SURVEY OF INDIA

GEODETIC REPORT

1933

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BRIGADIER H. J. COUCHMAN, D.S.O., M.C.,
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INTRODUCTION

1. 1932–33 was the first year completed under the new organization of the Geodetic Branch as tabulated in the Introduction to Geodetic Report Vol. VIII. Except for two sections of No. 14 Party, all units were in active operation and a satisfactory amount of work was completed. Pendulum work was suspended during Major Glennie's absence on leave.

2. *Base-lines.* (Chapter I). Three base-lines were measured in Burma, at Mergui, Amherst and Kalemyo with Lieut. I. H. R. Wilson in charge. That at Mergui is an old base which has never been considered quite trustworthy, but the new measure agrees with the old within one part in 150,000, which is satisfactory.

The invar wires have undergone considerable changes in length; the cause is difficult to discover, but it is possible that instability was excited during the determination of their temperature coefficients in 1931. As a result the base-lines measured this year are liable to error that may be as much as 1:300,000. The matter is discussed in Chapter V, paras 1 to 4.

The latest comparisons at Dehra Dūn show that the invar wires appear to have settled down, and good results are expected during the season 1933–34, when it is proposed to measure base-lines near Dālbandin in Baluchistān, near Poona, and south of Dibrugarh in the Assam Valley. So far as can be foreseen, these are the last three bases required for geodetic purposes in India.

In connection with the base-line at Dibrugarh, a reconnaissance will at the same time be started for a new primary series of triangulation to replace the old secondary Assam Valley Series.

3. *Levelling.* (Chapter II). The level nets of India and Burma were connected by a line of levels from Chittagong to Minbu via Akyab. Connection with the tide-gauges at Chittagong and Akyab shows that an error of about 3 feet occurred between these two places. The cause of this error has not been detected, and this section will have to be relevelled.

A secondary detachment was employed on levelling for the Bhakra Dam irrigation project in the Punjab.

No work was carried out on the High Precision level net, commenced in 1913.

The 1933–34 programme provides for the connection of the Burmese and Siamese nets by H.P. levelling from Kēngtūng to the Siamese frontier: revision levelling in the area disturbed by the Pegu earthquake of 1930: and a line of precision levelling from Mandalay to Lashio.

4. *Deviation of the vertical.* The present scheme is to complete two lines of deflection stations at close intervals across India: one from north to south through Cape Comorin, and one east to west from Burma to the Persian Frontier. The work was started in 1930 (see Geodetic Report Vol. VII). In 1932–33, the Burmese section of the east-and-west line was completed, 44 stations being observed. Details are given in Chapter III, with a chart and sections of the geoid. Captain Bomford was in charge of the work.

During 1933–34 this line will be continued from the Burmese Frontier and through Bengal, and the Burmese geoid will then be connected to that already mapped out in India. It is hoped that the Siamese and Indo-Chinese Survey Departments will be able to continue the work into their country. Work will also be started at Cape Comorin at the south end of the meridional line.

A longitude observation at Kēngtūng (Burma) completed the formation of a Laplace station there, (Chapter III, para 9).

5. *Dehra Dūn observatory.* The longitude observations at Dehra Dūn have been carried on as usual, (Chapter V paras 5 to 7). The Shortt clock is now in regular use and has been working well, and Dr. de Graaff Hunter's new type of transit has been giving satisfactory results. The observations have been made by Mr. R.B. Mathur and Mr. H.C. Banerjea.

The variation of latitude has now been observed for three complete years, and the work has therefore been stopped. As reported last year, the amplitude of the variation is very large, and this is ascribed to meteorological causes, (Chapter V, para 9). The observer has been Computer Jagdish Behari Mathur. It is hoped to resume the work at Agra at some future date.

Magnetic observations have been carried on as usual at Dehra Dūn, but there is no present hope of re-opening the Kodaikānal and Toungoo magnetic observatories.

6. *International Longitude Project.* Three transits have been employed at Dehra Dūn during October and November 1933, with four different observers, and the Rugby, Bordeaux and Saigon wireless signals have been regularly received. The results will be given in the report for 1934. (See also Chapter V para 8, of this report).

7. *Tide Predictions.* (Chapter VI). The tide-tables for 1934 have been prepared as usual, including predictions for Chāndbāli and Shortt Island for the first time.

8. *Changes of level in Bengal.* In Chapter VII, Section I, Captain Bomford deals further with the evidence of the existence of such change, with particular reference to criticisms made by Sir Sidney Burrard, who does not accept the conclusions reached in our Geodetic Report Vol. VI (1929–30).

Sir Sidney strongly recommends that a standard bench mark should be established on natural rock in the neighbourhood of Pārasnāth, to provide a point for future reference that would be undisturbed by alluvial settlements. We have paid particular attention to the provision of such marks in the new level net that was commenced in 1913, but it is unlikely that we shall be able to find money in the near future for the extension of this net in the direction of Bengal. For the purpose of the present comparison, however, any group of bench marks outside the alluvial area which has remained stable in the relative height between one mark and another is as good as a single rock-cut bench mark.

The evidence in favour of a 3-foot rise of the north-west of Bengal is accumulated from comparisons which cover a wide area; it will be of the greatest interest to see whether future levelling supports this evidence.

9. *Gravity.* As mentioned in para 1, no gravity observations have been made during 1932–33. In Chapter VII, Section II, Major Glennie contributes a note on the effect of terrestrial magnetism on invar pendulums. He concludes that work which has been done in India has not been seriously affected, but that mu-metal screens should be employed in future as an additional precaution.

The gravity gradiometer, which gave unsatisfactory results in 1931–32 (Geodetic Report Vol. VII, Chapter IV, Section II), has been modified by Messrs. Cooke, Troughton and Simms in England, and is now in good order.

The programme for 1933–34 includes 35 to 40 pendulum stations in SW. and south India, 10 stations in Ceylon, and 5 to 10 stations in the Maldive Islands, which Major Glennie will visit on the ship of the John Murray Oceanographic Expedition.

10. *Geodetic Reports.* The annual reports have hitherto been numbered as Vols. I to VIII. From the present report onwards they will be known by the year in which they are prepared. Thus the present report, for the period October 1932 to September 1933, which would have been known as Vol. IX, is entitled the Geodetic Report for 1933.

11. The personnel of the Geodetic Branch during the year is given on the following pages.

PERSONNEL* OF THE GEODETIC BRANCH, 1932–33

Director, Geodetic Branch

DR. J. DE GRAAFF HUNTER, M.A., SC. D., F. INST. P., to 25th Nov. 1932

COLONEL R. H. PHILLIMORE, D.S.O., from 26th Nov. 1932

OFFICE OF THE DIRECTOR, GEODETIC BRANCH

Ministerial Service

Head Assistant

Mr. Diwan Chand

Assistants

Mr. Ram Pat to 2nd Jan. 1933.
Mr. Bal Krishna Ojha to 1st Mar. 1933.
Mr. Krishna Lal Sharma from 2nd Mar. 1933.
19 Clerks.

COMPUTING AND TIDAL PARTY

(RECORDS AND RESEARCH)

Class I Service

Lt.-Colonel A. H. Gwyn, I. A. in charge, to 12th Nov. 1932.

(Charge was held by the Director, Geodetic Branch from 13th Nov. 1932 to 16th April 1933).

Captain G. Bomford, R.E., in charge from 17th April 1933.

Mr. B. L. Gulatee, M.A. (Cantab.), Mathematical Adviser.

OBSERVATORY SECTION

Class II Service

Mr. R.B. Mathur, B.A., (Tidal Assistant)

MAGNETIC OBSERVER

Mr. Shyam Narain, B.SC.

Lower Subordinate Service

6 Computers.

TIDAL SECTION

Upper Subordinate Service

Mr. H C. Banerjea, B.A.

Lower Subordinate Service

9 Computers.

COMPUTING SECTION

Upper Subordinate Service

Mr. M. Chatterji.

Mr. H. C. Deva, B.A.

Mr. A. K. Maitra, B.A.

Mr. C. B. Madan, B.A.

Mr. G. P Rao, M.A. to 7th July 1933.

Lower Subordinate Service

12 Computers.

1 Librarian.

CHART SECTION

(ADMINISTERED BY O.C. 2 D.O.)

Upper Subordinate Service

Mr. A. A. S. Matlub Ahmad to 30th April 1933.

Lower Subordinate Service

6 Surveyors and Draftsmen.

No. 14 PARTY (GEOPHYSICAL)

Class I Service

Captain G. Bomford, R.E., in charge, to 9th July 1933.

Major E. A. Glennie, D.S.O., R.E., in charge from 10th July 1933.

Lower Subordinate Service

1 Computer.

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* Excluding No. 1 Party, 20 Detachment, No. 2 Drawing and Forest Map Offices Printing, Photo-Zinco, Stores and Workshop Sections.

NO. 15 PARTY (TRIANGULATION AND LEVELLING)

Class I Service

Lieut. I. H. R. Wilson, R. E., in charge. to 5th Aug. 1933 and from 28th Aug. 1933 to 12th Sep. 1933.

Captain G. Bomford, R. E., in charge, from 6th Aug. 1933 to 27th Aug. 1933 and from 13th Sep. 1933.

Class II Service

Mr. N. N. Chuckerbutty, L.C.E.

Mr. M. N. A. Hashmie, B.A.

Upper Subordinate Service

Mr. J. N. Kohli.

Mr. Mohd. Faizul Hasan.

Mr. P. K. Chowdhury.

Mr. I. D. Suri to 15th June 1933.

Mr. L. R. Howard.

Mr. A. P. Dutta (Probationer) to 7th Nov. 1932.

Lower Subordinate Service

8 Computers.

2 Clerks.

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).

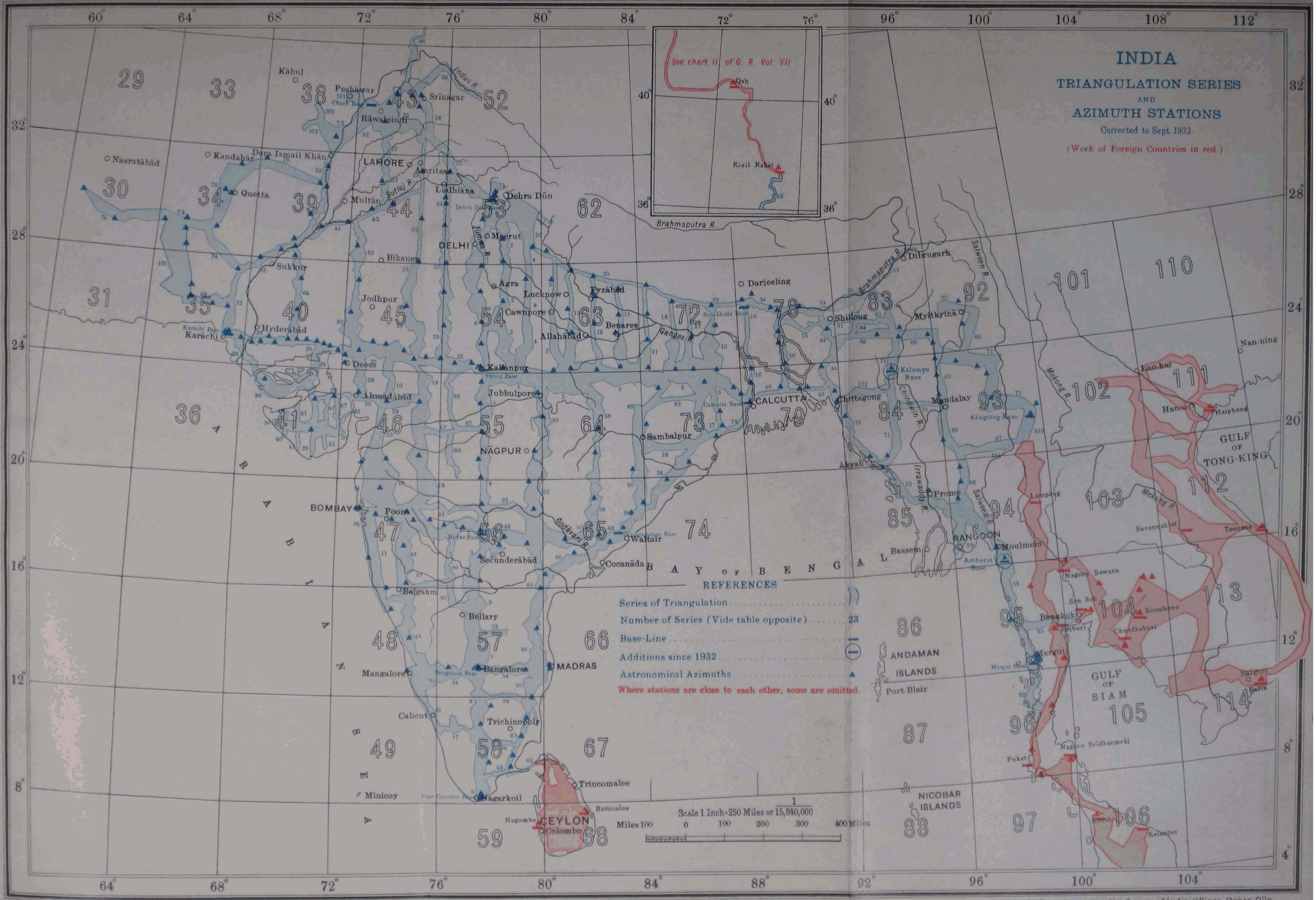
For 42 Series entering the Simultaneous Grinding (shown in italics below) Mean Square M = ± 1·04
For Series up to No. 107 ... ... Mean Square M = ± 1·52

No.	Name of Series	Seasons	± *m*	± M
1	South Pārasnāth Mer. ...	1831-39	3·308	3·26
2	Budhon Meridional ...	1833-43	2·242	2·46
3	*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	*Hurilāong Meridional* ...	1848-52	1·502	1·92
22	*North-West Himālaya* ...	1848-53	0·641	0·55
23	*Gurhāgarh Meridional* ...	1848-62	0·914	1·21
24	*East Coast* ...	1848-63	0·608	0·70
25	*Karāchi Longitudinal* ...	1849-53	0·558	0·60
26	*Abu Meridional* ...	1851-52	0·617	0·68
27	*North Pārasnāth Mer.* ...	1851-52	0·895	1·25
28	*Kāthiāwār Meridional* ...	1852-56	0·990	1·11
29	*Gujarāt Longitudinal* ...	1852-62	0·859	1·12
30	Kāthiāwār Lon. ...	1853	1·481	1·34
31	Sābarmati ...	1853-54	1·348	2·84
32	*Great Indus* ...	1853-61	0·359	0·43
33	*Rāhon Meridional* ...	1853-63	0·327	0·37
34	*Assam Longitudinal* ...	1854-60	0·579	0·71
35	*Cutch Coast* ...	1855-58	0·986	1·27
36	Kashmir Principal ...	1855-60	0·884	0·86
37	*Jogi-Tila Meridional* ...	1855-63	0·481	0·59
38	Sambalpur Lon. ...	1856-57	0·808	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

No.	Name of Series	Seasons	± *m*	± M
52	Burma Coast (*See* 106) ...	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	0·98
60	Hyderābād ...	1871-72	1·405	1·58
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	0·38
69	Makrān Longitudinal ...	1895-97	0·285	0·28
70	Mandalay Lon ...	1899-1909	1·696	1·98
71	Manipur Mer. ...	1890-1902, 1915-1916	0·750	0·81
72	Great Salween (*See* 105)	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
80	Upper Irrawaddy ...	1909-11	0·596	0·49
81	Jaintia Hills ...	1910-11	0·986	1·86
82	Bhir ...	1911-12	0·794	0·94
83	Rānchi ...	1911-12	1·840	2·34
84	Villupuram ...	1911-12	1·184	1·76
85	Sambalpur Meridional ...	1911-14	0·250	0·21
86	Indo-Russian Connection	1912-13	2·790	3·02
87	Khandwa ...	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	0·98
92	Middle Godāvari ...	1914-15	0·913	1·08
93	Kohima ...	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
99	Rangoon ...	1925-27	1·246	1·25
100	Kurram ...	1927-28	2·096	2·26
101	Peshāwar ...	1927-28	1·267	0·96
102	North Wazīristān ...	1927-28	1·895	2·47
103	Chittagong ...	1928-30	0·453	0·45
104	Mong Hsat ...	1929-31	0·441	0·38
105	Great Salween ...	1929-31	0·682	0·58
106	Burma Coast ...	1930-31	0·205	0·19
107	Dālbandin ...	1931-32	0·472	0·32

Mer. = Meridional   Lon. = Longitudinal.

* Replaced by 104.



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Heliozincographed at the Survey of India Offices, Dehra Dūn.

CHAPTER I

TRIANGULATION AND BASE MEASUREMENT

BY LIEUT. I. H. R. WILSON, R.E.

1. Summary. The season's programme consisted of the measurement of three base-lines in Burma. The first, at Mergui, was the re-measurement of the old base, which was measured with Colby Bars in one direction only in 1881–82. The other two, at Amherst and Kalemyo, were new bases and were connected by triangulation to the Burma Coast and the Manipur Meridional Series, respectively.

As stated in Geodetic Report Vol. VII, page 4, it was originally intended to have a base at Akyab, but though the ground proved suitable, a preliminary reconnaissance by Mr. L. R. Howard in March 1932, disclosed the fact that the majority of the stations of the Burma Coast Series in this neighbourhood had been destroyed by the local inhabitants. As it would have entailed the reobservation of about 10 of the old stations of that series before the connection could be effected, this site was abandoned, and the base was located near Kalemyo in the Upper Chindwin district.

The work was completed by the middle of March, and the health of the detachments was excellent throughout.

2. Organization. The party was organized in three detachments. No. 1 under Mr. L. R. Howard, carried out the lay-out of Mergui and Amherst bases and preliminary reconnaissance and lay-out for the Kalemyo base.

No. 2 under Mr. M. N. A. Hashmie, carried out the base extension and connection to geodetic triangulation at Amherst and Kalemyo.

No. 3 under Lieut. I. H. R. Wilson, R. E., with Mr. P. K. Chowdhury as assistant, carried out the actual measurement of the three bases.

It was considered best to have a separate detachment for the triangulation work because, although the Amherst base extended direct on to the G.T. side Sindaung H.S. Kyaikkamaw H.S., both these stations had been tampered with, and it was necessary to re-occupy two other stations in order to redetermine their positions. The Kalemyo site had not yet been reconnoitred, and it was not known what extra triangulation (to refix destroyed or damaged stations) would be necessary. To have allowed one detachment to do both the base-measurement and its extension involved the risk of not completing the programme in the time available. In actual fact the triangulation detachment started work some three weeks before the base-measurement detachment, and both completed work at Kalemyo within 3 days of each other.

3. General remarks. A new type of base tower was introduced, principally on the score of economy. Plates III and IV give some photographs, and Plate V gives a plan and section of this type of tower. It proved quick to build, economical, and suitable for the work. As it is of very light design the following precautions were taken to guard against the top mark being affected by subsidence or bending of the tower:

(*a*) The top mark-stone was laid by the triangulator himself (when placing his helio squads) from the bottom mark-stone, by a theodolite set up both at right angles to and in the line of the base, using the windows provided.

(*b*) The centring was checked again by the triangulator before actually observing from the station.

(*c*) On completion of the work the top mark-stone was removed, the tower knocked down to a height of about 9 feet, and then the top and all the windows were bricked up and cement-plastered. If required for work in the future, it is simple to excavate the bottom windows and lay a new top mark-stone from the ground one. This prevents the utilization of the old top mark-stone by future observers without checking it from the ground mark.

(*d*) When measuring the base, the base-plug was checked against the ground mark by a theodolite set up at right angles to the base, and the error (if any) was measured by scale and dividers.

With very slight modifications the procedure used on the Kĕngtūng base (see Geodetic Report Vol. VII, Chapter VI) was followed at all three bases this year. Direct levelling between tripods (i.e. carried out simultaneously with the base measurement) was never employed, owing to lack of sufficient officers. Except in one section of the Kalemyo base, the flatness of the ground made such levelling unnecessary. In this section at Kalemyo, the line crossed a hollow about 300 yards broad and 15 feet deep, and the 72-metre wire was used for passing in and out of the hollow. The flatter slope of the long wire results in a smaller height correction, so that the usual method of measuring the heights involved no unusual risk.

4. Invar wires. The same wires as were used in the measurement of the Kĕngtūng base were again used this season. Chapter V, paras 1 to 4, gives the results of the standardizations carried out before and after the field season, discusses the probable reasons for the changes, and deduces values for the lengths of the wires at each base. Wires Nos. 244 and 249, which had shown such great changes since the April 1931 standardization, were so paired that one went into each (i.e. south to north and north to south) measure of the base, and the arrangement was:

Field standards ...	...	Nos. 248 & 252
Pair I (North to South)	...	Nos. 243 & 249
Pair II (South to North)	...	Nos. 247 & 244

A close watch was kept on the results of the daily comparisons, to see that the difference between the two wires of each pair remained reasonably constant. The average difference per bay in each day's field-work was also checked, and where this did not agree (within reasonable limits) with the mean value given by the daily comparisons, the day's work in question was remeasured. By this means it was hoped to prevent inaccuracy by not allowing any sudden changes in the lengths of the wires to pass unnoticed.

5. Mergui Base. The old base at Mergui stretches from east to west across Mergui Island, a distance of about 3½ miles. It was divided into 4 sections of about 50 bays each, and no centre station was built. Owing to late rains the ground was waterlogged and the paddy uncut, with the result that platforms made of wooden sticks and sods had to be built for 90% of the tripod stations. The actual measurement of the base took 10 days. The fourth section was repeated in both directions as the original measures disagreed, owing to some undetected blunder having crept in the east-to-west measurement. Section 3 was also remeasured in one direction, as the result did not conform very well with the daily comparisons. The speed was slow, but work was both slow and tiring with 6 inches of mud and up to as much as 2 feet of water. It was eventually found convenient to limit each day's work to one section. The results were as follows.

Section No.	East to West		West to East		Mean value of each section
	No. 243	No. 249	No. 244	No. 247	
1	1250·381	1250·381	1250·382	1250·380	1250·381 metres
2	1249·595	1249·594	1249·593	1249·592	1249·593 ,,
3	1249·411	1249·410	1249·409*	1249·409*	1249·410 ,,
4	1215·853	1215·852	1215·855	1215·853	1215·853 ,,
Total ...	4965·240	4965·237	4965·239	4965·234	4965·237 metres

Mean length of Base, East to West (Wires 243 and 249) = 4965·238 metres.
Mean length of Base, West to East (Wires 244 and 247) = 4965·237 metres.

* Mean of ·408 and ·409, and of ·406 and ·413 respectively.

This gives a discrepancy between the two measures of about 1 in 5,000,000.

The angle at Natkalintaung H.S. was remeasured to ensure that the terminal marks had not shifted since the original work in 1881–82: the new value of the angle agreed with the old within 0·5 seconds.

6 Amherst Base. This base runs north and south in the paddy fields between Moulmein and Amherst. It is 8½ miles long and practically straight throughout, the bend at the centre station being only a few minutes of arc. Except for the two most northerly sections the paddy had been cut, and only a few mud platforms had to be built for the tripod positions. The actual measurement offered no difficulties, and the speed of the detachment varied from about 70 to 100 bays per day, though it was normally found best to limit a day's work to a section of 70 bays.

In the middle of the south half the line passed over the Kwanhla-chaung, a stream about 300 yards broad at high tide. This was crossed by two nearly equilateral triangles, the side crossing the stream being common to both. One side of each triangle was measured with both pairs of wires and the two deduced values of the common side agreed within 0·4 mm.

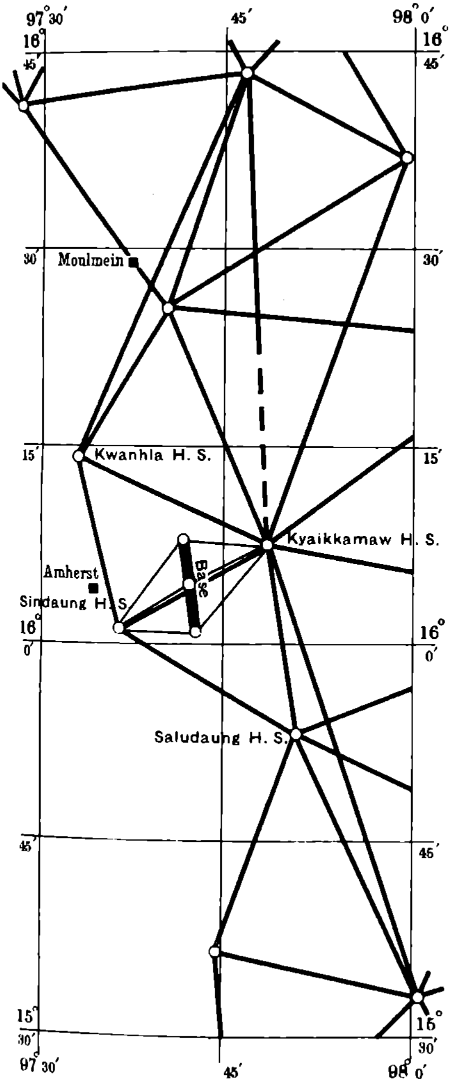
One pair of wires (Nos. 243 and 249) showed large changes of length during the first few days, but became steady later, and consequently the first three days' work was repeated, and the first results rejected. Sections 3 and 4 were also revised to give Mr. Hashmie, who was in charge of the triangulation detachment, some experience in the work. For these two sections direct levelling between the tripods was employed. The mean of the two sets of measures of these sections has been accepted. The results were as follows.

BASE-LINE CONNECTIONS

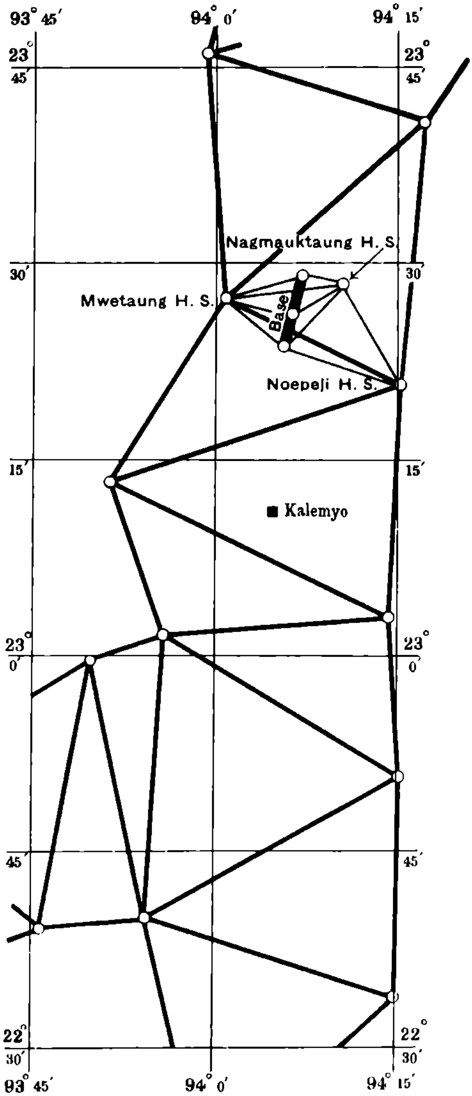
Geodetic triangulation of previous years

" " " 1932-33

Amherst Base



Kalemyo Base



REG. No. 88 D.D.D. 1933–350

Helio S. I. O. Dehra Dūn.

Scale $\frac{1}{1,000,000}$ or 1·014 Inches to 16 Miles

Miles 10 5 0 10 20 Miles

KALEMYO BASE. TERMINAL TOWER.

AS LEFT AFTER WORK.

WITH OBSERVATORY TENT FOR TRIANGULATION.

PLATE IV.

KALEMYO BASE. TERMINAL TOWER.

WITH INVAR WIRE IN POSITION.

