes all stations about equally by ·004.

Plate VIII



Helio. S. I. O. Dehra Dūn

To accompany Geodetic Report Vol. III

KASHMĪR

Fig. I. Deflection Anomalies

Plate IX.

Hayford Compensation

Reference Figure is the international Spheroid with deflections at Kaliānpur of 3″·02 S & 3″·17 W i.e. as best fitted to the Compensated geoid in India

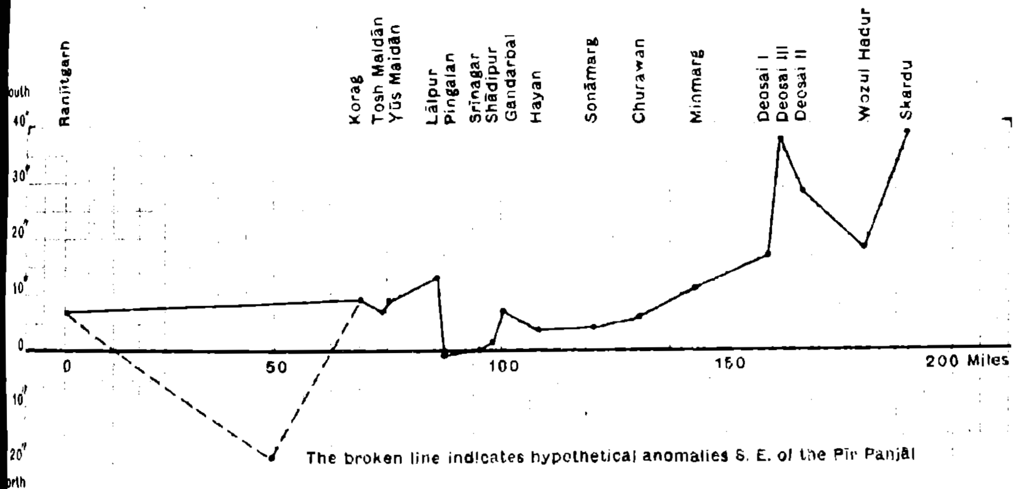


Fig. II. Geoidal Anomalies. Section of the Compensated geoid

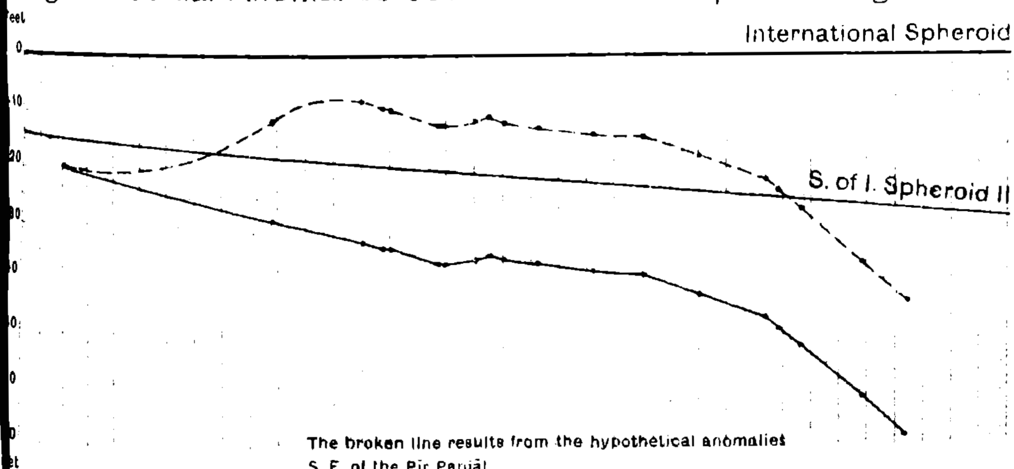
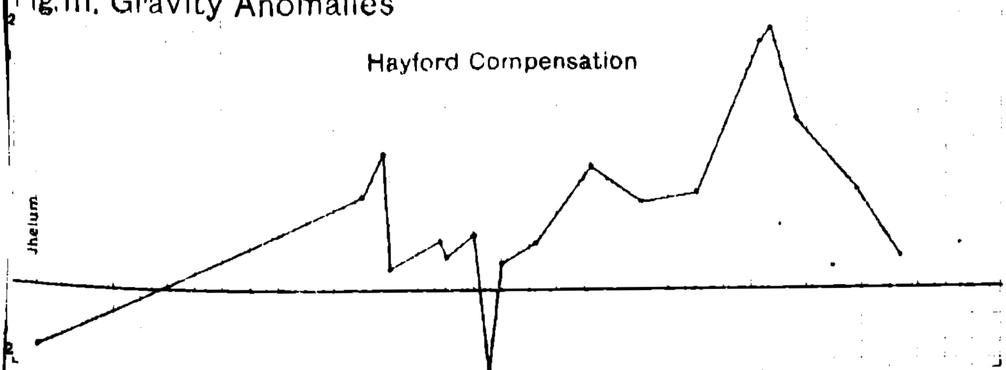


Fig. III. Gravity Anomalies

Hayford Compensation



No. 22 M. D. 1929 (C. O.) 81.-560

fringe of the Himālaya would suggest large northward anomalies in such a place. A small northward anomaly does occur at Murree, near by, and on the line of the section the outer range is more fully developed than at Murree. It is not unreasonable to assume a maximum anomaly of 15 seconds north* .

This assumption is shown in figure I with a broken line. The resulting corrected geoid is shown by a broken line in figure II. Kashmīr remains a depressed region, but this conformation could be produced by some excess density under the Pīr Panjāl and the Srīnagar valley, in combination with an overwhelming defect to the north.

If we reject the International spheroid and use the Survey of India spheroid II of 1927 instead, the observed southerly deflections are lessened (*vide* Table 4) and the initial geoidal depression at Ranjītgarh is also less†, namely 5 feet instead of 20 feet. This spheroid is shown by the second datum line in figure II. With reference to this datum, the broken line section is reasonable. We have defect in the Punjab and excess in Kashmīr in agreement with figure III. A large defect to the north is still indicated, of which we have no direct evidence, though it is not unreasonable. The Nepāl Himālaya has a great defect beyond its outer margin, and there may quite well be a similar‡ tendency on the SW. side of the Kara-koram.

A flaw in the argument is that the very large positive gravity anomalies observed on the Deosai find no counterpart in the geoidal section. We can only conclude that they are very local, a conclusion which is supported by the rapid changes in the deflection anomalies in these parts.

11. Conclusions.—Contradictions can be avoided if the following propositions can be admitted, but the propositions cannot be accepted as well established.

(1) Considerable northward deflection anomalies are likely to be found between Wazīrābād and the Pīr Panjāl pass. This is a point which could be fairly easily verified.

(2) The Kashmīr results agree well with those in the rest of India in being better fitted by the Survey of India spheroid II than by the International spheroid.

(3) The large anomalies under the Deosai are of very local extent and have little effect on the geoid.

(4) There is a large defect of density NE. of Skardu.

12. A note on the "compensated geoid".—Just as the geoid is an equipotential surface of the whole earth (reference spheroid, hills, compensation and anomalies), so is the compensated geoid the corresponding equipotential surface of the reference spheroid and anomalies only. Just as a geoidal section is obtained by integrating observed deflections. so is the compensated geoid obtained by integrating Hayford (or other) anomalies. Alternatively the height of the compensated geoid at a point may be obtained by calculating the potential, at that point, of all the surrounding topography and compensation, calculating the geoidal rise corresponding to such potential, and subtracting that rise from the height of the geoid. The latter is an easy computation. Tables have been prepared for it, and a chart showing the compensated geoid in India has been drawn.

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* cf. Dehra 19″ N., Kaulia (Nepāl) 18″ N, Kurseong 28″ N. These are with reference to Everest's spheroid and require reduction by about 4″ to change them to the International.

† From unpublished computations. It is the residual at point B in the solution for spheroid II.

‡ But far less extensive.

TABLE 4.—*Hayford residuals for latitude observations in Kashmīr & surrounding country*

Station	Authority for results	Hayford residual. Everest's spheroid	Hayford residual. International spheroid *	Hayford residual. Survey of India spheroid II†
		"	"	"
Ranjītgarh ...	Survey of India published	− 0·9	+ 5·3	+ 2·5
Murree ...	"	−10·4	− 3·6	− 6·3
Korag ...	Glennie 1925	− 0·3	+ 6·5	+ 3·8
Tosh Maidān ...	"	− 1·8	+ 5·0	+ 2·3
Yūs Maidān ...	"	− 0·3	+ 6·5	+ 3·8
Pingalan ...	"	− 8·3	− 1·5	− 4·1
Lālpur ...	"	+ 2·2	+ 9·1	+ 6·5
Bāramūla ...	"	+ 2·0	+ 9·0	+ 6·4
Srīnagar ...	"	− 7·3	− 0·4	− 3·0
Shādipur ...	"	− 5·7	+ 1·2	− 1·4
Gandarbal ...	"	− 1·8	+ 5·2	+ 2·6
Hayan ...	"	− 4·8	+ 2·2	− 0·4
Sonāmarg ...	"	− 4·0	+ 3·0	+ 0·4
Churawan ...	"	− 3·2	+ 4·0	+ 1·4
Minmarg ...	"	+ 0·5	+ 7·7	+ 5·2
Deosai I ...	"	+ 5·5	+12·8	+10·3
Deosai III ...	"	+20·9	+28·2	+25·7
Deosai II ...	"	+13·6	+21·0	+18·5
Wozul Hadur ...	De Filippi‡	+ 6·0	+13·5	+11·0
Skardu ...	" ‡	+21·0	+28·5	+26·0

* With deflections at Kaliānpur of 3″·02 S. and 3″·17 W. (i. e., as best fitted to the compensated geoid in India).

† a = 6,378,541. 1/ε = 292·4. Deflections 1″·98 S. and 2″·81 W. (i. e., the spheroid which best fits the compensated geoid in India).

‡ Preliminary value of the Hayford residual computed by the Survey of India.

TABLE 5.—*Hayford residuals for gravity observations in Kashmīr & surrounding country*

Station		Authority for results	Hayford residual
Wazīrābād	...	Glennie 1925	0·000
Jhelum	...	,,	−0·022
Rāwalpindi	...	,,	−0·047
Murree	...	,,	−0·025
Korag	...	,,	+0·034
Tosh Maidān	...	,,	+0·050
Yūs Maidān	...	,,	+0·008
Domel	...	,,	−0·048
Pingalan	...	,,	+0·012
Lālpur	...	,,	+0·017
Srīnagar	...	,,	+0·021
Shādipur	...	,,	−0·030
Gandarbal	...	,,	+0·010
Hayan	...	,,	+0·017
Sonāmarg	...	,,	+0·045
Churawan	...	,,	+0·032
Minmarg	...	,,	+0·035
Deosai I	...	,,	+0·090
Deosai III	...	,,	+0·095
Deosai II	...	,,	+0·062
Wozul Hadur	...	De Filippi *	+0·036
Skardu	...	,, *	+0·014

Standard gravity = 978·030 (1 + 0·005302 $\sin^2\phi$ − 0·000007 $\sin^2 2\phi$)

* Preliminary value of Hayford residual computed by the Survey of India.

CHAPTER VI

TRIANGULATION

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

1. General.—The triangulation commenced last year in Lower Burma on the Rangoon Series, was continued and completed by No. 15 Party. The series breaks off from the Burma Coast Series, where it crosses the Pegu Yoma hills, and extends southwards for a total length of 100 miles. Connections were made with No. 10 and 11 parties (topo), working to the east and west respectively, as a control for their minor triangulation; and a number of points were accurately fixed in Rangoon itself at the request of the Local Government.

The headquarters of the party was established at Pegu early in December and moved to Insein at the end of January, where it remained until work was completed in the middle of March when the party returned to Dehra Dūn.

2. Personnel.—The party took the field under Captain G. H. Osmaston, M.C., R.E., with 2 computers and 75 khalāsis. To avoid the heavy casualties experienced among the Dehra Dūn men in the previous season from malaria, all the menials, excepting a few skilled lampmen, were recruited from Hazāribāgh.

Mr. B. L. Gulatee was attached to the party for three months for instruction, and took charge of the reconnaissance.

3. Triangulation.—The new series consists of nine simple triangles running from the Burma Coast Series, starting in the north astride the forest clad Pegu Yomas and descending further south to the flat paddy fields of the delta, the terminal station being 20 miles south-west of Rangoon.

The difficulties of triangulating in this type of country, and the fact that the series was short, and incapable of great extension, made a simple chain of triangles preferable to more complicated figures. Definite connection with the minor triangulation of 1878 was made at one point only (Chanakpho h.s.), where the new value differs from the old by 3 feet in longitude and 28 feet in latitude. Several of the new stations were apparently close to the old sites of minor stations, but no mark could be found.

12-inch theodolite No. V by Troughton and Simms was used throughout the season. The graduation error of this instrument, as determined by comparison of readings of the same angles on different

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 = ±1·53

No.	Name of Series	Seasons	±*m*	±M
1	South Pūrasnāth Mer. ...	1831-39	3·308	3·26
2	Budhon Meridional ...	1833-43	2·242	2·46
3	*Amūa Meridional* ...	1834-38	1·647	1·88
4	*Rangīr 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	*Harilāong Meridional* ...	1848-52	1·502	1·92
22	*North-West Himālaya* ...	1848-53	0·641	0·55
23	*Garhāgarh 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	Kashmir Principal ...	1855-60	0·884	0·86
37	*Jogi-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, 1915-1916	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	Kohimā ...	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	0·83
98	Sind Sāgar Triangulation	1917-18	1·875	3·24
99	Rangoon ...	1925-27	1·246	1·25

Mer. = Meridional. Lon. = Longitudinal.

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To accompany Geodetic Report Vol. III

zeros, was unduly large. The mean value on one zero sometimes differed by as much as 8 seconds from that on another, and the graduation error accounted for 90 % of the 'probable error', in spite of observations always being taken on at least 12 different zeros.

This limitation, as well as the great weight of such an instrument, make it most desirable that new modern theodolites of much lighter design be tested with a view to their adoption for even the most precise triangulation. It remains to be seen whether small modern instruments with 3- or 4-inch circles are divided with sufficient accuracy to replace the older type.

The reconnaissance having been pushed well ahead during the last season, the work of observing progressed without interruption from the north; however on reaching the low-lying country round Rangoon in February the visibility became bad: owing to this, and the necessity for erecting towers and masts for observation purposes, the work then became rather slow.

The portable observation tower, designed by Dr. Hunter was employed. In this tower, the theodolite and observer are both supported by the same structure, but a system of independent stays and gimbals ensures that movements of the observer and tower are not imparted to the theodolite to any great extent.

This system has proved very effective, and, when tested at Dehra Dūn before starting for Burma, no difficulty was found in keeping the theodolite sufficiently level to take accurate vertical angles. On reading horizontal angles however, it was seen that the tower was inclined to twist, especially when sudden changes of temperature occurred, such as happen on a cloudy day with intervals of bright sunlight. This twist was never entirely eliminated, and the results show that the weight of an angle measured on the ground was four times that of one measured from the tower, but it is hoped that, by experiments, the results obtainable from such a tower will be improved. The convenience and economy effected show at once the tremendous advantage of a tower of this description over the old fixed trestle or masonry tower. It can be erected to a height of 60 feet in eight hours and the total weight is less than a ton.

Lattice-work masts 100 feet in height were used in ten-foot sections to support signals. A "Storm-King" pressure fed petrol lamp of about 500 c.p. was hoisted to the top at night and could be seen well up to 20 miles. It however failed on longer rays, owing to the mist. By day a new system was used, whereby the light of the sun was reflected by a helio situated on the ground, up to a second mirror fixed at the top of the mast, and thence to the observer. This method was very successful and should be of great use in close country, or when, on account of the hazy atmosphere or the length of the side, an opaque signal cannot be used. For details of the method *vide* § 7.

TABLE 1.—*Particulars of triangulation—Rangoon Series*

Serial No.	95
Name	Rangoon Series
Seasons	1925-27
Number of new stations built	9
Number of stations observed at	11
Number of triangles observed	9
Other figures observed	Nil
Length of triangulation in miles	105
Area of triangulation in sq. miles	2217
Mean length of side in miles	24·33
Average triangular error in seconds	1·57
m	1·246
M	1·25
Order of merit	54 B
Instrument used	12″ T & S No. V (17)
Number of intersected points fixed	35

4. Latitude observations.—An astronomical latitude was observed at Syriam station using the Talcott method with the 12-inch theodolite. The result showed a deflection of 6″·04 to the south, with a probable error of $\pm$ 0·67 of a second. The observations extended over 6 nights and included 55 distinct results, taken from 17 different pairs of stars. Stars from the Nautical Almanac alone were used.

5. Miscellaneous.—In spite of the locality being somewhat notorious for dacoities and other crimes, only two thefts, and these of minor importance, occurred, the inhabitants being everywhere most hospitable. It was impossible to avoid using old pagodas as stations to observe from, as every eminence was surmounted by a pagoda or shrine of some kind or other, some of which were in ideal positions. Objections were sometimes raised by the local people to permanent marks being left on a pagoda or shrine. In such cases a subsidiary station was built near by, although observations were actually taken from the top.

The district is malarious and a number of the personnel were affected during the season, but to nothing like the same degree as in the previous year, when adequate supplies of quinine were not taken.

Four elephants were lent to the party, while in the jungle, by Messrs Foucar & Co. and were invaluable for transport. Coolies were difficult to obtain in large numbers locally.

The climate of Lower Burma is suitable for principal triangulation from November till the end of March. In order to maintain figures of any size in the delta land, a tower and elevated signals are essential.

6. Heights.—Comparison of heights obtained by triangulation and other sources is given in Table 2, the heights of the former being fairly consistently a few feet lower than previous determinations, although at Kyanathpo (Chanakpho) the results are identical; at this station connection was made with a G. T. S. Bench-Mark a few feet away.

ELEPHANT TRANSPORT, PEGU YOMA JUNGLES.

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

TABLE 2.—*Comparison of heights*

(1) Station		(2) Height by 1926 Δⁿ.	(3) Height from other sources	(4) (3)−(2)
		feet	*feet*	*feet*
Taungnyo	H.S.	884·3	893 (Minor Δⁿ 1878)	+ 8·7
Mahazedi Pagoda	S.	232·6	237·4 (B.M. 1 mile distant)	+ 4·8
Kyanathpo	S.	154·7	168 (Minor Δⁿ 1878)	+13·3
,,	S.	154·7	154·7 (G.T.S. B.M.)	0·0
Syriam	S.	136·1	151·2 (Minor Δⁿ)	+15·1
Talokkon (Auxiliary Mark)	S.	4·0	10±5 (from P.W.D. B.Ms.)	+ 6±5

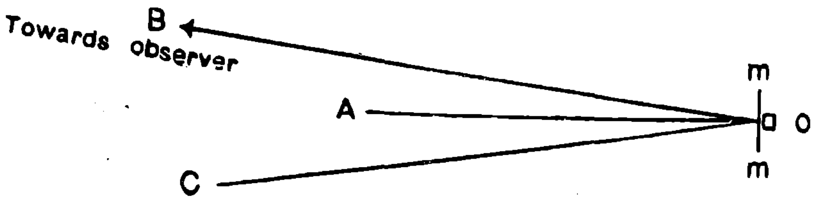
7. Note 1.—*Mast signals.*—To ensure accurate centering, a rocking arm was arranged at the top of the mast, which tilted up, when the lamp reached it, and allowed the lamp to be lowered on to a small bracket, a tapered spike on the bottom of the lamp exactly fitting into a hole in the bracket.

A 12-inch circular mirror was fixed directly below, tilted forward at some angle rather less then 45° with the vertical, and having its centre directly below the lamp hole.

When erecting the mast, the bracket and mirror were arranged so as to be on the side towards the observer.

To use the mirror as a heliograph, all that is necessary is to direct the sun's rays on to the upper mirror by means of a second large mirror on the ground, from a point where the observer's station is visible in the upper mirror.

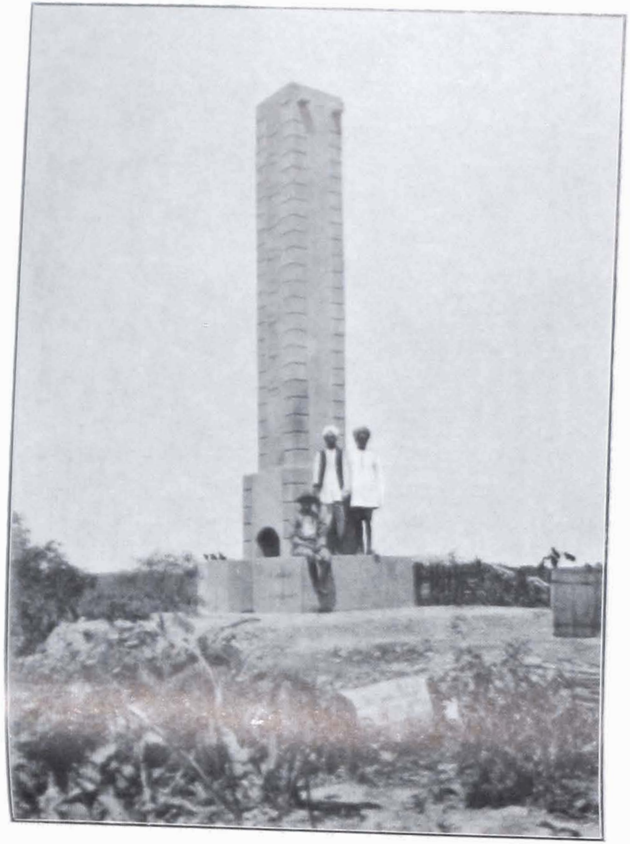
Fig. 1



In figure 1 the mast is shown in plan at 'O' and 'm m' represents the mirror at the mast-head. The problem is to find a point on the ground, from which the observer's station can be seen in the mirror m m. First, the position 'A' on the ground, where one's own reflection can be seen in the upper mirror, is found and marked with a peg. Using a plane-table or compass, the line 'O B', towards the observer, is then laid out. Now, in order to send light to the observer, using the mirror m m, clearly the source of light must be situated somewhere on the line O C, where the angle C O A = the angle AOB This line O C can easily be marked on the ground, and also a point found on it, from which the horizon is visible. From this position, or very near to it, the observer's station will be visible in m m.

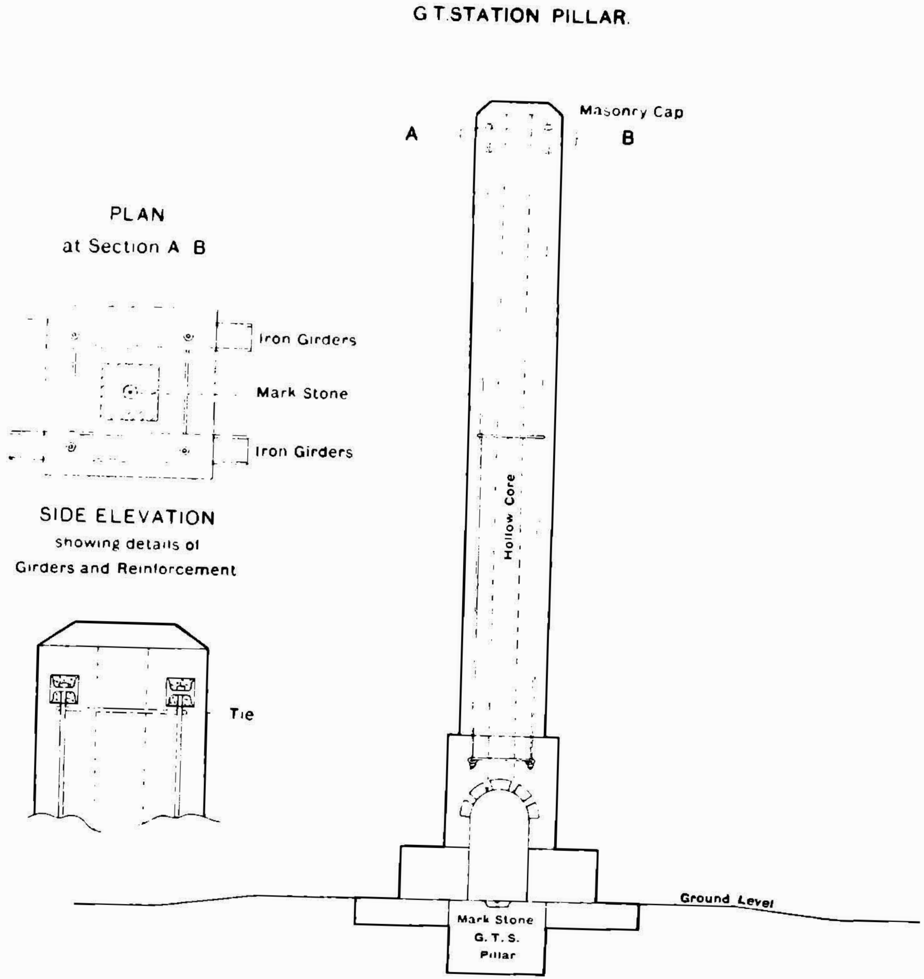
The procedure adopted was for the observer to shine a powerful helio in the direction of the mast, at a prearranged time. The lampman at the mast, having already found or been shown the approximate position from which he should see the observer's station, soon picked up the observer's light (by the method just described). Having once seen

PLATE XII.



G. T. PILLAR, KYANATHPO.

FIG. 3.



PLAN AND SIDE ELEVATION.

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

it, there was no further difficulty. He adjusted his ground helio at the same place and kept the light of the sun focussed on the top mirror, as long as required.

8. **Note II.**—*G.T. Pillar at Kyanathpo* (*Chanakpho*).—Observations at Kyanathpo (old Chanakpho) were taken from the Hunter tower, the instrument being 57 feet above the ground. This elevation was necessary to observe the rays to Taungnyo and Syriam, but, in any case, the station is surrounded by rubber plantations, and to see anything of the country for minor triangulation or plane-table work, the surveyor must be at least 20 feet above the ground.

A pillar of original design, of which a detailed description is appended, was therefore built over the old minor station. The dimensions of the pillar are shown in Fig. 3. The foundation was formed of Portland cement concrete, and the main core of first class brick, with concrete blocks at the four corners, reinforced with iron rods running up through them for the whole height of the pillar. These 4 rods pass through the flanges of two 'H' girders near the top and are secured to them with nuts. The 2 girders form projections, to which a platform can be tied very rapidly, and from which a triangulator or plane-tabler could work easily and comfortably, the plane-table or theodolite being entirely supported by the pillar. The centre of the pillar is hollow to allow for the accurate centering of a theodolite over the G. T. mark below, but the opening at the top is normally cemented over, as a protection from the weather. An arched opening at the base of the pillar gives access to the mark-stone, and metal rungs form a ladder to the top. The pillar was built entirely by Hazāribāgh khalāsis, the total cost of materials being Rs. 400. Fig. 2 is a photograph of the completed pillar.

CHAPTER VII

LEVELLING

BY N. R. MAZUMDAR

1. Organization.—No. 17 party was under the charge of Lt.-Colonel V. R. Cotter, I.A., until 1st May 1927 and then under the charge of Mr. N. R. Mazumdar up to the end of the survey year.

The field work of the party was divided between one main group for the Haveli irrigation project, and six detachments, as given in detail below. Field work on the Sutlej Valley project had been completed during the previous season, so the greater part of the personnel was diverted to the Haveli project, and this main group was at the same time re-entitled the Commercial Levelling Group. Work in this new area could not be commenced until January, when the rectangulation was sufficiently advanced, and field work continued until April. The other detachments of the party left Mussoorie for the field in October 1926; some returned to recess in April, but one stayed in the field until June, which is really too late for economical work.

(*a*) The Commercial Levelling Group under Mr. N. R. Mazumdar (Class II), with field headquarters at Multān, did the following levelling:—

Secondary levelling	...	...	313 miles
Tertiary double levelling	...	...	1,140 „
Tertiary single levelling	...	...	10,587 „

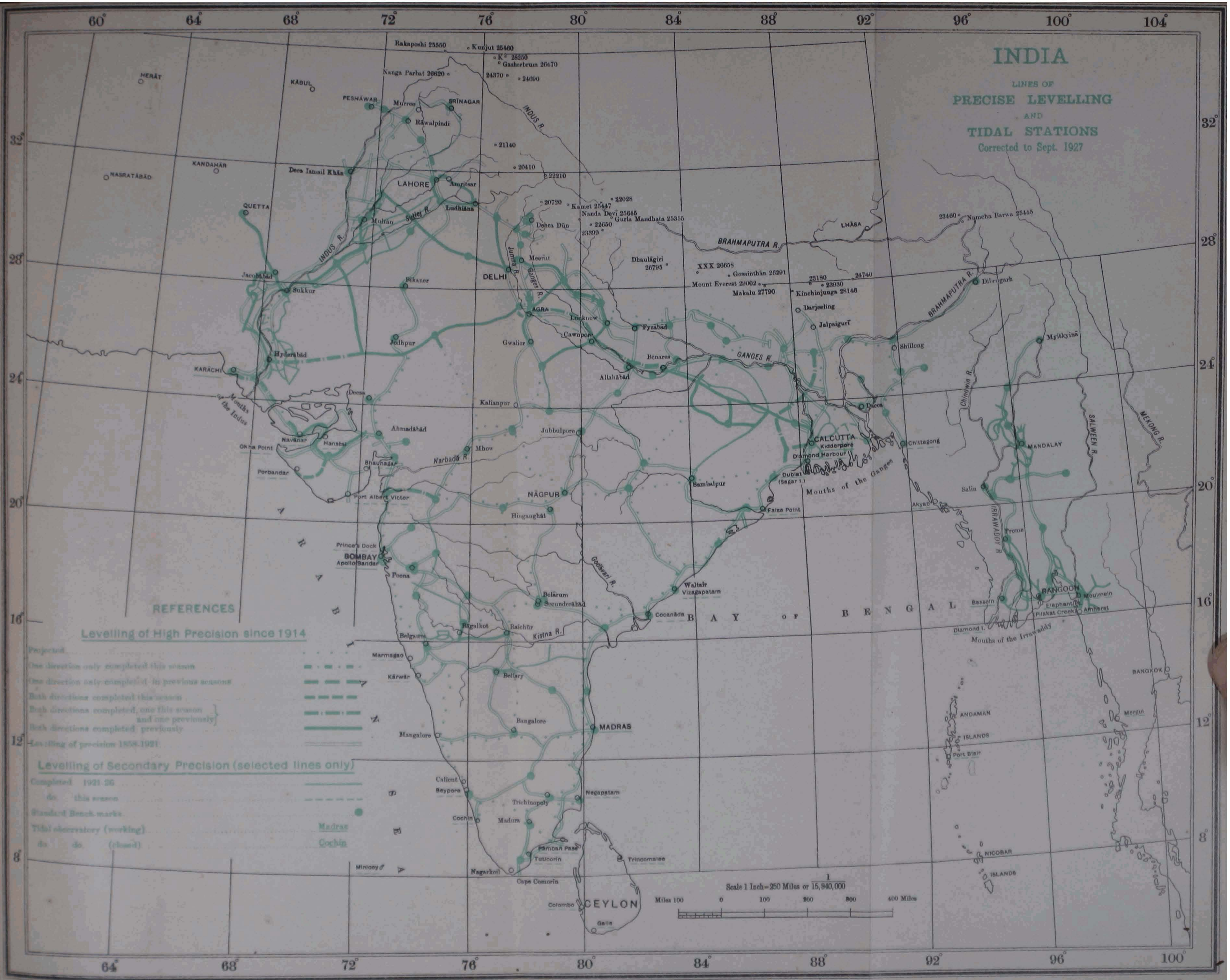
(*b*) No. 1 (single) detachment under Mr. I. K. Ponnappa (U.S.S.) did 38 miles of high precision levelling in the United Provinces and was then transferred to the Commercial Levelling Group.

(*c*) No. 2 (single) detachment under Mr. L. D. Joshi (U.S.S.) did 365 miles of high precision levelling in Sind and the Punjab.

(*d*) No. 3 (single) detachment under Mr. P. B. Roy (U.S.S.) did 422 miles of high precision levelling in Bombay.

(*e*) No. 4 (single) detachment under Mr. A. A. S. Matlub Ahmad (U.S.S.) did 457 miles of high precision levelling in the United Provinces.

(*f*) No. 5 (double) detachment under Mr. S. C. Mukerji (U.S.S.) did 550 miles of secondary levelling in the United Provinces and Bengal.



Published under the direction of Brigadier R. H. Thomas, D.S.O., Surveyor General of India.

HELIO. S.I.O. DEHRA DŪN

(g) No. 6 (double) detachment under Mr. D.H. Luxa (Class II) did 111 miles of secondary levelling in Burma.

Mr. K. K. Das (U.S.S.) was in charge of the computations at headquarters.

2. **Summary.**—The levelling completed consisted of:—

427 miles of high precision levelling in the fore direction.

854½ miles of high precision levelling in the back direction.

974 miles of secondary levelling.

11,727 miles of tertiary levelling, covering an area of 1905 square miles.

3. **Commercial Levelling Group.**—This group was employed in levelling for the Haveli canal project of the Punjab Irrigation Department. Mr. I. K. Ponnappa was in charge of the secondary levelling detachment and completed 313 miles of levelling with Mr. B. P. Rundev as second leveller. On completion of this work, the detachment was employed at headquarters for computations and preparation of charts.

The organization for tertiary levelling was as follows :—

Section	In charge	No. of Levellers	Area in	
			100-acre rectangles	25-acre rectangles
			sq. miles	sq. miles
1	Md. Faizul Hasan ...	14	42	437
2	Saiyid Nayar Hasan ...	12	324	317
3	Md. Ishak Khan ...	13	705	80
		Total ...	1071	834

The tertiary levelling was carried out on the same lines as in the Sutlej Valley project. Levelled heights were given to ground level at the corner stones of 25-acre and 100-acre rectangles, and also at intermediate points. Main rectangles were 25 miles by 15 miles. These were subdivided into 4 blocks, and double tertiary levelling was run round the sides of these blocks, connection being made to the tops of stones.

In previous seasons the staff had been placed directly on the top surface of the stones, but, as these surfaces are seldom horizontal, error was introduced when turning the staves from fore to back. To meet this source of error, conical brads were used this season. Plummets were also provided for the staves.

The rectangulation and levelling of this project were done in the same season. As the rectangulation was not sufficiently advanced when the levellers took the field, their progress was checked: it is most desirable that the rectangulation should be done a season ahead of the levelling.

The cost rate of this tertiary levelling, including the double tertiary control for 25-acre rectangles, was as follows. The cost rate for 100-acre rectangles would be half as much.

Nature of work	Cost per sq. mile	Cost per mile	Remarks
Field ...	Rs. 48·7	Rs. 6·3	Includes 14% for supervision and instrument charges.
Recess ...	,, 8·6	,, 1·1	
Total ...	Rs. 57·3	Rs. 7·4	

4. **No. 1 Detachment.**—This detachment under Mr. I. K. Ponnappa was employed on high precision levelling between Dehra Dūn and Mussoorie, taking temperatures at both staff and instrument. This special levelling was undertaken to assist Dr. Hunter in his investigation into refraction errors when levelling up continuous gradients.

The probable systematic error of this levelling worked out at ·00135 feet per mile; the permissible error is ·00106. The length of the line was 19 miles, in which there is a rise of 4,500 feet. To keep within permissible limits, the discrepancy between the fore and back levelling at the end of the line should not exceed 0·060 feet whereas the actual difference was 0·076 feet. If there is an undetermined difference of ·0001 feet between the length of the staves of the fore and back levellers, there would be a discrepancy of ·045 between the two levellers in the measurement of a height of 4,500 feet. Moreover, in a short line like this, it is doubtful whether accidental error will cancel out; the effect of these two causes might amount to ·060. To attain a high standard of precision in a short line with a large rise like this, it appears necessary to use staves made of a material such as invar, whose length can be very accurately determined and will remain constant.

On completion of the line, the detachment was transferred to the Commercial Levelling Group.

5. **No. 2 Detachment.**—This detachment under Mr. L. D. Joshi did the following levelling:—

(a) *Tatta-Nakhtarāna Mota* (part of new net-line 104 Viramgām-Tatta). Levelling in the fore direction was done from Tatta to Buhar, 66 miles; on arriving at Buhar it was found that on account of the season's heavy rain, the Rann of Cutch, through which the line passed, was flooded and impassable. The rest of the levelling of the line was therefore postponed until the next season. Heights of 5 primary and 57 secondary bench-marks were determined.

(*b*) *Parts of line 101 A.* Previous levelling over the new net-line 101 A (Hyderābād-Sukkur) had closed with an error of over a foot. Several parts suspected to be weak were now revised by Mr. Joshi but the revision has not disclosed any error. The whole line (168 miles) will be relevelled during the ensuing field season. 2 Primary protected and 99 secondary bench-marks were connected during the operation.

(*c*) *Amritsar-Lahore* (part of line 137 Ambāla to Lahore), and *Lahore to Wazīrābād* (part of line 136 Jhang to Lahore). This involved 116 miles of levelling connecting 16 primary and 132 secondary bench-marks; levelling was done in the fore direction only, back levelling will be done next season.

6. No. 3 Detachment.—This detachment under Mr. P. B. Roy did the following levelling :—

(*a*) *Rājkot-Porbandar in both directions* (*264 miles*). This is the new net-line 152. The route was along the Kāthiāwār Trunk road, the Shāpur-Saradiya branch of the Junagad State railway and the Kutiyāna-Porbandar road. 16 primary and 161 secondary bench-marks were connected. The fore levelling was done in the beginning and the back levelling towards the end of the season. The percentage of relevelment was 5°/₀.

(*b*) *Surat-Dhūlia* (*140 miles*). This is the new net-line 113; the route was along the road via Bārdoli, Kundaibāri Pass and the Tāpti Valley railway. 18 primary and 141 secondary bench-marks were connected. The fore levelling of the line was done in 1921-22, and the back levelling was done during the present season. The percentage of relevelment was 43°/₀, and in most cases the new work was found correct. The discrepancies are believed to be due to movements of bench-marks during the five years which elapsed between the fore and back levellings In future such a long interval should be avoided.

(*c*) *Check-levelling at Nāndgaon* (*4 miles*). To give a height to the standard bench-mark at Ahmadnagar a branch-line was run from Poona to Ahmadnagar in 1910-11. To strengthen the value of Ahmadnagar S.B.M., a line was run in 1921-22 from Nāndgaon via Manmād to Ahmadnagar; it closed with an error of 0·7 of a foot. In 1922-23, the line was continued up to Dhond. The circuit Poona-Ahmadnagar-Dhond had previously closed with an error of 0·05 of a foot which confirmed the value given to Ahmadnagar S.B.M. in 1910-11. The line Nāndgaon-Manmād-Ahmadnagar was adjusted provisionally, as no check-levelling was done at Nāndgaon in 1921-22. During this field season, check-levelling was carried out at that place; it was found that the bench-mark had not altered. It is proposed to accept the provisional adjustment and treat the line as a secondary one.

7. No. 4 Detachment.—This detachment under Mr. A. A. S. Matlub Ahmad did the following levelling:—

(*a*) *Muttra-Cawnpore.*—This is the new net-line 108. The route was by the Mainpuri-Agra-Muttra road, and then along the Ganges Canal. 18 primary and 272 secondary bench-marks were connected. The fore levelling had been done in 1925-26, and back levelling only was done during this season. The percentage of relevelment was 7°/ₒ.

Check-levelling at Agra showed that the S.B.M. at Agra has sunk by 0·1 of a foot.

(*b*) *Cawnpore-Benares.*—This is a part of the new net-line 119 (Cawnpore-Aurangābād). The route was along the Grand Trunk road, crossing the Ganges over the B.N.W. railway line at Allahābād. 18 primary and 229 secondary bench-marks were connected. Fore levelling had been done in 1925-26 and back levelling only was done during the present season. The percentage of relevelment was 6°/ₒ.

Levelling at Allahābād showed that the S.B.M has sunk by 0·15 of a foot.

8. No. 5 Detachment.—This simultaneous double levelling detachment under Mr. S. C. Mukerji levelled the following lines:—

(*a*) *Ghāziābād-Cawnpore* (*283 miles*) via Alīgarh and Tūndla along the E. I. railway line. This work was done for the E. I. railway. 6 primary and 307 secondary bench-marks were connected.

(*b*) *Khulnā-Mādārīpur* (*77 miles*) via Alaipur to Mollāhāt along the canal banks. 13 primary and 30 secondary bench-marks were connected.

(*c*) *Mollāhāt to Barisāl* (*97 miles*) via Kachuā along river banks and roads. 10 primary and 52 secondary bench-marks were connected.

(*d*) *Kachuā to Alaipur* (*62 miles*) via Morelganj along the river banks. 6 primary and 35 secondary bench-marks were connected.

The lines (*b*), (*c*) and (*d*) were done for the Government of Bengal.

(*e*) *Hastings-Dakhineswar*	11 miles
(*f*) *Hastings-Pujāli*	18 ,,
(*g*) *Levelling in Bally* (*Uttarpāra-Uttarpāra*)	2 ,,

The above 3 lines were done for the Calcutta Port Trust.

9. No. 6 Detachment.—This detachment under Mr. D. H. Luxa who was temporarily lent by the Officer in charge, Computing and Tidal Party, did the levelling of the following lines for the Burma Government:—

(a) *Thanatpin-Tongyi* (*26 miles*) via Ohne partly along railway line and partly along roads. 1 primary and 37 secondary bench-marks were connected.