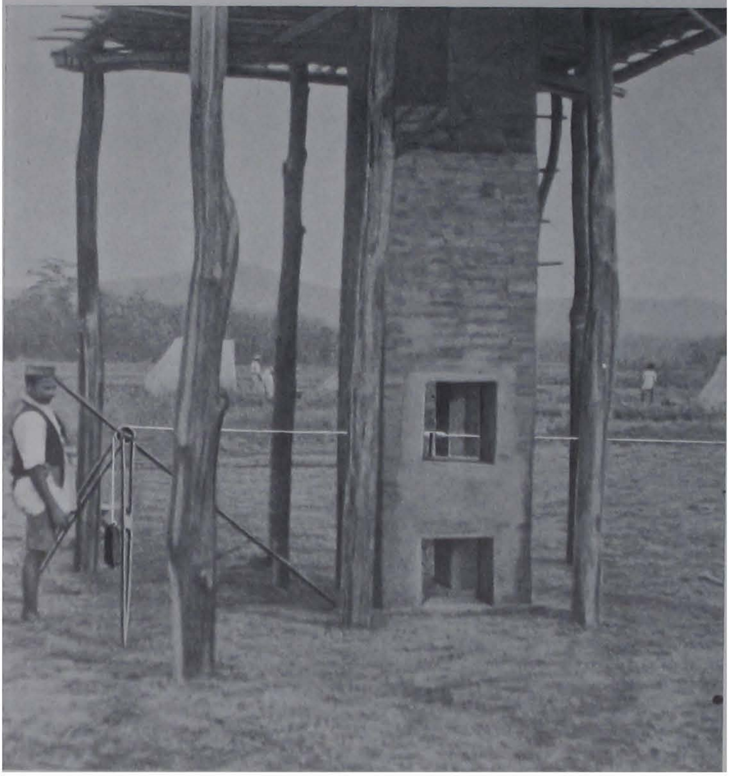
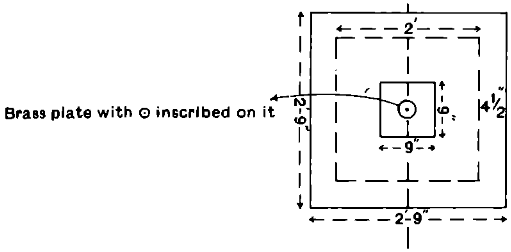


Plate V

BASE TERMINAL STATION

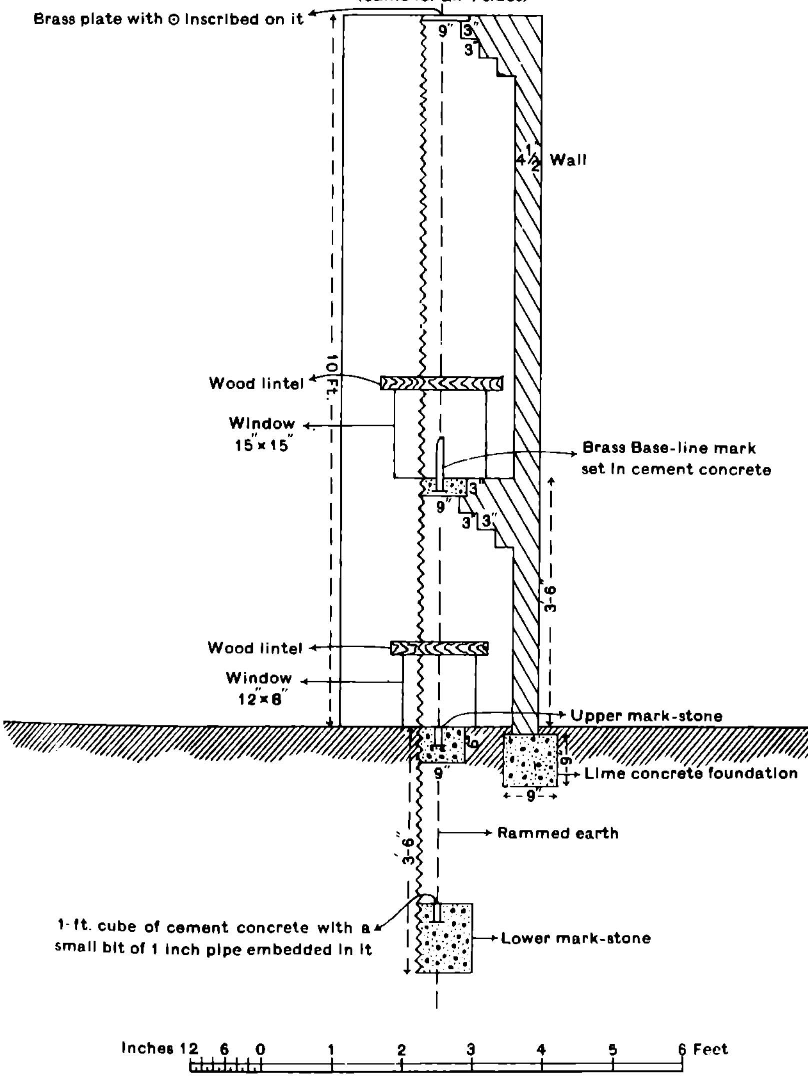
PLAN



½ brick wall, alternate stretchers and ½ headers, if pakka are available. If only kachcha mud bricks, the wall should be 6" or 9" thick with the proviso that the centre clear space is 1'-7"×1'-7".

ELEVATION

(Same for all 4 sides)



REG. No. 87 D.D.D. 1933

Helio S. I. O. Dehra Dun.

Section No.	North to South No. 243	North to South No. 249	South to North No. 244	South to North No. 247	Mean value of each section	
1	1702·102	1702·099	1702·100	1702·098	1702·100	metres
2	1653·981	1653·980	1653·980	1653·977	1653·979	,,
3	1646·393	1646·390	1646·391*	1646·390*	1646·391	,,
4	2029·105	2029·100	2029·100†	2029·101†	2029·102	,,
Total N. Half	7031·581	7031·569	7031·571	7031·566	7031·572	,,
5	1702·164	1702·161	1702·159	1702·163	1702·162	,,
6	1678·508	1678·505	1678·510	1678·513	1678·509	,,
River bay	305·916	305·916	305·916	305·916	305·916	,,
7	1425·310	1425·307	1425·310	1425·310	1425·309	,,
8	1438·741	1438·737	1438·738	1438·737	1438·738	,,
Total S. Half	6550·639	6550·626	6550·633	6550·639	6550·634	,,
Total length of base	13,582·220	13,582·195	13,582·204	13,582·205	13,582·206	metres

Length of Base, North to South (Wires 243 and 249) = 13,582·208 metres.
Length of Base, South to North (Wires 244 and 247) = 13,582·205 metres.

This gives a discrepancy between the two measures of less than 1 in 4,000,000.

0·001 metres have to be subtracted from the final value, as the base-plug at the North End Station was found to have shifted by this amount during the setting of the cement.

The extension was simple, as the base-line lies across the G.T. side Sindaung H.S.-Kyaikkamaw H.S., and once the positions of these stations were refixed, the base was long enough to allow direct extension to be employed. See Chart II.

7. Kalemyo Base. This base is about 30 miles north of Kalemyo, in the Kabaw valley. It consists of two halves, the north 3·8 and the south 2·8 miles long, with a bend of about 169° at the centre.

* Mean of ·392 and ·390 and of ·390 and 389 respectively.
† Mean of ·101 and ·099 and of ·099 and 103 respectively.

The sections of the base were all about 63 bays long, and either 1 or 1½ sections were measured per day. The line ran mainly through paddy fields with a few short stretches of jungle which had to be cleared. In the north half three steep-sided *nālas*, varying in depth from 15 to 25 feet, had to be crossed, one of which required the 72-metre wire, and the only difficulty encountered in the measurement of the base was that of getting the wires safely across these *nālas*. In spite of the precautions taken, one wire (No. 247) got slightly kinked owing to one of the wire-men slipping, while crossing a *nāla*.

Including reconnaissance, jungle clearing, and building the terminal towers, the measurement of this base was completed in 34 days.

No sections were remeasured, as the relative lengths of the wires agreed closely with their Amherst values.

The results were as follows.

Section No.	North to South		South to North		Mean value of each section
	No. 243	No. 249	No. 244	No. 247	
1	1509·821	1509·820	1509·827	1509·827	1509·824 metres
2	1548·075	1548·073	1548·078	1548·080	1548·076 ,,
3	1477·197	1477·197	1477·202	1477·204	1477·200 ,,
4	1500·626	1500·625	1500·631	1500·632	1500·629 ,,
Total N. Half	6035·719	6035·715	6035·738	6035·743	6035·729 ,,
5	1486·331	1486·330	1486·337	1486·336	1486·333 ,,
6	1496·538	1496·537	1496·540	1496·540	1496·539 ,,
7	1512·406	1512·404	1512·410	1512·411	1512·408 ,,
Total S. Half	4495·275	4495·271	4495·287	4495·287	4495·280 ,,
Sum of two * halves	10,530·994	10,530·986	10,531·025	10,531·030	10,531·009 metres

Sum of two halves from North to South (Wires 243 and 249) = 10530·990 metres.
Sum of two halves from South to North (Wires 244 and 247) = 10531·028 metres.

The discrepancy between the two measures comes to 1 in 280,000. This is a large discrepancy. It occurs in every section and is evidently due to error in the accepted lengths of the wires.

* As the base is not straight, this does not represent the distance between the two ends.

The latter, however, are in accordance with the daily comparisons between the wires, (see Chapter V, para 4), and no satisfactory explanation can be found for the discrepancy.

Owing to shifting of the base-plugs at the terminal stations, 0·002 metres must be subtracted from the final figure for the base (i.e. 0·003 is to be subtracted on account of the North End Station and 0·001 added on account of the South End).

A diagram showing the extension to the G.T. side Mwetaung H.S.–Noepeji H.S. is given in Chart II.

8. Astronomical observations. Astronomical latitudes and azimuths were observed at all the stations of the base net both for the Amherst and the Kalemyo bases, eleven stations in all. For latitude, 3 pairs of north and south circum-meridian stars were taken. In other respects, the programme was the same as that used at the Kēngtūng base (see Geodetic Report Vol. VII, Chapter VI, para 5). The results are given in Chapter III of this report, Table 2.

9. Final reduced values. To obtain the final reduced values of the three bases, the results have first to be brought to Indian feet by the relation

1 standard yard =0·914 399 20 metres.

1 Indian foot =0·333 331 886 standard yards.*

and then reduced to sea-level (spheroidal), the height correction being calculated for the spirit-levelled height *plus* the separation between geoid and spheroid at the place. The final values come out as follows.

(*a*) *Mergui Base.* The spheroidal height of this base is 318 feet viz., 18 feet, the height above sea-level *plus* 300 feet the estimated separation between geoid and spheroid. This gives a final reduced value for the length of the base of 16289·988 Indian feet or 4·2119208 log feet. The 1881–82 measure gave the value as 4·2119177 log feet†, and the triangulated value is 4·2119155. The triangulated value thus differs from the old measure by 22, and from the new by 53 in the seventh place of the log. Adjusting the Burma Coast Series in accordance with the new value of the Mergui base, the discrepancy in log side between the Indian and Siamese triangulation (see Geodetic Report Vol. VII, Chapter I, Table 1) at Khao Jamaya H.S. now comes to 0·0000423 instead of 0·0000476, an improvement of no significance.

(*b*) *Amherst Base.* The separation between geoid and spheroid is estimated to be 250 feet, making the spheroidal height of the base 264 feet. This gives a final reduced

* See Geodetic Report Vol. VII, Chapter VI, para 6.

† The published value is 4·2119239, but this was reduced to geoidal level. The figure now given is the length reduced to spheroidal level.

value of the length of the base of 44560·707 Indian feet or 4·6489521 log feet. The triangulated value in terms of the Burma Coast Series is 4·6489438 log feet, a discrepancy of 0·0000083.

By direct measurement the log of the ratio of the length of the two halves of the base (S:N) is $\bar{1}$·9692311 while the log ratio given by the angles measured at Sindaung H.S. and Kyaikkamaw H.S. is $\bar{1}$·9692312. The very small size of the discrepancy of 0·0000001 is of course due to chance.

(*c*) *Kalemyo Base.* The separation between geoid and spheroid is estimated to be 150 feet, making the spheroidal height 623 feet for the north half and 572 feet for the south half. This gives final reduced values of the length of the two halves of 19801·762 and 14747·969 Indian feet respectively, or 4·2967039 and 4·1687322 log feet. The triangulated values in terms of the Manipur Meridional Series are 4·2966911 and 4·1687197 log feet, a discrepancy of 0·0000126.

By direct measurement the log of the ratio of the two halves of the base (S:N) is $\bar{1}$·8720283, whereas that deduced from the angles at Mwetaung H.S and Nagmauktaung H.S. is $\bar{1}$·8720380. The discrepancy of 0·0000097 can readily be attributed to the small size of the angles on which the triangulated ratio depends.

As regards the actual accuracy of these bases, the limiting factor is the accuracy of the deduced values for the wires at each base: these are considered to be correct to 1 in 300,000 or 15 in the 7th place of the log side (see Chapter V of this report, para 4).

10. Discrepancies with triangulation. The discrepancies between the triangulated and directly measured values, given above, depend on triangulated values which resulted from the preliminary (1916) adjustment of the Burma quadrilateral. A better measure of the accuracy of the triangulati. .an be obtained by considering the closure of different series between base-lines, using unadjusted values. These are as follows.

From	To	Via series Nos.*	Distance	Dis .epancies
Calcutta ...	Kalemyo ...	48, 103	450 miles	+0·000 0066
Kalemyo ...	Amherst ...	71, 52	650 ,,	−0·000 0037
Kalemyo ...	Kēngtūng ...	71, 68, 72	650 ,,	−0·000 0054
Amherst ...	Kēngtūng ...	52, 66, 104	500 ,,	−0·000 0126
Amherst ...	Mergui ...	52	300 ,,	−0·000 0019

* See Chart I.

The figures in the last column are the measured lengths of the base-line mentioned in the second column *minus* the length obtained from triangulation based on the measured length of the base-line mentioned in the first column. They may be compared with the column $\triangle S$ of Professional paper No. 16 Table LII, which gives the closing errors between the other bases of the Indian triangulation. From this table it is seen that the Amherst–Kēngtūng misclosure is considerably greater than what has been usual, while the other misclosures are about the same as these in the rest of India.

CHAPTER II

LEVELLING

BY LIEUT. I. H. R. WILSON, R.E.

1. Organization. Two detachments only were formed, one detachment being employed on precise levelling for the Indo–Burma connection, and the other on secondary levelling for the Bhakra Dam Irrigation Project in the Punjab. This latter detachment also re-connected the standard bench mark at Bīkaner, which had been moved to a new site.

2. Summary of out-turn. The total out-turn of levelling was as follows:

Precise levelling 485* miles (540 gross)†.

Secondary levelling 349 miles (410 gross).

3. Work of No. 1 detachment. No. 1 detachment under Mr. I.D. Suri, with computer Hamid Ullah Khan as second leveller, was employed on secondary levelling in connection with the Bhakra Dam project for the Punjab Irrigation department. Details of the lines followed are given in Table 1. The total distance levelled was 349 miles (410 gross). On the completion of this work, levelling was carried out between the old and new portions of the Bīkaner standard B.M., which had had to be moved on account of building operations.

Work started on 11th October 1932 and closed on 5th February 1933. The country through which the levelling was carried out was flat, and 4 to 5 chain shots were used throughout.

4. Work of No. 2 detachment. No. 2 detachment under Mr. J.N. Kohli, with Mr. Mohd. Faizul Hasan, as second leveller, was employed on precise levelling for the Indo–Burma connection. Total mileage 485 miles (538 gross). Work started on 1st November 1932 and closed on 31st May 1933.

This line runs from Chittagong along the railway line to Dohazāri, then by road to Daroga Bāzār near Rāmu. From there it

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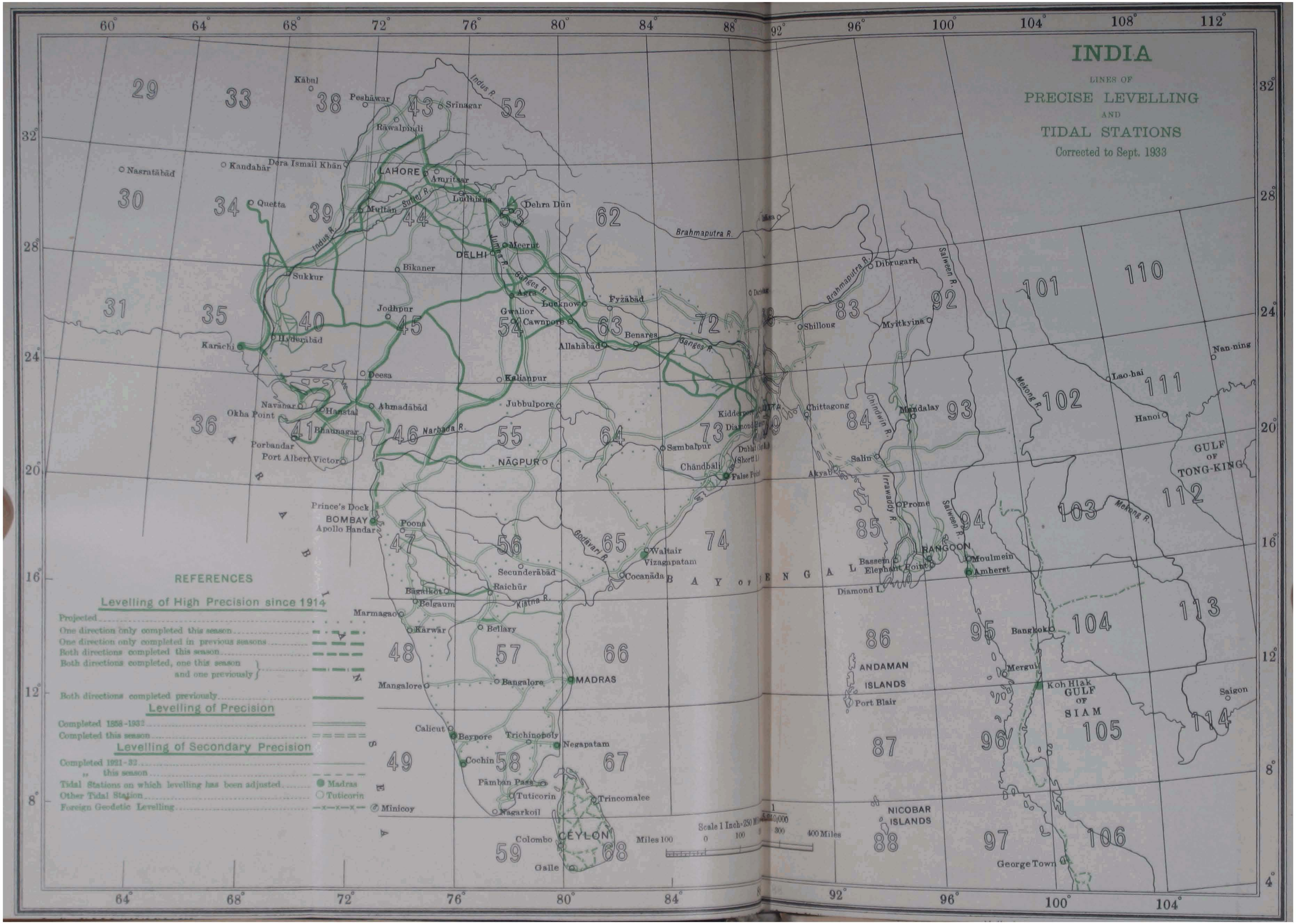
* Includes branch-line to Akyab.

† The first of these figures represents the direct distance levelled between terminal bench marks. The gross total includes additional check-levelling at ends, and branch-lines to G.T. stations etc. The gross figure for precise levelling also includes 1 mile in each direction for the reconnection of the standard B.M. at Bīkaner.


INDIA
LINES OF
PRECISE LEVELLING
AND
TIDAL STATIONS
Corrected to Sept. 1933
REFERENCES
Levelling of High Precision since 1914
Projected
One direction only completed this season
One direction only completed in previous seasons
Both directions completed this season
Both directions completed, one this season and one previously
Both directions completed previously
Levelling of Precision
Completed 1858-1932
Completed this season
Levelling of Secondary Precision
Completed 1921-33
" this season
Tidal Stations on which levelling has been adjusted
Madras
Other Tidal Station
Tuticorin
Foreign Geodetic Levelling
Minicoy
Scale 1 Inch = 250 Miles
Miles 100
0
100
300
400 Miles
Kābul
Peshāwar
Srīnagar
Rāwalpindi
Indus R.
Nasratābād
Kandahār
Dera Ismail Khān
LAHORE
Amritsar
Ludhiāna
Quetta
Multān
Sutlej R.
Dehra Dūn
Meerut
DELHI
Jumna R.
Bikaner
Sukkur
Agra
Ganges R.
Lucknow
Fyzābād
Jodhpur
Gwalior
Cawnpore
Benares
Allahābād
Karāchi
Hyderābād
Deesa
Kalianpur
Ahmadābād
Jubbulpore
Navanar
Okha Point
Hanstal
Bhaunagar
Narbada R.
Porbandar
Port Albert Victor
NĀGPUR
Sambalpur
Chāndbāli
False Point
Kidderpore
Diamond Harbour
Prince's Dock
BOMBAY
Apollo Bandar
Poona
Godāvari R.
Waltair
Vizagapatam
Secunderābād
Cocanāda
Bāgalkot
Raichūr
Belgaum
Kistna R.
Marmagao
Kārwār
Bellary
Mangalore
Bangalore
MADRAS
Calicut
Beypore
Trichinopoly
Negapatam
Cochin
Pāmban Pass
Tuticorin
Nagarkoil
Trincomalee
Colombo
CEYLON
Galle
A R A B I A N S E A
B A Y OF B E N G A L
Brahmaputra R.
Dibrugarh
Shillong
Chittagong
Myitkyina
Salween R.
Mandalay
Chindwin R.
Irrawaddy R.
Salin
Akyab
Prome
Bassein
Elephant Point
RANGOON
Moulmein
Amherst
Diamond I.
ANDAMAN ISLANDS
Port Blair
NICOBAR ISLANDS
Mergui
Bangkok
Koh Hlak
GULF OF SIAM
George Town
Mekong R.
Lao-hai
Hanoi
Nan-ning
GULF OF TONG-KING
Saigon
29 30 31 33 34 35 36 38 39 40 41 43 44 45 46 47 48 49 52 53 54 55 56 57 58 59 62 63 64 65 66 67 68 72 73 74 83 84 85 86 87 88 92 93 94 95 96 97 101 102 103 104 105 106 110 111 112 113 114

goes partly by road and partly across country via Maungdaw and Buthidaung to Wadaung, whence a branch-line runs to Akyab, closing on the standard B.M. and the Akyab tide-gauge. The main line then continues across country via Min Zechaung, Myohaung and Dalet to An, crossing the Arakan Yoma by the mule-track over the An pass, then down to Minbu via Ngape following the road. The country through which the line was carried consists largely of hills where only short shots were possible. Three tidal creeks had to be crossed, the largest of which was 35 chains wide. Both the target and the micrometer methods were used.

A large misclosure (3·707 feet) was found at Minbu rock-cut bench mark, so the levelling was continued to the standard bench marks at Magwe and Salin, which confirmed the error.

The Burma levelling is at present based on the Amherst tidal station. If we consider a circuit starting from Akyab which goes to Minbu and then, following the Burma levelling, closes on Amherst, we get a discrepancy of 0·838 feet between mean water-level (M.W.L.) at Akyab and M.W.L. at Amherst, Akyab being apparently the higher. These tidal observatories (Akyab and Amherst) are near the mouths of the Kaladan and Salween rivers respectively, but their positions with regard to the open sea are such that M.W.L. at either place is unlikely to be more than a few inches above mean sea-level. This error (0·838 feet) will be adjusted in the normal fashion between Akyab and Minbu, the published values of bench marks between Minbu and Akyab being left unchanged in accordance with the usual practice. As regards the portion Chittagong to Akyab, however, the levelling shows M.W.L. at Akyab to be 4·73 feet below M.W.L. at Chittagong. The Chittagong tidal observatory is 12 miles up the Karnaphuli river, so M.W.L. there is likely to be somewhat higher than M.W.L. at Akyab, but 4·73 feet is much more than would have been expected.

The following table shows the rise of M.W.L. at other riverain ports, for comparison.

River	Upper gauge	Lower gauge	Distance between gauges	Difference in M.W.L.
			miles	feet
Hooghly	Kidderpore ...	Diamond Harbour...	48	1·8
Hooghly	Diamond Harbour...	Saugor ...	43	0·7
Dhāmra	Chāndbāli ...	Chandnipal (mouth of Dhāmra river) .	19	3·4
Rangoon	Rangoon ...	Elephant Point ...	25	0·5
Moulmein	Moulmein ...	Amherst ...	30	3·5

From this table it can be seen that such a rise as 4·73 feet is unlikely, but the Port Engineer at Chittagong has provided information which is quite conclusive. There is a gauge at Juldia, 9 miles below Chittagong, which has twice been connected to Chittagong by spirit-levelling, and this gauge shows that M.W.L. at Juldia is only 0·75 feet below Chittagong. It is evident, therefore, that the latter cannot be more than about one foot above M.S.L. According to the levelling of 1881–82, which is based on False Point 700 miles away, this figure (one foot) is 1·86 feet*, which is in fairly satisfactory agreement.

It can only be concluded that there is an error of about 3 feet in the 1932–33 levelling between Chittagong and Akyab.

5. Invar staves. Invar staves, fitted with side bubbles and glass reflectors to enable the verticality of the staff to be checked by the observer at the time of reading were used by both detachments. They proved very satisfactory, and are an improvement on previous procedure.

6. Probable errors. The probable errors of the precise and secondary levelling were computed from the formula:

$$p.e. = \pm \frac{1}{3}\sqrt{\frac{\Sigma \Delta^2}{L}},$$

where Δ is the discordance between two levellers and L the total distance.

Detachment	Line	Probable error
		feet/miles $^{\frac{1}{2}}$
No. 1 Detachment	Chandigarh–Jagādhri ...	±0·00338
do.	Jagādhri-Karnāl ...	±0·00337
do.	Butāna-Chandāna ...	±0·00264
do.	Karnāl-Jīnd ...	±0·00274
do.	Rohtak-Pānipat ...	±0·00306
do.	Jākhal-Rohti ...	±0·00275
do.	Bhūrthala-Kotli Maurān	±0·00278
do.	Old S.B.M. to new S.B.M., Bīkaner ...	±0·00214
No. 2 Detachment	Chittagong-Magwe ...	±0·00467

7. Progress of the new level net. No high precision levelling was carried out during this field season, so the total figure given in the Geodetic Repot Vol. VII remains unchanged, i.e. out of 15,800 miles the equivalent of 8,915 miles has been completed.

* The original figure was 1·36 feet, but Tidal Records show that the water-level has since risen by about 0·5 feet.

TABLE 1. *Tabular statement of out-turn of work, season 1932–33.*

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: Rock-cut Protected	Primary: Other Primary	Secondary
		Mls.	Mls.	Mls.	feet	feet				
No. 1 Detachment.										
Branch-line 61 L Chandīgarh-Jagādhri	Oct. 32 to Nov. 32	66	16	82	1440	1830	1152	...	1	86
Branch-line 61 M Jagādhri-Karnāl	Nov. 32	36	6	42	214	325	496	...	...	59
Branch-line 61 N Butāna-Chandāna	Nov. 32	34	8	42	217	298	514	...	...	52
Branch-line 61 O Karnāl-Jīnd	Dec. 32	58	4	62	525	624	776	...	1	86
Branch-line 57 Y Rohtak-Pānīpat	Dec. 32	45	8	53	435	359	614	...	1	72
Branch-line 57 Z Jākhal-Rohti	Jan. 33	48	4	52	418	293	558	...	1	68
Branch-line 57 AA Bhūrthala-Kotli Maurān	Jan. 33 to Feb. 33	62	15	77	398	590	836	...	1	101
Branch-line 57 BB Bikaner old S. B. M. to new S. B. M. (back and fore)	Feb. 33	2	...	2	88	88	56	...	1	4
No. 2 Detachment.										
Branch-line 77 W Chittagong-Magwe	Nov. 32 to May 33	485*	53	538	25,310	24,741	12,348	...	10	193

* Includes branch-line to Akyab.

TABLE 2. *Check-levelling.*

Discrepancies between the old and new heights of bench marks.