Discrepancy with the old levelling at 12th mile ... ... — ·007 ft.

Discrepancy with the old levelling at 25th mile ... ... + ·014 ft.

(b) *Ohne-Thongwa-Ohne* (*85 miles*) via Kannyinaung-Simminaing and Kayan partly across country and partly along the railway line. 67 secondary bench-marks were connected.

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

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*
61A	Dehra Dūn-Mussoorie	± ·00278	± ·00135
113	Dhūlia-Surat	± ·00320	± ·00047
152	Porbandar-Rājkot	± ·00298	± ·00022
108	Muttra-Cawnpore	± ·00316	± ·00021
119	Cawnpore-Benares	± ·00289	± ·00004

Permissible probable accidental and systematic errors are ± ·00416 and ± ·00106 feet respectively. For remarks regarding the large systematic error in the Dehra Dūn-Mussoorie line *vide* § 4.

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

These are given below in foot and mile units:—

Detachment	Line	Probable error
No. 5 Dett.	Ghāziābād-Cawnpore	±·0029
"	Bally (Uttarpāra-Uttarpāra)	±·0027
"	Hastings-Dakhineswar	±·0016
"	Hastings-Pujāli	±·0022
"	Khulnā-Mādārīpur	±·0018
"	Mollāhāt-Barisāl	±·0021
"	Kachuā-Alaipur	±·0031
No. 6 Dett.	Thanatpin-Tongyi	±·0031
"	Ohne Thongwa-Ohne	±·0032
C.L. Group.	Garhmahārāja-Dāmāmiā	±·0042
"	Dāmāmiā-Aharbelā	±·0036
"	Rangpur-Muzaffargarh	±·0041
"	Muzaffargarh-Basti Malūk	±·0059
"	Shujābād-Sabuwālī	±·0038
"	Basti Malūk-Kabīrwāla	±·0038
"	Aharbelā-Multān	±·0036

11. Pamphlets.—No levelling pamphlets were published during the year but Nos. 39 and 41 and addendum slips for Nos. 35 and 40 are under publication. Secondary line 90 B situated in degree sheets 85 L and P was published.

12. Closure of circuits.—The new net circuit Agra-Hāthras-Bareilly-Sītāpur-Lucknow-Agra was completed during the year; it closed with an error of 0·125 of a foot in 527 miles.

A chain of new levelling from the referring bench-mark of Kidderpore Tidal Observatory to that of Karāchi Tidal Observatory was also completed by the shortest route via Aurangābād-Benares-Cawnpore-Muttra-Ajmer-Mārwār Pāli, Barmer and Kotri. This line closed with an error of −1·805 feet in 1663 miles between the old accepted heights above M. S. L. of the two referring bench-marks. In page 123 G.T. Vol. XIX it was explained that differences like these are no proof of differences of level of Bay of Bengal and Arabian Sea, but are due mainly to levelling errors. The difference is a large one, but, although the present levelling is of a higher degree of precision than the old levelling, it is premature yet to form any conclusion from it. Accidental error in a long line like this will have little effect and the systematic error per mile is therefore ±·00109 feet, which is rather large.

13. Progress of the new level net.—A list of new level net-lines with the mileages completed is given in Table 1.

14. Bench-marks.—It has recently been decided that the Survey of India can only be responsible for the maintenance of a limited number of bench-marks. About 1,000 reliable existing bench-marks have been selected and termed Primary Protected Bench-Marks. They occur at intervals of about 50 miles along all lines. Their numbers will be added to every year. The Survey of India will maintain these bench-marks, but will leave all others for the local authorities to maintain or not, as they wish.

Table 2 gives a list of these so far selected.

TABLE 1.—*Lines forming new level net of India as completed up to 1927*

Line No.	Name of line	Miles completed on main lines	Remarks
101	Karāchi-Khānpur (1920-23 & 24-26)	634	
102	Khānpur-Mārwār Pāli (1921-22 & 23-25)	363	
104	Viramgām-Tatta (1921-22 & 23-24)	347	Portion Nakhtarāna-Tatta not yet done.
105	Khānpur-Jhang (1914-15, 21-22 & 23-24)	255	
106	Jhang-Muttra (1915-16)	592	Portion Delhi-Muttra not yet done.
107	Muttra-Mārwār Pāli (1920-21)	323	
108	Muttra-Cawnpore (1925-27)	210	
109	Cawnpore-Bhopāl (1917-18)	143	Portion Jhānsi-Bhopāl not yet done.
113	Surat-Dhūlia (1921-22 & 26-27)	140	
118	Raipur-Aurangābād (1916-17)	60	Portion Raipur-Daltonganj not yet done.
119	Cawnpore-Aurangābād (1914-15 & 25-27)	308	
120	Aurangābād-Calcutta (1913-15 & 16-18)	334	
121A	Midnapore-Rānīganj (1924-26)	105	
137	Lahore-Ambāla (1919-20)	88	Portions Lahore-Amritsar & Ludhiāna-Ambāla not yet done
138	Ambāla-Delhi (1915-16)	122	
140	Muttra-Bareilly (1914-15)	107	Portion Muttra-Hāthras not yet done.
141	Bareilly-Rāmnagar (1919-20)	102	Portion Sītāpur-Rāmnagar not yet done.
142	Cawnpore-Rāmnagar (1915-16)	51	Portion Lucknow-Rāmnagar not yet done.
150	Kotri-Barmer (1924-26)	210	
151	Rānīganj-Dinājpur (1924-26)	239	
152	Rājkot-Porbandar (1926-27)	132	
153	Delhi-Bareilly (1914-15)	134	Portion Delhi-Meerut not yet done.
	Total ...	4999	

TABLE 2.—*List of Primary Protected Bench-Marks*

Degree sheet	No. of bench-mark
34J	21
34N	8
34O	21, 96
35L	1
35M	3, 4, 5, 6, 22, $23_{(2)}$, $28_{(1)}$, 59, 111
35N	1, 2, 59, 84
35P	3, 12, 67, 102, 109, 111, 114, 119, 160, 182
38L	14
38N	43
38P	1, 9, 12, 15
39D	6, 23, 56
39H	1, 4, 53, 69, 71, $98_{(27)}$, $103_{(17)}$
39I	1, 2, 18
39J	2, 4, 5, 6, $16_{(3)}$
39K	5, 7
39L	3, 5, 6, 7, 8, 9, 11, 15, 28, 58, 68, 87, 93
39M	1, 2, 3, 4, 5, 8, 12
39N	2, 3, 34, 51, $147_{(1)}$, 161
39O	2, 3, 4, 5, 7, 61, 86, 116, $178_{(21)}$, 179
39P	11
40A	78, 83, 84, 85, 86, 100, 101, 227, 228
40C	143, 152, 161, 187, $297_{(10)}$, $366_{(78)}$, 473
40D	1, 3, 6, 18, 29, 36, 59
40G	95, 147, 148, 202, 203, 210
40H	9
40I	2
40J	3
40K	12, 41, 49
40N	24
40O	23, 86, 222
41A	11, 14, 15, 16
41E	37, $52_{(49)}$, 56, 62, 107, 114, 120, 125
41F	29, 50, 51, 52, $59_{(14)}$, $61_{(1)}$
41G	32
41I	25, 27, 33, $42_{(16)}$, $44_{(15)}$, $52_{(10)}$, $57_{(8)}$, $64_{(3)}$
41J	76, $94_{(78)}$, $136_{(12)}$
41K	36, 73, 97
41M	9
41N	15, 68, $83_{(36)}$, 103
41O	7, 47
41P	5, 6
43C	1, 2, 5, 8, 52, 91
43D	1, 42, 44, 49, 51, 78, 101
43F	121
43G	57, 96, 128
43H	16, 35
43J	120
43K	10
43L	48, 72, 87
43O	58, 117
43P	15, 21
44A	6, 36, 71, 72
44B	19, 50
44C	3, 6, 12, 41
44E	12, 26, 46, 52, 57, 95
44F	2, 3, 17, 32, 36, 45, 80, 96, 148
44G	40
44H	15
44I	66, 139, 151, 175
44J	5, 42, 57, 98, 115, 165, 170, 218
44K	5, 44, 61, 66
44M	5, 34, 65
44N	15, 20
44O	19, 62
45C	15, 33
45D	84
45E	1, 46
45F	52
45G	1, 17
45H	14
45J	28, 90
45N	17, 55
46A	1, 12, 26, 52, 95, $103_{(7)}$
46B	1, 4, 12
46C	21, 70
46D	32, 45
46F	53, 111, 118
46G	18
46L	44, 66, 107, 113
46N	10, 40, 83
46O	16
46P	26, 34, 48
47A	29
47B	2, 9, 23
47E	87
47F	45, 53, 55, 64, 74, 92
47I	14, 40
47J	47, 157, 162, $257_{(11)}$, 271
47K	36, 75, 94, 121
47L	23, 108, 153
47N	36
47O	10, 50, 163
47P	14, 56
48E	4, 7, 21, 22
48I	23, 37, 96, 127
48J	45, 57, 59
48L	26

TABLE 2.—*List of Primary Protected Bench-Marks—(contd.)*

Degree sheet	No. of bench-mark	Degree sheet	No. of bench-mark
48M	1, 41, 42, 43	57J	14, 63
48P	47, 102	57L	3, 45, 100, 115
49M	17, 19, 20	57M	77
52D	53	57N	39, 88, 118, 125
53B	67, $73_{(22)}$, $113_{(15)}$, 135	57O	1, 5. 38, 109
53C	37, 58	57P	9, 23, 66
53D	32	58B	38, 106, 107
53E	29	58C	4, 5
53F	17, 40	58E	12, 36, 50, 69, 101
53G	19, 27, 41, 49, 63, 102, 156	58F	23
53H	83, 84, 214, 218, $375_{(7)}$, 409	58G	12, 31
53J	6, 9, 11, 57, 83	58H	22, 79, 80
53K	47, 100	58I	29
53L	50, 93, 179	58J	82, 125
53O	26	58K	2, 3, 8, 5, 18, 22, 40, 53
53P	31, 57, 126, 129, 142, 186, 305	58L	9
54A	5	58M	6, 17, 60
54B	31, 43	58N	1, 7, 10, 15, 19, 21, 39, 82, 83, 91, 95, 98, 107
54E	25, 137, 154	58O	6, 10, 24, 27, 29, 30, 34, 46, 47, 48
54F	4	62D	3, 16, 24, 63, 77
54G	4	63A	13, 14, 19, 26, 151, 208, 233, 247
54H	6, 8, 11, 13, 23	63B	64, 96, 168, 216
54I	7, 42, 61, 124, 162, 181, 183	63C	19
54J	10, 31	63D	41, 56
54K	51	63F	15, 19, 31, 43, 81, 95, 102, 107
54L	34, 49, 104	63G	55, 71, 81, $247_{(51)}$
54M	11, 107, $136_{(35)}$	63H	49, 70, 86
54N	9, 19, 192	63J	18, 24, 26, 35, 48, 64, 65, 82
54O	2, 5	63K	9, 58, 96, 174, 209
55A	2	63M	2, 10, 12
55D	4	63N	9, 19, 21, 32, 39, 57, 61, 71
55E	9, 23, 27, 34	63O	8, 18, 36, 51, 58, 59, 66, 94, 122
55H	3, 63, 70	64A	96, 137, 157
55I	32, 34	64C	12, 31, 72
55L	19, 44, 88	64E	13, 79
55M	9, 40, 104	64F	48
55N	2, 46	64G	75
55O	101, 148	64H	18
56C	1	64J	1, 13, 33, 58, 92
56D	32	64O	58, 84
56G	41, 58	65D	54, 55, 98, 163
56H	9, 30, 32, 55, 74	65H	17, 28
56I	4, 43	65I	6, 7, 17, 26, 27
56J	7, 26	65J	32
56K	7, 96, 103, 106	65K	40, 44
56O	15, 62, 79	65L	23, 24, 35
56P	1	65N	5, 34, 51, 131
57A	6, 72	65O	24, 28, 29, 30, 61, 71
57B	24, 25, 26	66A	64, $65_{(20)}$
57C	3, 9	66C	26, 28, 39, 64
57D	19, 28	72A	5, 10, 36, 61
57E	1, 73	72B	4, 18, 25, 39
57F	15	72C	3, 7
57G	1, 5, 76, 77, 78	72D	31, 100, 132
57H	21	72F	8, 16, 45, 49, 52, 68, 76, 89, 125, 143
57I	19, 83	72G	14, 20, $97_{(9)}$

TABLE 2.—*List of Primary Protected Bench-Marks—(concld.)*

Degree sheet	No. of bench-mark	Degree sheet	No. of bench-mark
72H	37, 45	79F	16
72J	11. 40, 46, 51	79I	38, 70, 77
72K	9	79J	33
72N	1, 5	79M	6, 17, 33
72O	15, 26, 176, 177	79N	1, 12, 33, 58
72P	37	83B	14, 55
73A	41, 53	83D	2, 21, 72, 84, 107, 111
73B	6	83F	40
73D	15, 82	83I	69
73E	17, 124	83J	52,58
73F	19, 72	83P	8
73H	43, 177. 194	84L	19, 61
73I	22, 122	84M	8, 40
73K	78	84N	15, 31, 170, 172
73L	45, 47. 48. 84	84O	1, 15
73M	35, 115, 128, 236	84P	12, 40, 67
73O	4, 26, 35, 45, 54	85L	10
74A	53	85M	16
74B	18, 44	85N	1, 20, 41, 104
74E	20, 35	85O	34, 176, 311, 339
78B	7, 18, 29, 33, 42, 87	85P	4, 135
78C	51, 86, 99, 118, 135, 155 (77)	92C	6
		92D	28
78D	39, 94, 147, 154. 160, 181, 198, 12.	92G	18
	220, 229, 242, 251	93B	2
78F	40, 46	93C	18, 68
78G	4, 41	93D	31, 90
78K	4	93H	1
78L	4, 72	94A	4, 64
78N	16	94B	5, 32, 85, 90
78O	62, 109	94C	32, 159
78P	8, 13, 36, 43, 46, 85	94D	15, 17, 18, 32
79A	40, 135, 147, 167, 178, 197, 204,	94G	9
	212, 228, 263	94H	21, 22, 24, 37, 105 10
79B	7, 368, 468, 536, 547	95I	1
79E	4, 52, 67, 75, 84, 102, 120, 130,		
	170, 178, 189		

TABLE 3.—*Tabular statement of out-turn of work, season 1926-27*

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)	Falls (feet)	Mean number of stations at which the instruments were set up	Number of bench-marks connected: Primary: Musto's type old	Musto's type new	Standard old	Standard new	Primary stations of triangulation old	Primary stations of triangulation new	Interred old	Interred new	Secondary: Rock-cut old	Rock-cut new	Inscribed old	Inscribed new	P. W. D. old	P. W. D. new	Railway old	Railway new	Embedded old	Embedded new
No. 1 Detachment																															
Part of line 61A Dehra Dūn to Mussoorie (1) (fore and back)	Sept. 26 to Oct. 26	19	43	62	...	...	..	19	43	62	4793·163	286·922	836	..	..	2	..	2	..	...	...	12	7	*4	35	...	...	...	...	...	...
	May. 27	18	65	10	...	...	...	18	65	10	4705·781	201·710	826																		
No. 2 Detachment																															
Part of net-line 104 (2) Portion Tatta-Mughalbhin-Bulhar (fore)	Oct. 26 to Nov. 26	46	22	38	19	28	76	65	51	14	255·980	305·477	822	...	...	1	.	1	3	..	.	...	1	22	30	...	...	...	...	4	...
Revision of 4 scattered bits in net-line 101A (3) Sukkur-Hyderābād (fore & back)	Dec. 26 to Mar. 27	183	44	20	..	...	..	183	44	20	836·855	887·634	2275	2	...	.	..	..	...	..	..	..	..	94	..	..	...	...	...	5	...
Part of line 137 (Lahore to Ambāla) Portion Amritsar to Lahore (fore)	Mar. 27 to Apr. 27	33	20	90	13	43	10	46	64	00	171·875	220·867	542	..	..	1	...	1	..	7		...	...	10	33	...	3	...	.	..	...

(1) Relevelled 4 mls. 19 chs. 18 lks. (2) Relevelled 0 ml. 55 chs. 98 lks. (3) Relevelled 15 mls. 4 chs. 56 lks. * Iron plug.

TABLE 3.—*Tabular statement of out-turn of work, season 1926-27*—(*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: Musto's type old	new	Rock-cut old	Protected new	Standard old	new	Primary stations of triangulation old	new	Interred old	new	Secondary: Inscribed old	new	P. W. D. old	new	Railway old	new	Embedded old	new
No. 2 Detachment (contd.)																															
Part of net-line 136 (Jhang to Lahore) (4) Portion Lahore-Wazīrābād (fore)	April 27 to May 27	64	36	90	4	13	10	69	50	00	463·996	419·773	744	...	6	...	...	...	...	...	...	1	...	8	71	...	2	2	...	3	...
No. 3 Detachment.																															
Net-line 152 Rājkot to Porbandar (5) (fore and back)	Oct. 26 to Dec. 26	132	23	36	2	18	34	134	41	70	1392·010	1799·391	1490	...	...	1	5	1	2	...	2	1	4	11	150	...	..	...	...	..	...
	Dec 26, April and May 27	132	60	04	2	79	84	135	59	88	1377·164	1784·371	1378																		
Net-line 113 Surat to Dhūlia (back) (6)	Jan. 27 to April 27	139	38	94	12	10	80	151	49	74	2722·686	1906·095	1736	...	...	...	...	2	...	...	...	1	15	17	124	..	...	...	...	...	...
Check-levelling at Nāndgaon	Jan. 27	...	...	...	3	68	98	3	68	98	...	..	48	...	...	.	...	...	...	...	...	1	...	4	2	...	...	...	...	...	...
No. 4 Detachment.																															
Net-line 108 Muttra to Cawnpore (7) (back)	Jan. 27 to April 27	209	78	16	26	79	24	236	77	4	1689·216	1536·196	2396	...	...	..	...	3	1	3	...	11	...	23	119	11	117	...	1	1	...

(4) Relevelled 1 ml. 26 chs. (5) Relevelled 7 mls. 43 chs. 60 lks. (6) Relevelled 69 mls. 46 chs. 20 lks. (7) Relevelled 18 mls. 42 chs. 56 lks.

TABLE 3.— *Tabular statement of out-turn of work, season 1926-27*—(*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: Musto's type old	new	Rock-cut Protected old	new	Standard old	new	Primary stations of triangulation old	new	Intorred old	new	Secondary: Inscribed old	new	P. W. D. old	new	Railway old	new	Embedded old	new
No. 4 Detachment—(contd.) Part of net-line 119 (Cawnpore to Aurangābād) (8) Portion Cawnpore to Benares	Oct. 26 to Jan. 27	204	03	08	15	65	14	219	68	22	1111·632	961·116	2184	...	..	...	...	3	1	2	...	12	...	22	201	1	5	...	...	...	...
At Ghāziābād	April 27	1	47	18	0	13	96	1	61	14	37·658	22·319	28	...	...	..	..	...	...	...	...	...	1	4	1	1	...	...	...	1	...
No. 5 Detachment																															
Ghāziābād to Cawnpore	Oct. 26 to Jan. 27	273	62	80	8	65	70	282	48	50	1317·745	1585·014	2598	...	..	.	..	1	...	1	1	2	1	12	293	...	...	...	...	2	...
Khulnā to Mādārīpur	Jan. & Feb. 27	71	46	00	5	59	70	77	25	70	354·661	350·840	556	...	...	...	...	...	...	...	1	3	9	6	21	1	1	...	...	...	1
Mollāhāt to Barisāl	Feb. & Mar. 27	70	10	90	26	15	60	96	56	50	231·141	227·546	662	...	...	...	...	1	...	...	...	2	7	7	45	..	...	.	...	...	.
Kachuā to Alaipur	Mar. & April 27	56	27	20	5	43	70	61	70	90	173·999	170·394	408	...	...	..	...	...	...	...	...	2	4	...	31	...	4	...	...		...
Uttarpāra to Uttarpāra R.S.	April 27	2	35	00	...	...	...	2	35	00	29·385	27·890	34	...	...	...	...	...	..	...	...	1	..	7	1	...	...	...	...	...	...

(8) Relevelled 13 mls. 30 chs. 66 lks.

TABLE 3.— *Tabular statement of out-turn of work, season 1926-27—(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: Musto's type old	new	Rock-cut Protected old	new	Standard old	new	Primary stations of triangulation old	new	Interred old	new	Secondary: Inscribed old	new	P. W. D. old	new	Railway old	new	Embedded old	new
No. 5 Detachment.—(contd.)																															
Hastings to Dakhineswar	April 27	11	22	10	...	...	...	11	22	10	84·133	94·918	120	...	1	...	...	...	...	...	...	...	.	10	5	...	1	..	...	1	...
Hastings to Pujāli	April 27	17	51	20	...	...	...	17	51	20	110·076	127·866	150	...	5	...	...	...	...	.	...	...	...	6	9	...	...	...	...	...	...
No. 6 Detachment.																															
Thanatpin to Tongyi	Jan. & Feb. 27	25	33	58	1	27	40	26	60	98	180·124	178·121	301	...	...	...	...	..	...	.	..	1	...	4	28	...	3	...	..	2	...
Ohne to Thongwa and Ohne	Jan. & Feb. 27	81	79	76	2	42	20	84	41	96	300·154	300·239	882	...	...	...	...	...	.	...	...	...	...	.	45	...	6	...	...	...	16
C. L. Group.																															
Garhmahārāja to Dāmāmiā	Nov. 26	53	75	14	0	59	50	54	54	64	210·500	202·951	540	...	...	...	...	...	...	...	...	...	..	4	51	...	...	.	...	5	5
Dāmāmiā to Aharbelā	Nov. & Dec. 26	35	43	00	1	18	00	36	61	00	128·214	169·131	292	...	...	...	...	...	...	...	...	...	...	3	30	...	...	..	...	3	3
Rangpur to Muzaffargarh	Dec. 26	46	19	50	6	49	50	52	69	00	237·837	281·999	434	...	..	.	...	...	...	...	...	.	..	2	46		...	...	.	3	2
Muzaffargarh to Basti Malūk	Dec. 26	38	05	50	1	65	00	49	70	50	265·636	276·365	454	...	...	...	...	...	...	...	.	...	.	...	44	...	...	.	...	3	4

TABLE 3.—*Tabular statement of out-turn of work, season 1926-27*—(*concld.*)

Detachments and lines levelled	Months	Distance levelled									Total number of feet		Mean number of stations at which the instruments were set up	Number of bench-marks connected																	
		Main line			Extras and branch lines			Total			Rises	Falls		Primary										Secondary							
														Musto's type		Rock-cut Protected		Standard		Primary stations of triangulation		Interred		Inscribed		P. W. D.		Railway		Embedded	
		Mls.	Chs.	Lks.	Mls.	Chs.	Lks.	Mls.	Chs.	Lks.	feet	feet		old	new	old	new	old	new	old	new	old	new	old	new	old	new	old	new	old	new
C. L. Group. —(contd.)																															
Shujābād to Sabuwālī	Dec. 26	22	31	00	...	...	...	22	31	00	93·054	118·463	196	...	...	...	...	...	...	...	...	...	...	...	22	...	...	...	...	1	1
Basti Malūk to Kabīrwāla	Dec. 26 to Jan. 27	61	64	00	...	...	...	61	64	00	275·390	222·862	538	...	...	...	...	...	...	...	...	...	...	10	44	...	...	...	...	2	6
Aharbelā to Multān	Jan. 27	33	52	00	...	...	...	33	52	00	163·881	188·178	332	...	...	...	...	1	...	...	...	...	...	6	31	...	...	...	...	1	3

TABLE 4.—*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 1926-27 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1926-27	
			miles		*feet*	*feet*	*feet*
		Line 104 (Viramgām-Tatta) at Tatta					
182	35 P	S.B.M. ...	0·0	1924-25 1925-26	0·000	0·000	0·000
185	,,	Stone prism ...	0·0	,,	− 0·791	− 0·792	−0·001
184	,,	,, ...	0·0	,,	− 0·749	− 0·749	0·000
183	,,	Iron bolt ...	0·0	,,	+ 0·119	+ 0·097	−0·022
186 (68)	,,	G.T.S. □ B.M. at Makli hills ...	0·2	,,	+ 8·272	+ 8·273	+0·001
181 (72)	,,	G.T.S. ○ B.M. ,, ,, ...	0·2	,,	+ 6·594	+ 6·590	−0·004
187 (69)	,,	Bridge ...	0·4	,,	−19·878	−19·877	+0·001
188	,,	,, ..	1·3	,,	−24·385	−24·396	−0·011
189 (70)	,,	Step ...	2·0	,,	−17·138	−17·151	−0·013
190	,,	Hospital ...	2·1	,,	−18·858	−18·874	−0·016
		Line 137 (Lahore-Ambāla) at Amritsar					
139	44 I	Interred ...	0·0	1909-10	0·000	0·000	0·000
142	,,	Gate ...	1·0	,,	+ 4·699	+ 4·693	−0·006
151	,,	Mark stone ...	3·2	,,	+ 2·053	+ 2·045	−0·008
138	,,	Bridge ...	1·5	,,	− 1·252	− 1·243	+0·009
137	,,	Pedestal ...	2·1	,,	− 0·942	− 1·004	−0·062
136	,,	Pavement ...	2·2	,,	− 1·117	− 1·176	−0·059
		Line 137 (Lahore-Ambāla) at Lahore					
66	44 I	Standard ...	0·0	1913-14	0·000	0·000	0·000
64	,,	Step ...	0·1	,,	− 1·436	− 1·483	−0·047
63	,,	Doorway ...	0·2	,,	− 0·197	− 0·235	−0·038
74	,,	Interred ...	7·6	,,	− 5·735	− 5·765	−0·030
75	,,	,, ...	8·1	,,	− 5·293	− 5·326	−0·033
72	,,	,, ..	8·7	,,	− 4·874	− 4·916	−0·042
60	,,	,, ...	9·2	,,	− 3·137	− 3·173	−0·036

TABLE 4.—*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 1926-27 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1926-27	
			miles		*feet*	*feet*	*feet*
		Line 136 (Jhang-Lahore) at Wazīrābād					
48	43 L	Interred ...	0·0	1922	0·000	0·000	0·000
47	"	Curb ...	1·2	"	+ 4·849	+ 4·835	−0·014
46	"	Heel ...	1·7	"	+ 4·870	+ 4·885	+0·015
45	"	Abutment ...	2·1	"	+14·991	+14·992	+0·001
		Line 152 (Rājkot-Porbandar) at Rājkot					
76	41 J	Standard at Rājkot ...	0·00	1921-22 1923-24	0·000	0·000	0·000
77	"	Boundary pillar ...	0·32	"	−17·556	−17·562	−0·006
94 (78)	"	(Type C) at Rājkot ...	0·64	"	−23·625	−23·618	+0·007
93 (42)	"	Clock tower Rājkot ...	0·17	"	− 7·582	− 7·586	−0·004
92 (75)	"	(Type B) at Rājkot ...	0·46	"	−19·089	−19·087	+0·002
86 (74)	"	G.T.S. O B.M. at Carnegie fountain	0·52	"	−15·955	−15·953	+0·002
87 (73)	"	G.T.S. O B.M. at museum ...	0·81	"	− 9·266	− 9·267	−0·001
88 (72)	"	G.T.S. O B.M. at telegraph office ...	0·87	"	−10·341	−10·341	0·000
89 (40)	"	G.T.S. O B.M. at high school ...	1·00	"	−10·348	−10·348	0·000
90 (71)	"	O at Rājkumār college	1·48	"	+ 0·564	+ 0·570	+0·006
91 (41)	"	G.T.S. O B.M. " "	1·51	"	+ 1·585	+ 1·588	+0·003
		Line 152 (Rājkot-Porbandar) at Porbandar					
43	41 G	G.T.S. □ B.M. at sea wall	0·00	1898-1902	0·000	0·000	0·000
44	"	G.T.S. B.M. B at sea wall ...	0·46	"	+11·230	+11·212	−0·018
45	"	□ G.T.S. B.M.C. at Tidal observatory ...	0·65	"	+ 1·341	+ 1·338	−0·003

TABLE 4.—*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 1926-27 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1926-27	
			miles		*feet*	*feet*	*feet*
		Line 33A (Nāndgaon-Ahmadnagar) at Nāndgaon					
44	46 L	Type B at Nāndgaon R.S.	0·00	1921-22	0·000	0.000	0 000
151	,,	G.T.S. O B.M. ,, ,, ,,	0·16	,,	+ 0·874	+ 0·873	−0·001
150	,,	,, ,, ,, I.B.	0·16	,,	+ 0·437	+ 0·438	+0·001
152	,,	G.T.S. O B.M. on bridge, T.P. 178/15	1·36	1926-27	...	−26·069	...
86	,,	G.T.S. O .M.H ,, ,, 179/13	2·26	1921-22	− 2·369	− 2·389	−0·020
153	,,	B.O.M. ,, ,, 180/12	3·21	1926-27	...	−22·925	...
87	,,	G.T.S. O B.M ,, ,, 181/2	3·71	1921-22	−40·510	−40·506	+0·004
		Line 113 (Surat-Dhūlia) at Dhūlia					
107	46 L	Standard at Dhūlia ...	0·00	1877-78 1883-84	0·000	0·000	0·000
147 (106)	,,	G.T.S. O B.M. at school ...	0·26	,,	− 5·482	− 5·491	−0·009
148 (108)	,,	,, at clock tower ...	0·53	,,	− 2·962	− 2·976	−0·014
109	,,	,, at Circle Inspector's office ...	0·66	,,	+ 2·246	+ 2·240	−0·006
110	,,	,, at Marathi school ...	0·85	,,	+11·279	+11·272	−0·007
77	,,	,, on bridge near M.S. 211 ...	1·01	,,	+ 8·628	+ 8·634	+0·006
76	,,	,, on M.S. 59 ...	1·21	,,	+12·946	+12·940	−0·006
111	,,	,, on rock near bridge No. 68 ...	2·06	,,	+37·563	+37·558	−0·005
149 (75)	,,	,, on bridge 68 ...	2·08	,,	+42·149	+42·074	−0·075
112	,,	,, on rock near level crossing ...	2·57	,,	+63·566	+63·550	−0·016

TABLE 4.—*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 1926-27 than when originally levelled
No.	Degree sheet	Description		Date of original-levelling	Original levelling	Check-levelling 1926-27	
			miles		*feet*	*feet*	*feet*
			Line 113 (Surat-Dhūlia) at Surat				
70	46 C	Standard at Surat ...	0·00	1875-78	0 000	0·000	0·000
76 (69)	,,	G.T.S. O at high school ...	0·16	,,	− 8·840	− 8·831	+0·009
68	,,	B.M. ,, at Jhaveri institute	0·24	,,	− 3·665	− 3·667	−0·002
67	,,	,, at female hospital	0·52	,,	− 2·236	− 2·238	−0·002
77 (66)	,,	,, at reservoir ...	0·70	,,	+ 2·524	+ 2·508	−0·016
78 (46)	,,	,, at clock tower ...	1·15	,,	− 3·077	− 3·097	−0·020
65	,,	,, at Parekh dispensary	1·18	,,	− 1·339	− 1·341	−0 002
79 (45)	,,	,, at *dharmsāla* ...	1·85	,,	− 1·457	− 1·562	−0·105
80 (63)	,,	,, at platform of Surat R.S.	2·03	,,	+ 15·174	+ 15·472	+0·298
81 (64)	,,	Type B at Surat R.S. ...	2·04	,	+ 14·029	+ 13·978	−0·051
			Line 108 (Muttra-Cawnpore) at Muttra				
25	54 E	S.B.M. at Muttra ...	0·00	1912-13	0·000	0·000	0·000
40	,,	Sessions judge's court ...	0·04	,,	+ 2·035	+ 2·033	−0·002
21	,,	Culvert ...	0·85	,,	+ 5·680	+ 5·681	+0·001
20	,,	Platform of Muttra Cantt. R.S.	1·45	,,	+13·527	+13·530	+0·003
19	,,	E. B. M. at ,, ,, ...	1·51	,,	+13·735	+13·694	−0·041
42	,,	Water trough ...	2·15	,,	+13·520	+13·512	−0·008
24	,,	Platform of Muttra Jn. R.S.	2·91	,,	+21·583	+21·565	−0·018
			Line 108 (Muttra-Cawnpore) at Cawnpore				
28	63 B	E.B.M. at Cawnpore ...	0·00	1868-69 1915-16	0·000	0·000	0·000
162	,,	Edward memorial hall ...	0·27	,,	+7·108	+ 7·105	−0·003
163	,,	Queen Victoria's statue ...	0·39	,,	+7·655	+ 7·658	+0·003
164	,,	Currency office ...	0·81	,,	−1·143	− 1·143	0·000
165	,,	Christ church ...	1·05	,,	−1·435	− 1·431	+0·004
167	,,	Ex Engineer's office ...	1·56	,,	−0·680	− 0·672	+0·008
168	,,	S.B.M. at Cawnpore ...	1·60	,,	−0·023	− 0·015	+0·008

TABLE 4.—*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: No.	Degree sheet	Description	Distance from starting bench-mark	Observed height above (+) or below (−) starting bench-mark, as determined by: Date of original levelling	Original levelling	Check-levelling 1926-27	Difference (check−original). The sign + denotes that the height was greater and the sign −, less in 1926-27 than when originally levelled
			miles		*feet*	*feet*	*feet*
		Line 119 (Cawnpore-Aurangābād) at Benares					
87	63 K	At monument ...	0·00	1863-65	0·000	0·000	0·000
89	"	At well ..	0·56	"	− 1·204	− 1·096	+0·108
73	63 O	At junction of roads ...	0·82	(1914-15 / 1916-17)	−11·431	−11·349	+0·082
74	"	E.B.M. at Benares ...	1·68	"	−16·725	−16·610	+0·115
94	63 K	At bridge ...	0·38	1863-65	− 1·983	− 1·881	+0·102
95	"	At well ...	0·77	"	+ 1·980	+ 2·099	+0·119
96	"	S.B.M. at Benares ...	0·80	"	+ 1·828	+ 1·920	+0·092
		Line 64 I (Ghāziābād-Cawnpore) at Ghāziābād					
192	53 H	Type B at mile Delhi 10...	0· 0	1866-67 1912-13	0 000	0·000	0·000
191	"	Toll bar house ...	0· 0	"	+ 3·715	+ 5·694	+1·979
190	"	Road bridge No. 1/382 ...	0· 6	"	+ 4·631	+ 6·614	+1·983
189	"	" " " ..	0· 7	"	+16·525	+18·508	+1·983
188	"	" " 4 ...	1· 8	"	+ 8·896	+10·877	+1·981
187	"	Culvert ..	1· 6	"	+13·358	+15·334	+1·976
190	53 H	B.M. ↖ R.L. 675·64 at bridge	0·00	1912-13	0·000	0·000	0·000
191	..	G.T.S. ○ on stone flooring ... B.M.	0·52	"	− 0·916	− 0·919	−0·003
192	..	Type B at toll bar ...	0·57	"	− 4·631	− 6·613	−1·982*
189	..	G.T.S. ○ at bridge ... B.M.	0·12	"	+11·894	+11·897	+0·003
188	..	G.T.S. ○ " ... B.M.	0·68	"	+ 4·265	+ 4·262	−0·003
187	..	G.T.S. ○ on culvert ... B.M.	1·03	"	+ 8·727	+ 8·723	−0·004

* Destroyed.

TABLE 4.—*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 1926-27 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1926-27	
			miles		*feet*	*feet*	*feet*
Line 64 I (Ghāziābād-Cawnpore) at Alīgarh							
7	54 I	S.B.M. at Alīgarh ...	0·00	1861-62	0·000	0·000	0·000
4	,,	G.T.S. O B.M. at distant signal ...	0·54	,,	+0·242	+0·223	−0·019
6	,,	G.T.S. O B.M. on brick flooring ...	0·50	,,	−5·858	−5·878	−0·020
69	,,	G.T.S. O B.M. on flooring ..	0·76	1915-16	−5·890	−5·897	−0·007
1	,,	Stone bench-mark ...	1·03	1861-62	−7·018	−7·018	0·000
Line 64 I (Ghāziābād-Cawnpore) at Hāthras							
214	54 I	Type A at Hāthras Road	0·00	1914-15	0·000	0·000	0·000
28	,,	G.T.S. O B.M. on platform ...	0·50	1905-06	+26·129	+26·103	−0·026
215	,,	,, at distant signal ...	1·18	1914-15	+12·418	+12·421	+0·003
27	,,	G.T.S. B.M. O on stone prism ...	1·80	1905-06	+ 7·578	+ 7·584	+0·006
Line 77 S (Khulnā-Mādārīpur) at Khulnā							
39	79 F	Type A at Khulnā ...	0·00	1921-22	0·000	0·000	0·000
40	,,	G.T.S. O B.M. on step ...	0·04	,,	+ 5·224	+ 5·209	−0·015
41	,,	,, ,, ...	0·08	,,	+ 3·505	+ 3·480	−0·025
42	,,	,, ,, ...	0·23	,,	+ 5·605	+ 5·601	−0·004
44	,,	□ on stone ...	0·28	,,	+ 4·250	+ 4·244	−0·006
43	,,	G.T.S. O B.M. on step ...	0·32	,,	+ 6·821	+ 6·802	−0·019

TABLE 4.—*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 1926-27 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1926-27	
			miles		*feet*	*feet*	*feet*
		Line 77 S (Khulnā-Mādārīpur) at Mādārīpur					
75	79 I	Type B at Mādārīpur G.T.S. ...	0·00	1912-13	0·000	0·000	0·000
74	„	O at verandah B.M. ...	0 06	„	+ 5·016	+ 5·009	-0·007
72	„	B.O.M. on zinc plate ..	4·98	„	+ 0·261	+ 0·272	+0·011
70	„	Type B at Kuniā ...	8·48	„	− 2·993	− 2·993	0·000
		Line 77 T (Mollāhāt-Barisāl) at Barisāl					
33	79 J	S.B.M. at Barisāl ...	0·00	1912-13	0·000	0·000	0·000
27	„	Type B „ G.T.S. ...	0·13	„	− 5·798	− 5·798	0·000
28	„	O on step B.M. ...	0·23	„	− 2·911	− 2·969	−0·058
29	„	„ „ „ ...	0·28	„	− 1·060	− 1·171	−0·111
30	„	„ „ „ ...	0·31	„	− 1·644	− 2·370	−0·726
32	„	„ „ „ ...	0 40	„	− 1·757	− 1·771	−0·014
31	„	„ at verandah ...	0·43	„	− 2·600	− 2·655	−0·055
26	„	„ on step ...	0·64	„	− 0·686	− 0·749	−0·063
35	„	„ „ „ ...	0·77	„	− 0·483	− 0·697	−0·214
		Line 88 G (Thanatpin-Tongyi) at Thanatpin					
37	94 C	G.T.S. O at Thanatpin B.M. ..	0·00	1909-10	0·000	0·000	0·000
36	..	„ on culvert ...	0·03	„	+ 1·966	+ 1·947	−0·019
101	..	E.B.M. at Thanatpin ...	0·17	1912-13-14	− 2·887	− 2·886	+0·001
		Line 88 G (Thanatpin-Tongyi) at Tongyi					
10	94 C	E.B.M. at Tongyi R.S. ...	0·00	1909-10	0·000	0·000	0·000
11	„	G.T.S. O on bridge No. 37 B.M. ...	0·29	„	− 1·262	− 1·194	+0·068
9	„	„ „ „ 36 ..	0·25	„	− 1·432	− 1·376	+0·056
8	„	„ „ „ 35 ...	1·05	„	− 0·827	− 0·758	+0·069

TABLE 4.—*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 1926-27 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1926-27	
			miles		*feet*	*feet*	*feet*
		Line 55 I (Garhmahārāja-Dāmāmiā) at Garhmahārāja					
160	39 N	E.B.M. at Garhmahārāja	0·00	1925-26	0·000	0·000	0·000
239	,,	,, ,, Haveli Qureshi	4·65	,,	+ 2·734	+ 2·728	−0·006
240	,,	B.○M. at plinth of school	4·72	,,	+ 5·381	+ 5·374	−0·007
241	,,	B.○M. at verandah ,,	4·75	,,	+ 5·356	+ 5·349	−0·007
242	,,	E.B.M. at Kot Bahadur Shah	11·20	,,	+ 9·893	+ 9·829	−0·064
243	,,	B.○M. on rectangular pillar	14·25	,,	+ 6·789	+ 6·628	−0·161
244	,,	B.○.M. on stone pillar ...	16·91	,,	+ 7·875	+ 7·669	−0·206
245	,,	E.B.M. at Doulwana ...	16·99	,,	+ 6·142	+ 5·924	−0·218
246	,,	B.○M. on rectangular pillar	23·19	,,	+ 0·772	+ 0·589	−0·183
		Line 55 I (Garhmahārāja-Dāmāmiā) at Shorkot					
96	44 B	E.B.M. at Dāmāmiā ...	0·00	1919-20	0·000	0·000	0·000
99	,,	G.T.S. ○ B.M. on parapet ...	2·43	,,	− 0·779	− 0·836	−0·057
98	,,	G.T.S. ○ B.M. at R.H. ...	2·69	,,	− 1·365	− 1·356	+0·009
97	,,	On stone ...	3·17	,,	− 1·702	− 1·701	+0·001
		Line 55 J (Dāmāmiā-Aharbelā) at Aharbelā					
217	39 N	E.B.M. at Aharbelā ...	0·00	1925-26	0·000	0·000	0·000
215	,,	B.○M. on masonry pillar	4·03	,,	+ 4·862	+ 4·865	+0·003
216	,,	G.T.S. ○ B.M. on traverse pillar	2·54	,,	+ 1·085	+ 1·140	+0·055
218	,,	B.○M. on culvert ...	0·80	,,	+ 5·895	+ 5·913	+0·018
		Line 55 L (Rangpur-Muzaffargarh) at Rangpur					
224	39 N	E.B.M. at Rangpur ...	0·00	1925-26	0·000	0·000	0·000
223	,,	G.T.S. ○ B.M. on bridge ...	0·01	,,	+ 2·218	+ 2·220	+0·002
221	,,	B.○M. at school ...	0·18	,,	+ 1·915	+ 1·919	+0·004
220	,,	G.T.S. ○ B.M. on bridge ...	0·53	,,	+ 5·026	+ 5·019	−0·0[illegible]7