Bench marks of the original levelling that were connected for check-levelling			Distance from starting bench mark	Observed height above (+) or below (−) starting bench mark, as determined by			Difference (check − original). The sign + denotes that the height was greater and the sign −, less in 1932-33 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1932-33	
			miles		*feet*	*feet*	*feet*
		At Chittagong on line 77 W.					
58	79 N	S.B.M. Chittagong...	0·00	1910-13	0·000	0·000	0·000
57	„	Culvert ...	0·02	„	+ 1·849	+ 1·858	+ 0·009
63 (*55*)	„	Embedded B.M. ...	0·93	„	− 0·969	− 0·959	+ 0·010
61	„	Pillar ...	2·40	„	− 53·977	− 54·009	− 0·032
54	„	Bridge ...	1·36	„	− 33·289	− 33·309	− 0·020
51	„	Rly. bridge ...	3·60	„	− 31·254	− 31·274	− 0·020
		Between Magwe and Salin on line 77 W.					
19	84 L	S.B.M. Magwe ...	0·00	1911-12	0·000	0·000	0·000
20	„	Culvert ...	0·20	„	− 1·089	− 1·089	0·000
21	„	Embedded B.M. ...	0·29	„	+ 0·911	+ 0·911	0·000
24	„	Rock in situ ...	4·01	„	+ 70·021	+ 70·036	+ 0·015
112 (*23*)	„	Embedded B.M. ...	4·28	„	− 4·467	− 4·390	+ 0·077
113 (*27*)	„	Iron plug ...	4·71	„	− 1·217	− 1·337	− 0·120
121 (*31*)	„	Embedded B.M. ...	2·36	„	− 1·781	− 1·870	− 0·089
124 (*33*)	„	Do. ...	3·36	„	+ 3·538	+ 3·420	− 0·118
125 (*34*)	„	Milestone ...	4·30	„	− 0·546	− 0·298	+ 0·248
128 (*35*)	„	Bridge ...	6·55	„	− 5·026	− 5·089	− 0·063
131 (*37*)	„	Zinc plate ...	9·88	„	− 8·821	− 8·916	− 0·095
134 (*38*)	„	Embedded B.M. ...	13·33	„	+ 18·869	+ 18·899	+ 0·030
136 (*39*)	„	Do. ...	15·19	„	+ 5·623	+ 5·172	− 0·451
137 (*40*)	„	Iron plug ...	15·68	„	+ 11·491	+ 10·910	− 0·581
43	„	Embedded B.M. ...	20·01	„	+ 24·633	+ 24·532	− 0·101
62	„	Zinc plate ...	31·66	„	+ 43·687	+ 43·554	− 0·133
61	„	S.B.M. Salin ...	31·68	„	+ 43·481	+ 43·347	− 0·134

TABLE 3. *List of triangulation stations connected by spirit-levelling, season 1932–33.*

Name of station		Height above mean sea-level: Spirit-levelling	Height above mean sea-level: Triangulation	Difference (Trian.—Lev.)	REMARKS
		feet	*feet*	*feet*	
			Burma Coast Series		
Sitalchhari	H.S.	431·756	434	+2	Upper mark-stone.
Lat. 22° 19′ 46″·127					
Long. 92 2 34·558					
			North-West Himālaya Series		
Chitan (Chautan)	S.	1035·250	1036	+1	Lower mark-stone.
Lat. 30° 28′ 14″·55					
Long. 77 1 31·23					
			Rāhon Meridional Series		
Ratha-khera	T.S.	740·617	738*	−3	Ground floor mark-stone.
Lat. 29° 17′ 7″·30					
Long. 76 17 27·55					
Janāl	T.S.	779·887	779*	−1	Ground floor mark-stone.
Lat. 30° 5′ 22″·48					
Long. 75 55 15·51					
Badalbar	T.S.	788·872	790*	+1	Ground floor mark-stone.
Lat. 30° 21′ 9″·12					
Long. 75 55 53·75					

* The heights published in the triangulation pamphlets refer to the top mark-stones, which are 30, 30 and 38 feet respectively above the ground floor mark-stones

CHAPTER III

DEVIATION OF THE VERTICAL

BY CAPTAIN G. BOMFORD, R.E.

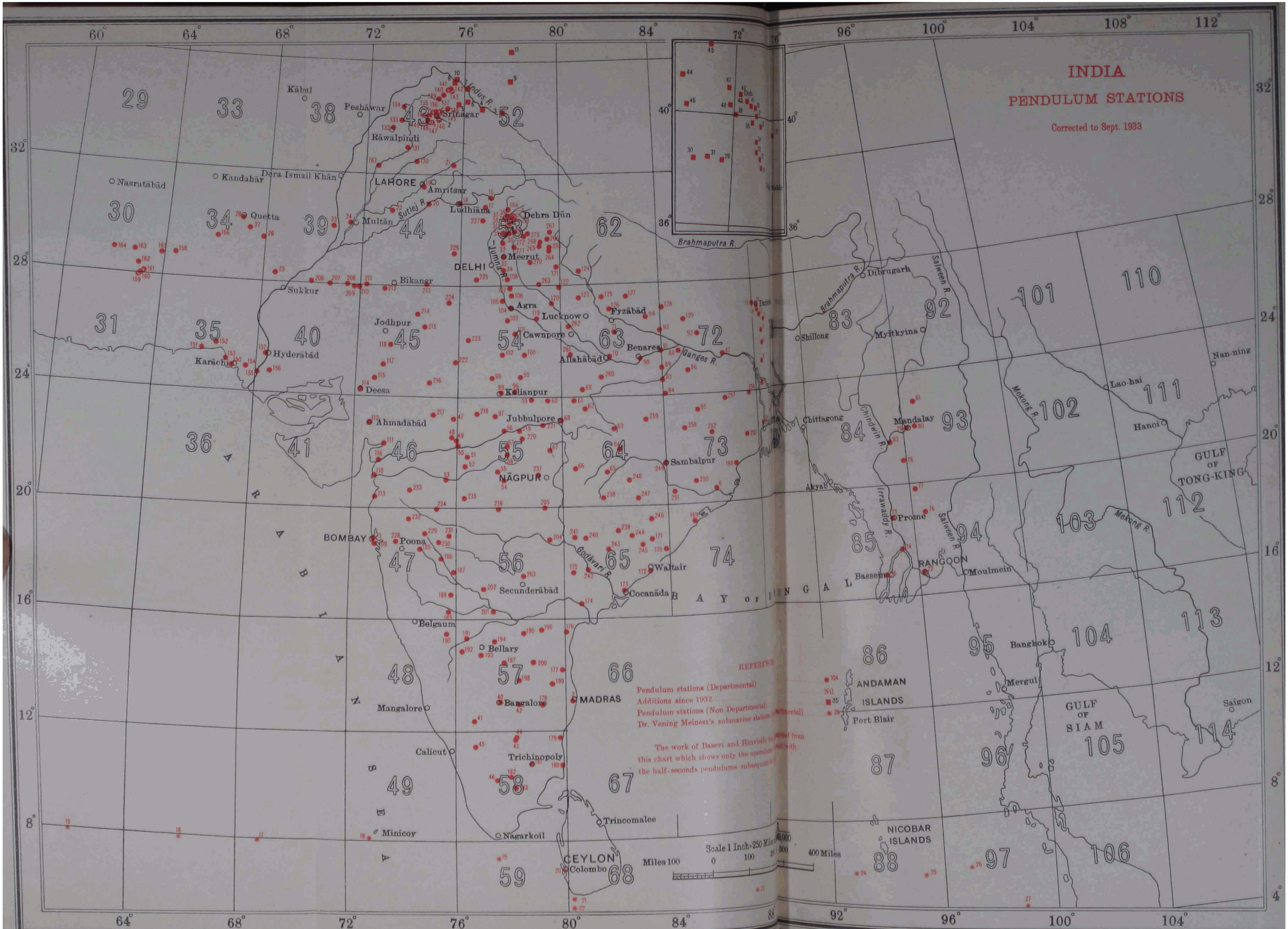
1. Summary. Both components of the deviation of the vertical were observed at 44 stations, at intervals of about 12 miles along a line stretching roughly east and west across Burma. The astronomical observations were made with a prismatic astrolabe, and personal equation was determined by comparative observations with a transit telescope at every fourth station. These observations provide a section of the geoid up to the frontiers of Siam and Indo-China. In 1933–34 this work is being continued to the west, from the Indo-Burmese frontier into Bengal, where the form of the Indian geoid is already fairly well known. In future years it is hoped to continue the section across India to the Persian frontier, and also to complete a meridional section from Kashmīr to Cape Comorin. A part of the latter was observed in 1930–31 (see Chart VIII), and work at the Cape Comorin end will be begun in 1933–34.

Longitude observations at Kēngtūng completed the formation of a Laplace station there.

2. Astronomical observations. The astrolabe used was of the Claude and Driencourt pattern, geodetic model. At each station observations were made on one night only, and lasted about two hours. About 30 stars were observed, 8 or 10 near the prime vertical and the rest fairly evenly distributed through the four quadrants. The inclusion of the prime vertical stars was to improve the accuracy of the east-and-west deviation, which is the important one in an east-and-west section of the geoid.

The transit was of the bent type, reversible, with a hand driven impersonal micrometer eye-piece. It was used on a portable iron stand. The normal programme was eight time stars and two azimuth stars. The instrument was set in the meridian by means of a table, previously prepared, showing the distance of Polaris from the meridian (in divisions of the micrometer eye-piece) at different hour angles.

The wireless receiver was Marconi's R.P. 11 type, used without the phasing unit, but with a 30-foot pole aerial in addition to the frame. Two signals were received on working days, generally the Rugby 10.00 and 18.00 G.S.T. signals (16.30 and 00.30 Burma time). They were received by the coincidence method, the telephone



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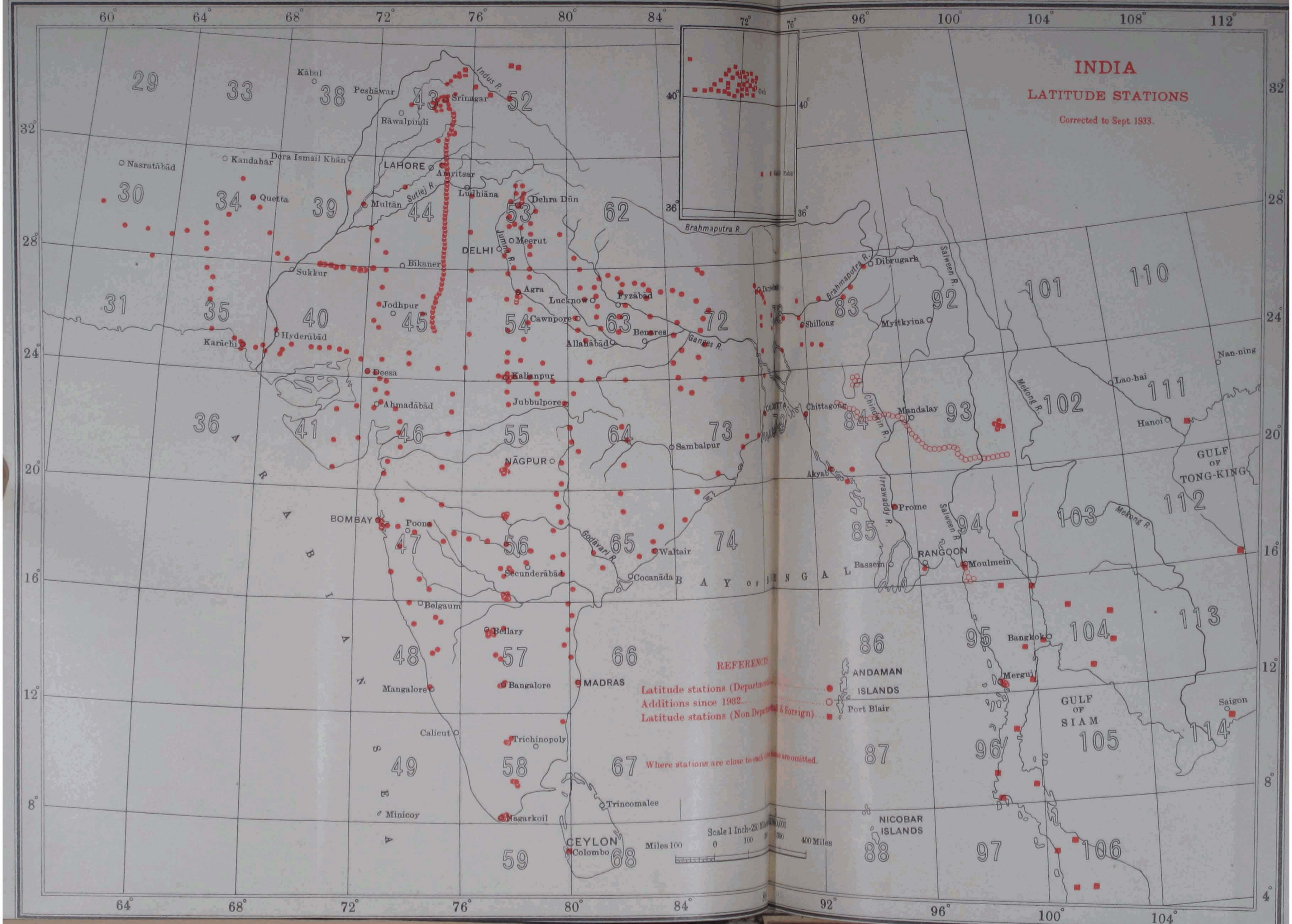
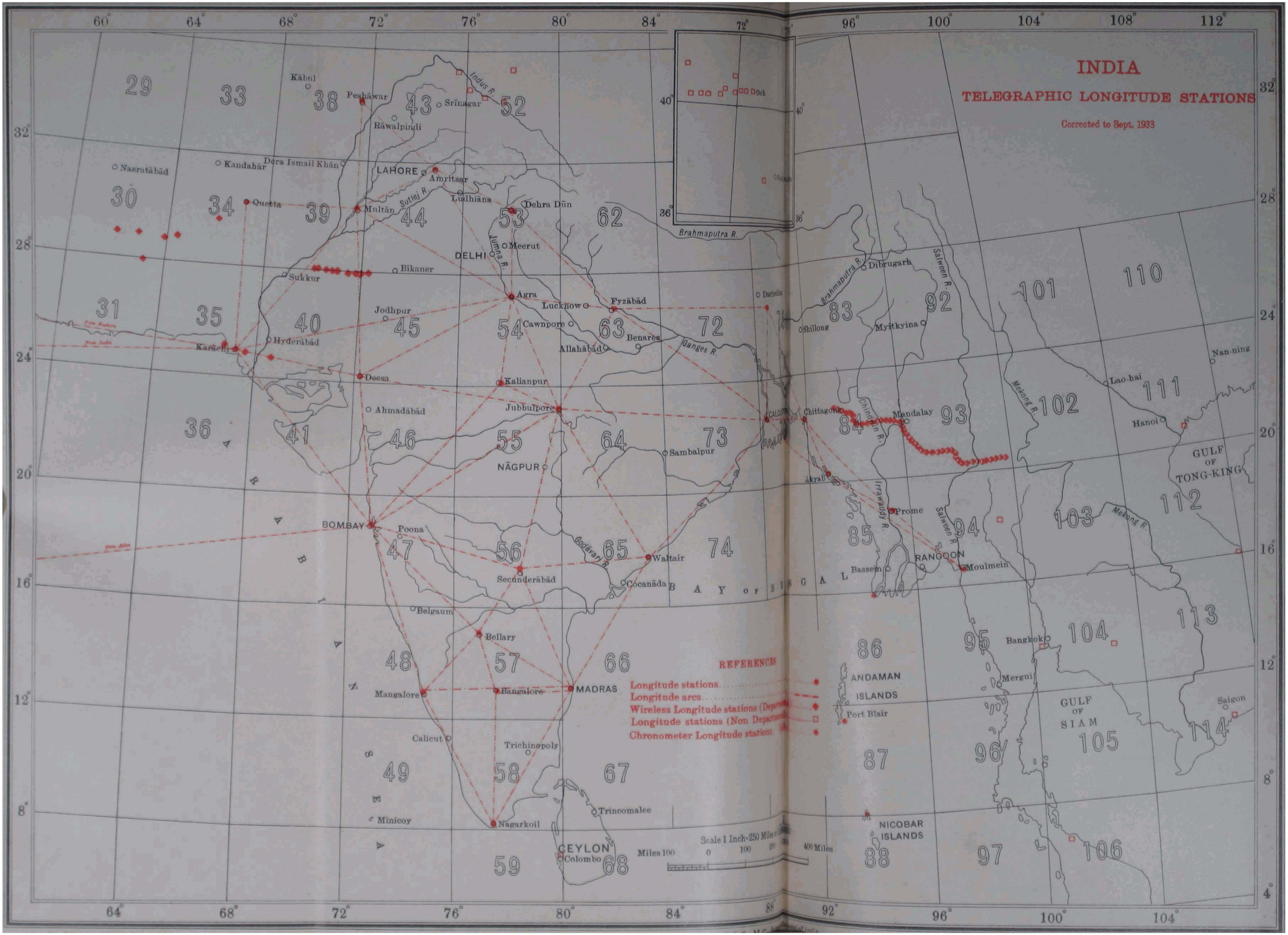
Published under the direction of Brigadier H.J. Couchman, D.S.O., M.C., ... General of India.

Heliozincographed at the Survey of India Offices, Dehra Dūn.


INDIA
LATITUDE STATIONS
Corrected to Sept 1933.
REFERENCES
Latitude stations (Departmental)
Additions since 1932
Latitude stations (Non Departmental & Foreign)
Where stations are close to each other some are omitted.
Scale 1 Inch = 250 Miles
Miles 100 0 100 200 300 400 Miles
LAHORE
DELHI
NĀGPUR
BOMBAY
MADRAS
CALCUTTA
RANGOON
CEYLON
ARABIAN SEA
BAY OF BENGAL
ANDAMAN ISLANDS
NICOBAR ISLANDS
GULF OF SIAM
GULF OF TONG-KING
Kābul
Peshāwar
Srinagar
Rāwalpindi
Nasratābād
Kandahār
Dera Ismail Khān
Amritsar
Ludhiāna
Quetta
Multān
Dehra Dūn
Meerut
Bikaner
Sukkur
Agra
Lucknow
Fyzābād
Jodhpur
Cawnpore
Benares
Allahābād
Hyderābād
Karāchi
Deesa
Kalianpur
Ahmadābād
Jubbulpore
Sambalpur
Chittagong
Mandalay
Poona
Secunderābād
Waltair
Cocanāda
Belgaum
Bellary
Mangalore
Bangalore
Calicut
Trichinopoly
Minicoy
Nagarkoil
Trincomalee
Colombo
Dibrugarh
Shillong
Myitkyina
Lao-hai
Nan-ning
Hanoi
Akyab
Prome
Bassein
Moulmein
Bangkok
Mergui
Port Blair
Saigon
Indus R.
Sutlej R.
Jumna R.
Ganges R.
Godāvari R.
Brahmaputra R.
Chindwin R.
Irrawaddy R.
Salween R.
Mekong R.



INDIA
TELEGRAPHIC LONGITUDE STATIONS
Corrected to Sept. 1933
REFERENCES
Longitude stations
Longitude arcs
Wireless Longitude stations
Longitude stations
Chronometer Longitude stations
Scale 1 Inch=250 Miles
Miles 100 0 100 400 Miles
Kābul
Peshāwar
Srīnagar
Indus R.
Rāwalpindi
Nasratābād
Kandahār
Dera Ismail Khān
LAHORE
Amritsar
Ludhiāna
Quetta
Multān
Sutlej R.
Dehra Dūn
Meerut
DELHI
Jumna R.
Bikaner
Sukkur
Agra
Lucknow
Fyzābād
Darjeeling
Jodhpur
Cawnpore
Benares
Allahābād
Ganges R.
Brahmaputra R.
Dibrugarh
Salween R.
Shillong
Myitkyina
Karāchi
Hyderābād
Deesa
Kalianpur
Jubbulpore
CALCUTTA
Chittagong
Chindwin R.
Mandalay
Mekong R.
Lao-hai
Nan-ning
Hanoi
Ahmadābād
NĀGPUR
Sambalpur
Akyab
Irrawaddy R.
Prome
GULF OF TONG-KING
BOMBAY
Poona
Godāvari R.
Waltair
Secunderābād
Cocanāda
B A Y OF B E N G A L
Bassein
RANGOON
Moulmein
Belgaum
Bellary
Bangkok
Mergui
ANDAMAN ISLANDS
Port Blair
Mangalore
Bangalore
MADRAS
GULF OF SIAM
Saigon
Calicut
Trichinopoly
A R A B I A N S E A
Minicoy
Nagarkoil
Trincomalee
NICOBAR ISLANDS
CEYLON
Colombo
29 30 31 33 34 35 36 38 39 40 41 43 44 45 46 47 48 49 52 53 54 55 56 57 58 59 62 63 64 65 66 67 68 72 73 74 83 84 85 86 87 88 92 93 94 95 96 97 101 102 103 104 105 106 110 111 112 113 114
60° 64° 68° 72° 76° 80° 84° 88° 92° 96° 100° 104° 108° 112°
32° 28° 24° 20° 16° 12° 8° 4°

circuit being interrupted by a break-circuit chronometer. The midnight signal was always strong and clear, but the afternoon signal was sometimes weak during early November and late February, and it is doubtful whether it could have been received during April to October. The Nauen 12.00 G.S.T. signal was sometimes used instead. On one occasion when no afternoon signal was received, two series of astrolabe observations were made, one closely centred on the midnight signal, and the other some hours earlier, to rate the chronometers.

Three chronometers were carried, a break-circuit sidereal chronometer by Mercer, a break-circuit mean-time chronometer by Kullberg, and a non-break-circuit sidereal by Dent. They were compared with each other at all times of wireless reception, and also at the end of astrolabe or transit observations. Mercer and Kullberg were directly compared on the chronograph. Dent was compared with Mercer by eye and tappet.

A two-pen chronograph was used, running at a speed of 0·3 inches per second. Siemens' inert cells were used for all purposes, except for the wireless high tension which was supplied by a Pertrix dry battery.

3. Personal equation. The Transit was used in addition to the astrolabe at every fourth station, and the differences between the longitudes determined by the two instruments are given in Table 1. The means shown in the third and fourth columns of the table indicate that there was no progressive change of personal equation during the season. The changes from day to day are due to casual error, not to change of personal equation, and a constant correction of $+ 0^s \cdot 12$ has been applied to astrolabe longitudes to bring them into terms of the transit.

The personal equation of the transit was determined by observations at Dehra Dūn before and after the field work. The results are given below:

5th October, 1932	$5^h\ 12^m\ 11^s \cdot 76$ *		
9th ,, ,,	11 ·84	$11^s \cdot 85$ (9th–11th)	$11^s \cdot 89$ (all)
11th ,, ,,	11 ·85		
15th March, 1933	11 ·87	11 ·92 (15th–21st)	
16th ,, ,,	11 ·90		
17th ,, ,,	11 ·95		
21st ,, ,,	11 ·91		

The old value of the longitude of Dehra Dūn, which is in the same terms as all other Indian longitude stations, is $5^h\ 12^m\ 11^s \cdot 77$, so that the transit requires a correction of $- 0^s \cdot 12$ to bring it to these terms, and the total correction to the astrolable longitudes is $0^s \cdot 00$.

* Rejected. The observer was out of practice.

If it had been known that the astrolabe personal equation would be constant throughout the season, it would have been better to have made the comparative observations at Dehra Dūn with the astrolabe itself, and the transit observations could have been dispensed with entirely. In a future year, with the same observer, it would be safe to do this, but with a different observer (whose personal equation might not be sufficiently constant), the transit would have to be taken out to work. Comparative observations at Dehra Dūn would, however, be made with both instruments, so that if the personal equation did prove to be constant it could be directly determined from the Dehra Dūn observations, instead of indirectly through the transit observations.

4. Geodetic positions. The geodetic positions of the astronomical stations were obtained by resection from existing triangulated points, except in three cases when they were fixed by traverse from trigonometrical stations. Six to eight points were generally used for the resection, with a polaris azimuth if their distribution was at all imperfect or their identification especially doubtful. In some cases, when few clear points could be seen, the distance to one or two of the nearest was measured by means of a 10-chain base.

Except at 8 stations where only a quarter-inch map was available, and at one other where there was no local detail, the trigonometrical resection was checked by a plane-table fixing, from the published one-inch maps. The possibility of fixing by plane-table from map detail is of importance from the point of view of getting rapid work, especially in flat country where trigonometrical fixings are difficult. At 35 stations the worst difference between the trigonometrical and plane-table values of latitude and longitude was as much as 5½ seconds, a serious amount: the average was 2·3 seconds. It must be remembered that the stations were selected with a view to getting good trigonometrical fixings, and not with a view to having clear local detail to fix from on the plane-table. The worst discrepancies occurred in the middle of thickly jungle-covered hills. It is concluded that every effort should be made to obtain trigonometrical fixings, but that in a locality where the two methods are found to agree well, a proportion of plane-table fixings could be accepted, if necessary, at places where clear local detail was available and self-consistent. (See Geodetic Report Vol. VII, Chapter IV, para 4).

5. Probable errors. The probable errors of the different processes are discussed below:

(*a*) *Determination of local time by astrolabe.* The accordance of the different groups of four stars gives an average probable error of $0''\cdot40$ in latitude, and $0^{s}\cdot018$ in time, for a night's work.

(*b*) *Time keeping of clocks between stars and wireless.* The three clocks having been compared at the time of wireless reception, their discrepancies from the "mean clock" at the time of star observation give a probable error of $0^s \cdot 017$ for the probable error of the mean.

(*c*) *Determination of time by transit.* The accordance of different time stars gives $0^s \cdot 017$ for the probable error of a night's work.

Combining (*a*), (*b*) and (*c*) gives $0^s \cdot 030$ for the probable difference between the astrolabe and transit on any one night. The figures in Table 1, however, give $0^s \cdot 043$ for the probable value of this difference, a larger figure, as is generally obtained when external evidence is compared with internal. The figures given in (*a*), (*b*) and (*c*) above should therefore be multiplied by $1 \cdot 43$, when considering the probable error of the whole operation.

(*d*) *Wireless reception.* The error of reception is negligible compared with other sources of error, say $0^s \cdot 01$, but the error of its comparison with local time at Greenwich must be considered. This is probably not greater than $0^s \cdot 01$. Total $0^s \cdot 014$.

(*e*) *Personal equation.* The figures of Table 1 give $0^s \cdot 012$ for the probable error of the mean difference between transit and astrolabe. The figures of para 3 give $0^s \cdot 012$ for the probable error of the personal equation of the transit, but this is clearly too low, for they are not all independent: March is consistently higher than October. It is well known that the longitude of a place always appears to fluctuate, and the probable error of a few days' work cannot be taken as less than $0^s \cdot 020$. Combining this with $0^s \cdot 012$ for transit *minus* astrolabe gives $0^s \cdot 023$ for the probable error of the total personal equation of the astrolabe.

(*f*) *Geodetic fixing.* The possible error can be estimated from the resection diagrams. In 10% of cases it is 2 seconds of arc, and it averages $0'' \cdot 9$. The probable error is of course less than the possible error, and may be taken as not more than $0'' \cdot 4$ or $0^s \cdot 027$.

Of the above errors all except (*e*), personal equation, are casual errors, independent at adjacent stations. The total casual probable error is therefore $0'' \cdot 6$ in latitude and $0^s \cdot 047$ (or $0'' \cdot 7$) in longitude, to which must be added a probable systematic error of $0^s \cdot 023$ (or $0'' \cdot 35$) in longitude only*. In determining the difference of geoidal height between two stations 12 miles apart, an error of $0'' \cdot 7$ corresponds to $0 \cdot 21$ feet, while one of $0'' \cdot 35$, corresponds to $0 \cdot 10$ feet. The total probable error in the height of the geoid after 44 stations is therefore $\sqrt{44 \times (0 \cdot 21)^2 + 44^2 \times (0 \cdot 10)^2}$ or $4 \cdot 6$ feet.

* This ignores systematic error due to imperfection of the geodetic triangulation framework. It may well be appreciable, and results will change when the triangulation is re-adjusted, but that is a matter for discussion at the time of re-adjustment.

6. Narrative of season's work. The party consisted of:

Captain G. Bomford, R.E.
1 Computer.
20 *Khalāsis.*
15 Wa coolies, permanently engaged.
45 Yunanese ponies (35 to start with).
2 Interpreters.

Work started at Monywa on the Chindwin river on 2nd November. The coolies and ponies were obtained from Syed Ismail of Kēngtūng, who delivered them at Monywa within one day of the appointed date. From Monywa the party moved west, making observations, until the Indian frontier was reached west of Haka in the Chin Hills. They then marched back to Monywa, and worked east to the Indo-Chinese frontier, completing the geoidal section on 24th February, and returning via Kēngtūng, where the coolies and ponies were discharged. Except for a few wet days and cloudy nights in November, the weather was very good throughout. The *khalāsis* and coolies suffered considerably from fever, colds and sore feet in November and December, but otherwise kept well. One Wa cooly died and one had to be discharged. The ponies also got into very bad condition in the Chin Hills, partly because the steepness of the road, and partly because they could get no rice.

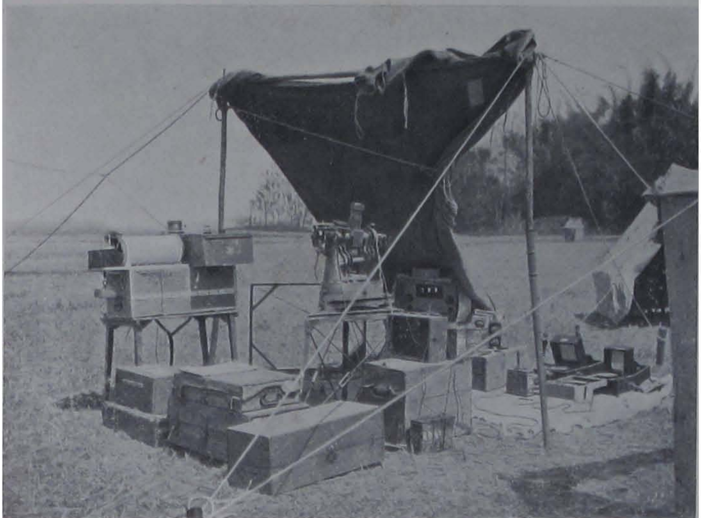
The normal routine was to march in the early morning, reaching the next station in the afternoon. The trigonometrical fixing and polaris azimuth were observed in the evening. The next morning the observatory was set up, computations were carried out, and wireless signals were taken in the afternoon. Stars and the night wireless signal were taken at night, and camp was moved the next morning. Provided the weather is good, and the road not too devious, it is possible to observe 15 stations a month on this system. Between 23rd December and 24th February conditions were favourable and 32 stations were observed in 64 days.