TABLE 4.—*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 1926-27 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1926-27	
			miles		*feet*	*feet*	*feet*
Line 55 L (Rangpur-Muzaffargarh) at Muzaffargarh							
124	39 N	E.B.M. at Engineer's office	0·00	1912-13	0·000	0·000	0·000
122	,,	G.T.S. ○ B.M. on bridge ...	1·19	,,	+ 9·057	+ 9·045	−0·012
123	,,	G.T.S. ○ B.M. at church ...	1·77	,,	+ 5·205	+ 5·157	−0·048
127	,,	○ 393·7 / 393·7 on pillar ...	2·23	,,	+11·519	+11·470	−0·049
131	,,	E.B.M. at railway station	2·82	,,	+ 2·616	+ 2·608	−0·008
Line 55 M (Muzaffargarh-Basti Malūk) at Basti Malūk							
37	39 O	E.B.M. at Basti Malūk ...	0·00	1914-15	0·000	0·000	0·000
35	,,	G.T.S. ○ B.M. on lock-gate ...	2·62	,,	+ 4·740	+ 4·796	+0·056*
34	,,	G.T.S. ○ B.M. on culvert ...	3·22	,,	+ 3·871	+ 3·864	−0·007
33	,,	↑ on bridge ...	4·52	,,	+ 0·865	+ 0·951	+0·086*
32	,,	B.M.○ on culvert ..	5·42	,,	+ 3·084	+ 3·105	+0·021
Line 55 N (Basti Malūk-Kabīrwāla) at Kabīrwāla							
51	39 N	E.B.M. at Kabīrwāla ...	0·00	1911-12	0·000	0·000	0·000
52	,,	G.T.S. ○ B.M. at S. verandah R.H.	0·07	,,	+ 5·361	+ 5·344	−0·017
53	,,	G.T.S. ○ B.M. ,, ,,	0·16	,,	+ 5·321	+ 5·309	−0·012
54	,,	G.T.S. ○ B.M. at Tahsīldār's office	0·20	,,	+ 4·367	+ 4·350	−0·017

* Disturbed.

TABLE 4.—*Check-levelling*—(*concld.*)

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 1926·27 than when originally levelled.
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1926-27	
			miles		*feet*	*feet*	*feet*
		Line 55 N (Basti Malūk-Kabīrwāla) at Kabīrwāla—(contd.)					
55	39 N	G.T.S. at Nāib Tahsīldār's O office ... B.M.	0·22	1911-12	+4·299	+4·272	−0·027
56	,,	G.T.S. O at hospital ... B.M.	0·28	,,	+4·375	+4·360	−0·015
57	,,	G.T.S. ⊙ on bridge ... B.M.	0·50	,,	+9·006	+8·971	−0·035
		Line 55 K (Aharbelā-Multān) at Multān					
34	39 N	Standard B.M. at Multān	0·00	1912-13	0·000	0·000	0·000
41	,,	G.T.S. O under church tower B.M.	0·10	,,	+2·474	+2·479	+0·005
42	,,	G.T.S. O at chaplain's office B.M.	0·15	,,	+1·793	+1·788	−0·005
44	,,	G.T.S. at block 28 of hos- O pital ... B.M.	0·36	,,	+1·955	+1·955	0·000
43	,,	G.T.S. O ,, 26 ,, B.M.	0·46	,,	+1·753	+1·758	+0·005
91	,,	G.T.S. O on bridge ... B.M.	1·74	1907-08	+5·046	+5·058	+0·012

TABLE 5.—*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 1926-27 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1926-27 (unadjusted)	
			miles		*feet*	*feet*	*feet*
		Part of Line 61A (Dehra Dūn-Mussoorie)					
10	53 J	Shaw's Refraction station	0·00	1861-62 1903-04 Revised 1905-07	0·000	0·000	0·000
9	"	S.B.M. at Dehra Dūn ...	0·02	"	+ 1·587	+ 1·583	− 0·004
8	"	Cole's Satellite station	0·14	"	+ 2·451	+ 2·443	− 0·008
12	"	Iron plug	0·21	"	− 5·769	− 5·775	− 0·006
6	"	S.B.M., D.G.B's office ...	0·30	"	− 2·767	− 2·760	+ 0·007
17	"	↑ at Brewery godown	5·46	"	+ 687·824	+ 687·835	+ 0·011
19	"	G.T.S. ⩚ B.M. on rock in situ ...	7·49	"	+ 1166·124	+ 1166·194	+ 0·070
20	"	" " " ...	8·00	"	+ 1448·073	+ 1448·141	+ 0·068
21	"	" " " ...	8·67	"	+ 1630·778	+ 1630·827	+ 0·049
36	"	B.○M. " " ...	16·35	"	+ 3582·959	+ 3583·016	+ 0·057
37	"	" " " ...	16·48	"	+ 3636·741	+ 3636·809	+ 0·068
38	"	G.T.S. ⩚ B.M. " " ...	16·56	"	+ 3666·762	+ 3666·832	+ 0·070
40	"	B.○M. " " ...	17·24	"	+ 3912·073	+ 3912·132	+ 0·059
41	"	G.T.S. ⩚ B.M. " " ...	17·49	"	+ 4 03·933	+ 4003·986	+ 0·053
42	"	G.T.S. ○ B.M. " " ...	17·62	"	+ 4047·101	+ 4047·161	+ 0·060
43	"	G.T.S. ⩚ B.M. " " ...	17·64	"	+ 4053·234	+ 4053·294	+ 0·060
44	"	B.○M. " " ...	18·10	"	+ 4224·291	+ 4224·309	+ 0·018
45	"	G.T. Survey ○ Bench Mark at Library	18·37	"	+ 4343·603	+ 4343·631	+ 0·028
50	"	G.T.S. ○ B.M. at Christ Church	18·63	"	+ 4411·583	+ 4411·596	+ 0·013
51	"	B.○M. on rock in situ...	18·77	"	+ 4505·958	+ 4505·966	+ 0·008

TABLE 5.—*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 1926-27 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1926-27 (unadjusted)	
			miles		*feet*	*feet*	*feet*
		Line 108 (Muttra-Cawnpore)					
		Revision of parts of lines 65, 65A, 66, 62 and 63B					
25	54 E	S.B.M. at Muttra ...	0·0	1912-13	0·000	0·000	0·000
40	,,	Sessions Judge's *kachahri*	0·1	,,	+ 2·035	+ 2·033	−0·002
21	,,	Culvert at junction of roads	0·9	,,	+ 5·680	+ 5·681	+0·001
20	,,	Platform of Muttra Cantt. R S.	1·4	,,	+ 13·527	+ 13·530	+0·003
161 (*19*)	,,	Embedded B.M. at Muttra Cantt. R.S.	1·5	,,	+ 13·735	+ 13·694	−0·041
42	,,	Water trough ...	2·2	,,	+ 13·520	+ 13·512	−0·008
24	,,	Platform of Muttra Jn. R.S.	2·9	,,	+ 21·583	+ 21·565	−0·018
33	54 I	Stone B.M. at Agra ...	33·6	1861-62 1915-16	− 9·69	− 9·804	−0·109
128	,,	Church of England, Agra	33·7	,,	− 7·538	− 7·647	−0·109
127	,,	Old post office ,, ...	34·3	,,	− 8·653	− 8·760	−0·107
126	,,	Drain on Ajmer road ...	34·6	,,	− 15·067	− 15·176	−0·109
125	,,	Culvert No. ½ ...	35·1	,,	− 41·204	− 41·298	−0·094
224 (*124*)	,,	S.B.M. at Agra ...	35·7	,,	− 34·668	− 34·861	−0·193
123	,,	Agra Fort R.S. ...	35·8	,,	− 31·764	− 31·856	−0·092
225 (*125*)	,,	7th pier Jumna bridge ...	36·3	,,	− 46·339	− 46·401	−0·062
121	,,	14th ,, ,, ,, ...	36·4	,,	− 46·457	− 46·553	−0·096
120	,,	Culvert E. of Jumna bridge R.S.	36·6	,,	− 44·225	− 44·337	−0·112
119		Goods shed ,, ,,	37·0	,,	− 44·638	− 44·739	−0·101
42	,,	Fīrozābād T.S. ...	62·8	1864-65	− 3·318	− 3·541	−0·223
278 (*60*)	,,	Stone B.M. at Ghiror ...	90·4	,,	− 33·505	− 33·912	−0·407
66	,,	Canal M.S. No. 26 ...	96·8	,,	− 35·248	− 35·512	−0·264
67	,,	,, ,, ,, 28 ...	98·8	,,	− 38·532	− 38·804	−0·272
68	,,	,, ,, ,, 31 ...	101·8	,,	− 40·255	− 40·564	−0·309
101 (*17*)	54 M	Stone B.M. at Singhpur ...	103·4	,,	− 42·975	− 43·369	−0·394
110 (*16*)	,,	,, ,, ,, Mainpurī ...	108·7	,,	− 49·811	− 50·185	−0·374
18	,,	Canal M.S. No. 34 ...	104·8	,,	− 43·878	− 44·176	−0·298
21	,,	,, ,, ,, 40 ...	110·8	,,	− 49·150	− 49·448	−0·298
22	,,	,, ,, ,, 42 ...	112·8	,,	− 52·724	− 53·036	−0·312
126 (*26*)	,,	,, ,, ,, 48 ...	118·8	,,	− 60·001	− 60·254	−0·253
28	,,	,, ,, ,, 49 ...	119·8	,,	− 59·107	− 59·409	−0·302
30	,,	,, ,, ,, 52 ...	122·9	,,	− 64·001	− 64·268	−0·267

TABLE 5.—*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 1926-27 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1926-27 (unadjusted)	
			miles		*feet*	*feet*	*feet*
		Line 108 (Muttra-Cawnpore) ***Revision of parts of lines 65, 65A, 66, 62 and 63B—(contd.)***					
133 (32)	54 M	Canal M.S. No. 55 ...	125·9	1864-65	− 66·079	− 66·414	−0·335
134 (34)	,,	Stone B.M. at Tariā ...	126·0	,,	− 66·517	− 66·857	−0·340
136 (35)	,,	Bisungarh T.S. ...	131·7	,,	− 41·956	− 42·317	−0·361
9	54 N	Kalsān T.S. ...	150·0	,,	− 59·629	− 59·916	−0·287
107 (11)	,,	Stone B.M. at Bahosi ...	147·8	,,	− 86·764	− 87·152	−0·388
126 (19)	,,	,, ,, ,, Aimah bridge	161·3	,,	−102·776	−102·900	−0·124
146 (32)	,,	,, ,, ,, Kakwān ...	174·4	,,	−111·073	−111·155	−0·082
40	63 B	,, ,, ,, Jagatpur ...	186·5	,,	−126·046	−126·164	−0·118
51	,,	,, ,, ,, Bara Sirohi	198·2	1864-65 1915-16	−136·796	−136·839	−0·043
280 (161)	,,	Canal M.S. No. 129 ...	201·6	,,	−141·741	−141·807	−0·066
174	,,	Canal bridge near M.S. 6 from Cawnpore ...	202·1	1917-18	−144·915	−144·943	−0·028
160	,,	E.I.R. bridge No. 267 ...	202·4	1864-65 1915-16	−139·135	−139·159	−0·024
158	,,	,, ,, 254 ...	207·0	,,	−145·022	−145·044	−0·022
169	,,	Canal bridge, Generalganj	207·5	1917-18	−144·263	−144·280	−0·017
28	,,	(Type B) at Cawnpore ...	208·7	1868-69 1915-16	−153·161	−153·170	−0·009
162	,,	King Edward memorial hall ...	209·0	,,	−146·053	−146·065	−0·012
163	,,	Queen Victoria's statue ...	209·1	,,	−145·506	−145·512	−0·006
164	,,	Currency office ...	209·5	,,	−154·304	−154·313	−0·009
165	,,	Christ church, Cawnpore	209·7	,,	−154·596	−154·601	−0·005
167	,,	Ex. Engineer's office ,, ...	210·2	,,	−153·841	−153·842	−0·001
168	,,	S.B.M. at Cawnpore ...	210·3	,,	−153·184	−153·185	−0·001

TABLE 5.—*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 1926-27 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1926-27 (unadjusted)	
			miles		*feet*	*feet*	*feet*
Part of Line 119 (Cawnpore-Aurangābād)							
Revision of parts of lines 65, 66, 67, 67A, 59, 70 and 70A							
168	63 B	S.B.M. at Cawnpore ...	0·0	1868-69 1915-16	0·000	0·000	0·000
167	,,	Ex. Engineer's office ...	0·1	,,	− 0·657	− 0·658	−0·001
165	,,	Christ church ...	0·5	,,	− 1·412	− 1·418	−0·006
164	,,	Currency office ...	0·8	,,	− 1·120	− 1·128	−0·008
163	,,	Queen Victoria's statue ...	1·2	,,	+ 7·678	+ 7·671	−0·007
162	,,	K. Edward memorial hall	1·3	,,	+ 7·131	+ 7·119	−0·012
28	,,	E.B.M. at Cawnpore ...	1·6	,,	+ 0·023	+ 0·015	−0·008
288 (*150*)	,,	Naronha's exchange ...	1·7	1864-65 1915-16	+ 5·291	+ 5·264	−0·027
151	,,	Well near M.S. Allahābād 119 ...	3·6	,,	+ 6·260	+ 6·256	−0·004
152	,,	Culvert No. 2/618 ...	4·2	,,	+ 9·041	+ 9·046	+0·005
157	,,	,, ,, 2/610 ...	12·1	,,	− 4·457	− 4·404	+0·053
70	,,	Stone B.M. Mahārājpur ...	13·8	,,	− 7·321	− 7·289	+0·032
83	,,	,, Aung ...	27·2	1864-65	− 15·298	− 15·244	+0·054
93	,,	,, Malwa R.S. ...	41·6	,,	− 22·055	− 22·055	0·000
3	63 C	,, Fatehpur ...	51·1	,,	− 42·469	− 42·422	+0·047
62	63 G	Stone B.M. Arrahpur ...	66·1	1864-65 1915-16	− 55·490	− 55·361	+0·129
70	,,	,, Katoghan ...	76·1	,,	− 61·037	− 60·945	+0·092
71	,,	Majilgaon T.S. ...	76·7	,,	− 12·154	− 12·068	+0·086
80	,,	Stone B.M. Saini ...	87·3	,,	− 62·311	− 62·241	+0·070
81	,,	Karra T.S. ...	91·2	,,	− 24·872	− 24·809	+0·063
92	,,	Stone B.M. Koh Kbirāj ...	100·5	,,	− 79·331	− 79·306	+0·025
102	,,	,, Pura Mufti ...	113·5	,,	− 91·778	− 91·817	−0·039
247 (*51*)	,,	S.B.M. at Allahābād ...	123·6	1920-21	− 89·658	− 89·918	−0·260
251 (*100*) (*53*)	,,	Muir Central College ...	126·7	,,	− 97·318	− 97·477	−0·159
59 (*54*)	,,	Suitors' shed ...	127·2	,,	− 93·986	− 94·185	−0·199
158	,,	Collector's *kachahri* ...	127·3	,,	− 92·330	− 92·532	−0·202
162 (*47*)	,,	D.J. water trough ...	126·0	,,	−117·79[illegible]	−117·983	−0·189
163 (*46*)	,,	Bridge No. M. 79 ...	126·6	,,	−127·555	−127·745	−0·190
45	,,	Manohar Das' well ...	127·8	,,	−122·224	−122·396	−0·172

TABLE 5.—*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 1926-27 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1926-27 (unadjusted)	
			miles		*feet*	*feet*	*feet*
		Part of Line 119 (Cawnpore-Aurangābād)					
		Revision of parts of lines 65, 66, 67, 67A, 59, 70, and 70A—(contd.)					
253 (58)	63 G	Allahābād Fort ...	127·9	1920-21	−108·942	−109·139	−0·197
254 (57)	,,	Sentry box ...	128·0	1898-99	−109·289	−109·411	−0·122
56	,,	,, ,,	128·0	,,	−118·631	−118·790	−0·159
124	,,	Stone B.M. at Jhūsi ...	130·9	1863-65	−107·080	−107·204	−0·124
257 (87)	63 K	Alexandar's monument ...	203·6	,,	−152·166	−152·477	−0·311
89	,,	Gobardhan's well ...	204·1	,,	−153·370	−153·573	−0·203
73	63 O	Well near M.S. Calcutta 421	204·4	1914-15 1916-17	−163·597	−163·826	−0·229
74	,,	(Type B) at Benares ...	205·3	,,	−168·891	−169 087	−0·196
94	63 K	Bridge on Barnā river ...	204·0	1863-65	−154·149	−154·358	−0·209
61 (95)	,,	Well at Commissioner's *kachahri*	204·3	,,	−150·186	−150·378	−0·192
96	,,	S.B.M. at Benares ...	204·4	,,	−150·338	−150·557	−0·219
		Line 74 C (Howrah-Uttarpāra) at Bally					
849 (327)	79 B	G.T.S. ○ B.M. on step ...	0·00	1924-25	0·000	0·000	0·000
447	,,	Type A at Uttarpāra ...	0·17	,,	− 1·817	− 1·822	−0·005
848 (326)	,,	G.T.S. ○ B.M. at bridge ...	0·61	,,	+ 3·049	+ 3·062	+0·013
841	,,	,, on stone ...	1·45	,,	+ 1·954	+ 1·932	−0·022
842	,,	B.M. ○ Above M.S.L. on stone ...	1·62	,,	− 1·059	− 1·079	−0·020
843	,,	G.T.S. ○ B.M. on stone ...	1·94	,,	+ 2·409	+ 2·376	−0·033
845	,,	B.M. ○ Above M.S.L. on stone ...	2·34	,,	+ 1·721	+ 1·687	−0·034
844	,,	G.T.S. ○ B.M. on stone ...	2·44	,,	+ 1·511	+ 1·497	−0·014

TABLE 5.—*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 1926-27 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1926-27 (unadjusted)	
			miles		*feet*	*feet*	*feet*
Line 77 (Howrah-Ramganj) from Hastings to Dakhineswar							
357	79 B	G.T.S. ○ B.M. at Hastings bridge .	0·00	1882-83	0·000	0·000	0·000
362	,,	G.T.S. ○ B.M. ,, ...	0·04	,,	+ 2·722	+ 2·756	+0·034
29	,,	Top of masonry pillar ...	0·64	,,	−11·531	− 11·525	+0·006
356	,,	○ G.T.S. on stone ...	0·70	,,	− 8·617	− 8·579	+0·038
355	,,	B.○M. on marble step ..	1·11	,,	− 8·592	− 8·593	−0·001
30	,,	,, on stone ...	1·47	,,	−10·902	−10·881	+0·021
31	,,	,, ,, ...	1·85	,,	−11·788	−11·796	−0·008
32	,,	,, ,, ...	2·59	,,	−11·918	−12·072	−0·154
353	,,	G.T.S. □ B.M. at mint ...	3·43	,,	−12·880	−12·882	−0·002
467	,,	B.⊙W. on base of drain ...	6·27	1921-22	+ 1·436	+ 1·553	+0·117
Line 74 B (Kidderpore-Dublat) from Hastings to Pujāli							
357	79 B	G.T.S. ○ B.M. at Hastings bridge ...	0·00	1882-83	0·000	0·000	0·000
358	,,	,, B on coping ...	0·58	,,	−13·723	−13·637	+0·086
359	,,	,, A ,, ...	0·62	,,	−13·723	−13·641	+0·082
102	,,	G.T.S. ○ B.M. at step ...	7·51	1881-83	−15·521	−15·491	+0·030
103	,,	G.T.S. □ B.M. at Akra ...	7·55	,,	−15·300	−15·334	−0·034
109	,,	G.T.S. ○ B.M. on step ...	8·51	,,	−14·163	−14·420	−0·257

TABLE 6.—*List of triangulation stations connected by spirit-levelling, season 1926-27*

Name of station	Height above mean sea level		Difference Trian.—Levelling	Remarks
	Spirit-levelling	Triangulation		
	feet	*feet*	*feet*	
Kāthiāwār Minor Meridional No. 1 Series				
Pājod T.S. Lat. 21° 32′ 54″·48 Long. 70 03 47·21	96·842	98	+1	
Rangīr Meridional Series				
Seontāra (Saunthra) T.S. Lat. 26° 42′ 25″·60 Long. 79 35 31·93	501·994	501·2	−1	
East Calcutta Longitudinal Series				
Hatiāra (Hātiāra) T.S. Lat. 23° 09′ 29″·86 Long. 89 52 19·68	12·856	16	+3	

TABLE 7.—*Results of comparison of staves with standard steel tape No. 2, Line 61A, season 1926-27*

Date of comparison	Length of staff—10 feet		Remarks
	No. of staff		
	A 23	B 23	
	feet	*feet*	
20-9-26 ...	−0·0005	−0·0004	Clear
23-9-26 ...	−0·0003	−0·0004	Sky cloudy but bright sun & light wind after a heavy hail storm
26-9-26 ...	−0·0004	−0·0005	Clear and light cool breeze
28-9-26 ...	−0·0003	−0·0004	Clear and cool breeze
1-10-26 ...	−0·0003	−0·0003	Clear
2-10-26 ...	−0·0005	−0·0006	Scattered clouds and cool breeze
4-10-26 ...	−0·0002	−0·0002	Scattered clouds
6-10-26 ...	−0·0003	−0·0004	do.
8-10-26 ...	−0·0003	−0·0004	Clear and cool breeze
11-10-26 ...	−0·0006	−0·0007	Clear and light breeze
13-10-26 ...	−0·0010	−0·0015	Scattered clouds and light cool breeze
15-10-26 ...	−0·0006	−0·0008	do.
17-10-26 ...	−0·0015	−0·0016	Clear
3-5-27 ...	−0·0053	−0·0060	Very cloudy
4-5-27 ...	−0·0051	−0·0060	Scattered clouds & high cool breeze
5-5-27 ...	−0·0046	−0·0054	Light do.
7-5-27 ...	−0·0048	−0·0058	Scattered clouds and high cool breeze
11-5-27 ...	−0·0056	−0·0061	Clear and light breeze
13-5-27 ...	−0·0044	−0·0054	Clear
16-5-27 ...	−0·0053	−0·0059	Cloudy and light breeze
18-5-27 ...	−0·0047	−0·0056	Clear and light breeze
21-5-27 ...	−0·0053	−0·0056	do.
24-5-27 ...	−0·0058	−0·0064	do.
26-5-27 ...	−0·0059	−0·0064	Hazy and breeze
28-5-27 ...	−0·0060	−0·0061	Cloudy
1-6-27 ...	−0·0051	−0·0056	Clear and very light breeze
3-6-27 ...	−0·0056	−0·0068	Clear and light breeze

TABLE 7.—*Results of comparison of staves with standard steel tape No. 3, Lines 104, 101A, 137 & 136, season 1926-27*—(*contd*).

Date of comparison		Length of staff—10 feet		Remarks
		No. of staff		
		20A	20B	
		feet	*feet*	
18-10-26	...	−0·0005	+0·0014	Light scattered clouds
25-10-26	...	−0·0015	+0·0000	Clear
5-11-26	...	−0·0013	−0·0001	do.
22-11-26	...	−0·0028	−0·0019	do.
2-12-26	...	−0·0015	−0·0025	do.
2-12-26	...	−0·0015	−0·0025	do.
12-12-26	...	−0·0023	−0·0030	do.
21-12-26	...	−0·0024	−0·0036	Clear & cool breeze
3-1-27	...	−0·0033	−0·0044	Light scattered clouds and cool breeze
11-1-27	...	−0·0031	−0·0045	Clear
17-1-27	...	−0·0034	−0·0039	Clear and breeze
26-1-27	...	−0·0036	−0·0047	Clear
5-2-27	...	−0·0026	−0·0032	do.
16-2-27	...	−0·0022	−0·0030	do.
25-2-27	...	−0·0034	−0·0045	do.
9-3-27	...	−0·0042	−0·0051	Cloudy and windy
20-3-27	...	−0·0029	−0·0048	Clear
28-3-27	...	−0·0038	−0·0047	do.
8-4-27	...	−0·0032	−0·0037	Cloudy
8-4-27	..	−0·0032	−0·0037	do.
17-4-27	...	−0·0024	−0·0039	Clear
27-4-27	...	−0·0040	−0·0055	do.
11-5-27	...	−0·0018	−0·0027	do.

TABLE 7.—*Results of comparison of staves with standard steel tape No. 3, Line 152, season 1926-27*—(*contd.*)

Date of comparison		Length of staff—10 feet		Remarks
		No. of staff		
		16A	16B	
		feet	*feet*	
30-10-26	...	−0·0066	−0·0009	Clear
8-11-26	...	−0·0096	−0·0026	do.
15-11-26	...	−0·0097	−0·0030	Clear & cool breeze
22-11-26	...	−0·0095	−0·0028	Clear
30-11-26	...	−0·0091	−0·0028	do.
7-12-26	...	−0·0089	−0·0021	do.
14-12-26	...	−0·0099	−0·0032	do.
22-12-26	...	−0·0100	−0·0032	Clear & cool breeze
20-4-27	...	−0·0083	−0·0019	Clear
26-4-27	...	−0·0079	−0·0013	Clear & high wind
6-5-27	...	−0·0072	−0·0011	Clear
14-5-27	...	−0·0073	−0·0006	Clear & high wind
19-5-27	...	−0·0071	−0·0007	Clear

TABLE 7.—*Results of comparison of staves with standard steel tape No. 4, Lines 119 and 108, season 1926-27—(contd.)*

Date of comparison	Length of staff—10 feet		Remarks
	No. of staff		
	O 2	O 5	
	feet	*feet*	
19-10-26 ...	+0·0032	+0·0006	Clear
29-10-26 ...	+0·0029	−0·0005	do.
4-11-26 ...	+0·0021	−0·0004	do.
10-11-26 ...	+0·0026	+0·0000	do.
20-11-26 ...	+0·0018	−0·0014	do.
25-11-26 ...	+0·0013	−0·0015	Clear & cool breeze
1-12-26 ...	+0·0012	−0·0010	Clear
9-12-26 ...	+0·0009	−0·0015	do.
19-12-26 ...	+0·0009	−0·0017	do.
26-12-26 ...	+0·0008	−0·0016	do.
3-1-27 ..	+0·0011	−0·0015	do.
10-1-27 ..	−0·0004	−0·0026	do.
10-1-27 ...	−0·0004	−0·0026	do.
17-1-27 ...	+0·0002	−0·0021	do.
26-1-27 ...	+0·0004	−0·0023	do.
1-2-27 ...	+0·0001	−0·0020	do.
8-2-27 ...	+0·0003	−0·0021	do.
15-2-27 ...	+0·0004	+0·0021	do.
22-2-27 ...	−0·0000	−0·0025	Clear & high breeze
2-3-27 ...	−0·0003	−0·0020	Clear
10-3-27 ...	−0·0008	−0·0024	Cloudy
16-3-27 ...	−0·0007	−0·0021	Clear
25-3-27 ..	−0·0002	−0·0021	do.
1-4-27 ...	−0·0014	−0·0031	do.
9-4-27 ...	−0·0027	−0·0043	do.
16-4-27 ...	−0·0023	−0·0045	do.
Check-levelling at Ghāziābād			
21-4-27 ...	−0·0019	−0·0036	Clear

TABLE 7.—*Results of comparison of staves with standard steel tape No. 10, Lines 64I, 77S, 77T, 77U, 74C, 77C & 74B, season 1926-27*—(*contd.*)

Date of comparison	Length of staff—10 feet				Remarks
	No. of staff				
	O 1	O 3	23 A	E 1	
	feet	*feet*	*feet*	*feet*	
16-10-26 ...	−0·0004	+0·0013	−0·0040	−0·0021	Light scattered clouds
27-10-26 ...	−0·0017	−0·0005	−0·0065	−0·0036	Clear
4-11-26 ...	−0·0020	−0·0006	−0·0078	−0·0041	do.
16-11-26	−0·0031	−0·0009	−0·0079	−0·0041	Clear & cool breeze
29-11-26 ...	−0·0040	−0·0025	−0·0102	−0·0056	do.
7-12-26 ...	−0·0020	−0·0017	−0·0078	−0·0044	Clear
17-12-26 ...	−0·0028	−0·0021	−0·0083	−0·0050	do.
26-12-26 ...	−0·0031	−0·0022	−0·0087	−0·0050	Clear & cool breeze
5-1-27 ...	−0·0030	−0·0024	−0·0078	−0·0042	Clear
15-1-27 ...	−0·0036	−0·0027	−0·0095	−0·0056	do.
29-1-27 ...	−0·0032	−0·0021	−0·0077	−0·0047	Light scattered clouds
7-2-27 ...	−0·0016	−0·0007	−0·0069	−0·0032	Clear
17-2-27 ...	−0·0019	−0·0002	−0·0055	−0·0019	Clear & cool breeze
27-2-27 ...	−0·0002	+0·0003	−0·0047	−0·0023	Clear
9-3-27 ...	−0·0015	+0·0003	−0·0050	−0·0022	do.
20-3-27 ..	−0·0003	+0·0015	−0·0045	−0·0014	do.
1-4-27 ...	+0·0001	+0·0018	−0·0032	−0·0001	do.
10-4-27 ...	+0·0003	+0·0021	−0·0029	−0·0007	do.
17-4-27 ...	−0·0003	+0·0021	−0·0035	−0·0001	do.

TABLE 7.—*Results of comparison of staves with standard steel tape No. 5, Lines 88G & 88H, season 1926-27*—(*contd.*)

Date of comparison	Length of staff—10 feet				Remarks
	No. of staff				
	19A	19B	22B	23B	
	feet	*feet*	*feet*	*feet*	
7-1-27 ...	+0·0005	+0·0020	+0·0010	+0·0020	Clear and cool breeze
15-1-27 ...	+0·0001	+0·0016	−0·0005	+0·0006	do
22-1-27 ...	+0·0005	+0·0019	+0·0002	+0·0013	do
30-1-27 ...	+0·0003	+0·0016	+0·0003	+0·0011	Light scattered clouds & sudden gusts of cool breeze
8-2-27 ...	+0·0003	+0·0016	+0·0002	+0·0012	Light scattered clouds
16-2-27 ...	−0·0002	+0·0014	−0·0001	+0·0012	Scattered clouds, sudden gusts of cool breeze, & heavy rain on night of 11th Feb.
25-2-27 ...	−0·0010	+0·0006	−0·0015	−0·0005	Clear and cool breeze

TABLE 7.—*Results of comparison of staves with standard steel tape No. 2, Lines 55 I to 55 O, season 1926-27—(concld.)*

Date of comparison	Length of staff—10 feet				Remarks
	No. of staff				
	A 23	B 23	17 B	O 1	
	feet	*feet*	*feet*	*feet*	
8-11-26 ...	−0·0023	−0·0028	−0·0043	−0·0024	Cloudy and cool breeze
12 11-26 ...	−0·0023	−0·0025	−0·0042	−0·0031	Clear & cool breeze
22-11-26 ...	−0·0031	−0·0039	−0·0050	−0·0036	do
28-11-26 ...	−0·0024	−0·0038	−0·0055	−0·0034	Clear
4-12-26 ...	−0·0032	−0·0044	−0·0046	−0·0043	do
12-12 26 ...	−0·0036	−0·0046	−0·0051	−0·0032	Clear and cool breeze
21 12-26 ...	−0·0030	−0·0039	−0·0045	−0·0033	do
28-12-26 ...	−0·0039	−0·0046	−0·0052	−0·00[illegible]5	Light clouds
3-1-27 ...	−0·0042	−0·0052	−0·0060	−0·0038	Clear & light breeze
9-1-27 ...	−0·0042	−0·0048	−0·0057	−0·0058	Light clouds & cool breeze
17-1-27 ...	−0·0040	−0·0054	−0·0062	−0·0041	Light clouds and strong cool breeze
24-1-27 ...	−0·0041	−0·0054	−0·0069	−0·0046	Clear & cool breeze

Chapter VIII

RESEARCH and TECHNICAL NOTES

BY CAPTAIN G. BOMFORD, R.E.

I. Personal Equation Apparatus

1. Necessity for personal equation apparatus.—For the International Longitude Observations in 1926 the Survey of India at Dehra Dūn used 2 transit telescopes and one prismatic astrolabe. The transits were fitted with impersonal micrometer eye-pieces, but for the astrolabe no such device is at present available. It was not possible to interchange observers with the other observatories, nor could the observers meet and compare their personal equations. It was therefore essential to employ some means of determining their absolute personal equations. The apparatus here described was made in the workshops at Dehra Dūn with such material as was available. Comparison with the results of the transits gives a means of judging the reliability of the results obtained. They are satisfactory on the whole, although the instrument contains many obvious imperfections, optical and mechanical. An improved pattern is now being made, and it is hoped and expected that it will give uniformly satisfactory results.

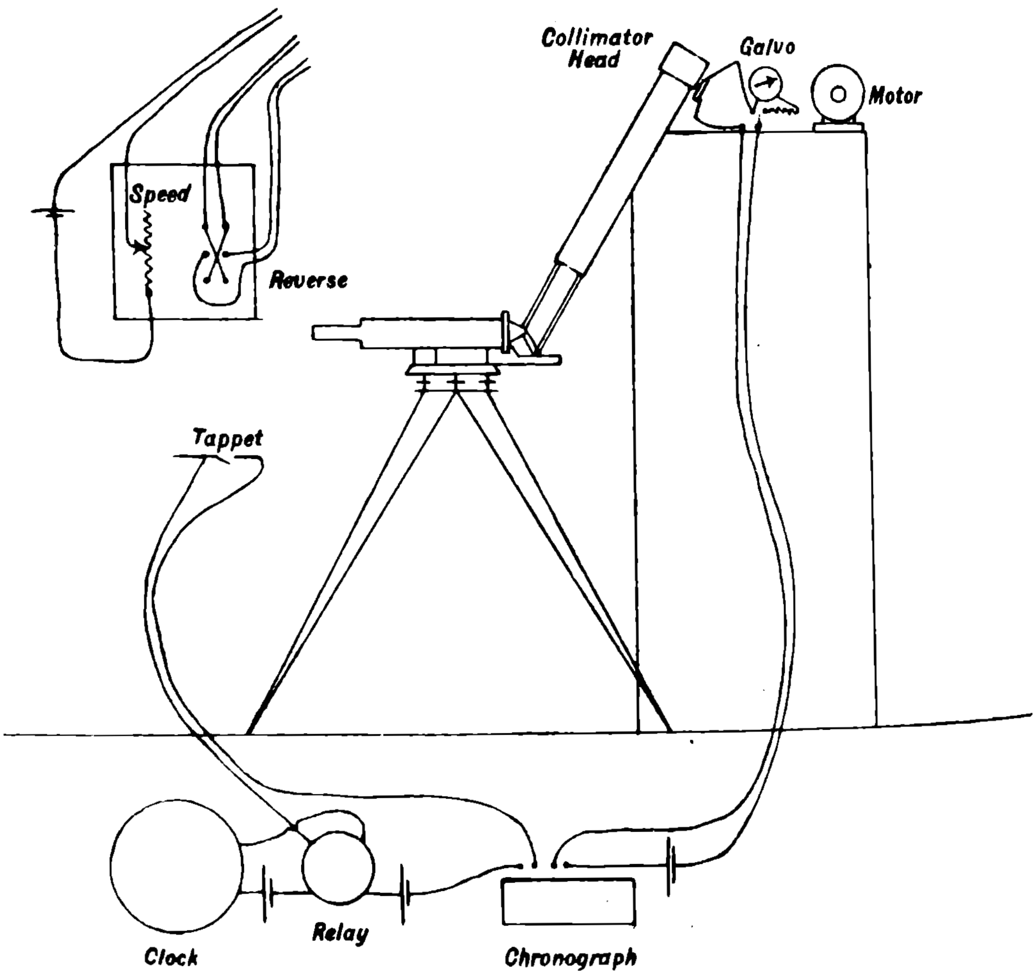
A similar instrument for use with transit telescopes was designed by Lt.-Colonel W.M. Campbell, R.E., in 1880. It is described under the name of an "Idiometer" in Vol. IX of the Operations of the G. T. Survey, chapter V. It was used in the field in 1880-81. It was not satisfactory and its use was discontinued.

The present instrument works on the same general principle. An artificial star is seen in the telescope: at the moment of passage, the circuit of one pen of a chronograph is automatically broken, while the observer breaks the circuit of the other pen by a tappet held in the hand. The difference between the time of the two breaks is a measure of his personal equation.

The two chief desiderata for the accurate determination of personal equation are :—

(1) That the circumstances of a real star observation should be reproduced with all the exactitude which can possibly be achieved. The observer should determine his personal equation by looking through the eye-piece of his own instrument and break the circuit with his usual tappet.

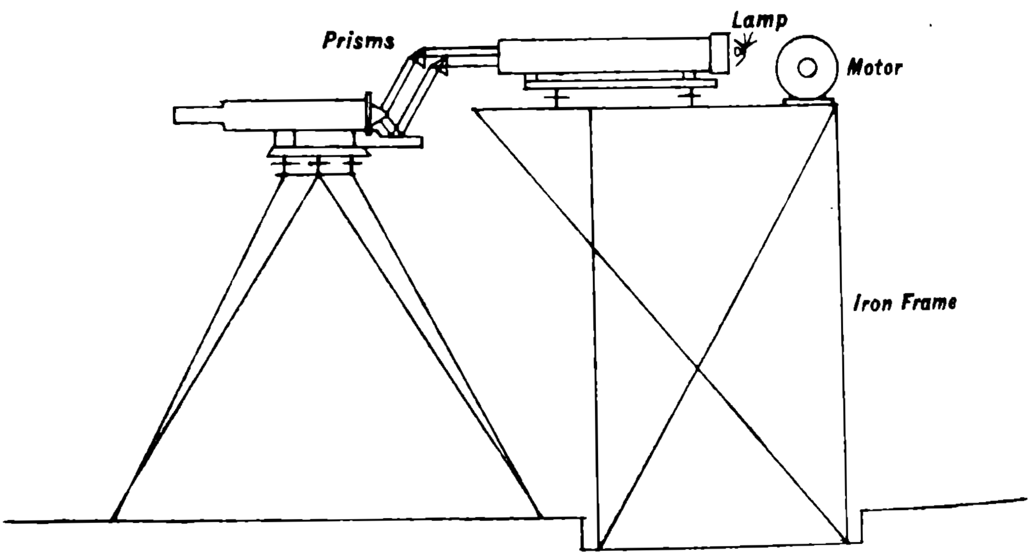
Fig. 1



Personal Equation Apparatus.

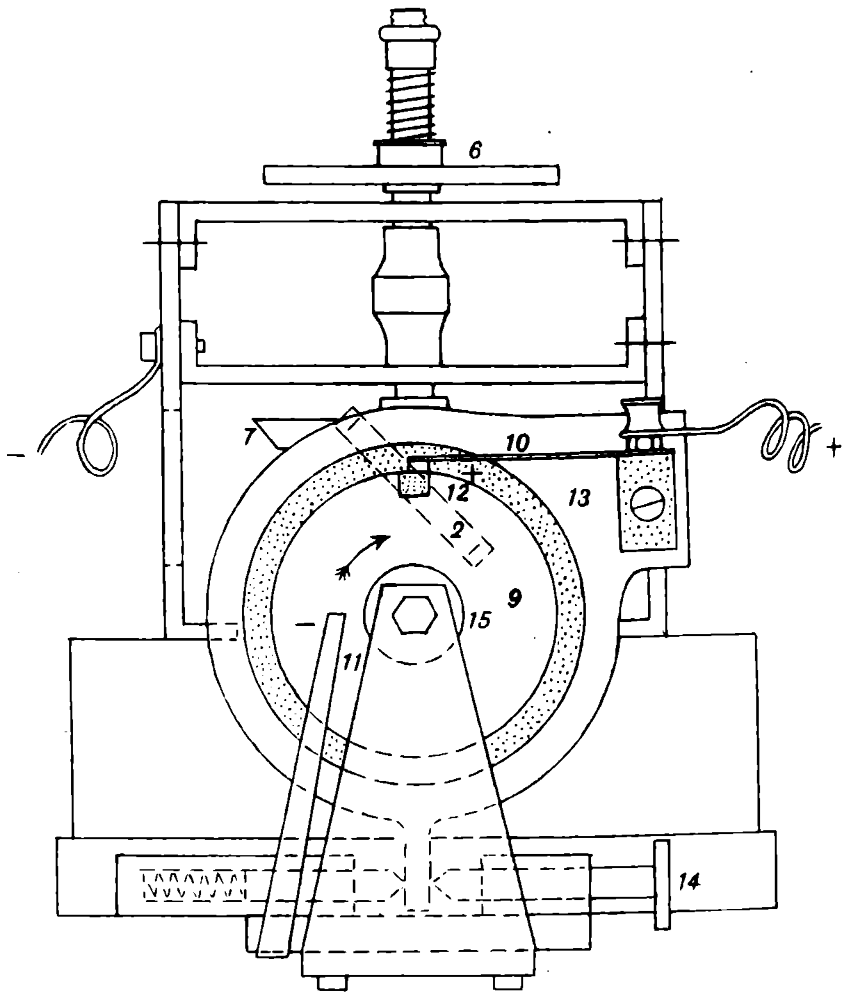
Fig. 2

An improved pattern.