7. Computations. The following computations were carried out in the field: geodetic fixing, wireless reception and clock comparisons, transit computations, and the reading of the astrolabe chronograph sheets. The geodetic fixing was always computed before leaving the station in case misidentification of points called for further work, and the wireless reception and clock comparison were completed at the following station, in order to obtain early warning of any irregularity in the chronometer.

The computations were completed in recess in the Observatory Section.

The wireless times have been corrected in accordance with the "definitive" lists of the Bulletin Horaire. The geodetic fixings are in terms of the latest G.T. values, i.e. those now published in the

LONGITUDE OBSERVATORY AT KENGTUNG.



triangulation pamphlets, amended by the 1929–31 re-observation of the Mong Hsat Series as preliminarily adjusted on to the Great Salween Series.

8. The geoidal section. Table 2 on pages 24 to 29 gives the deflections obtained, with reference to the Everest and International* spheroids. Chart XI has been constructed from these deflections with rather doubtful extensions to Kalemyo and Kĕngtūng based on deflections observed in connection with the base-lines there. The geoidal contours are based on an arbitrary datum, since the section is not yet connected to the Indian geoid, and the contour values may perhaps have to be changed by as much as 20 feet.

Plate XII gives a section of the geoid along a straight line across the area surveyed. It also shows the topography, and the compensated geoid. The latter has not been calculated by integration of the Hayford anomalies, as all have not yet been computed, but by calculation of the separation between the two surfaces, as explained in Geodetic Report Vol. V, pages 77 to 79.

Until the work of 1933–34 connects this section to the rest of India, discussion is premature. It can be noted that the geoid follows the topography in rising under the Chin Hills and the Shan plateau, especially the latter, and in being relatively depressed under the Chindwin–Irrawaddy plain. The greatest depression occurs under the tertiary Pondaung Range at the foot of the Chin Hills.

There is a noticeable constancy in the meridional deflection, which averages 5″ or 6″ south. Similar values have been obtained at Prome, Rangoon, Moulmein and Mergui. If these values are typical of southern Burma, the total rise of the geoid between Mandalay and Mergui will evidently be very great, but more data are needed. It is to be hoped that the Siamese Survey will observe latitudes along their meridional arc.

9. Kengtung Laplace station. The completion of the Laplace station at Kĕngtūng shows the necessary correction to the geodetic azimuth there to be $-12''\cdot 3$. A correction of $-10''$ had been anticipated (Geodetic Report Vol. VII, Chapter IV, para 8) and the result is satisfactory. The deflections previously deduced from the Kĕngtūng azimuth stations require consequent modification, and revised values are included in the table at the end of this chapter. The deflections based on azimuth observations near the Kalemyo base (see Chapter I) are based on the assumption that the proper correction to geodetic azimuth is $-8\frac{1}{2}''$ there, this figure being obtained by interpolation between Chittagong ($-7''$) and Kĕngtūng.

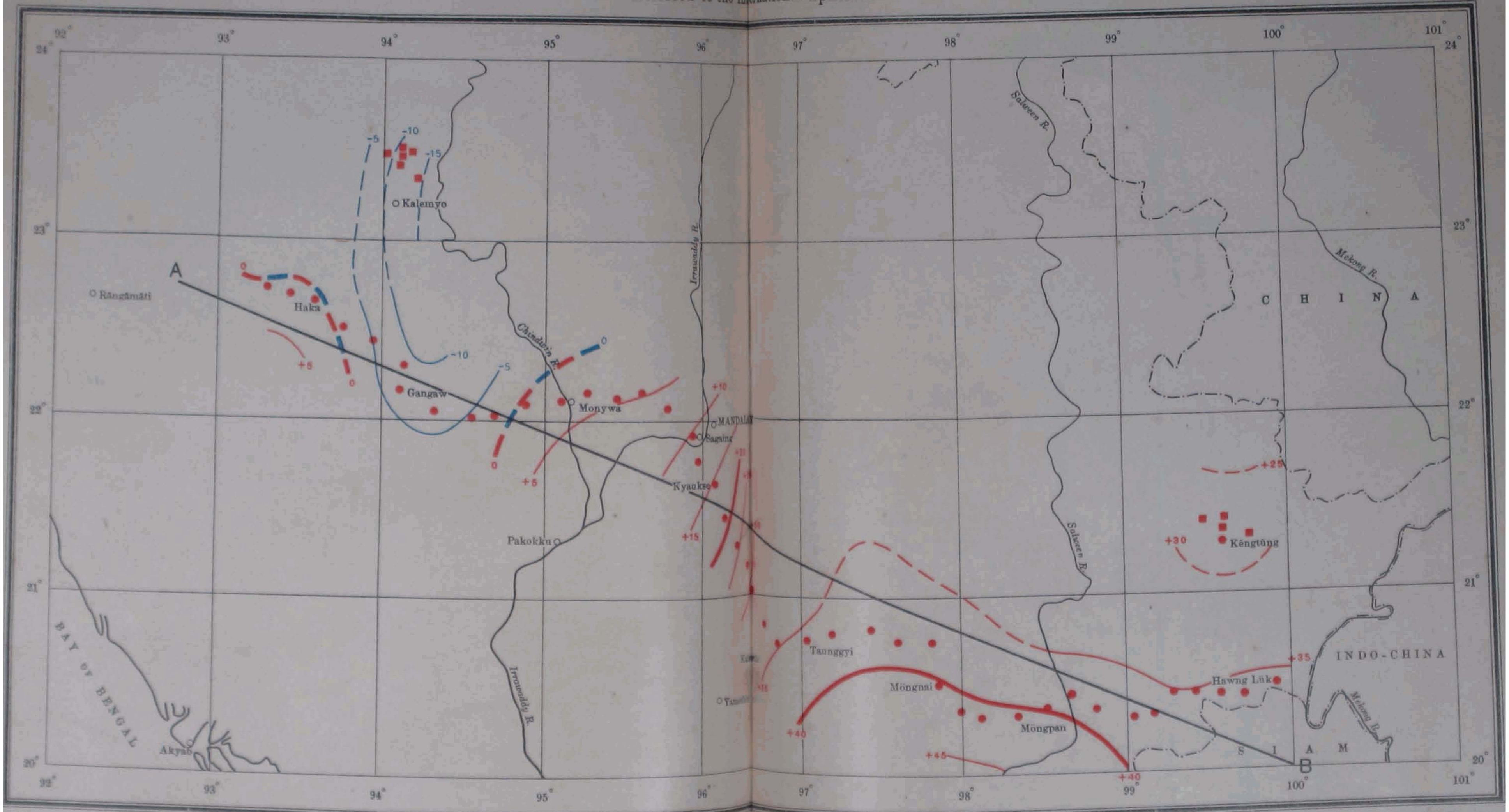
* i.e. International axes and deflections of 3″·02 S. and 3″·17 W. at Kaliānpur origin.

TABLE 1. *Longitude by transit* minus *Longitude by astrolabe*

Date		Difference	Means		
1932		secs.	secs.	secs.	secs.
Nov.	3	+ ·04	+ ·14		
	7	+ ·23			
	19	+ ·12	+ ·14	+ ·13	
	28	+ ·15			
Dec.	23	+ ·10	+ ·10		
	31	+ ·11			
1933					+ ·12
Jan.	8	+ ·25	+ ·13		
	16	+ ·01			
	25	+ ·10	+ ·08	+ ·11	
Feb.	2	+ ·07			
	10	+ ·10			
	18	+ ·12	+ ·13		
Mar.	1	+ ·17			

THE GEOID IN BURMA
Referred to the International Spheroid

Chart XI



REG. No. 188 D.O.O. 1932-358

Latitude and Longitude stations .... ●

Latitude and Azimuth stations .... ■

Scale 1/3,421,440 or 1 Inch to 54 Miles

Miles 20 10 0 20 40 60 80 Miles

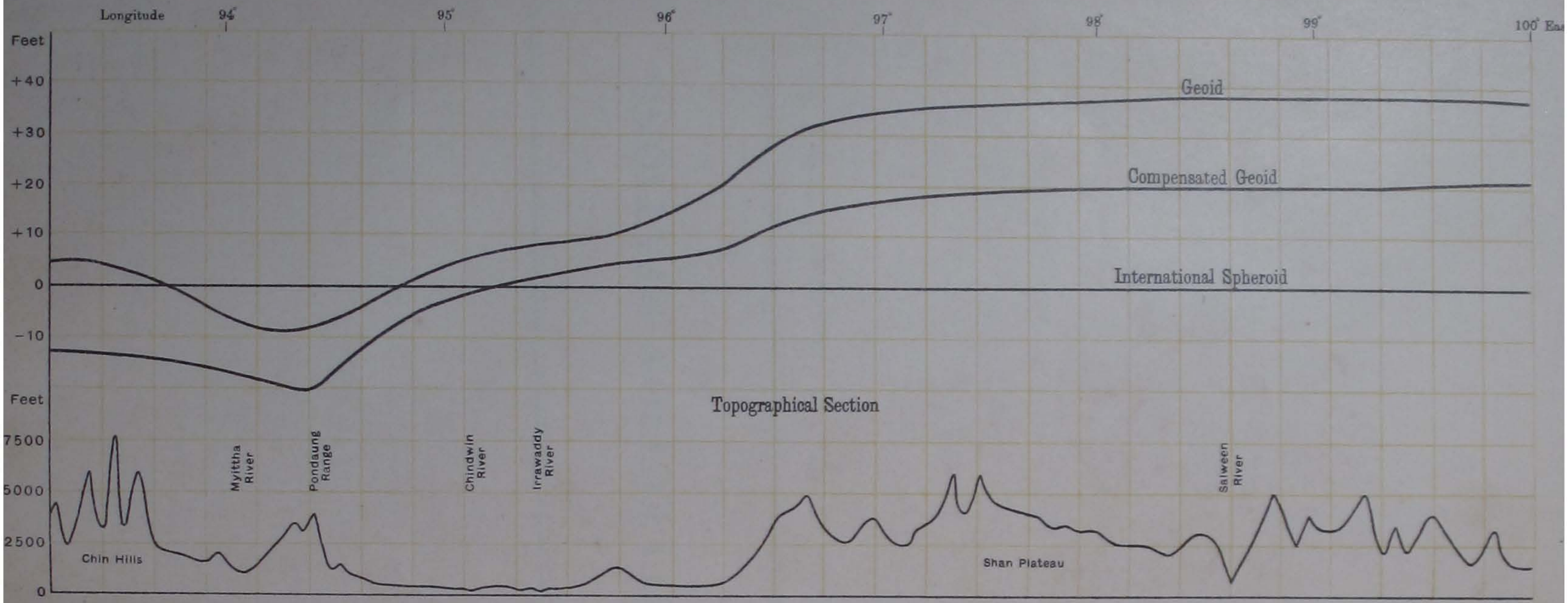
Helio S. I. O. Dehra Dun

Geoidal contours at 5-foot intervals. The contour datum is arbitrary, but probably not in error by more than 20 feet. A-B is the line on which Plate XII gives Sections.

Plate XII

THE GEOID IN BURMA

Sections on Line A-B of Chart XI



REG. No.105 D.D.D. 1933-350

Helio S. I. O. Dehra Dun

Note:— The datum of the geoid and compensated geoid contours is arbitrary. Connection with India may show that the sections require to be raised or lowered as much as 20 feet.

Scale 1/3,421,440 or 1 inch to 54 Miles

Miles 20 10 0 20 40 60 80 Miles

DEFLECTION STATIONS

Third Addendum to Table 1 of "Supplement" to G. R. Vol. VI.

TABLE 2

Serial No.	Sheet No.	Observed at	Height in feet	International Spheroid Deflections		Calculated Deflections. Hayford System		Calculated Deflections. Uncompensated Topography to 2564 miles	
				Meridian	P.V.	Meridian	P.V.	Meridian	P.V.
				"	"	"	"	"	"
631	84 F	Ishan Taung ...	2000†	+ 6·2	+22·6				
632	F	Chaupidaung ...	5000†	+ 7·5	+19·2				
633	F	Haka ...	6000†	+14·0	+11·4				
634	F	Chauria Klang	6000†	+ 7·9	− 3·1				
635	F	Koi Zang Klang	3500†	+ 6·4	+ 0·3				
636	J	Yinmabin ...	400*	+ 6·6	−15·8	− 1·0	+ 3·1	− 5·3	+ 3·7
637	J	Chinbyit ...	500*	+ 9·4	−12·0	− 0·1	+ 5·3	− 4·6	+ 7·2
638	J	Aingma ...	900*	+ 6·4	− 7·2	− 1·3	+ 5·9	− 5·9	+ 6·6
639	J	Kanthet ...	1800*	+ 6·7	− 0·8	− 1·7	+ 2·6	− 6·7	+ 3·5
640	J	Gangaw ...	700*	+ 9·4	+ 8·3	− 0·1	+ 1·6	+ 0·3	+ 5·5
641	J	Kywenan ...	550*	+ 7·7	+ 5·5	+ 0·4	− 0·7	− 3·9	− 1·0
642	N	Kyaungywa ...	250*	+ 9·0	− 3·5	+ 0·6	+ 1·8	− 2·8	+ 0·2
643	N	Kyaukka ...	500*	+ 8·0	− 7·6	− 0·7	− 1·2	− 0·8	− 1·4
644	N	Gweyin ...	600*	+ 6·1	+ 1·9	− 0·7	+ 0·5	− 3·7	− 3·4
645	N	Shwegyaunggan	300*	+ 7·6	− 2·1	− 0·2	− 0·5	− 3·5	− 6·6
646	N	Yinmagyin ...	400*	+ 7·8	− 5·6				
647	O	Paganyat ...	200*	+ 5·6	− 8·3				
648	O	Sagainpanya ...	300*	+ 6·7	− 6·8				
649	93 C	Kyaukse ...	300*	+ 6·5	− 8·0				
650	C	Yewun ...	300*	+ 3·0	− 9·4				
651	C	Nagu ...	400*	+11·9	−21·0				
652	C	Yengan ...	4000*	+ 1·9	−11·7				
653	C	Le-ywa ...	4000*	+ 1·3	−13·3				
654	D	Pwela ...	4400*	+ 4·3	− 3·3				
655	D	He-ho ...	3900*	+ 2·5	+ 0·3				

* Approximate heights.
† Very rough heights.

DEFLECTIONS 1932–33

EVEREST'S SPHEROID						Serial No.
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections		
				Meridian	P.V.	
° ′ ″	° ′ ″	° ′ ″		″	″	
A 22 26 49·5	A 93 57 44·9			+ 4·9	+12·4	631
G 22 26 44·6	G 93 57 34·6					
A 22 30 52·0	A 93 46 52·1			+ 6·1	+ 9·1	632
G 22 30 45·9	G 93 46 45·4					
A 22 38 47·3	A 93 37 09·6			+12·5	+ 1·3	633
G 22 38 34·8	G 93 37 11·4					
A 22 40 31·5	A 93 27 45·9			+ 6·4	−13·1	634
G 22 40 25·1	G 93 28 03·3					
A 22 44 04·3	A 93 18 16·5			+ 4·8	− 9·6	635
G 22 43 59·5	G 93 18 30·1					
A 22 04 58·7	A 94 53 20·7			+ 5·4	−26·7	636
G 22 04 53·3	G 94 53 52·7					
A 22 02 33·5	A 94 41 28·2			+ 8·2	−22·8	637
G 22 02 25·3	G 94 41 56·0					
A 22 01 41·0	A 94 33 37·1			+ 5·2	−17·9	638
G 22 01 35·8	G 94 33 59·5					
A 22 04 03·5	A 94 20 46·7			+ 5·5	−11·3	639
G 22 03 58	G 94 21 02					
A 22 10 31·9	A 94 07 57·6			+ 8·2	− 2·1	640
G 22 10 23·7	G 94 08 03·0					
A 22 19 56·4	A 94 09 15·8			+ 6·4	− 4·8	641
G 22 19 50·0	G 94 09 24·1					
A 22 05 42·1	A 95 05 20·3			+ 7·9	−14·5	642
G 22 05 34·2	G 95 05 39·0					
A 22 10 17·5	A 95 15 31·8			+ 6·8	−18·7	643
G 22 10 10·7	G 95 15 55·2					
A 22 07 07·0	A 95 26 11·0			+ 5·0	− 9·2	644
G 22 07 02	G 95 26 24					
A 22 08 43·7	A 95 37 05·3			+ 6·5	−13·3	645
G 22 08 37·2	G 95 37 22·8					
A 22 04 20·4	A 95 46 25·7			+ 6·7	−16·9	646
G 22 04 13·7	G 95 46 47·0					
A 21 55 45·6	A 95 56 06·6			+ 4·6	−19·7	647
G 21 55 41·0	G 95 56 31·0					
A 21 46 13·5	A 95 58 28·2			+ 5·8	−18·3	648
G 21 46 07·7	G 95 58 51·1					
A 21 37 28·8	A 96 06 14·1			+ 5·6	−19·6	649
G 21 37 23·2	G 96 06 38·3					
A 21 26 50·6	A 96 11 06·5			+ 2·2	−21·1	650
G 21 26 48·4	G 96 11 32·3					
A 21 16 48·3	A 96 18 24·9			+11·1	−32·8	651
G 21 16 37·2	G 96 19 03·2					
A 21 09 49·5	A 96 25 47·4			+ 1·1	−23·5	652
G 21 09 48·4	G 96 26 15·8					
A 21 00 10·6	A 96 31 18·2			+ 0·6	−25·2	653
G 21 00 10·0	G 96 31 48·3					
A 20 50 40·3	A 96 40 32·0			+ 3·8	−15·3	654
G 20 50 36·5	G 96 40 51·6					
A 20 43 08·5	A 96 49 25·5			+ 2·0	−11·7	655
G 20 43 06·5	G 96 49 41·2					

TABLE 2

Serial No.	Sheet No.	Observed at	Height in feet	International Spheroid Deflections		Calculated Deflections. Hayford System		Calculated Deflections. Uncompensated Topography to 2564 miles	
				Meridian	P.V.	Meridian	P.V.	Meridian	P.V.
				"	"	"	"	"	"
656	93 H	Taunggyi ...	4700*	+ 8·2	−11·5				
657	H	Ho-nam ...	4200*	+ 2·8	− 4·1				
658	H	Möng Pawn ...	4700*	+ 4·9	+ 2·6				
659	H	Wān Maü ...	3300*	+ 6·1	+ 2·2				
660	H	Hai-pak ...	3200*	+ 6·0	+ 1·4				
661	H	Möngnai ...	3200*	+ 4·4	+ 3·7				
662	L	Langhko ...	1000*	+ 5·3	− 0·1				
663	L	Wan Hsa-wa ...	3300*	+ 9·6	+ 1·4				
664	L	Möngpan ...	2200*	+ 5·9	+ 0·3				
665	L	Loi Sang ...	4000*	+12·5	+ 2·4				
666	L	Wān Hsa-la ...	800*	+ 8·5	+ 0·9				
667	L	Wān Nā-niu ..	2100*	+ 3·5	+ 7·1				
668	P	Möngit ...	2500*	+ 3·2	− 0·6				
669	P	Loi Pang ...	4000*	+ 8·6	+ 0·3				
670	P	Hsupkin ...	1900*	+ 5·9	+ 1·8				
671	P	Loi Hsam-Hsum	5000*	+ 6·2	− 3·5				
672	P	Wān Mönghawm	1900*	+ 5·3	− 1·0				
673	P	Pangkaw ...	2800*	− 0·4	+ 1·6				
674	P	Hawng Lük ...	1300*	+ 3·1	− 0·4				
675	84 I	Noepeji H.S.	2756	+ 1·4	+10·7				
676	I	Mwetaung H.S.	3381	+ 4·4	+28·9				
677	I	Nagmauktaung H.S.	2406	+ 0·6	+25·7				
678	I	Kalemyo Base North S.	515	− 3·3	+26·4				
679	I	Kalemyo Base Centre S.	434	− 2·0	+33·3				
680	I	Kalemyo Base South S.	437	0·0	+36·6				

* Approximate heights.

DEFLECTIONS 1932-33—(*Contd.*)

EVEREST'S SPHEROID						
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections Meridian	Deflections P.V.	Serial No.
° ′ ″	° ′ ″	° ′ ″		″	″	
A 20 46 20·6 G 20 46 12·9	*A* 97 01 35·1 *G* 97 02 03·4			+ 7·7	−23·5	656
A 20 48 32·1 G 20 48 29·8	*A* 97 13 30·5 *G* 97 13 51·0			+ 2·3	−16·3	657
A 20 48 49·4 G 20 48 45·0	*A* 97 26 52·7 *G* 97 27 06·2			+ 4·4	− 9·7	658
A 20 45 28·5 G 20 45 22·8	*A* 97 36 55·4 *G* 97 37 09·4			+ 5·7	−10·2	659
A 20 44 31·9 G 20 44 26·3	*A* 97 49 47·0 *G* 97 50 02·0			+ 5·6	−11·1	660
A 20 30 26·1 G 20 30 22·0	*A* 97 52 07·2 *G* 97 52 19·7			+ 4·1	− 8·8	661
A 20 20 16·6 G 20 20 11·5	*A* 98 00 06·3 *G* 98 00 23·1			+ 5·1	−12·8	662
A 20 18 53·5 G 20 18 44·1	*A* 98 08 03·0 *G* 98 08 18·3			+ 9·4	−11·4	663
A 20 19 00·9 G 20 18 55·1	*A* 98 22 06·3 *G* 98 22 22·9			+ 5·8	−12·6	664
A 20 22 26·4 G 20 22 14·0	*A* 98 32 33·6 *G* 98 32 48·1			+12·4	−10·6	665
A 20 27 06·6 G 20 26 58·2	*A* 98 39 01·2 *G* 98 39 17·4			+ 8·4	−12·2	666
A 20 21 35·3 G 20 21 31·9	*A* 98 50 41·3 *G* 98 50 50·8			+ 3·4	− 6·0	667
A 20 18 25·0 G 20 18 21·9	*A* 99 02 07·4 *G* 99 02 25·3			+ 3·1	−13·9	668
A 20 19 35·4 G 20 19 26·9	*A* 99 09 20·4 *G* 99 09 37·5			+ 8·5	−13·1	669
A 20 26 26·8 G 20 26 21·0	*A* 99 16 56·6 *G* 99 17 12·2			+ 5·8	−11·7	670
A 20 27 04·8 G 20 26 58·7	*A* 99 25 00·5 *G* 99 25 21·8			+ 6·1	−17·0	671
A 20 25 46·4 G 20 25 41·1	*A* 99 33 57·9 *G* 99 34 16·6			+ 5·3	−14·6	672
A 20 25 06·0 G 20 25 06·4	*A* 99 43 21·0 *G* 99 43 37·2			− 0·4	−12·2	673
A 20 28 11·3 G 20 28 08·2	*A* 99 55 39·0 *G* 99 55 57·4			+ 3·1	−14·3	674
A 23 20 53·9 G 23 20 54·2	*G* 94 15 08·5	A 117 43 33·2 G 117 43 41·6	Mwetaung	− 0·3	+ 0·2	675
A 23 27 50·8 G 23 27 48·1	*G* 94 00 53·5	A 297 38 01·4 G 297 38 01·9	Noepeji	+ 2·7	+18·4	676
A 23 28 33·5 G 23 28 34·6	*G* 94 10 25·4	A 84 59 40·0 G 84 59 41·9	Mwetaung	− 1·1	+15·2	677
A 23 29 06·4 G 23 29 11·4	*G* 94 07 01·5	A 76 14 13·6 G 76 14 15·2	Mwetaung	− 5·0	+15·9	678
A 23 26 03·6 G 23 26 07·3	*G* 94 05 47·9	A 110 23 03·5 G 110 23 02·1	Mwetaung	− 3·7	+22·8	679
A 23 23 40·7 G 23 23 42·4	*G* 94 05 27·1	A 134 14 18·4 G 134 14 15·6	Mwetaung	− 1·7	+26·1	680

TABLE 2

Serial No.	Sheet No.	Observed at	Height in feet	International Spheroid Deflections		Calculated Deflections. Hayford System		Calculated Deflections. Uncompensated Topography to 2564 miles	
				Meridian	P.V.	Meridian	P.V.	Meridian	P.V.
				"	"	"	"	"	"
681	94 H	Kyaikkamaw H.S.	1944	+ 8·0	− 0·3				
682	H	Sindaung H.S.	942	+ 5·4	+ 3·8				
683	H	Amherst Base North S.	31	+ 5·1	− 1·3				
684	H	Amherst Base Centre S.	28	+ 4·5	− 3·1				
685	H	Amherst Base South S.	34	+ 4·1	+ 4·5				

DEFLECTIONS 1932–33—(*Concld.*)

EVEREST'S SPHEROID						
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections		Serial No.
				Meridian	P.V.	
° ′ ″	° ′ ″	° ′ ″		″	″	
A 16 08 08·3 G 16 07 59·1	*G* 97 48 24·5	A 58 19 24·1 G 58 19 37·8	Sindaung	+ 9·2	−12·8	681
A 16 01 10·2 G 16 01 03·5	*G* 97 36 48·4	A 300 37 03·4 G 300 37 15·9	Saludaung	+ 6·7	− 8·7	682
A 16 08 18·1 G 16 08 11·8	*G* 97 41 52·9	A 34 30 28·2 G 34 30 42·2	Sindaung	+ 6·3	−13·8	683
A 16 04 31·0 G 16 04 25·2	*G* 97 42 25·1	A 58 14 07·1 G 58 14 21·6	Sindaung	+ 5·8	−15·6	684
A 16 00 59·4 G 16 00 54·0	*G* 97 42 55·3	A 91 32 08·8 G 91 32 21·1	Sindaung	+ 5·4	− 8·0	685

Corrigenda to the First Addendum to

For details of stations serial Nos.

Serial No.	Sheet No.	Observed at	Height in feet	International Spheroid Deflections		Calculated Deflections. Hayford System		Calculated Deflections. Uncompensated Topography to 2564 miles	
				Meridian	P. V.	Meridian	P. V.	Meridian	P. V.
				"	"	"	"	"	"
619	93 O	Kēngtūng Base North S.	2557	+ 1	−10	−3·6	+2·8	−12·4	+ 0·2
620	O	Loi Hpalan H.S.	7618	+ 8	+ 8	−0·3	+7·6	− 8·5	+ 5·4
621	O	Kēngtūng Base Centre S.	2546	+ 3	−11	−1·7	+1·3	−11·6	− 1·7
622	O	Loi Makho H.S.	6219	+11	−12	+3·0	−7·5	− 5·5	−10·2
623	O	Kēngtūng Base South S.	2586	+ 8	+ 2	+1·0	+1·9	− 3·3	− 0·6

Table 1 of "Supplement" to G. R. Vol. VI.

619 to 623 *substitute* the following:

EVEREST'S SPHEROID						
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections		Serial No.
				Meridian	P. V.	
° ′ ″	° ′ ″	° ′ ″		″	″	
A 21 24 37 G 21 24 36	G 99 36 58	A 86 12 41·9 G 86 13 03·7	Loi Hpalan	+ 1	−24	619
A 21 24 15 G 21 24 07	G 99 29 13	A 200 25 50·0 G 200 26 04·4	Loi Mi	+ 8	− 5	620
A 21 21 33 G 21 21 30	G 99 36 46	A 110 19 54·3 G 110 20 16·2	Loi Hpalan	+ 3	−25	621
A 21 18 34 G 21 18 23	G 99 46 49	A 145 32 02·4 G 145 32 24·8	Loi Mi	+11	−26	622
A 21 18 24 G 21 18 15	A 99 36 19 G 99 36 33	A 130 27 21·8 G 130 27 38·6	Loi Hpalan	+ 8	−11	623

Chapter IV

COMPUTATIONS AND PUBLICATION OF DATA

BY CAPTAIN G. BOMFORD, R. E.

1. Junction with Ceylon triangulation. The principal triangulation of Ceylon was observed between 1858 and 1906, and was joined to the Indian triangulation by a series of triangles across the intervening strait and islands. During the last few years the Ceylon survey department have remeasured their two bases, observed two astronomical azimuths, and recomputed the whole triangulation. The results are given in their "Report on the recomputation of the Principal Triangulation", dated 1932.

The origin of the triangulation is near Colombo, where astronomical values of the latitude and longitude have been observed and accepted. The Everest spheroid has been used. The discrepancies between Ceylon and Indian values at the junction at Delft are given in Table 1.

TABLE 1. *Discrepancies between Ceylon and Indian triangulation.*

	(a) Indian values	(b) Ceylon values*	(a)—(b)
Latitude of Amanakamunai S. ...	9° 33′ 7″·84	9° 33′ 12″·99	− 5″·15
Longitude of Amanakamunai S. ...	79 39 28 ·08	79 39 15 ·76	+ 12 ·32
Log side Amanakamunai–Crimunai S.(*Indian feet*)	4·5631195	4·5630763	+ 0·0000432
At Amanakamunai, azimuth of Crimunai ...	321° 14′ 31″·5	321° 14′ 22″·9	+ 8″·6

The Indian values given in Table 1 are those now in current use, as published in the triangulation pamphlets. They are open to modification in three respects, namely:

* These values differ slightly from those obtained from the original recomputation of the triangulation. Since completing the recomputation, the Ceylon survey have thought it proper to take account of the small difference between the new British foot, in which the lengths of their standard tapes are expressed, and the Indian foot which is usually used for the definition of Everest's spheroid. The figures given here result from this modification.