Personal Equation Apparatus.

Fig. 3



Ebonite shown thus:- ⁙

Personal Equation Apparatus.

FIG. 5.

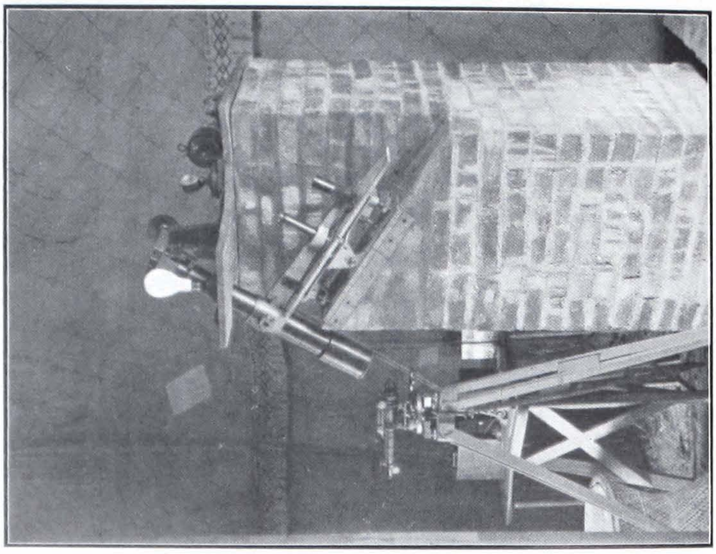


FIG. 6.

PERSONAL EQUATION APPARATUS.

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

If possible, the imitation star should so resemble a real one that he is hardly conscious of the difference.

(2) The various measures of personal equation should be freely interspersed with the star observations. It is thought almost useless to determine it at the beginning and end of a field season, and undesirable to do so only at the beginning and end of a night's work. It seems likely that when running off a rapid series of measures one after the other, the personal equation may differ widely from its value during the series of real stars.

2. Description of the apparatus.—The following is a description of the instrument at present in use (*vide* Figs. 1, 3, 4, 5 & 6). The "star" is a very small hole in a piece of smooth strong paper, rendered opaque with Indian ink. It is illuminated by a 100 C. P. lamp with a diffusing bulb, the light of which is directed on to the star by a small mirror (2), (*vide* Figs. 3 & 4), immediately over the latter. The lamp and mirror do not move with the star. The star is mounted on the diaphragm of a micrometer in place of the usual cross wires, in the focal plane of a collimator. The collimator is mounted on a brick pillar, and is inclined at an angle of 60° over the prism and mercury of an astrolabe. The elaborate mounting seen in Figs. 5 & 6 is not essential. Two images of the star are seen in the astrolabe, as usual. The micrometer screw is generally placed in the vertical plane containing the collimator and the astrolabe. Movement is imparted to the star by the rotation of the micrometer screw by a small electric motor. A worm wheel (3), driven by the motor, is mounted with the bearings of its shaft on a frame which makes no contact with the collimator. It drives a wheel on the collimator head, whose spindle (4), is co-axial with the collimator. The drive is then transmitted to the micrometer screw through 2 gear wheels, (5) & (6), and a bevel gear, (7) & (8).

The drive through the worm is found to be very smooth and free from vibration. The object in having the first spindle co-axial with the collimator, is that the whole collimator head may be turned at will through any angle, so that the motion of the star is no longer contained in the vertical plane, and it reproduces in the astrolabe the more horizontal motion of stars seen away from the prime vertical.

The speed and direction of the star's motion are controlled by a switchboard at the observer's left hand. Slow motion can also be imparted by hand, by means of a string passing round a pulley near the switchboard and round another pulley on the same shaft as the worm (*vide* Fig. 5).

A brass wheel (9), the "contact wheel", with a flat rim rotates with the micrometer screw. A brush (+ in the Fig.) bears on its rim, and another (—) bears on one side nearer the centre. A piece of ebonite is let into the rim, so that the current between the brushes is broken every revolution. These two brushes are connected with one pen of the chronograph and make the automatic break.

The (+) brush is fixed to, but insulated from, a plate (13), which is carried on the boss of the bevel wheel (8), but does not rotate with it. The relative position of the brush and ebonite contact breaker can be changed by means of a slow motion screw (14), which holds and rotates the plate (13), or for large movements the milled headed screw (15) is slacked off, and the contact wheel (9) can then be turned freely, and the ebonite can be brought under the brush without moving the star.

To give stability to the micrometer screw, which is held against its spherical seating (16) by the usual light spring, a thrust bearing is provided at (17). The pressure on this is applied by slight springing in the plate (18), carefully adjusted by the screw (19). With this support the micrometer screw rotates freely and works accurately.

One wheel (6), in the drive, holds its spindle by a friction grip regulated by a spring and screw. This is provided to avoid risk of stripping the micrometer thread if it comes to the end of its run.

The circuit of the 2nd chronograph pen contains the clock relay, beating seconds, and the observer's tappet. The pen equation of the chronograph must be accurately determined. This has been done by putting both circuits in series. Both pens then beat seconds together.

3. Procedure when observing.—The procedure when observing is as follows.—The pen equation is first measured. The observer then views the star through the astrolabe and brings the two images side by side by means of the motor and finally with the hand movement. He then goes to the back of the collimator and sets the brush in line with the ebonite contact breaker as shown in Fig. 3, by slacking off the milled headed screw if necessary, and finally with the slow motion screw. To facilitate the setting, a small galvanometer is included in the circuit, and the brush is so set that the circuit is just broken. The galvanometer must be shorted when the chronograph is required to work, as it will not carry sufficient current. The coincidence of the two images is then verified and improved if possible. Setting the brush sometimes moves the star. When the brush is correctly set, the circuit will be broken every time the star returns to the position in which it gives level images in the astrolabe.

The images are then run apart with the motor for about 10 seconds, and then reversed so as to come together at the apparent speed of a real star's passage. The speed may be varied. The observer records its passage on his tappet and this constitutes one measure. Five or six such measures make a group. At the end of a group the images are again brought side by side and the setting of the brush is corrected for such error as may be found. The magnitude of the error is noted, and a small correction is applied to the final result, deduced from the average value of the closing error of all the groups, and the rate at which the contact wheel moves, on the assumption that the error has accumulated at a constant rate throughout each group. Errors of 0·05 seconds occurred frequently, due largely no doubt to inaccuracy in setting the images level, but also in part to slip in the mechanism or to temperature changes in the collimator, as evidenced by the occasional constant sign of the errors throughout the evening. About 12 such groups have been measured each night. Pen equation has been measured four times a night.

In order to comply with the two desiderata previously mentioned, it is clearly advisable to have the instrument set up actually at the station of observation, immediately to the north or south of the astrolabe, so that the latter may be turned on to it, when desired, and the personal equation measured without interruption. With the instrument in its present form, mounted on a heavy brick pillar, it was feared that trouble would arise with refraction, so this was not done. For the first month the instrument was set up indoors, and the astrolabe was taken into it, three times a night, and measures were made. For the second month it was set up in a tent, as close to the station as was thought safe (about 20 feet south), and another astrolabe was placed beneath it. Only a small pattern astrolabe was available for this. After observing every two real stars, the observer went to the tent and made two measures of his personal equation. The same tappet was used throughout.

It is thought that the latter arrangement is the better.

4. Proposed improvements.—The instrument, which is now being made, will be mounted horizontally on an wooden stand (*vide* Fig. 2). It is hoped that this will cause no irregular refraction when mounted in front of the astrolabe on the station at which star observations are made. By means of the two reflecting prisms the 3-inch collimator, which is available, will fully cover the field of the astrolabe, instead of utilising merely the edges of the collimator objective, as at present. The lamp, which illuminates the star, will be placed close to the aperture and a small 6-volt lamp, such as can be used in the field, will suffice. The present means for adjusting the brush and contact wheel is not satisfactory and will be improved. The possibility of rotating the collimator head and so changing the direction in which the star moves, will be eliminated, as it is thought that the observer concentrates entirely on the relative vertical motion of the two images, and is practically unaware of any horizontal motion which they may possess in common. It is intended that the instrument should be portable and that it should accompany the astrolabe into the field.

5. Two types of personal equation.—In Vol. XVII of the Operations of the G.T. Survey, chapter IV, it is suggested that personal equation consists of two terms, the first being the time taken for an eye impression to actuate the hand, and the second being due to the linear distance by which the eye fails to make a correct bisection. As applied to the astrolabe, the equivalent of the latter term would be a constant tendency to consider the two images level, when they are actually separated by a constant difference. It is clear that this instrument measures the first term only, and also that it is the only one which is required, provided the reflected image is always kept on the same side of the direct image. For, if this is done, the error in time caused by recording the passage of a star when (say) the right hand image is always slightly lower than the left hand, will be of opposite sign for east and west stars, being in fact equivalent to a small change in the prism angle.

6. Results.—The results of observations made in October to November 1926 are summarised below. The line "Deduced" has been obtained as follows. Assuming the longitude of Dehra Dūn to be that obtained for the whole series of operations, and applying the usual correction for the rate of propagation of wireless signals, the times of reception at Dehra Dūn of each day's signals have been deduced from the published results of 7 other observatories. Comparison with the times of reception according to the Dehra Dūn astrolabe observations, uncorrected for personal equation, gives the deduced values of the personal equation entered below.

Observer G.B.—Late Personal Equation in seconds of time.

	Oct. 1-17 6 days	Oct. 17-31 8 days	Nov. 1-15 4 days	Nov. 16—Dec. 1st. 8 days	Mean
Measured ...	·117	·103	·090	·111	·107
Deduced ..	·131	·115	·132	·081	·111
Error .	− ·014	− ·012	− ·042	+ ·030	− ·004

Observer H.W.W.*

	Oct. 1-17 6 days	Oct 17-31 4 days	Nov.1-15 5 days	Mean
Measured ...	·027	·092	·064	·055
Deduced ...	·145	·198	·186	·172
Error ..	− ·118	− ·106	− ·122	− ·117

* With this observer the instrument is a failure.

Observer G.H.O.

For four days, Nov. 22-27. Measured ·016 early. Deduced ·073 early. Error + ·057.

II. The Height of Mount Everest

1. Previous values.— Although the Survey of India has always retained the original value of 29,002 feet for the height of Mount Everest, other figures have been suggested. They are here summarised, and 29,050 feet is given as the most probable value.

(*a*) The height 29,002 feet assigned to Mount Everest is reckoned as being measured above a spheroid with axes equal in length to those of Everest's spheroid, placed so as to be tangent to the geoid in the plains south of Nepāl. In deriving this height, the refraction was computed on a somewhat irrational basis.

(*b*) The height 29,141 feet, derived by Colonel Burrard in his "Geography of the Himālaya & Tibet", is reckoned above the same spheroid as regards the observations from the plains, but the computation of the refraction has been more reasonably treated. His values, obtained from hill stations, are heights above Everest spheroids, tangent to the geoid at those stations; i.e. they are all above different spheroids.

(*c*) The height 29,149 $\pm 4 \cdot 6$ feet given by Dr. Hunter in 1922 in his lecture in Madras, is reckoned as being measured above an Everest spheroid parallel to *the* Everest spheroid, but shifted vertically so as to coincide with the geoid in the plains south of Nepāl. It cannot be said to be above Everest's spheroid (*vide* Note II). A reduction of about 30 feet is required to bring it into terms of Everest's spheroid, as therein defined.

(*d*) The height 29,080 feet with a possible error of 30 feet, given by Dr. Hunter in the same lecture is a geoidal height. For the reasons given in Note I it seems to be a little too high. In round numbers 29,050 is suggested as the most probable value.

2. Conclusion.—

(1) 29,050 feet is a fair value for the height of Mount Everest above the geoid.

(2) We must use geoidal heights and not spheroidal. (*vide* Note III).

(3) We ought not yet to make any changes in our accepted height.

3. Note I.—*The geoidal rise between the plains and Mount Everest.*—Dr. Hunter estimated the geoidal rise between the plains and Mount Everest as 70 feet. On the assumption that perfect Hayford compensation exists, we can calculate this rise. The result is 80 feet, agreeing well with Dr. Hunter. But we have evidence that these hills are not perfectly compensated. At Kurseong the Hayford deflection is 23″, the observed deflection is 51″. At Kaulia, (in Nepāl) these figures are 15″ and 33″. That is to say that at stations between the plains and the peaks the actual deflections are double the calculated deflections. If we were to generalise from this, we would say that the true geoidal rise under Mount Everest was double the calculated rise, i. e. 160 feet, giving 28,990 feet for the height of the peak. Such a generalisation would probably be wrong; the actual deflections at points close to the hill are very unlikely to be twice the calculated values. Also it may happen that the excess matter which causes the anomalies at Kurseong and Kaulia, lies south of the peaks, and so will cause deflections further north to be less than those calculated, giving a partial cancellation. Nevertheless, such evidence as we have, indicates that the geoidal rise is greater than Dr. Hunter's estimate of 70 feet, and that the geoidal height of the peak is less than 29,080 feet.

4. Note II.—*The definition of Everest's spheroid.*—The full specification of a spheroid of reference involves five quantities (apart from any question of its density):—

(a) & (b) The length of its two axes, or of one axis and the flattening.

(c) & (d) The angle (two components) between the spheroid and the geoid at some specified place (the origin).

(e) The vertical separation between the spheroid and the geoid at some specified place. This last is essential for heights, but not so very essential for latitudes and longitudes.

Of the above, (a) & (b) were defined by Colonel Everest, who also implicitly defined (c), the meridional component of the deflection at Kalīānpur, when he decided on the fundamental latitude of that place. Similarly General Walker implicitly defined (d), the other component, when he decided on a fundamental azimuth. (*vide* Dr. Hunter's Professional Paper 16).

The fifth quantity (e) has never been clearly specified. If the survey had been based on a single base-line, this quantity also would have been specified by the reduction of that base to "sea level". Whatever height had been used in the reduction of the base, would have been a height above the spheroid and thereby the position of a point on the spheroid would have been defined, namely, so many feet below the mark of such and such station, and hence so many feet above or below the geoid underneath that station, which is what is required. Unfortunately our Indian Survey has several bases; all have been reduced by their geoidal heights, and all give inconsistent values of the quantity (e).

This was inevitable in the absence of any knowledge of the separation between geoid and spheroid (which is not ordinarily available before the triangulation is computed), because Everest's spheroid as defined by (a), (b), (c) & (d) above, does not lie parallel to the geoid. Nor, of course, could any spheroid do so exactly. The discrepancies at our base-lines amount to 100 feet in height.

In his chart of the geoid, published as chart I of the Geodetic Report Vol. I., Dr. Hunter has arbitrarily chosen to make the geoid and spheroid coincide at Madras. This was not intended to constitute a definition of the quantity (e).

In our recent work on the geoid in India we have found it necessary to define this quantity, and have done so by taking the mean height of the geoid above the spheroid under the Indian bases to be zero. Incidentally this results in almost exact coincidence between geoid and spheroid at Kaliānpur. This definition appears the best possible. In the plains south of Nepāl, the geoid is about 30 feet below this spheroid.

5. Note III.—*Geoidal heights versus spheroidal.*—The arguments in favour of using geoidal heights are as follows:—

(1) Everest's spheroid has never yet been used for heights, having only very recently been sufficiently completely defined. All spirit-levelled heights are geoidal. Ordinary triangulation with fairly short rays, also gives a close approximation to geoidal heights.

(2) The height of mean sea level at Madras is 50 feet below Everest's spheroid; at Karāchi it is 50 feet above. Such heights could not be shown on maps. No change in the recently defined datum can remove these inconsistencies. No possible spheroid can keep within 20 feet of mean sea level in India.

(3) Spheroidal heights can never be obtained with the same high accuracy as spirit-levelled geoidal heights. It is only in the case of distant peaks lying in country full of large anomalous deflections, that the spheroidal height can be obtained with greater accuracy.

(4) In hills the geoidal height is a measure of the amount of work you must do to get to the top, in the plains it gives the fall available for canals. There is very little in it, but the geoidal height is the logical one to use.

PUBLICATIONS

OF THE

SURVEY OF INDIA

Obtainable from the Director, Geodetic Branch, Survey of India, Dehra Dūn, U.P.

SYNOPSIS

Part I—Numerical Data

Part II—Geodetic Works of Reference

* Part III—Historical and General Reports

* Part IV—Catalogues and Instructions

* Part V—Miscellaneous Papers

*** Publications detailed in Parts III, IV and V are also obtainable from the Officer in charge, Map Record and Issue Office, 13, Wood Street, Calcutta.**

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Price in Indian money		English equivalent	
Rupees	Annas	Shilling	Pence
0	2	0	3
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.

An Index chart of the published triangulation pamphlets is given at page 164.

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

Levelling Pamphlets—

(i) **Levelling of Precision**—giving heights and descriptions of all *Bench-marks*, 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	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.

Line number	Situated in degree sheets	Published in	Price
52A (Ruk to Sehwān) ..	35 M & N and 40 A	1928	As. 6
52B (Daur to Lundo) ...	40 B & C	,,	,,
52C (Shāhpur to Mahrābpur) ..	35 N and 40 A,B,C, F & G	,,	,,
52D (Tando Alāhyār to Hyderābād)	40 C & D	,,	,,

Levelling Pamphlets—(*Continued*).

Line number	Situated in degree sheets	Published in	Price
52E (Rohri to Jām Sahib) ...	40 A, B & E	1928	As. 6
52F (Shāhpur to Mīrpur Purāna)...	40 B, C & G	,,	,,
52G (Lāndhi canal bungalow (39th mile) to Khipro) ...	40 C & G	,,	,,
52H (Khipro to Ghulām Bhurgari)	40 G	,,	,,
52 I (Mīrpur Khās to Tando Ghulām Alī via Umarkot and Dādāh) ...	40 C, D, G & H	,,	,,
52J (Mīrpur Khās to Tando Ghulām Alī via Dīgrī) ...	40 G	,,	,,
52K (Dīgrī to Dādāh) ...	40 G & H	,,	,,
70J (Barākar to Hazāribāgh Road)	73 I and 72 H & L	,,	As. 12
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
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
77Q (Calcutta to Nārāyanpur) 77R (Nārāyanpur to Nārāyanpur)	79 B	,,	Re. 1
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—(*Concluded*).

Line number	Situated in degree sheets	Published in	Price
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
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	,	Re. 1-8

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.*

Tide-Tables—(*Continued*).

(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.*

(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, F.R.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 I_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.

G.T.S. Volumes—(*Continued*).

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.
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 N.W. Quadrilateral —the Computations.

Vol. III—**North-West Quadrilateral**—The Principal Triangulation, the Base-Line Figures, the Karāchi Longitudinal, N.W. Himālaya, and the Great Indus Series. Dehra Dūn, 1873. (Out of print).

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 elsewhere
Appendix No. **3.** On the Theory, Use and History of the Convertible Pendulum.
Appendix No. **4.** On the Length of the Seconds Pendulum determinable from Materials now existing.
Appendix No. **5.** A Bibliographical List of Works relating to Pendulum Operations in connection with the Problem of the Figure of the Earth.

G.T.S. Volumes—*(Continued).*

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.*

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 and 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.*

G.T.S. Volumes—(*Continued*).

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.*

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.

G.T.S. Volumes—(*Concluded*).

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.

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**".

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 I 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.*

Annual Reports &c.—(*Continued*).

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 Somāliland 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.*

(*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.*

Annual Reports &c.—(*Continued*).

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 Morê. Photo-Litho Office—New method of preparing Layer plates—Dovelopments 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.*

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.*

Annual Reports &c.—(*Concluded*).

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.*

(*e*) **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.*

Vol. III—**1226-27**—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.*

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.)	

Departmental Orders.—(*Continued*).