(*a*) The Indian triangulation has never been adjusted on to its Laplace stations. It is known that Indian geodetic azimuths require a correction of $-3''$ at Madras and of $-8''$ at Cape Comorin, which suggest a correction of $-6\frac{1}{2}''$ at the Ceylon junction. This reduces the discrepancy to $2''$, a very satisfactory figure*. Future adjustment on to Laplace stations will also change Indian latitudes and longitudes, but the changes are not likely to exceed $1''$.

(*b*) The value given for the Indian longitude has not been corrected by the $-3''\cdot16$ referred to in the Supplement to Geodetic Report Vol. VI, page viii. For the reasons there given, it is not intended ever to apply this correction, and when considering the longitudes of Ceylon stations in Indian terms, it is convenient to impose on Ceylon the same error as exists in the Indian triangulation.

(*c*) The whole of the scale discrepancy may readily be attributed to the weakness of a very short side which occurs in the Indian triangulation at Kachi Tīvu, 15 miles SW. of the junction. At this point the width of the series is reduced to only 4,000 feet. It is therefore probably best to use the Ceylon log side for the calculation of the Indian triangulation between Kachi Tīvu and Delft. This reduces the Indian latitude of Āmanakamunai by $0''\cdot06$ and the longitude by $0''\cdot05$. These changes are of practically no consequence.

The discrepancies in latitude and longitude can, of course, be attributed to deviation of the vertical at the Ceylon origin. To express Ceylon co-ordinates in Indian terms, they must be corrected by about $-5''$ in latitude and $+12''$ in longitude. The resulting deflections at Colombo are $5''$ south and $9''$† east, which are reasonable values.

The Ceylon triangulation is not of the highest geodetic accuracy, and the Indian connecting series is very weakly laid out. Nevertheless, in view of the comparatively small area involved, the Ceylon triangulation is amply accurate for the extension of the Indian geoid, as soon as opportunity occurs for the observation of astronomical latitudes and longitudes there. It is unlikely that errors in this triangulation will introduce deflection errors of as much as half a second anywhere in Ceylon.

2. Minor triangulation. The adjustment of old topographical triangulation on the N.W. Frontier has been continued. The adjustment of all triangulation in 1/M sheet 34 has been completed, and sheet 35 is in hand.

* This discrepancy is still further reduced to $\frac{1}{2}''$ if the Ceylon fundamental azimuth at their origin is corrected for the deviation of the vertical there, which amounts to $9''$ in Indian terms.

† Not $12''$ cos ϕ, but $(12''-3''\cdot16)$ cos ϕ. See Supplement to G.R. Vol. VI. pages viii and ix.

E. Company, Survey of India, have made a connection between two spirit-levelled bench marks at Quetta and the primary station Mashelak H.S. The discrepancy between the spirit-levelled and the published triangulated heights is $-8 \cdot 6$ feet, which is satisfactory, and all the geodetic and minor triangulation in Baluchistān is now being brought into spirit-levelled terms.

A large amount of compilation and adjustment has been undertaken for No. 1 Topographical Party in 1/M sheets 45 and 55.

The Anglo Persian Oil Company have recently communicated details of triangulation which connects the Mesopotamian triangulation, based on Fāo (see Chart XX, at end), with some triangulation of 1918–20, which had previously been based on Bushire in independent terms. This Bushire triangulation can now be brought into Fāo terms, which have been made the basis of all the other Mesopotamian and west Persian triangulation series. The completion of this work by the A.P.O.C. is of interest in that it is the last link in a continuous chain of triangulation from Indo-China to Egypt, although many parts of the chain are of very rough exploratory or active-service quality, which can have no possible scientific value. The fact that continuous triangulation does actually exist may, however, serve to encourage the future undertaking of a geodetic connection.

3. Secular change of Himalayan heights. Observations of the heights of several Himālayan peaks were made from Mussoorie in 1905–09 and in 1932, see Professional Paper No. 14 and Geodetic Report Vol. VIII, Chapter VII. Another short series of observations was made in February 1933 by Mr. N.N. Chuckerbutty, which confirms the conclusion, previously arrived at, that no measurable change in the heights of the peaks has occurred. The system of observation and computation was the same as described in Vol. VIII, and the results are given below, in feet:

	Bandarpūnch	Srikānta	Jaonli	Kedārnāth	Nāg Tibba
1932 *minus* 1907–08	$-0 \cdot 8$	$+4 \cdot 2$	$-1 \cdot 8$	$-1 \cdot 6$	$+0 \cdot 1$
1933 *minus* 1907–08	$-0 \cdot 3$	...	$-1 \cdot 8$	$+3 \cdot 8$	$+0 \cdot 8$

Observations between Mussoorie and Dehra gave a result almost the same as that obtained in 1932, and make the discrepancy (Triangulated height) − (Spirit-levelled height) equal to $-1 \cdot 18$ feet.

4. Publications. The triangulation data for 16 Indian degree sheets have been compiled. One Persian triangulation pamphlet has been printed, and three Indian pamphlets have been reprinted. Addendum pages for 10 Indian degree sheets have been printed.

The levelling data of about 1300 miles of high precision levelling and of 350 miles of precise levelling have been sent to press as addenda to existing levelling pamphlets. Seven lines of secondary levelling, totalling 410 miles have been sent to press for reproduction, and 21 secondary pamphlets with 3500 miles of data have been reproduced by gestetner.

In addition to the above, the following publications have been seen through the press:

(a) Geodetic Report Vol. VIII.

(b) *The Geography and Geology of the Himālaya Mountains and Tibet*, Parts I and II, by Colonel Sir S. G. Burrard. Parts III and IV are still in the proof stage.

(c) Handbook of Topography, Chapter XII, *Air Survey*. Not quite completed.

(d) Report to the International Union of Geodesy and Geophysics on the geodetic work of the Survey of India during 1930–33.

5. Lambert grid. The Computing Office has continued to be largely occupied with the conversion of triangulation data on the N.W. Frontier into terms of the Lambert grid. During the current year about 7700 points have been converted, 6500 classified to indicate the quality of their fixing, and 8400 compiled for publication. Out of an estimated total of 25000, 15800 have now been converted, 17400 classified, and 10500 compiled. None of the proposed "Grid triangulation pamphlets" have yet been sent to press.

6. Miscellaneous work. In addition to a large number of smaller pieces of work, 118 barometric and hypsometric heights in south Persia have been computed for Sir Aurel Stein. The records of old trans-frontier explorations, which had got into some confusion in the course of time, have been sorted out and card-indexed.

7. Chart section. The chart section has completed the following work:

(a) Charts for 12 triangulation pamphlets.

(b) Charts for 6 grid triangulation pamphlets.

(c) Chart for 1 levelling pamphlet.

(d) 18 charts and plates for Geodetic Report Vol. VIII.

(e) 16 plates for the *Geography and Geology of the Himālaya Mountains and Tibet.*

(f) 8 figures for the Handbook of Topography, Chapter XII.

(g) About 60 other miscellaneous charts and diagrams.

CHAPTER V

OBSERVATORIES

BY CAPTAIN G. BOMFORD, R.E.

1. Standardization of 24-metre invar wires. The six 24-metre invar wires of the base-line party have been standardized on several occasions in connection with the 1932–33 base measurements in Burma, (see Chapter I), and have shown some great and unaccountable changes of length. The lengths of the wires at different times are given below, the figures being millimetres in excess of 24 metres under standard conditions*.

Wire Numbers	243	244	247	248	249	252
April 1931 ...	−0·34	−1·74	+1·03	+1·12	+1·01	+2·41
Sept. 1932 ...	−0·43	−2·51	+1·15	+1·40	+3·70	+2·66
April 1933 ...	−0·19	−2·34	+1·36	+1·75	+3·86	+3·08
May 1933 ...	−0·14	−2·27	+1·58	+1·76	+4·06	+3·14
July 1933 ...	−0·14	−2·30	+1·54	+1·71	+4·05	+3·07
Sept. 1933 ...	−0·15	−2·32	+1·54	+1·70	+4·06	+3·07

The comparison in April 1931 was after the measurement of the Kēngtūng base, during which the wires had undergone little change in length (see Geodetic Report Vol. VII, page 19). Between April 1931 and September 1932 no work was done with the wires except the determination of their coefficients of expansion in October 1931 (Vol. VII, page 12). Nevertheless, during this interval wire No. 249 increased by over 2½ mm, 244 decreased by nearly 1 mm and the other four wires showed smaller, but serious, changes. The range of temperature to which they were exposed for the determination of their coefficients (24° to 36° C with a slow rate of change) cannot be held responsible, and no satisfactory explanation can be discovered. The tank in which they were hung during the expansion experiments is rather narrow, and it is possible that difficulty in

* At 28° C. in catenary under a tension of 10 kilogrammes.

fastening and unfastening them from their hooks in this tank may have caused some bending near the end scales. This is not thought to be a probable explanation, since care was always taken to avoid such damage, but during a repetition of the expansion experiment in 1933 (see para 3) the risk was avoided entirely and no changes of length occurred.

Between September 1932 and April 1933 the wires were taken to Burma and three bases were measured (see Chapter I). On return from the field all 6 wires showed an increase: about 1 in 60,000 in Nos. 248 and 252 which had been used as field standards, and about 1 in 120,000 in the others. The probable progress of the changes between the three base-lines is discussed in para 4. As regards the cause of the changes, their comparative equality in the four working wires negatives the suggestion of casual ill-treatment in the field, and it is thought that they are probably due to instability set up by the unknown cause of the changes which occurred before September 1932. The greater change in the two standard wires is comparable with that found during the Kēngtūng base measurement, but on a larger scale. At that base the two standard wires increased by 1 in 350,000 while the working wires remained almost unchanged.

Between the comparisons of April and May 1933, the wires remained at Dehra Dūn, but were unwound from their drums and exercised for 10 days, thereby roughly reproducing the circumstances of a base measurement. All six wires showed a further increase, which amounted to 1 in 100,000 in 247 and 249, and 1 in 500,000 in the others.

Between the comparisons of May and July 1933, no work was done except a re-determination of the temperature coefficients (see para 3). No large changes took place, and the average change was a shortening of 1 in 750,000. The July comparison was a rough one, and this apparent change may not be real.

The wires were again re-compared in September 1933, no work having been done in the interval, and showed no significant change since July (i.e. an average shortening of 1 in 750,000 since May). It appears that the wires are now stable while lying wound on their drums, but it is still possible that their lengths will increase when they are at work. Three base-lines are included in the programme for 1933–34, and it will fortunately be convenient to bring the wires back to Dehra Dūn for re-standardization between each base*. This should greatly reduce the liability to error. One of the field standards will be reserved for use every fourth day, instead of using both daily, and it is to be hoped that this wire at any rate will undergo little change of length. It is also hoped to obtain two new invar wires which may be more stable.

Except in July 1933, all the above comparisons are the mean of two days' work, the wires having been hung on the comparator each

* Comparisons after the first of these bases have revealed increases of 1:500,000 in 243 and 244, and no significant changes in the other four. Jany. 1934.

day, and the 4-metre invar bar having been run along the comparator each morning and afternoon. The results are shown in Plate XIII and Table 1. Plate XIII has been prepared on the assumption that the 4-metre invar bar has retained the length which was ascertained in 1930, but in Table 1 it has been assumed that in 1932–33 this bar was 1 in 1,000,000 longer than it was in 1930, (0·5 in 1,000,000 per annum having been its rate of increase between 1914 and 1930). Comparisons with the 4-metre nickel-steel bar (which is supposed to be stable) in 1930 and 1933 confirm the latter assumption, which will be further checked when the 4-metre invar bar is next compared with the nickel and silica metres. The black lines in Plate XIII show the lengths which have, from time to time been accepted for the comparator, and the two red lines show what now appear to have been the true lengths (ignoring growth in the 4-metre invar bar). The differences between the red and black lines are not material. The separation between the two red lines suggests that the invar tape of the comparator grows about 1 in 1,000,000 per annum faster than the invar bar, but the change between 1930–31 and 1932–33 may possibly be due to a movement of the end marks, which are not cut on the tape but clamped to it.

The standardization of the six 24-metre wires in September 1933 was undertaken with the special object of discovering whether the one-hour's "exercise", which it has been customary to give the wires every day between unwinding and beginning work, has any good effect. On September 18th the wires were not exercised before comparison, while on the 19th they were. The figures in Table 1 show that the mean difference between these two days was only 1 in 2,500,000, so it is concluded that exercise is not necessary. It is thought that, besides wasting time, the exercise may in the long run contribute to the increases of length which have occurred, and in future it will be omitted.

The comparisons were made by Captain G. Bomford and Mr. R. B. Mathur until May 1933, and by Captain Bomford and Mr. B. L. Gulatee since.

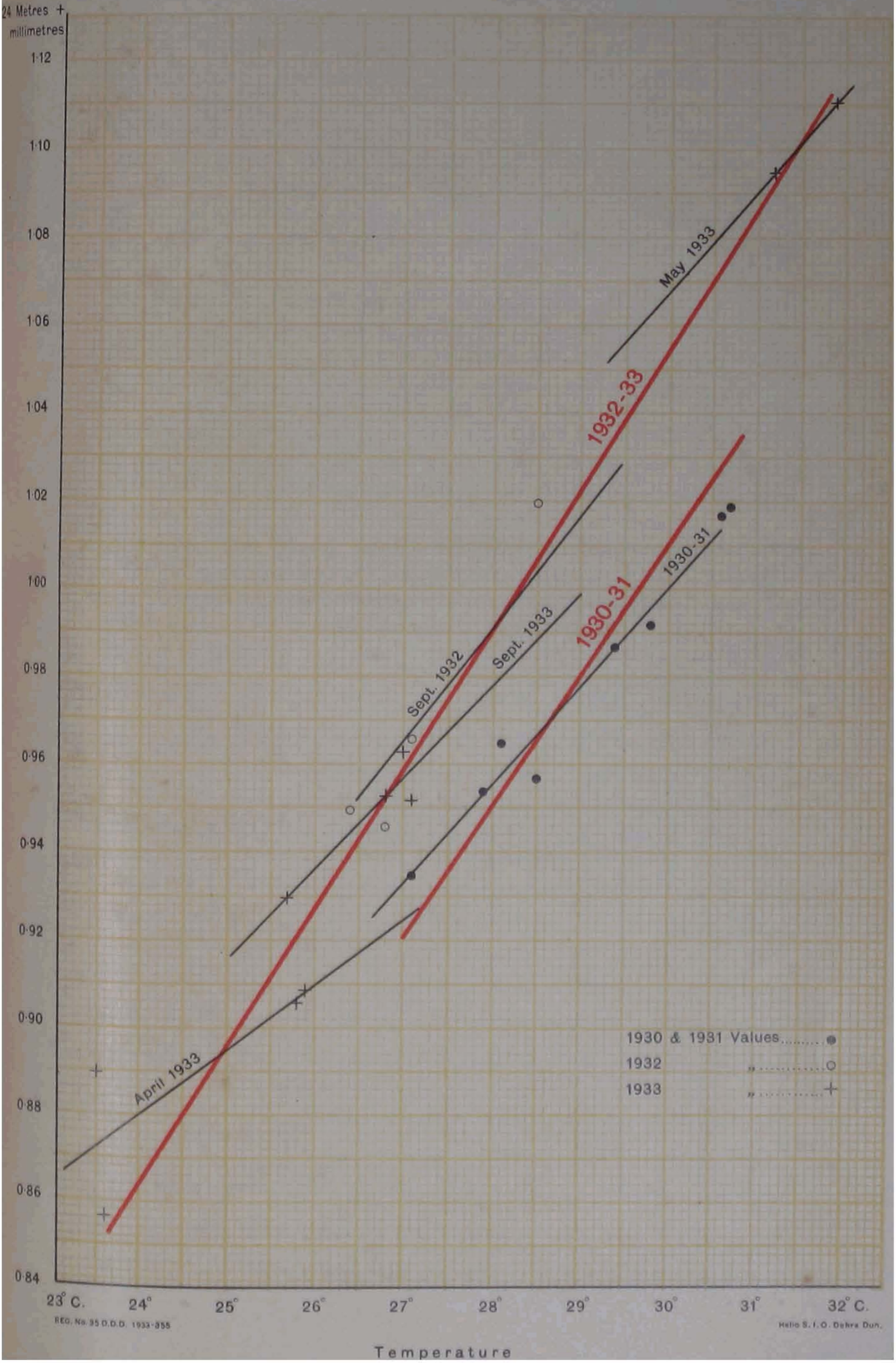
2. 8-metre wire and 4-metre tape. A new 8-metre wire, No. 983, made by Messrs. Carpentier of Paris was received in June 1931. Its N.P.L. certificate, dated March 1931, shows its length at 28° C to be 8 m + 0·24 mm. In September 1932 it was found to be 8 m + 0·23 mm and in April 1933 8 m + 0·53 mm, an increase of 1 in 25,000. This great increase is not serious, as the wire is so seldom used, but it is hard to explain, and it goes against the idea that the increases in the other wires in the field were due solely to instability resulting from their earlier disturbance.

The 4-metre invar tape was standardized and found to be 4 m + 1·42 mm in September 1932 and 4 m + 1·40 mm in April 1933, a change of no significance.

Plate XIII

24-metre Comparator, 1930-33

Length, ignoring growth of 4-metre bar



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3. Temperature coefficients of invar wires. At the Kēngtūng base in 1931 the mean temperature of measurement was nearly the same as that of standardization, and the temperature coefficients had little influence on the result. At the three bases measured in 1932–33 the accepted lengths of the wires have been influenced by inter-comparisons made in the cold of the early morning, and a rather large discrepancy between the measures of the Kalemyo base (see Chapter I, page 7) suggested that the temperature coefficients might be responsible. They were accordingly re-determined on the comparator in July 1933, but the values obtained in 1931 were substantially confirmed, and the discrepancy remains unexplained.

Three separate determinations were made, the range of temperature being from about 24° C to 35° C. The wires were not kept in the tank continuously, but were placed in it one at a time. The air temperature was 29° C, so each wire experienced a sudden change of 5° or 6° C six times. It is thought that this is less dangerous than the risk of rough handling which the wires are exposed to if all six are kept in the narrow tank at once, and subsequent standardizations have shown that no great change of length has resulted (see para 1).

The results are given below, the figures being increases in millimetres per 24 metres per °C, under a tension of 10 kilogrammes.

Wire Numbers	243	244	247	248	249	252
1st determination ...	+ ·0082	+ ·0074	− ·0023	− ·0018	− ·0014	− ·0026
2nd ,, ...	+ ·0075	+ ·0065	+ ·0012	− ·0050	− ·0046	− ·0059
3rd ,, ...	+ ·0028	+ ·0046	− ·0039	− ·0042	− ·0017	− ·0048

The following figures compare the mean of the above with the results obtained in 1931 (see Vol. VII, page 12).

	Wire Numbers	243	244	247	248	249	252
1	Field Measure 1931 ...	+ ·0050	+ ·0058	− ·0005	− ·0030	...	...
2	Comparator 1931 ...	+ ·0050	+ ·0053	− ·0005	− ·0017	− ·0063	− ·0057*
3	Comparator 1933 ...	+ ·0062	+ ·0062	− ·0017	− ·0037	− ·0025	− ·0044
4	Mean	+ ·0054	+ ·0058	− ·0009	− ·0028	− ·0044	− ·0050
5	Old value	+ ·0050	+ ·0056	− ·0005	− ·0024	− ·0063	− ·0020

Note: 0·0240 corresponds to 1 in 1,000,000 per °C.

*For Wire No. 252 the three figures were + ·0053, − ·0063 and − ·0051. At the time, the mean of all three was accepted. But the further experience now obtained shows that + ·0053 is an unduly wide value, and that it should properly be rejected.

Line 5 in the above table gives the figures which have previously been accepted, and line 4 gives those which are now considered the best. The largest change is 1 in 1,000,000 per 8° C, while in four wires it is only one-eighth of this. Apart from No. 249, which is a wire that has given trouble in other respects, these means should be sufficiently accurate for all purposes, except possibly at very low temperatures where the true coefficients may be materially different.

The observers were Captain Bomford and Mr. Gulatee.

4. Changes in wires during Base measurement. As stated in para 1, the six wires all showed changes on returning from the measurement of the three base-lines. It is a matter of importance to make the best possible estimate of the proportion of these changes which occurred between each base. The data available are the standardizations described in para 1, and the results of daily comparisons between the wires which were made in the field.

Results of field comparisons. Increases in wires in millimetres from September 1932, assuming No. 252 to have remained constant.

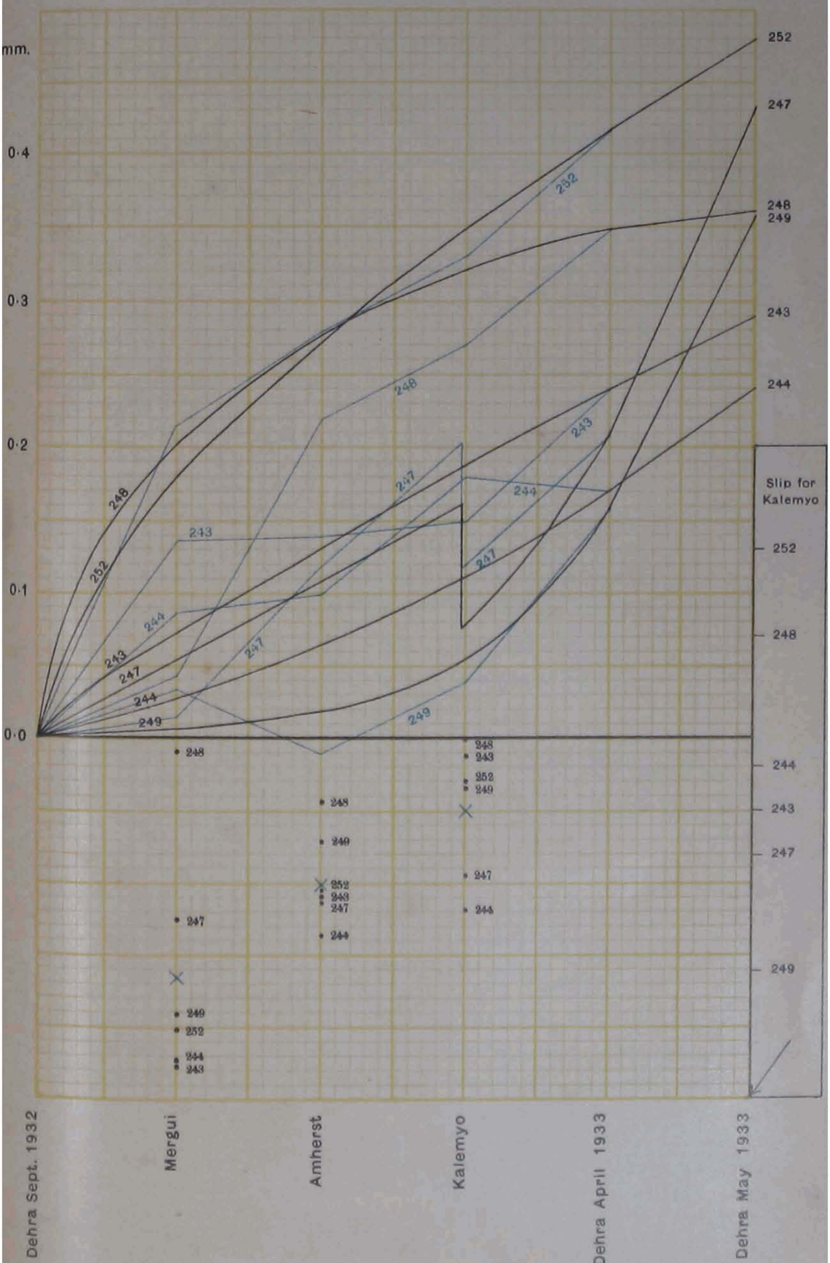
Wire Numbers	243	244	247	248	249
Mergui Base ...	−·08	−·13	−·20	−·17	−·18
Amherst Base ...	−·14	−·18	−·16	−·06	−·29
Kalemyo Base ...	−·18	−·15	−·21	−·06	−·29

On Plate XIV, along the ordinates marked "Dehra April" and "Dehra May" are plotted the increases found in the six wires in April and May 1933. These two standardizations suggest that 247 and 249 were changing rapidly at the end of the season, and that 248 and 252 had increased more rapidly at the beginning. The six smooth* black curves give what would be the most plausible assumptions regarding the progress of the changes of length, if the field inter-comparisons were not available. The results of the field comparisons must, however, be accepted, and this condition must modify the black curves. It also provides a criterion by which the accuracy of the finally accepted lengths may be judged. Suppose the differences in the lengths of the wires at (say) Kalemyo to be plotted on a slip of paper, as shown in the margin of Plate XIV. If the curve showed the truth, placing the 252 mark on the slip against the 252 curve at the Kalemyo ordinate would cause the 248 mark to fall on the 248 curve, and so on. This condition is not perfectly satisfied, and it is required to obtain blue curves which fulfil this condition but depart from the black curves as little as possible. The bottom of the slip is marked by an arbitrarily placed arrow. Placing the 252 mark against its curve, the point of the arrow is marked by the dot 252 below the zero line, and 5 other dots are similarly

* The jump in 247 is on account of an accident to this wire on the first day on which it was used at Kalemyo. Comparisons before and after the accident showed that it was shortened by 0·08 mm.

Changes in lengths of Invar Wires

Increases from Sept. 1932



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obtained from the other marks and curves. The blue cross represents the mean of these dots. The point of the arrow is then placed on the blue cross, and with the slip in this position the blue curves are drawn through the marks on the slip.

A similar process has been carried out on the Amherst and Mergui ordinates, and the resulting blue curves give the increases from September 1932 which have been finally accepted for each wire.

Combining these increases with the known lengths of the wires in September 1932 (see para 1) gives the following lengths for each wire during the measurement of each base. The figures are millimetres in excess of 24 metres at 28° C.

Wire Numbers	243	244	247	248	249	252
Mergui ...	−0·29	−2·42	+1·17	+1·44	+3·73	+2·88
Amherst ...	−0·29	−2·41	+1·27	+1·62	+3·69	+2·94
Kalemyo ...	−0·28	−2·33	+1·27*	+1·67	+3·74	+2·99

The degree of scatter of the dots below the zero line in Plate XIV is a measure of the accuracy with which the progress of the changes of length has been determined. The probable errors of the "mean wire", determined from this scatter, are as follows.

Mergui ±1·0 in 1,000,000
Amherst ±0·4 in 1,000,000
Kalemyo ±0·6 in 1,000,000

The last two figures may by chance be lower than the truth, but little doubt is felt that the length of the mean wire at each base is known within 1 in 300,000 for certain, and it is considered that this, although worse than what is usually hoped for, is a sufficient degree of accuracy for geodetic purposes.

5. Longitude. Observations of the longitude of Dehra Dūn have been continued as in previous years. The bent transit was not available during the winter, as it was taken into the field, and from October 1932 to May 1933 another transit was used, fitted with Dr. de Graaff Hunter's "Shutter" (see para 6). From June to September 1933 an exceptionally heavy monsoon caused considerable interruption of the programme, and all available clear nights were used for testing the three transits required for the international longitude project of October and November 1933. All three instruments consequently contribute to the results for these four months. The observers were Mr. R. B. Mathur and Mr. H. C. Benerjea.

* After kinking.

The resulting values of the longitude are given in Table 2, and the monthly means are given below, as determined from the Bordeaux, Rugby and Nauen signals, with "demi-definitive" corrections.

	Bordeaux	Rugby	Nauen
	h m s	h m s	h m s
October 1932 ...	5 12 11·70	5 12 11·73	5 12 11·75
November „ ...	11·79	11·77	11·81
December „ ...	11·85	11·83	...
January 1933 ...	...	11·83	11·73
February „ ...	11·78	11·77	11·79
March „ ...	11·79	11·82	11·85
April „ ...	...	11·84	...
May „ ...	...	11·84	...
June „ ...	...	11·78	...
July „ ...	...	11·68	...
August „ ...	11·87	11·84	...
September „ ...	11·83	11·78	...

It has been discovered that in the past a systematic error has occurred in the reading of the transit chronograph sheets. The contacts of the impersonal micrometer make a small tick on the chronograph sheet, and on the first face the time of the beginning of the tick is recorded while on the second face the time of the end of the tick is required. But for the last seven years the beginning of the tick has been recorded on both faces. The necessary correction averages about $0^s\cdot04$, but varies a little according to the adjustment of the contact.

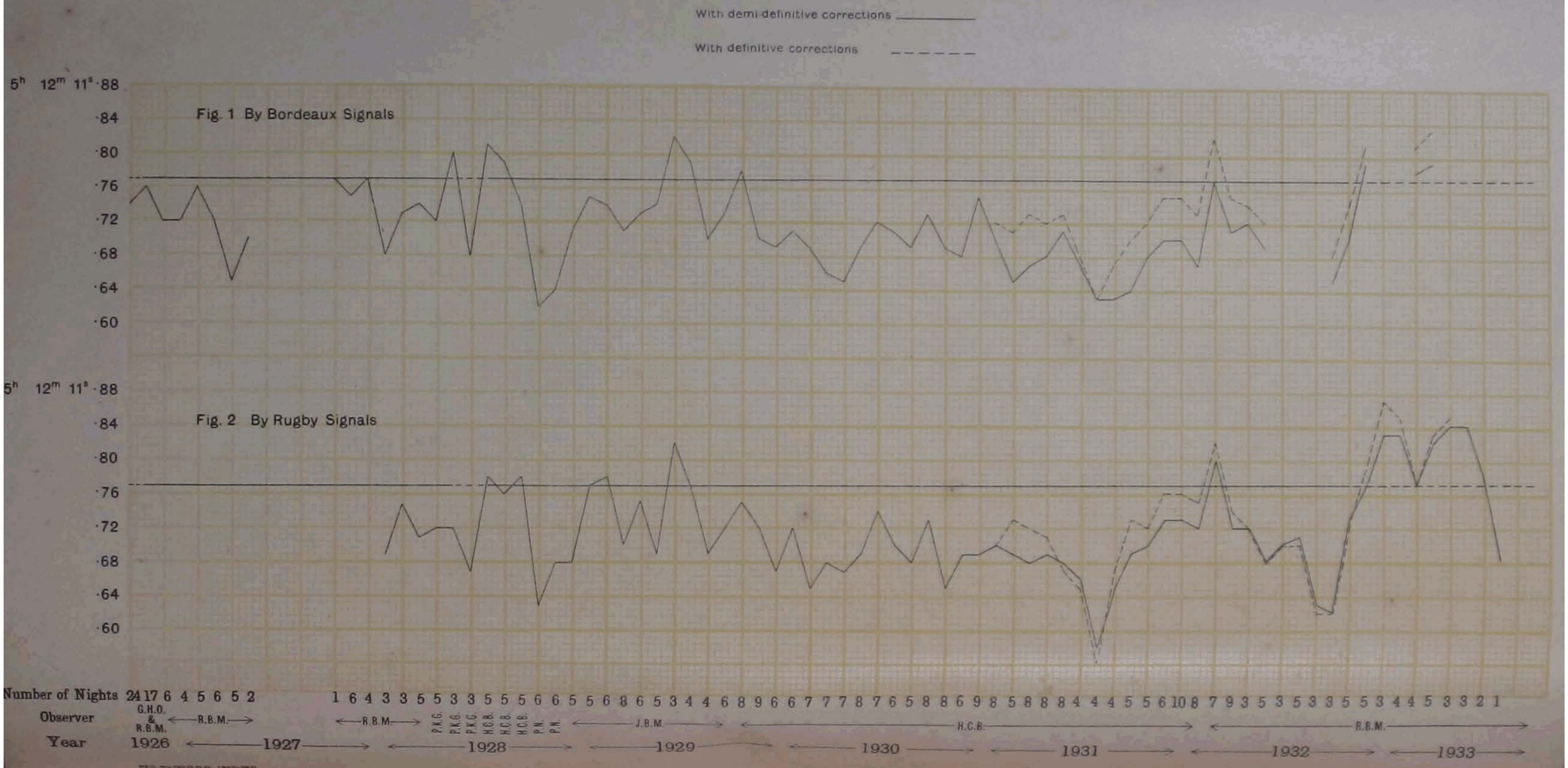
The value of the longitude of Dehra Dūn found in the international project of 1926 is thus reduced from $5^h 12^m 11^s\cdot79$ to $5^h 12^m 11^s\cdot75$. The value obtained telegraphically in 1894–96 was $5^h 12^m 11^s\cdot77$, so it happens that the disagreement with this value is neither increased nor decreased. Plate XV shows the apparent variation of the longitude from month to month, as derived from the Rugby and Bordeaux signals.

The values of the longitude of Dehra Dūn given in these Geodetic Reports have always been obtained after applying the "demi-definitive" corrections to times of the wireless signals. Since 1931 "definitive" corrections are available, but to maintain continuity it has appeared preferable to continue to use the demi-definitive corrections, which depend on the Greenwich or Paris observatories only, rather than to change to the definitive corrections as given by the "international clock". For comparison, Plate XV also shows the results obtained by using the definitive corrections.

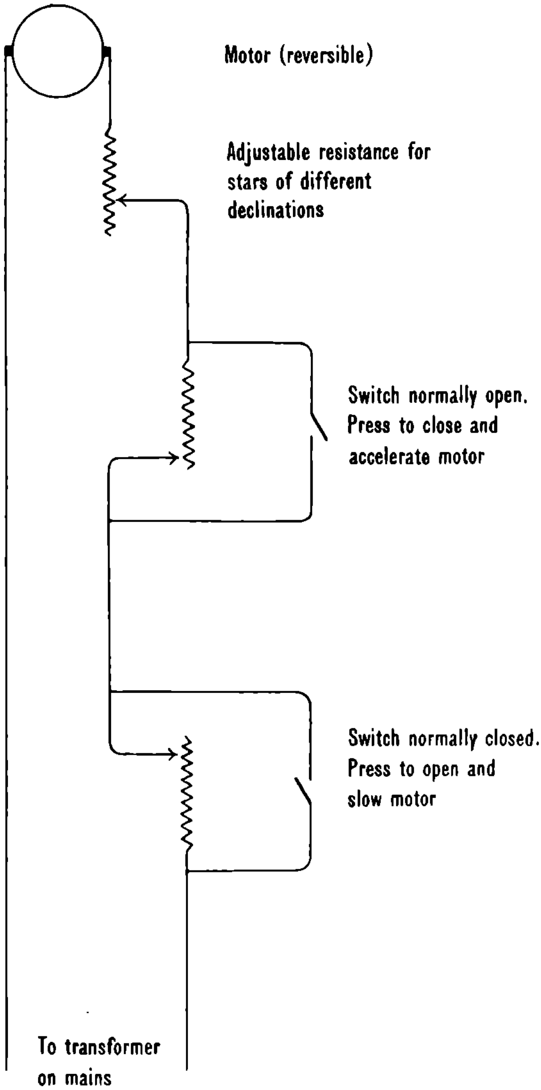
Plate XV

LONGITUDE OF DEHRA DŪN

by Bent Transit Instrument except where 11ˢ·77 line is broken.



Electric Drive for Transit



Inspection of Plate XV shows that the variations during 1931, 1932 and 1933 have been larger than in the preceding years. Change of instrument is presumably partly responsible for the higher values during the last twelve months.

6. Transit telescopes. Dr. de Graaff Hunter's new shutter-type of transit has been brought into regular use. As explained in Geodetic Report Vol. VIII, Chapter II, the principle of the instrument is that the eye-piece contains a fixed illuminated scale, while the star is ordinarily obscured by a small shutter. At every third second the clock momentarily opens the shutter, the star is seen, and its position is read against the scale. Change of face eliminates any correction for collimation or uncertainty in the value of the scale divisions, and the computation is a simple one. Furthermore it is hard to see any possible cause for personal equation in the mean of stars of both north and south aspect. This transit will be employed by four different observers during the international longitude project of 1933 (see para 8), which will give it a thorough test.

The instrument known as the North Transit (Geodetic Report Vol. III, Chapter I) has been fitted with an electric drive, made by Messrs. Cooke, Troughton and Simms. An 18-volt D.C. electric motor is mounted on springs on the base of the lifting fork, whence the drive is through a worm gear and a leather belt to a pulley concentric with the transit axis. The drive is then carried to the eye-piece by toothed gearing, a shaft down the length of the telescope, and another worm. This drive works very well and no vibration is noticeable.

The speed of the motor is controlled by a variable resistance. It was originally intended that the observer should hold this resistance in his hand and maintain the coincidence between wire and star by regulating the resistance. In practice this was not found very satisfactory, and the observer is now provided with two press-buttons, pressure on one of which checks the motor, and on the other causes sudden acceleration.

For each star the variable resistance is set to a position previously determined by calibration, and on the appearance of the star the speed is verified and corrected if not apparently perfect. As soon as the star reaches the working position, the observer ceases to operate the variable resistance, and maintains perfect coincidence by means of occasional light touches on the two press buttons. It is generally found necessary to touch the buttons three or four times during the passage of a star. The electrical connections are shown diagrammatically in Plate XVI.

7. Clocks. The Riefler clock ran uninterruptedly throughout the year, with well-regulated temperature and pressure, except that the temperature rose between 1° and 2°C during June, July and August. The errors and rate of the clock as deduced from Rugby time signals are shown in Table 3.

The Shortt clock has been in regular use since March 1933, since when the pressure has been steady, and there have been no interruptions. On the makers' recommendation the clock is being run from accumulators instead of dry cells. It is thought that the use of dry cells was probably responsible for some of the troubles which occurred before that date. The errors and rate of the clock since March are shown in Table 4.

8. International longitude project. A repetition of the 1926 international project is taking place in October and November 1933. At Dehra Dūn three transits are being employed, the electrically driven transit, the new shutter transit, and the hand-driven bent transit. No astrolabe is being used. Four observers, of whom two will be on duty daily, will take turns with the three instruments, so there will be twelve different combinations of observer and instrument, and it is hoped that personality will be well eliminated.

The observatory is not equipped with apparatus for the automatic registration of wireless signals, but it is thought that the coincidence system is likely to be equally free from errors, if not more so.

Instrumental lags are not being directly determined. The breaking of a contact by the movement of the chronograph pen on which time stars are recorded causes the periodic disablement of the wireless receiver, which is required for reception by the coincidence method. Lags are thus entirely eliminated provided that they do not vary between the hours of wireless reception and star observation. Provided currents are kept constant there seems very little risk of any systematic variation between these hours. The constancy of the current is checked by ammeters, and regulated if necessary.

The wireless signals which are being received are Bordeaux 8.01 G.M.T., Rugby 9.55 and 17.55, and Saigon 11.00 and 19.00.

9. Latitude variation. The third full year of the latitude variation programme has been completed by Computer J. B. Mathur, and the work has now been discontinued. Table 5 shows the groups which have been used to form the chain (the same as in the previous years), and the differences of latitude derived from successive pairs of groups. The closing error of $0''\cdot05$ is satisfactory. These differences, which are attributable to declination errors, should be nearly constant from year to year, and the results of previous years are shown for comparison in Table 6. The figures for different years vary within a satisfactorily narrow range. Table 7 gives the monthly mean values of the latitude during the third year.

Plate XVII shows the observed variation of latitude at Dehra Dūn during the last three years. The values here are not quite identical with those given in Table 7 and the corresponding tables of previous years (Geodetic Reports Vol. VII, page 28, and Vol.

VIII, page 14), since the values finally accepted for the declination errors of groups are the means of the three years' determinations as given in Table 6.

Plate XVII also shows the variations in the latitude of Dehra Dūn which would result from the polar movements determined by the international latitude stations.* As remarked in Geodetic Report Vol. VIII, page xiii, the variation actually observed is too large. If the layers of equal air density in the atmosphere above the station are inclined at an angle of one degree, the assumption of equal refraction for stars at equal and opposite zenith distances will result in an error of one second of arc in the calculated latitude. Plate XVII then suggests that these layers are tilted upwards towards the north by about 30 minutes more in the months of October, November and December than they are in May, June, July and August.

Plate XVIII, which is reproduced from the publications of the Indian Meteorological Department†, depicts the lines of equal air density at sea-level during the months of November and June. From them it is seen that the north-and-south slope of the layers of equal density in the neighbourhood of Dehra Dūn is about zero in June, while in November the density is increasing towards the north at the rate of about 10 Gm/M^3 per 200 miles. This is equivalent to a slope of about 1 minute upwards towards the north. In December the slope is about twice as much. These charts thus reveal changes in the slopes which are approximately in phase with the changes required to explain the latitude anomalies, but whose magnitude is only about one-twentieth‡ of what is required. The charts however are constructed from observations made at widely separated places, and cannot be expected to give the exact variation at any particular place. Dehra Dūn stands at the foot of the outer Himālayan range (peaks of the Mussoorie ridge rise 5,000 feet above Dehra eight miles away to the north), and it is quite reasonable to suppose that the variations at this spot may be many times the average of northern India.

Whatever may be the exact cause, it seems clear that latitude observations at Dehra Dūn are heavily affected by meteorological conditions, and that Dehra Dūn can make no direct contribution to our knowledge of the Pole's periodic movements. But it is thought that by drawing attention to the abnormal results which can be obtained if meteorological conditions are ignored, the observations may contribute materially to the elucidation of anomalies at other

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* "Report upon the work of the International Latitude Service, during the Period 1930·0—1933·0" by Hisashi Kimura.

† Scientific Notes Vol. III, No. 19 "Distribution of Air Density at M.S.L. over India", by U.N. Ghosh, M.Sc., 1930.

‡ In Geodetic Report Vol. VIII, this fraction is given as 1/5: the annual change of slope had been wrongly calculated to be 6 minutes.

stations. Other latitude stations are probably more remote from abrupt topographical relief than Dehra Dūn, and meteorological effects will generally be much less, but an ordinary tilting of the layers of equal density, not much greater than that shown in Plate XVIII, may be responsible for such anomalies as the Kimura term in the apparent variation of latitude. The remedy, of course, is to place latitude variation stations in areas where the meteorological conditions are sufficiently well known, and where the topography is sufficiently regular for the meteorological variations to be small and calculable. The Survey of India have some hope of being able to renew their observations, at Agra in the plains of the United Provinces, at some future date. At Agra there is practically no topographical relief, and an upper air meteorological station is already operating.

10. Magnetic observations. The usual programme of magnetic observations has been carried on at the Dehra Dūn observatory, consisting of a continuous magnetographic record of declination, horizontal force, and vertical force, controlled by observations of dip daily, and of declination and horizontal force three times a week.

The magnetographs have worked regularly during the year, except that deterioration of the mirror in the V.F. magnetograph caused the loss of six days' traces during April. The mirror has since been replaced by a new one. The galvanometer of the earth inductor became insensitive during August 1933. This has occurred before in continuous wet weather, and is presumed to be due to failure of the insulation. Artificial drying caused some improvement, and the trouble disappeared when the monsoon ceased.

The mean values of the magnetic elements at Dehra Dūn in 1932 were:

Declination	...	E. 1° 5′·4
Dip	...	N. 45° 37′·3
Horizontal Force	...	0·33032 C.G.S.
Vertical Force	...	0·33755 C.G.S.

The mean scale values of the magnetographs, for an ordinate of 1/25th inch were:

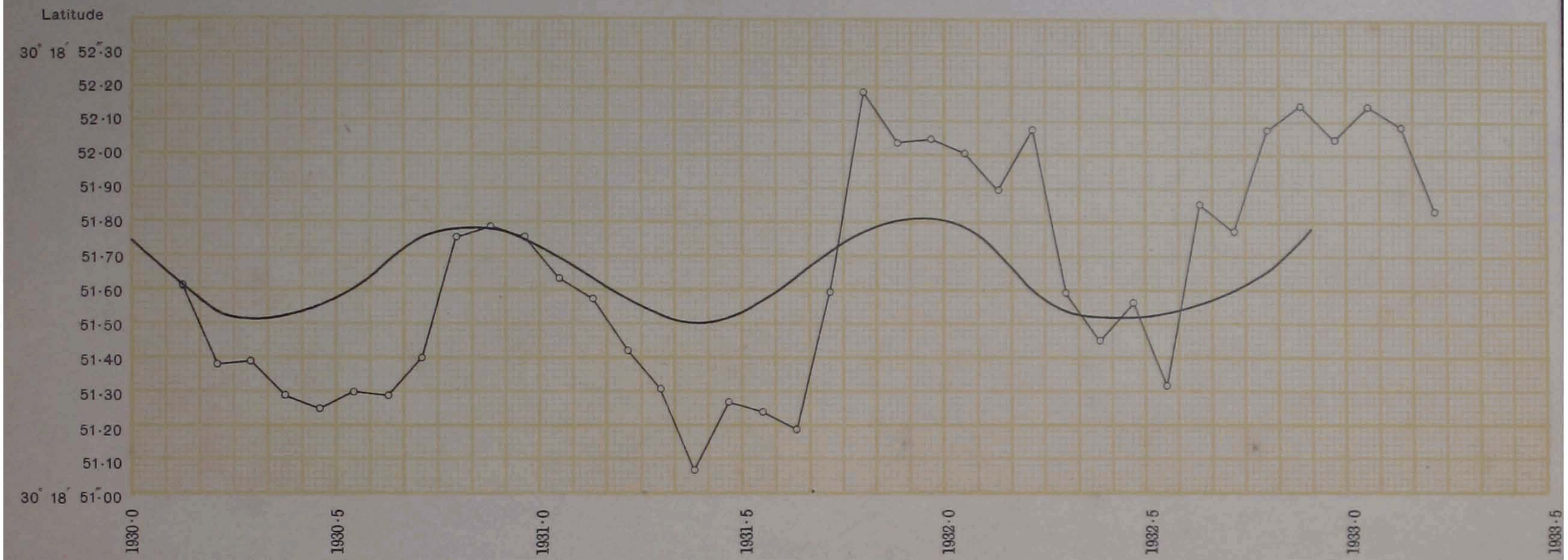
Declination	...	1·03 minutes
Horizontal Force	...	4·24 gammas
Vertical Force	...	9·98 to 11·77 gammas.

The mean temperature of the year in the observatory was 27·0°C, with maxima and minima of 27·8°C and 26·6°C respectively.

The moment of inertia of magnets Nos. 17 and 5 B were determined in September and October 1933, and log $\pi^2 K$ was found to be 3·41429 and 3·37741 respectively. These figures are in fair accord with previous determinations. That for No. 17 may be compared

Plate XVII

Variation of Latitude at Dehra Dūn



The plotted points are the values observed at Dehra Dūn. The smooth curve is deduced from the observations of the International Latitude stations.

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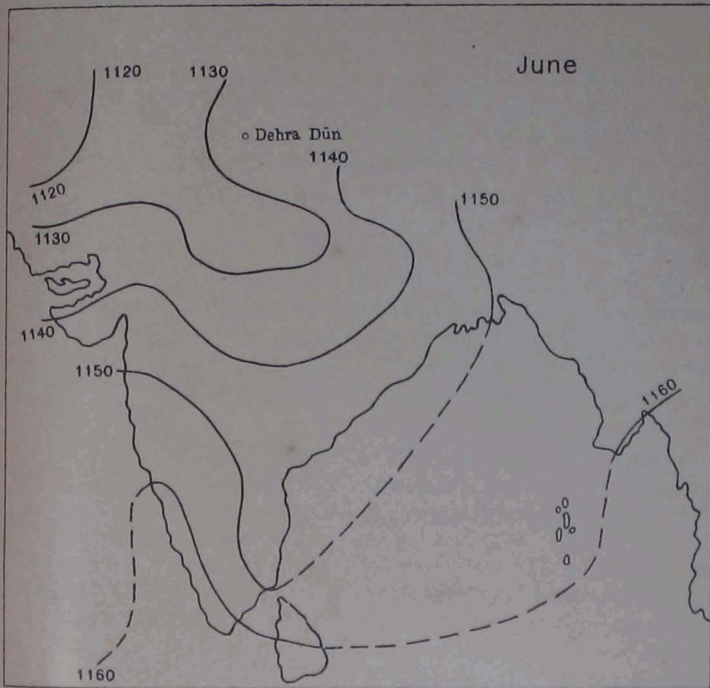
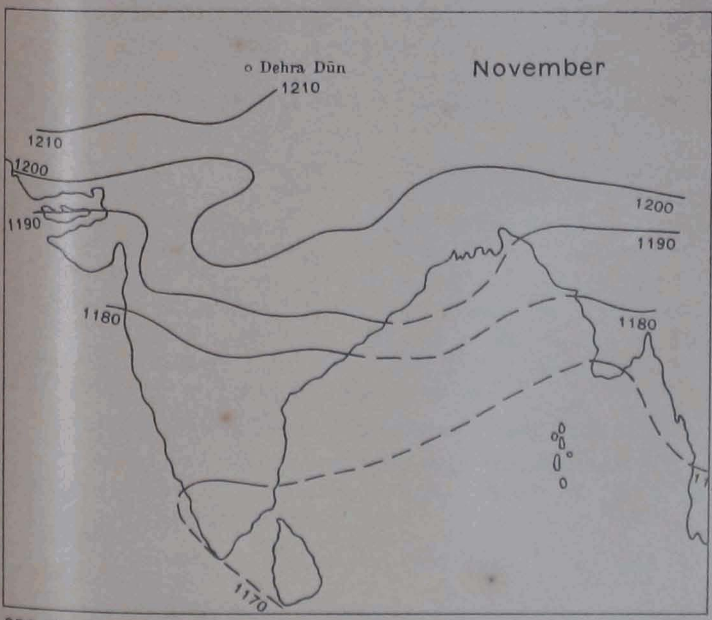
Air Density at M. S. L. Isopycnics at intervals of 10 Gm./M^3.





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with previous values given in Geodetic Report Vol. VII, Plate XXII. The values which have been accepted for 1932 are 3·41441 and 3·37745 for the two magnets.

The observed values of the factor log $(1+P/r^2+Q/r^4)^{-1}$ for magnetometers Nos. 17 and 5 have been $\bar{1}\cdot99415$ and $\bar{1}\cdot99346$ in 1932. These values are in reasonably close agreement with the figures given in Vol. VII page 140*, and the values accepted have been $\bar{1}\cdot99415$ and $\bar{1}\cdot99292$, the same as before.

Table 8 shows the monthly values of the magnetic collimation, the distribution factors, and the magnetic moment for No. 17: and Table 9 gives similar information for No. 5. The fall of the moment of No. 17, which began with the temperature experiments made in 1930 (See Vol. VII, page 120), appears to have ceased. In No 5 it has been fairly constant since February 1930†. In each instrument the observed monthly mean value of the moment has been accepted for the reductions, in accordance with the policy stated in Vol. VII, page 122.

Table 10 gives the mean monthly values of the Declination and H. F. base-lines, and the H. F. base-lines for 1931 are also given for comparison. The values given by magnetometer No. 17 only have been accepted. The difference between No. 17 and No. 5, which used to be about 10γ (Geodetic Report Vol. VII, page 140), suddenly increased to about 40γ in June 1931, and has remained at that figure ever since. The base-line values suggest that the change occurred in No. 5, and this is confirmed by the changes in the annual mean H. F. According to No. 17 the annual changes are reasonable, while No. 5 gives an unexpectedly large change in 1930 to 1931.

Table 11 gives the mean monthly values of the elements for 1931 and 1932, and the annual changes for the period. Tables 12 to 15 give the mean hourly deviations from the monthly means and Table 16 gives the classification of the magnetic character of all days of 1932.

The proposal to reopen the Kodaikānal and Toungoo observatories remains in abeyance for financial reasons. Without them it is not possible to complete the work begun in 1930–31, when half the field repeat stations were revisited.

11. Miscellaneous. The Omori seismograph was in operation throughout the year, and Table 17 gives a list of the earthquakes recorded. Good records were obtained of the shocks of December 25th 1932, March 2nd, June 25th and August 25th 1933, in Kansu, Japan, Sumatra and Szechwan respectively.

The usual meteorological observations were made at 8 a.m. daily.

A short course of instruction in field astronomical observations was given to the Class II and U. S. S. Officers of No. 2 Drawing Office during November 1932.

* In 1931 the observed values of log $(1+P/r^2+Q/r^4)^{-1}$ were $\bar{1}\cdot99422$ and $\bar{1}\cdot99313$ for Nos. 17 and 5 respectively.

† In 1931 the mean value of the magnetic moment of No. 5 was 938·45.

TABLE 1. *Lengths of 24-metre wires.*

Date	Wire	Temperature	Wire *minus* Base observed	Length of wire at 28°C.
		°		
12-9-32	243	26·9	−1·401 mm	24m −0·410mm
	244	27·0	−3·478	−2·485
	247	26·9	+0·169	+1·153
	248	26·8	+0·419	+1·397
	249	27·0	+2·719	+3·702
	252	27·0	+1·685	+2·667
14-9-32	243	27·6	−1·442	−0·437
	244	27·7	−3·529	−2·521
	247	27·9	+0·141	+1·152
	248	27·9	+0·379	+1·390
	249	27·7	+2·681	+3·686
	252	28·0	+1·637	+2·650
4-4-33	243	25·1	−1·122	−0·187
	244	25·1	−3·271	−2·335
	247	25·0	+0·473	+1·388
	248	24·8	+0·852	+1·758
	249	24·8	+2·953	+3·854
	252	24·2	+2·194	+3·080
7-4-33	243	24·8	−1·114	−0·182
	244	25·0	−3·274	−2·339
	247	25·0	+0·413	+1·328
		25·5	+0·396	+1·319
	248	25·1	+0·818	+1·729
	249	25·2	+2·966	+3·875
	252	25·2	+2·176	+3·083
30-5-33	243	32·7	−1·264	−0·137
	244	32·6	−3·400	−2·277
	247	32·8	+0·412	+1·571
	248	32·8	+0·584	+1·752
	249	32·3	+2·903	+4·065
	252	32·9	+1·941	+3·124
31-5-33	243	31·0	−1·234	−0·137
	244	31·0	−3·352	−2·256
	247	30·9	+0·466	+1·580
	248	30·6	+0·658	+1·769
	249	31·0	+2·920	+4·046
	252	30·1	+2·047	+3·151
21-7-33	243	28·1	−1·157	−0·140
	244	28·1	−3·315	−2·298
	247	28·1	+0·525	+1·542
	248	28·0	+0·695	+1·712
	249	28·0	+3·030	+4·047
	252	28·0	+2·052	+3·069

(*Continued*).

TABLE 1. *Lengths of 24 metre wires*—(*contd.*)

Date	Wire	Temperature	Wire *minus* Base observed	Length of wire at 28°C
		°		
18-9-33	243	27·1	−1·115mm	24m −0·127 mm
	244	27·1	−3·304	−2·316
	247	27·1	+0·571	+1·553
	248	27·1	+0·723	+1·703
	249	27·0	+3·079	+4·055
	252	27·1	+2·094	+3·072
19-9-33	243	26·4	−1·140	−0·163
	244	26·3	−3·290	−2·315
	247	26·2	+0·575	+1·536
	248	26·4	+0·739	+1·703
	249	26·2	+3·096	+4·051
	252	26·2	+2·109	+3·063

TABLE 2. *Variation of Longitude of Dehra Dūn from accepted value as determined by reception of wireless signals from Bordeaux, Rugby and Nauen, 1932–33.*

Date (Greenwich)		Instrument used	No. of time stars		Observed values *minus* accepted value*					
					With demi-definitive corrections			With definitive corrections		
			North	South	Bordeaux	Rugby	Nauen	Bordeaux	Rugby	Nauen
1932					s	s	s	s	s	s
Oct.	1	North transit (hand driven)	6	4	−0·09	−0·04	...	−0·04	−0·01	...
	5		4	4	...	−0·07	...	...	−0·05	...
	9		4	4	−0·05	−0·07	...	−0·02	−0·05	...
	14		4	4	...	−0·01	...	...	−0·10	...
	18	Shutter transit	3	4	...	−0·02	...	...	−0·03	...
	25		4	6	...	−0·05	−0·02	...	−0·05	−0·02
	30		4	6	−0·08	−0·01	...	−0·05	−0·01	...
Nov.	4		3	5	+0·04	−0·02	+0·02	+0·07	−0·01	0·00
	9		5	6	+0·02	0·00	...	+0·04	+0·01	...
	13		4	5	+0·02	+0·02	...	+0·04	+0·03	...
	17		3	4	0·00	+0·01	...	+0·02	+0·02	...
	27		3	5	...	0·00	+0·06	...	+0·04	+0·08
Dec.	4		3	5	...	+0·11	...	...	+0·15	...
	12		5	5	...	−0·08	...	...	−0·05	...
	18		3	5	+0·08	+0·12	...	+0·15	+0·17	...
	25		4	4	...	+0·07	...	...	+0·12	...
1933										
Jan.	2		3	3	...	+0·05	...	...	+0·08	...
	6		4	5	...	+0·12	...	...	+0·15	...
	14		3	4	...	+0·07	...	...	+0·10	...
	26		4	5	...	−0·02	−0·04	...	0·00	−0·06
Feb.	1		3	4	...	+0·01	+0·07	...	−0·01	+0·11
	6		5	5	...	−0·09	...	...	−0·09	...
	15		4	4	−0·01	+0·03	−0·03	+0·02	+0·03	−0·01
	19		5	4	+0·07	+0·07	...	+0·09	+0·07	...
	28		4	5	−0·04	0·00	...	−0·01	+0·02	...
Mar.	5		5	5	...	+0·03	...	...	+0·04	...
	10		5	5	+0·05	+0·07	+0·10	+0·07	+0·08	+0·09
	15		5	5	...	+0·05	+0·06	...	+0·06	+0·05
	21		3	5	+0·01	+0·03	...	+0·06	+0·06	...
	26		4	5	+0·01	+0·05	...	+0·05	+0·07	...
	31		3	6	...	+0·06	...	...	+0·08	...
April	11		4	4	...	+0·05	...	...	+0·07	...
	17		4	4	...	+0·11	...	...	+0·11	...
	28		4	5	...	+0·05	...	...	+0·05	...
May	9		3	4	...	+0·06	...	...	+0·07	...
	16		4	4	...	+0·04	...	...	+0·06	...
	26		5	4	...	+0·10	...	...	+0·11	...