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.
3. * Regulations on the subject of Language Examinations for Officers of the Survey of India. Calcutta, 1914.
4. * Map Publication Orders 1908-1914 (Superintendent, Map Publication's Orders.)—Calcutta, 1914.
5. Specimens of papers set at Examinations for the Provincial Service.—Dehra Dūn, 1927. *Price Re. 1.*

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.*

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Catalogues and Lists.—(*Continued*).

8 **Green Lists**—Part I—List of Officers in the Survey of India (annually to date 1st January), Calcutta. *Price As. 10.*

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. 3-6.*

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—

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.*

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Tables and Star Charts.—(*Continued*).

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. Catalogue of 249 Stars for epoch 1st Jan. 1892, from observations by the Survey, Dehra Dūn, 1893. *Price Rs. 2.*

16. * 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.*

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, 1922. *Price Re. 1.*

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Survey of India Hand-Books.—(*Continued*).

Chapter VII—Trans-frontier Reconnaissance. Third Edition, 1924. *Price As. 8.*

" " —Addendum, 1928. *Price As. 8.*

" VIII—Surveys in time of war, 1926 *Price As. 8.*

" IX—Forest Surveys and Maps.—revised, 1925. *Price As. 8.*

" X—Map Reproduction. Second Edition, 1919. *Price As. 8.*

" XI—Geographical maps. Second Edition, 1926. *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).

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. *Report on the Working of the Light Field Litho Press (experimental) in November, and December 1910, with Appendices, by Lieut. A.A. Chase, R.E. Calcutta, 1911.

(i) Notes on some of the Methods of Reproduction suitable for the Field.

(ii) Suggested Equipment Tables for the Light Field Litho Press, (experimental).

5. *Report on a trial of the equipment of the 1st (Prince of Wales' Own) Sappers and Miners, for reproducing maps in the field, by 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.

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Notes and Instructions.—(*Continued*).

8. A Booklet of Instructions with full description and tables for The Hunter Short Base, compiled by Major C. M. Thompson, I.A. Dehra Dūn, 1928. *Price As. 8.*

9. *Instructions for taking Magnetic Observations, by J. Eccles, M. A. Dehra Dūn, 1896. (Out of print).

10. **Rectangular Co-ordinates.**—On a Simplification of the Computations relating to, by J. Eccles, M. A. Dehra Dūn, 1911. *Price Re. 1.*

11. ***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).

12. *Amended Instructions for the Survey and Mapping of Town Guide Maps. August 1919

13 *Notes on boundary ribands on maps of the Survey of India, by Major F. Fraser Hunter, D.S.O., I.A. Calcutta, 1922.

14. *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.

15. **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.	*Price Rs. 2.* per part
„ II.—The Principal Mountain Ranges of Asia.	
„ III.—The Rivers of the Himālaya and Tibet.	
„ IV.—The Geology of the Himālaya.	

2 *Report on the Identification and Nomenclature of the Himālayan Peaks as seen from Kātmāndu, Nepāl, by Captain H. Wood, R.E. Calcutta, 1904.

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)

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Unclassified Papers.—(*Continued*).

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'Armēe", 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.*

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.*

4. *Investigations regarding Gravity and Isostasy by W. Heiskanen (Translated by V. Pelts Esq. Revised and completed by Major C. M. Thompson, I.A.) Dehra Dūn, 1928.

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).

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Unclassified Papers.—(*Concluded*).

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).

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.

(5) Nickel-steel alloys and their application to Geodesy. (Translated from the French).

(6) Theory of electric projectors. (Translated from the French).

No 8—**Magnetic**—Experiments made to determine the temperature coefficients of Watson's Magnetographs, by Captain H. A. Denholm Fraser, R.E. Calcutta, 1905. *Price Re. 1.*

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Professional Papers.—*(Continued).*

No. 9—**Geodesy**—An Account of the Scientific work of the Survey of India, and a Comparison of its progress with that of Foreign Surveys. Prepared for the use of the Survey Committee assembled in 1905, by Lt.-Colonel S. G. Burrard, R. E., F. R. S. Calcutta, 1905. *Price Re. 1.*

No. 10—**Pendulums**—The Pendulum Operations in India, 1903-1907, by Major G. P. Lenox-Conyngham, R. E. Dehra Dūn, 1908. *Price Rs 2-8.*

No. 11—**Refraction**—Observations of Atmospheric Refraction, 1905-09, by H. G. Shaw, Survey of India. Dehra Dūn, 1911. (Out of print).

No. 12—**Geodesy**—On the Origin of the Himālaya Mountains, by Colonel S. G. Burrard, C. S. I., R. E., F. R. S. Calcutta, 1912. *Price Re. 1.*

No. 13—**Isostasy**—Investigation of the Theory of Isostasy in India, by Major H. L. Crosthwait, R.E. Dehra Dūn, 1912. (Out of print)

No. 14—**Refraction**—Formulæ for Atmospheric Refraction, and their application to Terrestrial Refraction and Geodesy, by J. de Graaff Hunter, M.A. Dehra Dūn, 1913. *Price Rs. 2.*

No. 15—**Pendulums**—The Pendulum Operations in India and Burma, 1908-13, by Captain H. J. Couchman, R.E. Dehra Dūn, 1915. *Price Rs. 2-8.*

No. 16—**Geodesy**—The Earth's Axes and Triangulation, by J. de Graaff Hunter, M.A. Dehra Dūn, 1918. *Price Rs. 4.*

No. 17—**Isostasy**—Investigations of Isostasy in Himālayan and neighbouring regions by Colonel Sir S. G. Burrard, K.C.S.I., R.E., F.R.S. Dehra Dūn, 1918. (Out of print).

No. 18—**Isostasy**—A criticism of Mr. R. D. Oldham's memoir "The structure of the Himālayas and of the Gangetic Plain", by Lt.-Colonel H. McC. Cowie, R.E. Dehra Dūn, 1921. *Price Rs. 1-8.*

No. 19—**Aerial Photography**—Experiments in Aeroplane Photo Surveying, by Major C. G. Lewis, R.E., and Captain H. G. Salmond, (Late R.A.F.). Dehra Dūn, 1920. *Price Rs. 1-8.*

No. 20—**Air Survey**— Reconnaissance Survey from Aircraft, by Lt.-Colonel G. A. Beazeley, D.S.O., R.E. Dehra Dūn, 1927. *Price Rs. 1-8.*

No. 21—**Rectangulation**—Irrigation and Settlement Surveys 1926, by Major J. D. Campbell, D.S.O., R.E. Dehra Dūn 1927. *Price Rs. 1-8.*

No. 22—**Levelling**—Three Sources of Error in precise levelling, by Captain G. Bomford, R.E. Dehra Dūn, 1929. *Price Rs. 1-8.*

Departmental Papers Series.*

No. 1—**Type**—A consideration of the most suitable forms of type for use on maps, by Captain M. O'C. Tandy, R.E. Dehra Dūn, 1913.

No. 2—**Symbols**—A review of the Boundary Symbols used on the maps of various countries, by Captain M.O'C. Tandy, R.E. Dehra Dūn, 1913.

No. 3—**Maps**—Extract from "The New Map of Italy, Scale 1: 100,000", by Luigi Giannitrapani. Translated from the Italian by Major W. M. Coldstream, R.E. Dehra Dūn, 1913.

No. 4—**Town Surveys**—A report on the practice of Town Surveys in the United Kingdom and its application to India, by Major C. L. Robertson, C.M.G., R.E. Dehra Dūn, 1913.

No. 5—**Stereo-plotter**—The Thompson Stereo-plotter and its use, with notes on the field work, by Lieut. K. Mason, R.E. Dehra Dūn, 1913.

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Departmental Papers Series.*—(*Continued*).

No. 6—**Levelling**—Levelling of High Precision, by Ch. Lallemand. Translated from the French by J. de Graaff Hunter, M.A. Dehra Dūn, 1914.

No. 7—**Standard Bars**—Bar Comparisons of 1907-08, by Major H. McC. Cowie, R.E. Dehra Dūn, 1915.

No. 8—**Helio-Zincography**—Report on Rubber Off-set Flat bed Machine Printing, by Captain S. W. Sackville Hamilton, R.E. Calcutta, 1915.

No. 9—**Stereo-Auto-Plotting**—A translation of Paul Corbin's French Stéréo Autogrammétrie, by Lt.-Colonel H. McC. Cowie, R.E. Dehra Dūn, 1922.

No. 10—**Projection**—The Lambert Conical Orthomorphic Projection, by Lt.-Colonel C. M. Thompson, I.A. Dehra Dūn 1929.

Professional Forms.

A large number of forms for the record and reduction of Survey Operations are stocked at Dehra Dūn.

List of more important contributions by the Officers of the Survey of India to various extra-departmental publications and related articles.

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).
8. ||Geological interpretations of Geodetic Results, by Colonel Sir S. G. Burrard, K.C.S.I., R.E., F.R.S. (Geographical Journal, October 1918).
9. ||War Surveys in Mesopotamia, by Colonel F. W. Pirrie, C.M.G. I.A. (Geographical Journal, December 1918).
10. ||Air Photography in Archæology, by Lt.-Colonel G. A. Beazeley, D.S.O., R.E. (Geographical Journal, May 1919).

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† Obtainable from Messrs. Dulau & Co., 37, Soho Square, London, W., or Messrs. Harrison & Sons, St. Martin's Lane, London, or the Royal Society at Burlington House, London.

‡ Obtainable from the Institution of Royal Engineers, Chatham.

§ Obtainable from Charles Robert Johnson at the offices of "Engineering", 35 and 36, Bedford Street Strand, London, W. C.

|| Obtainable from the Royal Geographical Society, Kensington Gore, London. S.W. 7.

List of more important contributions by the Officers of the Survey of India &c. &c.—(*Continued*).

11. *Mapping from Air Photographs, by Lt.-Colonel M. N. MacLeod, R.E. (Geographical Journal, June 1919).

12. *Reminiscences of the Map of Arabia and Persian Gulf, by Lt.-Colonel F. F. Hunter, D.S.O., I.A. (Geographical Journal, December 1919).

13. *Central Kurdistan, by Major K. Mason, M.C., R.E. (Geographical Journal, December 1919).

14. *Surveys in Mesopotamia during the War, by Lt.-Colonel G. A. Beazeley, D.S.O., R.E. (Geographical Journal, February 1920).

15. †A lecture on the Earth's Axes and Figure, by J. de Graaff Hunter, M.A. (The Observatory, May 1920).

16. *A brief review of the evidence upon which the Theory of Isostasy has been based, by Colonel Sir S. G. Burrard, K.C.S.I., R.E., F.R.S. (Geographical Journal, July 1920).

17. *A note on the topography of the NunKun Massif in Ladākh, by Major K. Mason, M.C., R.E. (Geographical Journal, August 1920).

18. *Notes on the Canal System and Ancient Sites of Babylonia in the time of Xenophon, by Major K. Mason, M.C., R.E. (Geographical Journal, December 1920).

19. ‡An Exploration in South-East Tibet, by Major H. T. Morshead, D.S.O., R.E. (Royal Engineers Journal, January 1921).

20. ‡Topographical Air Survey (with plates and maps), by Lt.-Colonel G. A. Beazeley, D.S.O., R.E. (Royal Engineers Journal, February 1921).

21. ‡Projection of Maps.—A review of some Investigations in the Theory of Map Projections, by A. E. Young, and Colonel Sir S. G. Burrard, K.C.S.I., R.E., F.R.S. (Royal Engineers Journal, March 1921).

22. ‡Report on Expedition to Kamet, 1920, by Major H. T. Morshead D.S.O., R.E. (Royal Engineers Journal, April 1921).

23. *The Circulation of the Earth's Crust, by Lt.-Colonel E. A. Tandy, R.E. (Geographical Journal, May 1921).

24. §Johnson's Suppressed Ascent on E 61., by Major K. Mason, M.C., R.E (Alpine Journal, November 1921).

25. *Stereographic Survey. The Autocartograph, by Lt.-Colonel M. N. MacLeod, D.S.O., R.E. (Geographical Journal, April 1922).

26. ‡The "Canadian" photo-topographical method of Survey, by Captain and Bt. Major E. O. Wheeler, M.C., R.E. (Royal Engineers Journal, April 1922).

27. §The Survey of Mr. W. H. Johnson in the K'un Lun in 1865, by Major K. Mason, M.C., R.E. (Alpine Journal, November 1922).

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* Obtainable from the Royal Geographical Society, Kensington Gore, London, S.W. 7.

† Obtainable from Messrs Taylor & Francis, Red Lion Court, Fleet Street, London, W.C.

‡ Obtainable from the Institution of Royal Engineers, Chatham.

§ Obtainable from Alpine Club, 23 Savile Row, London, W. 1.

List of more important contributions by the Officers of the Survey of India &c. &c.—(*Continued*).

28. *Gravity Survey, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. (A Dictionary of Applied Physics, Vol. III).

29. *Trigonometrical Heights and Atmospheric Refraction, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. (A Dictionary of Applied Physics, Vol. III).

30. Geodesy, by Colonel Sir G. P. Lenox-Conyngham, Kt., R.E., F.R.S. and J. de Graaff Hunter, M.A., SC.D., F. INST. P. (Enc. Brit. 12th Edition, Vol. XXXI, 1922).

31. †The proposed Determination of Primary Longitudes by International Co-operation, by Colonel Sir G. P. Lenox-Conyngham, Kt., R.E., F.R.S. (Geographical Journal, February 1923).

32. †Recent Developments of Air Photography.—(1) The adjustment of Air Photographs to Survey points, by Lt.-Colonel M. N. MacLeod, D.S.O., R.E. (Geographical Journal, June 1923).

33. ‡Mount Everest, by Major H. T. Morshead, D.S.O., R.E. (Royal Engineers Journal, September 1923).

34. †Kishen Singh and the Indian Explorers, by Major K. Mason M.C., R.E. (Geographical Journal, December 1923).

35. §Electrical registration of height of water at any time in Tidal Prediction, by J. de Graaff Hunter, M.A., SC.D, F. INST. P. (Journal of Scientific Instruments, Vol. I, No. 8, May 1924).

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).

40. †The Problem of the Shaksgam Valley, by Colonel Sir Francis Younghusband, K.C.S.I., K.C.I.E. (Geographical Journal, September 1926).

41. †The Shaksgam Valley and Aghil Range, by Major K. Mason, M.C., R.E. (Geographical Journal, April 1927).

42. A Break-Circuit for Pendulum Clocks, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. (Bulletin Géodésique No. 14, April, May, June 1927, Paris).

43. †A Graphical Discussion of the Figure of the Earth, by A. R. Hinks, C.B.E., F.R.S. (Geographical Journal, June 1927).

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* Obtainable from Messrs MacMillan & Co. Limited., St. Martin's Street., London, W.C., Bombay, Calcutta, Madras, Melbourne.

† Obtainable from the Royal Geographical Society, Kensington Gore, London, S.W. 7.

‡ Obtainable from the Institution of Royal Engineers, Chatham.

§ Obtainable from the Institute of Physics, 90 Great Russel Street, London, W.C. 1.

|| Obtainable from H.M. Stationary office, Adastral House, Kingsway, London, W.C. 2. 28, Abingdon Street, London, S.W.

¶ Obtainable from the office of Nature, St. Martin's Street, London, W.C. 2.

List of more important contributions by the Officers of the Survey of India &c. &c.—(*Concluded*).

44. *Survey on Active Service, by Captain G. F. Heaney, R.E. (Royal Engineers Journal, June 1927).

45. A Report on the Geodetic work of the Survey of India for the period 1924-27, by J. de Graaff Hunter, M.A., SC.D., F. INST. P., presented at the third meeting of the International Union of Geodesy and Geophysics, Prague, September 1927.

46. †The Stereographic Survey of the Shaksgam, by Major K. Mason, M.C., R.E. (Geographical Journal, October 1927).

47. †Figure of the Earth: correspondence by J. de Graaff Hunter, M.A., SC.D., F. INST. P. (Geographical Journal, December 1927).

48. †Figure of the Earth: correspondence by Captain G. Bomford, R.E. (Geographical Journal, December 1927).

49. †Reply to Captain G. Bomford's letter on Figure of the Earth (No. 48 of list), by Captain G. T. McCaw and A. R. Hinks, C.B.E., F.R.S. (Geographical Journal, December 1927).

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).

52. ‡Some Applications of the Geoid by J. de Graaff Hunter, M.A., SC.D., F. INST. P. (The Observatory, June 1928).

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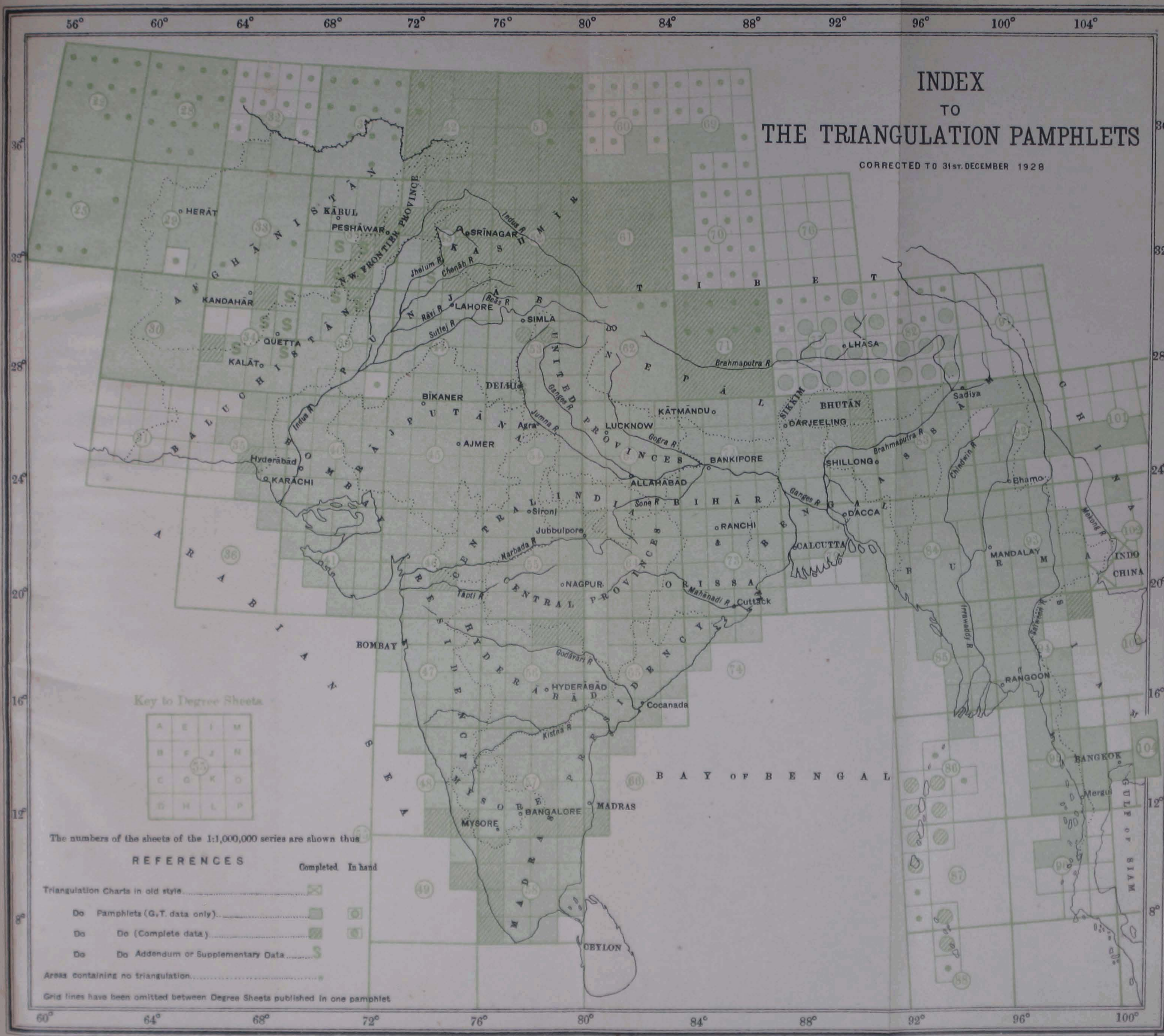
* Obtainable from the Institution of Royal Engineers, Chatham.

† Obtainable from the Royal Geographical Society, Kensington Gore, London, S.W. 7.

‡ Obtainable from Messrs Taylor and Francis, Red Lion Court, Fleet Street, London, W.C.

Geod. Br. P.O.—450—1929.

Chart XIX



Reg. No. 1758 O.D.D. 1929 (C.O.)S. I.—500

Scale $\frac{1}{20,000,000}$ or 1·013 Inches to 320 Miles

Miles 100 50 0 100 200 300 400 500 Miles

Heliozincographed at the Survey of India Offices, Dehra Dūn.

To accompany Geodetic Report Vol. III