* Accepted value of Longitude is $5^h\ 12^m\ 11^s \cdot 77$.

(Continued).

TABLE 2. *Variation of Longitude of Dehra Dūn from accepted value as determined by reception of wireless signals from Bordeaux, Rugby and Nauen 1932–33—(contd.)*

Date (Greenwich)		Instrument used	No. of time stars North	No. of time stars South	Observed values *minus* accepted value* With demi-definitive corrections Bordeaux	Rugby	Nauen	With definitive corrections Bordeaux	Rugby	Nauen
1933					s	s	s	s	s	
June	1	Electric transit	1	3	...	...	...	...	...	...
	8	Bent transit	4	5	...	+0·07	...	...	+0·07	...
	12	Electric transit	3	4	...	...	...	...	...	...
	18	Do.	3	4	...	−0·05	...	...	−0·03	...
July	15	Bent transit	4	4	...	−0·09	...	...	−0·11	...
Aug.	2	Electric transit	2	2	...	0·00	...	...	+0·01	...
	10	Do.	5	6	+0·12	+0·13	...	+0·15	+0·15	...
	25	Bent transit	4	3	+0·08	+0·08	...	+0·11	+0·10	...
Sept.	2	Do.	3	3	...	0·00	...	...	...	...
	6	Electric transit	4	4	...	...	...	...	...	...
	14	Shutter transit	4	5	+0·20	+0·11	...	...	...	...
	28	Bent transit	5	5	−0·09	−0·09	...	...	...	...

* Accepted value of Longitude is $5^h\ 12^m\ 11^s{\cdot}77$.

Note: In the above table one value of the longitude is given by the association of each observation of local time with the wireless signal received at the least interval from it i.e., generally either during the same night or preceding afternoon. Individual night's observations have not been smoothed to give a more uniform clock error. The reputed times of emission of the wireless signals have been corrected by the amounts given in the Admiralty Notices to Mariners in the case of Rugby and Nauen signals, and by the demi-definitive corrections of the Bulletin Horaire in the case of Bordeaux signals. In addition, for all the three signals, values with definitive corrections of the Bulletin Horaire, are given up to June 1933. When deducing the longitude from Bordeaux (with demi-definitive corrections), a correction of $0^s{\cdot}02$ has been added to the reputed Greenwich time of emission, on account of this having been computed (by the Bulletin Horaire) on the assumption that the Longitude of Paris is $0^h\ 9^m\ 20^s{\cdot}93$, whereas the more recent value is $0^h\ 9^m\ 20^s{\cdot}91$ (see La Participation Francaise à la Revision des Longitudes Mondiales, Lambert, p. 103). The speed of propagation has been taken to be 300,000 km. per second.

TABLE 3. *Error, rate, temperature and pressure of Riefler clock No. 450 by Rugby time signals during 1932–33.*

Date		Error		During preceding period			Remarks
				Rate * per day	Pressure	Temperature	
1932		m	s	s	mm	C	
Oct.	1	−0	14·42	+0·10	598	26·6°	
	5		14·06	+0·08	598	26·5	
	9		13·73	+0·08	598	26·5	
	14		13.16	+0·12	598	26·6	
	18		12·75	+0·10	598	26·5	
	23		12·25	+0·11	598	26·6	
	28		11·82	+0·09	598	26·6	
	30		11·55	+0·14	598	26·6	
Nov.	4		10·85	+0·14	597	26·4	
	9		10·22	+0·13	597	26·6	
	13		09·86	+0·09	598	26·6	
	16		09·53	+0·11	598	26·7	
	27		08·51	+0·09	598	26·7	
Dec.	3		07·79	+0·12	598	26·6	
	12		06·61	+0·13	598	26·8	
	17		05·99	+0·12	598	26·7	
	19		05·84	+0·08	598	26·7	
	25		05·21	+0·11	598	26·7	
1933							
Jan.	2		04·36	+0·11	598	26·6	
	6		03·94	+0·11	598	26·5	
	13		03·14	+0·12	598	26·7	
	15		02·85	+0·15	598	26·7	
	28		01·16	+0·13	598	26·7	
Feb.	3		00·28	+0·15	598	26·7	
	6	+0	00·12	+0·13	598	26·7	
	15		01·41	+0·14	598	26·7	
	19		02·01	+0·15	598	26·8	
	28		03·25	+0·14	598	26·7	
Mar.	5		04·04	+0·16	598	26·9	
	10		04·84	+0·16	598	26·7	
	15		05·71	+0·17	598	26·9	
	21		06·66	+0·16	598	26·7	
	26	+0	07·51	+0·17	598	26·7	

* +ve rate = gaining, −ve rate = losing. *(Continued).*

TABLE 3. *Error, rate, temperature and pressure of Riefler clock No. 450 by Rugby time signals during 1932-33—(contd.)*

Date		Error		During preceding period			REMARKS
				Rate * per day	Pressure	Temperature	
1933		m	s	s	mm	C	
Mar.	31	+0	08·31	+0·16	598	26·7°	
Apr.	11		10·11	+0·16	598	26·7	
	17		11·04	+0·15	598	26·7	
	28		12·87	+0·16	598	26·7	
May	9		14·53	+0·14	598	26·7	
	16		15·63	+0·16	598	26·7	
	26		17·21	+0·16	598	27·0	
June	1		18·14	+0·16	600	28·0	
	8		19·21	+0·15	600	28·1	
	12		19·92	+0·18	602	28·9	
	18		20·82	+0·15	603	29·1	
July	14		26·03	+0·20	601	28·0	
Aug.	2		29·03	+0·16	600	27·9	
	11		31·89	+0·33	600	27·8	
	26		35·38	+0·23	600	27·7	
Sept.	2		37·05	+0·24	598	26·7	
	14		39·92	+0·23	598	26·5	
	28	+0	43·48	+0·25	598	26·4	

* +ve rate = gaining, −ve rate = losing.

Note: The corrections of the Admiralty Notices have been applied to the times of emission of the signals.

TABLE 4. *Error, rate, temperature and pressure of Shortt clock No. 34 by Rugby time signals during 1932–33.*

Date		Error		During preceding period				Remarks
				Rate* per day	Pressure	Oil gauge	Temperature	
1933		m	s	s	mm of mercury	mm	C°	
Mar.	10	−0	03·28	...	29·3	26·9	26·4	
	15		03·07	+0·04	29·0	28·4	26·5	
	21		03·01	+0·01	29·0	29·7	26·7	
	26		02·83	+0·04	29·0	30·3	26·7	
	31		02·75	+0·02	29·0	31·0	26·8	
Apr.	11		02·51	+0·02	29·0	32·0	26·6	
	17		02·43	+0·01	29·0	32·9	26·8	
	28		02·37	+0·01	29·0	33·6	26·7	
May	9		02·18	+0·02	29·0	34·4	26·7	
	16	−0	04·14	+0·01	29·0	34·7	26·7	Batteries renewed, 2 sec. lost in slave.
	26		04·06	+0·01	29·0	35·1	26·7	
June	1		04·11	−0·01	29·0	35·6	27·2	
July	13		04·12	0·00	29·1	38·3	28·1	Batteries renewed.
Sept.	14	−0	03·82	...	29·1	36·6	26·4	do. do.
	28	+0	20·85	...	29·1	36·4	26·3	do. do.

* +ve rate = gaining, −ve rate = losing.

Note: The corrections of the Admiralty Notices have been applied to the times of emission of the signals.

TABLE 5. *Latitude variation at Dehra Dūn.*
Declination errors of groups in 1932–33.

Groups	Right Ascension		Dates	Latitude by evening group *minus* morning group
	Evening	Morning		
	h m h m	h m h m		
I—II	8 18 to 10 09	12 22 to 14 50	5th Feb. '32 to 9th April '32	−0″·30 ± ″·04
II—III	12 22 to 14 50	16 00 to 18 04	13th April '32 to 2nd June '32	+0·05 ± ·02
III—IV	16 00 to 18 04	18 56 to 20 58	27th May '32 to 26th July '32	+0·05 ± ·05
IV—V	18 56 to 20 58	22 11 to 1 04	10th Aug '32 to 5th Oct. '32	+0·02 ± ·07
V—VI	22 11 to 1 04	3 04 to 5 14	11th Oct. '32 to 2nd Dec. '32	+0·05 ± ·05
VI— I	3 04 to 5 14	8 18 to 10 09	8th Dec. '32 to 9th Feb. '33	+0·08 ± ·05
			Closing error ...	−0″·05

TABLE 6. *Declination errors of groups in 1930–33.*

Groups	1930-31	1931-32	1932-33	Mean	Probable Error of Mean	Accepted value
	″	″	″	″	″	″
I—II	+ ·13	+ ·30	+ ·30	+ ·24	± ·046	+ ·27
II—III	+ ·12*	+ ·02	− ·05	+ ·03	± ·036	+ ·06
III—IV	− ·16*	− ·12	− ·05	− ·11	± ·024	− ·10
IV—V	− ·14	− ·05	− ·02	− ·07	± ·028	− ·06
V—VI	− ·11	− ·16	− ·05	− ·11	± ·022	− ·10
VI— I	− ·06	− ·06	− ·08	− ·07	± ·006	− ·07
Closing error ...	− ·22	− ·07	+ ·05	− ·09	...	·00

*Revised values.

TABLE 7. *Latitude variation at Dehra Dūn.*
Preliminary Results for 1932–33.

Month		Monthly mean Latitude			Residuals Month *minus* Year
February	1932.	30°	18′	51″·89	+0″·04
March	„			52·07	+0·22
April	„			51·62	−0·23
May	„			51·49	−0·36
June	„			51·64	−0·21
July	„			51·40	−0·45
August	„			51·90	+0·05
September	„			51·82	−0·03
October	„			52·09	+0·24
November	„			52·15	+0·30
December	„			52·04	+0·19
January	1933.	30	18	52·14	+0·29
		Annual mean		51·85	...

TABLE 8. *Mean values of the constants of Magnetometer No. 17 in 1932.*

Month	Declination constants	H. F. constants			
	Mean magnetic collimation	Distribution factors			Mean values of *m*
		$P_{1\cdot2}$	$P_{2\cdot3}$	$\log (1 + P/r^2 + Q/r^4)^{-1}$	
		cm²	cm²		C.G.S.
January ...	− 6′ 09″	6·25	6·31	Observed $\bar{1}\cdot99415$ Accepted $\bar{1}\cdot99415$	801·37
February ...	− 6 04	6·11	6·20		·47
March ...	− 6 07	6·10	6·36		·49
April ...	− 6 03	6·19	6·94		·75
May ...	− 6 08	5·80	7·21		·62
June ...	− 6 07	5·80	6·65		·92
July ...	− 5 55	5·99	7·37		·50
August ...	− 6 04	5·99	6·96		·30
September	− 6 02	6·15	7·05		·48
October ...	− 6 07	6·16	7·53		·47
November	− 6 05	6·27	7·29		·41
December	− 6 04	6·04	7·37		801·45

TABLE 9. *Mean values of the constants of Magnetometer No. 5 in 1932.*

Month	H. F. constants			
	Distribution factors			Mean values of m
	$P_{1 \cdot 2}$	$P_{2 \cdot 3}$	$\log (1 + P/r^2 + Q/r^4)^{-1}$	
	cm²	cm²		C G.S.
January ...	7·08	7·98	Observed $\bar{1}$·99346 Accepted $\bar{1}$·99292	938·25
February ...	7·04	7·78		·13
March ...	7·15	7·27		937·95
April ...	7·13	7·64		·94
May ...	7·27	7·54		·91
June ...	7·18	7·70		·60
July ...	6·99	7·82		·57
August ...	7·22	7·76		·54
September	6·87	7·72		·38
October ...	7·15	7·40		·58
November	7·09	7·98		·55
December	7·15	7·37		937·73

TABLE 10. *Observed Base-line values of Magnetographs at Dehra Dūn from Magnetometers No. 17 and No. 5.*

Month	1931		1932		
	H. F. by No. 17	H. F. by No. 5	Declination	H. F. by No. 17	H. F. by No. 5
	C.G.S.	C.G.S.	° ′	C.G.S.	C.G.S.
January	{ 0·32 661 764 }	{ 0·32 683 784 }	0 28·0	0·32 774	0·32 824
February	761	786	28·0	771	818
March	759	791	28·4	773	819
April	774	788	28·2	779	822
May	782	797	28·5	787	822
June	779	818	28·6	787	825
July	787	826	28·5	783	828
August	779	822	28·3	781	825
September	772	825	27·8	779	831
October	783	829	28·4	783	828
November	774	822	28·5	775	828
December	0·32 776	0·32 829	0 28·7 } 0 31·2* }	0·32 778	0·32 832

* From 11ʰ on 22nd.

N.B. The values given by No. 17 have been accepted.

TABLE 11. *Monthly mean values of the Magnetic elements and their annual changes, Magnetometer No. 17, Dehra Dūn, 1931 and 1932.*

Month	Horizontal force			Declination			Dip			Vertical force		
	1931	1932	Annual change	1931	1932	Annual change	1931	1932	Annual change	1931	1932	Annual change
	C. G. S.	C. G. S.	γ							C. G. S.	C. G. S.	γ
January	0·32974	0·33019	+45	E. 1° 10′·0	E. 1° 6′·7	−3′·3	N. 45° 35′·5	N. 45° 36′·6	+1·1	0·33662	0·33729	+67
February ...	978	14	+36	9·8	6·6	−3·2	35·4	36·4	+1·0	664	20	+56
March	981	19	+38	9·7	6·6	−3·1	35·3	36·6	+1·3	665	29	+64
April	0·33003	19	+16	9·7	6·3	−3·4	34·7	37·1	+2·4	676	39	+63
May	09	32	+23	8·3	6·0	−2·3	34·3	37·1	+2·8	674	53	+79
June	16	42	+26	8·4	5·5	−2·9	35·0	37·1	+2·1	694	63	+69
July	27	44	+17	8·3	4·8	−3·5	35·5	37·7	+2·2	715	77	+62
August	08	37	+29	7·9	4·9	−3·0	36·4	37·1	+0·7	714	58	+44
September ...	06	27	+21	8·3	4·2	−4·1	36·8	37·6	+0·8	722	58	+36
October	07	43	+36	7·5	4·5	−3·0	37·1	37·9	+0·8	727	80	+53
November ...	0·32996	38	+42	7·8	4·3	−3·5	37·4	38·0	+0·6	723	77	+54
December ...	0·33012	0·33046	+34	E. 1 7·4	E. 1 4·3	−3·1	N. 45 37·4	N. 45 37·8	+0·4	0·33738	0·33781	+43
Mean ...	0·33001	0·33032	+30	E. 1° 8′·6	E. 1° 5′·4	−3·2	N. 45° 35′·9	N. 45° 37′·3	+1·4	0·33698	0·33755	+58

γ = 0·00001 C. G. S.

TABLE 12. *Declination at Dehra Dūn in 1932* (determined from five selected quiet days in each month).

Month	Monthly mean values *	Hourly deviation from the mean																								
		Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.
	E. 1°+ ′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January ...	6·7	+0·1	0·0	0·0	0·0	−0·2	−0·4	**−0·5**	−0·5	−0·5	+0·9	**+1·8**	+0·8	0·0	−0·3	−0·4	−0·5	−0·4	0·0	+0·1	+0·1	+0·2	+0·2	+0·1	+0·2	+0·2
February ...	6·6	+0·1	+0·1	0·0	−0·1	−0·3	−0·3	−0·6	−0·5	+0·3	+1·4	+1·6	**+1·9**	−0·1	0·0	−0·7	−0·8	**−0·9**	0·0	−0·1	0·0	−0·1	−0·2	−0·1	−0·1	0·0
March ...	6·6	+0·1	+0·1	−0·1	−0·1	−0·3	−0·3	−0·4	+0·1	+1·1	**+1·9**	+1·6	+0·4	−0·7	**−1·1**	−1·0	−0·6	0·0	0·0	−0·2	−0·2	−0·2	−0·1	−0·1	+0·1	+0·1
October ...	4·5	+0·2	+0·2	+0·1	+0·1	0·0	−0·1	−0·2	+0·5	+1·5	**+1·6**	+1·1	0·0	−1·5	**−2·0**	−1·6	−0·7	−0·2	+0·2	+0·2	−0·1	0·0	+0·1	+0·1	+0·2	+0·5
November ...	4·3	+0·7	+0·5	+0·4	+0·2	−0·3	−0·5	−0·4	−0·3	+0·3	**+0·8**	+0·8	0·0	**−0·7**	−0·7	−0·6	−0·5	−0·1	0·0	+0·1	+0·1	0·0	+0·2	+0·3	+0·3	+0·2
December ...	4·3	+0·2	+0·3	+0·2	−0·2	−0·2	−0·4	−0·5	0·0	**−1·0**	−0·2	**+0·4**	+0·4	+0·3	+0·3	+0·3	+0·1	+0·1	+0·3	+0·2	+0·1	0·0	0·0	+0·1	+0·3	+0·3
Winter Means ...	5·5	+0·2	+0·2	+0·1	0·0	−0·2	−0·3	−0·4	−0·1	+0·3	+1·1	**+1·2**	+0·6	−0·5	−0·6	**−0·7**	−0·5	−0·3	+0·1	+0·1	0·0	0·0	0·0	+0·1	+0·2	+0·2
April ...	6·3	+0·2	+0·2	+0·3	+0·6	+0·5	+0·3	+0·7	+1·8	+2·7	**+2·9**	+1·5	−0·5	−2·1	**−2·7**	−2·4	−1·7	−1·1	−0·5	−0·1	−0·3	−0·5	−0·3	+0·2	+0·2	+0·2
May ...	6·0	+0·4	+0·4	+0·5	+0·4	+0·3	+0·4	+1·5	+2·3	**+2·8**	+2·5	+1·1	−0·5	−1·9	**−2·8**	−2·5	−2·1	−1·5	−0·8	−0·3	−0·2	−0·4	−0·4	−0·1	0·0	+0·3
June ...	5·5	+0·1	+0·4	+0·4	+0·4	+0·5	+1·0	+2·1	**+3·0**	+3·0	+2·6	+1·1	−1·1	−1·9	**−2·4**	−2·3	−2·2	−1·6	−1·1	−0·5	−0·5	−0·6	−0·6	+0·1	+0·4	+0·2
July ...	4·8	+0·2	+0·6	+0·7	+0·8	+0·7	+0·8	+1·9	**+2·4**	+2·3	+1·5	+0·5	−1·4	−2·6	**−2·7**	−2·4	−1·6	−0·9	−0·3	+0·1	−0·1	−0·2	−0·2	+0·1	+0·1	+0·3
August ...	4·9	+0·2	+0·4	+0·3	+0·4	+0·7	+0·9	+1·9	+2·9	**+3·1**	+2·4	+0·6	−1·5	−2·6	**−3·0**	−2·6	−2·1	−1·1	−0·3	+0·1	−0·4	−0·4	−0·3	−0·2	+0·1	+0·2
September ...	4·2	+0·3	+0·3	+0·6	+0·7	+0·8	+0·8	+1·1	+2·0	**+2·1**	+1·0	−0·7	−2·0	**−2·6**	−2·5	−1·5	−0·4	+0·6	+0·9	+0·1	0·0	−0·2	−0·1	0·0	+0·1	+0·2
Summer Means ...	5·3	+0·2	+0·4	+0·5	+0·6	+0·6	+0·7	+1·5	+2·4	**+2·7**	+2·2	+0·7	−1·2	−2·3	**−2·7**	−2·3	−1·7	−0·9	−0·4	−0·1	−0·3	−0·4	−0·3	0·0	+0·2	+0·2

* Obtained from the mean of all hours for the five selected quiet days in each month.

NOTE. The mean declination for any hour in a month may be obtained by applying the hourly deviation for that hour with the sign given, to the monthly mean. Figures in thick type indicate the maximum and minimum values of the hourly deviation.

TABLE 13. *Horizontal force at Dehra Dūn in 1932* (determined from five selected quiet days in each month).

Month	Monthly mean values *	Hourly deviation from the mean																								
		Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ		γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
January ...	33019	− 2	− 2	− 5	− 4	− 5	− 2	− 1	+ 3	+ 6	+ 5	+ 7	+ 6	+ 3	+ 2	+ 4	+ 2	+ 2	+ 1	0	− 4	− 5	− 7	− 6	− 2	− 3
February ...	14	− 8	− 6	− 5	− 5	− 5	− 5	− 4	− 1	+ 1	+ 3	+ 8	+ 4	+ 4	+ 4	+ 6	+ 6	+ 3	+ 1	− 1	− 2	+ 3	0	0	0	0
March ...	19	− 5	− 7	− 6	− 4	− 5	− 5	− 4	− 2	+ 3	+ 9	+15	+21	+21	+16	+ 8	+ 1	− 6	− 6	− 8	− 9	− 8	− 7	− 7	− 7	− 6
October ...	43	− 1	− 2	0	− 2	+ 1	+ 3	+ 4	+ 2	− 5	− 7	− 5	− 4	+ 5	+ 7	+ 6	+ 2	+ 1	− 2	− 2	− 3	− 4	− 4	− 3	− 1	− 3
November ...	38	− 6	− 3	− 2	− 3	− 2	+ 1	+ 1	+ 6	+ 7	+ 7	+ 4	+ 4	+ 6	+ 3	+ 3	+ 3	+ 1	− 1	− 1	− 2	− 3	− 3	− 4	− 2	− 4
December ...	46	− 6	− 4	− 3	− 2	− 5	− 5	− 3	+ 3	+ 8	+13	+16	+15	+14	+ 4	+ 9	− 6	− 5	− 5	− 5	− 4	− 7	− 7	− 5	− 3	− 2
Winter Means ...	33030	− 5	− 4	− 4	− 3	− 4	− 2	− 1	+ 2	+ 3	+ 5	+ 8	+ 8	+ 9	+ 6	+ 6	+ 1	− 1	− 2	− 3	− 4	− 4	− 5	− 4	− 3	− 3
April ...	33019	− 2	0	+ 3	+ 3	− 4	− 6	− 3	− 7	− 9	− 6	+ 3	+ 1	+ 4	+ 9	+ 8	+10	+ 6	+ 1	− 4	− 2	− 1	− 1	+ 2	+ 3	+ 2
May ...	32	− 2	− 1	− 1	0	+ 1	+ 1	− 1	− 4	−10	−13	−10	− 6	0	+ 3	+ 8	+ 9	+ 7	+ 3	− 1	0	+ 3	+ 6	+ 2	+ 3	+ 5
June ...	42	− 6	− 6	− 5	− 6	− 7	− 5	− 2	− 1	− 4	− 3	0	+ 3	+ 2	+11	+12	+10	+ 5	+ 1	+ 1	+ 1	+ 2	+ 6	+ 3	+ 2	+ 1
July ...	44	− 4	− 3	− 3	− 4	− 3	− 2	− 3	− 3	0	− 1	− 1	+ 5	+11	+13	+15	+10	0	− 6	− 5	− 6	− 5	− 3	− 4	− 2	0
August ...	37	− 2	− 4	− 3	− 2	− 4	− 3	− 3	− 3	− 5	− 9	0	+ 8	+12	+15	+10	+ 6	+ 3	− 2	− 2	− 2	0	+ 1	+ 1	+ 1	+ 4
September ...	27	0	+ 4	+ 4	+ 4	+ 1	+ 2	+ 2	− 7	−13	−14	−11	+ 5	+ 3	+10	+11	+ 6	+ 2	− 2	0	− 2	− 1	− 1	− 1	+ 6	+ 3
Summer Means ..	33034	− 3	− 2	− 1	− 1	− 3	− 2	− 2	− 4	− 7	− 8	− 3	+ 3	+ 5	+10	+11	+ 9	+ 4	− 1	− 2	− 2	0	+ 1	+ 1	+ 2	+ 3

γ = 0·00001 C. G. S.

* Obtained from the mean of all hours for the five selected quiet days in each month.

NOTE. The mean horizontal force for any hour in a month may be obtained by applying the hourly deviation for that hour with the sign given, to the monthly mean. Figures in thick type indicate the maximum and minimum values of the hourly deviation.

TABLE 14. *Vertical force at Dehra Dūn in 1932* (determined from five selected quiet days in each month).

Month	Monthly mean values *	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.
		Hourly deviation from the mean																								
	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
January ...	33729	+ 2	− 1	0	0	0	+ 1	0	0	+ 2	+ 3	− 1	− 5	− 4	− 1	− 1	− 1	+ 1	+ 3	+ 3	+ 1	+ 1	0	+ 2	+ 3	+ 2
February ...	20	0	+ 1	+ 2	+ 2	+ 1	+ 1	0	0	+ 1	+ 1	− 1	0	+ 1	− 1	+ 1	− 3	− 2	− 1	+ 1	− 2	− 1	− 3	− 3	+ 1	− 4
March ...	29	+ 4	+ 1	+ 1	+ 1	0	− 2	0	+ 1	+ 3	0	− 5	− 3	− 8	− 3	− 2	+ 1	+ 1	+ 1	0	+ 1	+ 2	0	+ 3	+ 3	+ 4
October ...	80	+ 5	+ 6	+ 6	+ 5	+ 5	+ 5	+ 5	+ 7	+ 6	+ 3	− 1	−10	−13	− 9	− 5	− 1	0	0	0	0	0	+ 1	+ 1	+ 1	+ 1
November ...	77	− 1	0	0	0	0	0	0	+ 3	+ 2	+ 1	− 5	− 3	− 3	− 3	0	0	+ 2	+ 1	0	0	0	0	+ 1	+ 1	0
December ...	81	+ 3	+ 3	+ 3	+ 3	+ 2	+ 2	+ 1	0	+ 1	+ 2	0	− 4	− 2	− 2	− 2	− 1	+ 3	+ 3	0	− 1	− 3	− 3	− 3	− 3	− 4
Winter Means ...	33753	+ 2	+ 2	+ 2	+ 2	+ 1	+ 1	+ 1	+ 2	+ 3	+ 2	− 2	− 4	− 5	− 3	− 2	− 1	+ 1	+ 1	+ 1	0	0	− 1	0	+ 1	0
April ...	33739	+ 1	+ 2	+ 1	+ 1	0	+ 1	+ 2	+ 3	+ 2	− 2	− 9	−16	−13	− 7	− 2	+ 2	+ 4	+ 4	+ 2	+ 3	+ 4	+ 4	+ 4	+ 5	+ 6
May ...	53	+ 3	+ 3	+ 3	+ 3	+ 3	+ 4	+ 8	+ 5	+ 2	− 3	−10	−13	−13	−11	− 6	− 2	0	0	+ 1	+ 3	+ 4	+ 4	+ 5	+ 5	+ 5
June ...	63	+ 3	+ 3	+ 2	+ 2	+ 3	+ 5	+ 9	+ 7	+ 1	− 3	−11	−13	−15	−12	− 9	− 3	− 1	+ 4	+ 6	+ 4	+ 5	+ 5	+ 6	+ 7	+ 8
July ...	77	+ 4	+ 4	+ 6	+ 4	+ 4	+ 5	+ 8	+ 5	+ 2	− 4	−10	−14	−14	−12	− 6	− 5	− 3	+ 2	+ 3	+ 2	+ 3	+ 3	+ 4	+ 4	+ 5
August ...	58	− 1	− 1	0	0	0	+ 1	+ 4	+ 4	0	− 6	−13	−12	−12	− 6	− 1	+ 3	+ 3	+ 4	+ 4	+ 3	+ 5	+ 5	+ 7	+ 7	+ 7
September ...	58	+ 2	+ 2	+ 2	+ 2	+ 2	+ 2	+ 2	+ 3	+ 2	− 4	− 7	− 9	− 9	− 6	− 1	+ 3	+ 2	0	− 1	− 1	+ 1	+ 2	+ 2	+ 4	+ 2
Summer Means ...	33758	+ 2	+ 2	+ 2	+ 2	+ 2	+ 3	+ 6	+ 5	+ 2	− 4	−10	−13	−13	− 9	− 4	0	+ 1	+ 2	+ 3	+ 2	+ 4	+ 4	+ 5	+ 5	+ 6

γ = 0·00001 C.G.S.

* Obtained from the mean of all hours for the five selected quiet days in each month.

NOTE. The mean vertical force for any hour in a month may be obtained by applying the hourly deviation for that hour with the sign given, to the monthly mean. Figures in thick type indicate the maximum and minimum values of the hourly deviation.

TABLE 15. *Dip at Dehra Dūn in 1932* (determined from five selected quiet days in each month).

Month	Monthly mean values *	Hourly deviation from the mean																								
		Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon	13	14	15	16	17	18	19	20	21	22	23	Mid.
	N. 45° + ′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January ...	36·6	+ 0·2	0·0	+0·3	+0·2	+0·3	+0·1	+0·1	−0·2	−0·3	−0·1	−0·5	**−0·6**	−0·4	−0·2	−0·3	−0·2	−0·1	+0·1	+0·1	+0·3	+0·3	**+0·4**	+0·4	+0·2	+0·2
February ...	36·4	**+ 0·4**	+0·3	+0·3	+0·3	+0·3	+0·3	+0·2	0·0	0·0	−0·1	**−0·5**	−0·2	−0·2	−0·3	−0·3	−0·5	−0·3	−0·1	+0·1	0·0	−0·2	−0·2	−0·2	0·0	−0·2
March ...	36·6	**+ 0·5**	+0·4	+0·3	+0·3	+0·3	+0·1	+0·2	+0·1	−0·1	−0·5	−1·1	−1·3	**−1·5**	−1·0	−0·5	0·0	+0·3	+0·3	+0·4	+0·5	+0·5	+0·4	+0·5	+0·5	+0·5
October ...	38·0	+ 0·2	+0·4	+0·2	+0·3	+0·1	0·0	0·0	+0·2	**+0·5**	+0·4	+0·2	−0·4	**−1·0**	−0·9	−0·6	−0·2	−0·1	0·0	0·0	+0·1	+0·1	+0·2	+0·1	0·0	+0·1
November ...	38·0	**+ 0·3**	**+0·2**	+0·1	+0·2	+0·1	0·0	0·0	−0·2	−0·2	−0·3	−0·4	−0·4	**−0·5**	−0·3	−0·2	−0·2	+0·1	+0·2	+0·1	−0·3	+0·2	+0·2	+0·3	+0·2	+0·2
December ...	37·8	**+ 0·5**	+0·4	+0·3	+0·2	+0·4	+0·4	+0·2	−0·2	−0·4	−0·6	−0·8	**−1·0**	−0·8	−0·3	−0·6	+0·3	+0·4	+0·4	+0·2	+0·2	+0·2	+0·2	+0·1	0·0	−0·1
Winter Means ...	37·2	**+ 0·4**	+0·3	+0·3	+0·3	+0·3	+0·2	+0·1	−0·1	−0·1	−0·2	−0·5	**−0·7**	−0·7	−0·5	−0·4	−0·1	+0·1	+0·2	+0·2	+0·1	+0·2	+0·2	+0·2	+0·2	+0·1
April ...	37·1	+ 0·1	+0·1	−0·1	−0·1	+0·2	+0·3	+0·2	**+0·5**	+0·5	+0·2	−0·6	**−0·9**	−0·9	−0·8	−0·5	−0·4	−0·1	+0·1	+0·3	+0·2	+0·3	+0·3	+0·1	+0·1	+0·2
May ...	37·1	+ 0·3	+0·2	+0·2	+0·2	+0·1	+0·1	+0·5	+0·5	**+0·7**	+0·5	0·0	−0·3	−0·6	**−0·7**	−0·7	−0·5	−0·4	−0·1	+0·2	+0·2	+0·1	−0·1	+0·2	+0·1	0·0
June ...	37·1	+ 0·5	+0·5	+0·4	+0·4	+0·5	+0·5	**+0·6**	+0·4	+0·3	0·0	−0·6	−0·8	−0·9	**−1·2**	−1·1	−0·7	−0·3	+0·1	+0·3	+0·1	+0·1	0·0	+0·1	+0·2	+0·4
July ...	37·7	+ 0·4	+0·3	+0·5	+0·4	+0·3	+0·4	**+0·6**	+0·4	+0·1	−0·1	−0·5	−1·0	**−1·3**	−1·3	−1·0	−0·8	−0·2	+0·4	+0·4	+0·4	+0·4	+0·3	+0·4	+0·3	+0·3
August ...	37·1	+ 0·1	+0·2	+0·2	+0·1	+0·2	+0·2	**+0·4**	+0·4	+0·3	+0·2	−0·6	−1·0	**−1·2**	−1·1	−0·5	−0·1	0·0	+0·3	+0·3	+0·3	+0·3	+0·2	+0·3	+0·3	+0·1
September ...	37·6	+ 0·1	−0·1	−0·1	−0·1	+0·1	0·0	0·0	+0·6	**+0·8**	+0·6	+0·2	−0·7	−0·6	**−0·8**	−0·6	−0·1	0·0	+0·1	0·0	+0·1	+0·1	+0·2	+0·2	−0·1	0·0
Summer Means ...	37·3	+ 0·3	+0·2	+0·2	+0·2	+0·2	+0·3	+0·4	+0·5	+0·5	+0·2	−0·4	−0·9	−0·9	**−1·0**	−0·7	−0·4	−0·2	+0·2	+0·3	+0·2	+0·2	+0·2	+0·2	+0·2	+0·2

* Obtained from the mean of all hours for the five selected quiet days in each month.

NOTE. The mean dip for any hour in a month may be obtained by applying the hourly deviation for that hour with the sign given, to the monthly mean. Figures in thick type indicate the maximum and minimum values of the hourly deviation.

Dehra Dūn { Lat. 30° 19′ 19″ N. / Long. 78 03 19 E. } TABLE 16. *Classification and dates of Magnetic disturbances at Dehra Dūn in 1932.*

Dates 1932	January	February	March	April	May	June	July	August	September	October	November	December
1	C	C	C	C	(C)	C	(C)	C	C	C	C	C
2	S	(C)	M	S	C	C	C	S	C	C	C	C
3	S	G	M	C	S	C	(C)	S	C	C	C	C
4	(C)	M	M	(C)	C	(C)	C	C	(C)	C	C	C
5	(C)	S	S	C	S	(C)	S	S	C	C	C	(C)
6	C	S	S	C	C	C	S	(C)	G	(C)	(C)	(C)
7	S	C	S	S	C	C	C	C	C	C	C	C
8	S	S	C	C	(C)	S	C	C	S	(C)	(C)	M
9	S	C	S	C	C	C	C	C	C	C	C	C
10	S	M	M	C	C	C	C	(C)	C	C	C	C
11	S	M	C	(C)	C	C	C	C	(C)	C	(C)	C
12	S	S	(C)	(C)	C	C	C	S	(C)	(C)	C	(C)
13	C	C	(C)	S	C	C	C	C	C	C	C	C
14	C	(C)	C	C	C	C	C	C	C	C	S	G
15	S	C	(C)	C	C	(C)	(C)	C	C	G	S	S
16	S	(C)	(C)	C	S	C	M	(C)	C	C	M	S
17	C	(C)	C	C	C	C	C	C	C	C	S	S
18	C	C	S	S	C	C	C	C	C	C	C	C
19	C	S	C	C	(C)	C	C	C	S	(C)	C	C
20	(C)	M	C	C	(C)	S	C	(C)	C	M	C	C
21	(C)	C	S	(C)	C	C	C	C	(C)	S	(C)	(C)
22	(C)	S	S	G	C	C	C	C	C	C	C	C
23	C	S	C	G	C	C	C	C	M	S	C	C
24	S	S	C	S	C	(C)	C	C	S	C	C	S
25	M	C	(C)	C	C	C	C	C	M	C	S	C
26	S	C	C	C	(C)	C	C	(C)	C	C	C	C
27	M	(C)	C	C	C	C	(C)	M	C	S	(C)	C
28	M	C	M	C	S	(C)	(C)	G	(C)	C	C	C
29	C	C	M	(C)	G	C	C	M	C	(C)	C	C
30	C	...	S	C	M	C	C	S	C	C	C	(C)
31	S	...	M	...	C	...	C	C	...	C	...	C
C	15	16	16	23	25	28	28	23	24	26	25	25
S	13	8	8	5	4	2	2	5	3	3	4	4
M	3	4	7	...	1	...	1	2	2	1	1	1
G	...	1	...	2	1	...	...	1	1	1	...	1
VG	...	...	...	...	...	...	...	...	...	...	...	...

C = Calm. S = Slight. M = Moderate. G = Great. (C) = Selected quiet day.

TABLE 17. *Earthquakes recorded at Dehra Dūn during 1932–33.*

No.	Date	Indian standard time: 1st P. T.	2nd P. T.	Long wave	Maximum	Finish	Intensity of record	Distance	Remarks
	1932	h m s	h m s	h m s	h m	h m		miles	
1	Oct. 2	...	...	...	...	...	slight	...	Times not read. Lines overlapping due to paper getting loose.
2	„ 16	18 10 40†	18 20 30†	18 28 10	18 30	19 02	slight	4800	
3	„ 29	16 41 20	16 43 20	16 44 50	16 45	16 57	slight	700	
4	Nov. 13	10 25 00†	10 31 10	10 36 40†	10 37	11 07	slight	2700	
5	Dec. 4	13 49 40	13 59 10	14 09 00	14 11	15 14	moderate	4900	
6	„ 7	23 01 30†	23 08 10†	23 12 40	23 15	23 29	slight	2800	
7	„ 21	12 21 50†	12 29 10†	12 39 40	12 49	14 19	slight	4000	
8	„ 25	7 36 40	7 39 40	7 42 20	7 43	9 49	very great	1200	Kansu.
	1933								
9	Jan. 9	7 34 20	...	7 35 00	7 35	8 14	slight	200	Felt at Lahore and Ferozepore.
10	„ 22	1 02 20	1 11 20	1 23 10	1 26	3 07	great	4900	
11	Feb. 23	...	...	14 58 00	15 02	15 45	slight	..	
12	Mar. 2	23 10 20	23 17 50	23 22 00	23 33	3 20	very great	3200	Destructive in Japan.
13	„ 6	18 38 20†	18 40 20†	18 42 00	18 43	18 57	slight	700	Felt in Bengal and Assam.
14	„ 17	21 35 50†	21 44 50	21 58 50	22 05	22 41	slight	5200	
15	„ 18	1 11 20	1 19 20	1 31 50	1 40	2 08	slight	4500	
16	Apr. 9	8 25 50†	8 33 30	8 45 50	8 48	9 16	slight	4300	
17	„ 19	12 21 10	12 26 50	12 34 40	12 35	13 02	slight	2800	
18	„ 23	11 35 30	11 41 40	11 51 30†	11 59	12 24	slight	3200	Destructive in Kos, Aegean Sea.
19	„ 23	13 01 20	...	...	13 19	13 33	slight	..	
20	„ 27	8 18 10	8 28 30	8 47 10†	8 57	9 30	slight	6500	
21	May 8	...	17 23 00†	17 27 30	17 28	18 05	slight	2300	
22	„ 16	6 49 00	6 53 30	6 59 00	7 06	7 51	slight	2100	
23	June 7	17 20 50	17 24 20	17 26 50	17 27	17 46	slight	1400	
24	„ 19	3 16 40	3 24 20†	3 37 40	3 40	4 55	moderate	4400	
25	„ 25	3 33 20	3 39 30	3 44 00	3 53	6 35	very great	2600	Destructive in Bencoolen south Sumatra.
26	July 3	20 46 50†	...	...	20 53	21 09	slight	...	
27	„ 9	18 10 40†	18 18 40	18 31 30	18 34	19 32	slight	4500	
28	„ 23	2 37 00	2 47 40	3 05 30†	3 17	4 08	slight	6600	
29	Aug. 4	23 10 20	23 12 40†	23 15 30†	23 19†	23 35†	slight	1000	
30	„ 11	14 28 40	14 32 10	14 34 30	14 36	15 13	slight	1300	
31	„ 12	22 35 10†	22 35 40†	22 36 00†	22 36†	22 37†	slight	200	
32	„ 13	15 31 20†	15 32 00†	15 32 50	15 33	15 39	slight	300	
33	„ 20	17 30 50	17 35 30†	17 43 20†	17 50	17 57	slight	2400	
34	„ 25	13 25 50	13 29 30	13 32 50	13 34	15 07†	very great	1500	Epicentre in China near 37°N. & 100°E.
35	„ 29	4 10 20	4 19 40†	4 31 20†	4 41	6 24	slight	5100	
36	Sept. 26	...	0 24 10	0 27 20	0 28	1 39	slight	1700	

† Recognized with difficulty.

CHAPTER VI

TIDES

BY CAPTAIN G. BOMFORD, R.E.

1. Tidal observations. During the year under report registrations by automatic tide-gauges were continued by the port authorities at the following stations:—Aden, Karāchi, Bombay, Madras, Calcutta (Kidderpore), and Rangoon: and at Colombo and Trincomalee under the supervision of the Superintendent Trigonometrical Surveys, Ceylon. The times and heights of the tides were also recorded on tide-poles, during daylight only, at Bhāvnagar, Chittagong and Akyab.

The Madras tide-gauge was closed down on 31st August 1933 as a measure of economy. The predictions at Madras have always been good, and this course involves little risk. The gauges at Colombo and Trincomalee will probably also be closed early in 1934.

A complete list of stations at which tidal registrations have been carried out in India, with dates, is given in Geodetic Report Volume V (1929), pages 31 to 33.

2. Inspections. The port officials inspected the gauge at Rangoon in September 1932 and May 1933, at Kidderpore in December 1932, at Bombay in April 1933, and at Aden in May 1933.

All the records have been satisfactory without breaks of more than three days at a time, except for a stoppage of a fortnight at Kidderpore in December 1932, when the gauge was overhauled.

3. Harmonic analysis. The analysis of the 1931–32 observations at Chāndbāli and Shortt Island on the Orissa coast has been completed, and predictions have been included in the Tide-tables for 1934. The constants are given in Table 1. Chāndbāli, although it is some way up a river, has been fully analysed as an open-sea port. After analysis, predictions were made on the machine for the period which had been analysed. These predictions have been compared with the observations on which the analysis was based, and as a result the following corrections have been applied to the predictions at Chāndbāli: +30 minutes to all times of low water, and +20 minutes to times of high water from December to June inclusive.

4. Corrections to predictions. Empirical corrections have been applied to the predicted tides for 1934 at Kidderpore, Rangoon and Chittagong. At the two former places they are the same as in the previous years, as given in Geodetic Reports Vols. VI and VIII respectively. The Chittagong corrections are given in Table 2 of this report.

5. Tide-tables. The tide-tables for 1934 have been prepared and issued in their usual form, Basrah being omitted, and Chāndbāli and Shortt Island included for the first time. Separate pamphlets have been printed for Bombay, the Hooghly River and the Rangoon River, and advance predictions for various ports have been sent as usual to the Hydrographic departments in England, the United States and Japan.

The amount realized by the sale of tide-tables during the year ending 30th September 1933 was Rs. 4817/11/-, exclusive of agents' commission.

6. Accuracy of predictions. The greatest error recorded in the height of low water during 1932 at the ports mentioned in para 1 is given in Table 3. Tables 4 to 14 give detailed results of comparisons between the predictions and the times and heights actually recorded at these ports. The predictions at Aden are better than the previous year's as regards times, while those at Bhāvnagar and Madras show some increase in the number of comparatively large errors recorded in the last two columns of the table: but these changes are not so marked as to be of any significance.

TABLE 1. *Values of the harmonic tidal constants for Shortt Island and Chāndbāli, 1931–32.*

Tide Symbol	Shortt Island $A_0 = 5\cdot762$ ft.		Chāndbāli $A_0 = 5\cdot304$ ft.	
	H	κ	H	κ
Short period	ft.	°	ft.	°
S_1	0·026	206·26	0·058	140·18
S_2	1·392	300·73	0·883	10·57
S_4	0·030	212·75	0·036	305·07
S_6	0·005	182·49	0·007	244·84
S_8	0·004	273·90	0·004	156·97
M_1	0·010	134·54	0·014	181·75
M_2	3·012	268·25	2·401	330·73
M_3	0·025	56·93	0·030	184·91
M_4	0·095	139·69	0·284	220·80
M_6	0·020	85·08	0·031	348·24
M_8	0·006	109·81	0·019	244·08
O_1	0·132	332·65	0·158	4·58
K_1	0·379	346·10	0·351	19·11
K_2	0·412	303·15	0·220	9·70
P_1	0·145	331·98	0·092	23·14
J_1	0·023	335·95	0·015	57·96
Q_1	0·012	101·39	0·013	39·56
L_2	0·178	241·72	0·322	318·39
N_2	0·626	260·02	0·433	331·60
ν_2	0·090	218·92	0·132	266·06
μ_2	0·061	310·89	0·259	85·35
T_2	0·106	25·82	0·098	17·88
MS_4	0·073	180·49	0·250	258·94
$2SM_2$	0·025	209·28	0·091	228·14
$2N_2$	0·055	227·11	0·077	160·90
M_2N*	0·047	134·13	0·117	215·81
M_2K_1*	0·041	330·67	0·035	252·59
$2M_2K_1$*	0·011	358·81	0·024	138·20
Long period				
M_m	0·059	196·95	0·180	63·60
M_f	0·064	17·32	0·123	19·50
MS_f	0·090	328·12	0·323	14·22
S_a	0·755	161·74	1·561	166·33
S_{sa}	0·339	97·81	0·313	358·74

* Or MN_4, MK_3, $2MK_3$ respectively.

TABLE 2. *Corrections applied to Chittagong for 1934.*

Month	Tide	Dates			
		1st-15th		16th-31st	
		Time	Height	Time	Height
		minutes	*feet*	*minutes*	*feet*
January ...	High Low	+ 11 + 12	+0·3 +0·7	+ 10 + 8	+0·2 +0·7
February ...	High Low	+ 7 + 8	+0·2 +0·8	+ 7 + 5	+0·2 +0·6
March ...	High Low	+ 8 + 5	0·0 +0·6	+ 8 + 6	−0·1 +0·5
April ...	High Low	+ 5 + 6	+0·1 +0·5	+ 10 + 11	0·0 +0·4
May ...	High Low	+ 12 + 12	−0·1 +0·5	+ 11 + 11	−0·2 +0·4
June ...	High Low	+ 9 + 12	+0·2 +0·8	+ 8 + 10	+0·2 +1·0
July ...	High Low	+ 9 + 9	+0·1 +0·5	+ 10 + 7	0·0 +0·6
August ...	High Low	+ 7 + 7	+0·2 +0·6	+ 10 + 10	+0·2 +0·8
September ..	High Low	+ 13 + 14	+0·1 +0·8	+ 16 + 16	0·0 +0·8
October ...	High Low	+ 19 + 21	+0·3 +0·9	+ 20 + 20	+0·3 +0·8
November ...	High Low	+ 20 + 21	0·0 +0·6	+ 18 + 19	+0·3 +0·7
December ...	High Low	+ 17 + 15	+0·3 +0·6	+ 11 + 12	+0·4 +0·7

The above corrections are based on the mean fortnightly results of the comparisons between the predicted and actual times and heights from 1923 to 1931.

TABLE 3. *Greatest differences between predicted and actual heights of low water during 1932.*

Serial number	Port	Predicted *minus* Actual	Date
		feet	
1	Aden	+ 0·7	30th October.
2	Karāchi	+ 0·9	5th and 6th June.
		− 0·9	3rd April and 17th December.
3	Bhāvnagar	− 4·3	24th March.
4	Bombay (Apollo Bandar)	+ 1·0	25th March, 23rd April and 17th December.
		− 1·0	1st and 3rd August and 16th October.
5	Colombo	− 0·6	26th January and 18th, 19th and 24th August.
		+ 0·6	5th June and 10th December.
6	Trincomalee ...	− 1·0	26th November.
7	Madras	− 1·5	24th November.
8	Kidderpore (Calcutta)...	+ 2·6	11th September.
9	Chittagong	− 2·2	16th June.
10	Akyab	− 2·1	23rd March.
11	Rangoon	− 2·1	14th April.

TABLE 4. *Mean errors E_1* and E_2* for 1932.*

ADEN

PERIOD 1932	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.	0·7 feet of height H. W.	L. W.
	+	–	+	–	+	–	+	–								
Jan. 1-15		1·7	0·2			3·6	0·1		4·8	0·2	8·6	0·2	0	0	0	0
16-31	0·5		0·0		0·9			0·0	3·9	0·1	3·8	0·1	0	0	0	0
Feb. 1-15		3·7	0·2			1·0	0·1		6·7	0·2	6·3	0·2	0	0	0	0
16-29	0·0			0·0	2·4			0·1	6·6	0·1	10·1	0·2	1	1	0	0
Mar. 1-15		4·4	0·0			1·4		0·1	9·8	0·1	7·2	0·2	2	0	0	0
16-31		1·6	0·0			0·7		0·0	6·3	0·1	7·5	0·2	0	1	0	0
April 1-15		12·1	0·1			7·7	0·0	...	12·5	0·2	8·8	0·1	1	0	0	0
16-30		6·5		0·0		10·2		0·0	10·1	0·1	10·9	0·2	0	1	0	0
May 1-15		5·5	0·0			7·3	0·0		6·0	0·2	7·7	0·2	0	1	0	0
16-31		7·4		0·0		7·0		0·1	8·5	0·1	9·3	0·1	2	0	0	0
June 1-15		6·4		0·0		5·0		0·0	7·2	0·1	6·6	0·1	0	0	0	0
16-30		8·2	0·0			5·7		0·1	10·6	0·2	9·3	0·2	1	0	0	0
July 1-15	0·6			0·2	5·6			0·1	4·6	0·2	7·3	0·2	0	0	0	0
16-31	1·3		0·0			1·8		0·0	4·5	0·1	5·1	0·1	0	0	0	0
Aug. 1-15		1·6	0·0			1·6	0·0		4·4	0·1	4·4	0·1	0	0	0	0
16-31		4·5		0·2	2·5			0·3	7·7	0·2	5·3	0·3	1	0	0	0
Sept. 1-15		1·4		0·2		2·6		0·2	3·6	0·2	4·5	0·2	0	0	0	0
16-30		8·2		0·1		2·9		0·2	8·8	0·1	7·1	0·2	0	1	0	0
Oct. 1-15		8·2		0·2		4·1		0·3	10·5	0·2	6·3	0·3	1	0	0	0
16-31	2·0			0·0	1·5			0·1	7·7	0·2	5·8	0·3	1	0	0	0
Nov. 1-15		2·9	0·2		0·3		0·1		6·3	0·2	6·8	0·1	1	1	0	0
16-30		1·5		0·0		1·4		0·1	7·3	0·1	10·5	0·2	0	2	0	0
Dec. 1-15	0·6			0·1		2·5		0·1	8·3	0·1	5·4	0·2	0	0	0	0
16-31		4·1		0·1	0·8			0·1	6·6	0·2	3·9	0·2	0	0	0	0
TOTALS...	5·0	89·9	0·7	1·1	14·0	66·5	0·3	1·9	173·3	3·6	168·5	4·4	11	8	0	0
MEANS ...	– 3·5		– 0·0		– 2·2		– 0·1		7·2	0·2	7·0	0·2				

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

TABLE 5. *Mean errors E_1* and E_2* for 1932.*

KARĀCHI

PERIOD 1932	MEAN ERRORS (Predicted – actual)												Number of errors exceeding			
	E_1*								E_2*				30 minutes of time		0·9 feet of height	
	H. W. Time		H. W. Height		L. W. Time		L. W. Height		H. W. Time	H. W. Ht.	L. W. Time	L. W. Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		feet		minutes		feet		minutes	feet	minutes	feet				
	+	–	+	–	+	–	+	–								
Jan. 1-15	2·4			0·4	5·8			0·1	7·2	0·4	13·3	0·2	0	2	0	0
16-31	8·6			0·6	11·8			0·3	13·1	0·6	15·2	0·3	3	3	7	0
Feb. 1-15	1·3			0·5	10·9			0·2	7·2	0·5	14·4	0·3	0	4	1	0
16-29	12·8			0·4	17·4			0·0	15·8	0·4	18·0	0·2	5	4	0	0
Mar. 1-15	7·7			0·6	13·0			0·3	13·2	0·6	16·4	0·3	4	4	0	0
16-31	9·6			0·4	19·6			0·1	15·9	0·4	20·3	0·2	4	6	0	0
April 1-15	7·2			0·4	8·3			0·2	10·5	0·4	13·0	0·3	2	2	0	0
16-30	2·8			0·2	9·6		0·1		7·7	0·2	13·2	0·2	0	1	0	0
May 1-15	2·3			0·2	8·6			0·2	8·6	0·2	10·1	0·3	0	3	0	0
16-31	5·5			0·0	6·3		0·2		7·4	0·2	11·2	0·3	0	0	0	0
June 1-15	3·4			0·1	12·9		0·2		7·6	0·2	14·7	0·3	0	4	0	0
16-30	7·0			0·4	8·8			0·2	9·7	0·4	14·8	0·2	0	2	0	0
July 1-15	5·2			0·4	8·6		0·0		8·7	0·4	12·1	0·2	1	0	0	0
16-31		0·5		0·3		0·8		0·1	10·7	0·3	10·1	0·2	2	1	1	0
Aug. 1-15	2·0			0·4	6·6			0·0	7·5	0·4	8·2	0·2	0	1	0	0
16-31	3·3			0·5	12·5			0·3	8·0	0·5	13·1	0·3	0	3	0	0
Sept. 1-15	6·2			0·4	6·1		0·0		8·0	0·4	10·3	0·1	0	1	0	0
16-30	2·9			0·4	15·0			0·2	8·5	0·4	15·9	0·2	1	2	0	0
Oct. 1-15	4·9			0·5	5·0			0·2	7·1	0·5	7·5	0·3	0	2	0	0
16-31	9·0			0·6	17·8			0·3	10·0	0·6	17·9	0·4	3	4	5	0
Nov. 1-15	3·3			0·2	4·1		0·1		7·2	0·2	9·0	0·1	0	0	0	0
16-30	9·4			0·3	17·6		0·0		11·3	0·3	18·1	0·2	1	6	0	0
Dec. 1-15		4·1		0·1		5·5	0·1		11·9	0·3	15·5	0·2	3	2	0	0
16-31		3·8		0·1	5·1		0·3		11·2	0·2	13·9	0·4	2	1	0	0
TOTALS...	116·8	8·4		8·4	231·4	6·3	1·0	2·7	234·0	9·0	326·2	5·9	31	58	14	0
MEANS ...	+ 4·5		– 0·4		+ 9·4		– 0·1		9·8	0·4	13·6	0·2				

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

TABLE 6. *Mean errors E_1* and E_2* for 1932.*

BHĀVNAGAR

PERIOD 1932	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	12·2			1·2		23·7		1·1	14·1	1·2	24·3	1·2	0	7	8	7
16-31	5·8			0·3		19·3		1·1	15·5	0·6	28·4	1·2	1	6	3	7
Feb. 1-15	14·2			0·8		17·9		0·7	15·4	0·8	23·5	1·2	0	6	7	7
16-29	10·9		0·0			24·9		1·3	14·6	0·4	37·1	1·6	0	8	1	7
Mar. 1-15	16·9			0·3		16·6		0·7	16·9	0·5	21·8	1·3	0	6	3	7
16-31	10·9			0·1		26·9		1·1	11·9	0·6	36·3	1·5	0	7	3	5
April 1-15	11·5			0·4		14·1		0·1	11·5	0·4	22·9	0·9	0	2	2	6
16-30	6·5			0·2		24·2		0·1	13·0	0·9	29·6	1·1	0	4	6	8
May 1-15	8·4			0·6		5·9	0·6		9·1	0·7	10·5	0·8	0	0	4	7
16-31	8·1			0·6		19·0	0·0		13·9	1·2	20·1	0·8	1	6	6	7
June 1-15	15·7			0·4		7·7	1·1		15·7	0·8	8·7	1·1	0	0	5	8
16-30	13·6			0·5		17·8	0·5		14·8	0·8	24·2	0·5	0	4	5	2
July 1-15	15·7			0·6		10·9	0·9		15·7	0·8	13·4	1·0	0	0	5	7
16-31	11·3			0·9		12·5	0·6		15·3	0·9	22·3	0·9	0	5	5	7
Aug. 1-15	7·5			0·9		22·6	0·5		9·3	0·9	22·9	0·9	0	6	4	6
16-31	10·4			0·1		12·6	0·7		12·6	0·5	16·4	0·9	0	4	1	6
Sept. 1-15	3·8			0·3		31·0	0·5		6·1	0·7	32·2	1·3	0	9	3	10
16-30	10·5			0·1		11·3	0·6		10·9	0·4	21·6	1·0	0	3	1	7
Oct. 1-15	7·3			0·4		23·3	0·2		13·1	0·7	23·7	1·0	0	3	3	6
16-31	17·8			0·4		8·6	0·5		17·8	0·6	22·3	1·0	1	4	3	7
Nov. 1-15	8·4			0·0		18·8	1·1		12·8	0·3	18·8	1·3	0	3	1	12
16-30	15·3			0·0		16·1	1·2		15·3	0·5	16·7	1·3	0	3	0	8
Dec. 1-15	7·8		0·3			17·7	0·7		14·5	0·7	17·7	0·8	0	3	4	5
16-31	11·9		0·1			20·6	0·4		14·3	0·7	21·8	1·2	0	3	1	10
TOTALS ...	262·4		0·4	9·1		424·0	10·1	6·2	324·1	16·6	536·2	25·8	3	102	84	169
MEANS ...	+ 10·9		− 0·4		− 17·7		+ 0·2		13·5	0·7	22·3	1·1				

* E_1 is with regard to sign: E_2 is without regard to sign.
† Actual values are tide-pole readings during daylight only.

TABLE 7. *Mean errors E_1* and E_2* for 1932.*

BOMBAY (APOLLO BANDAR)

PERIOD 1932	MEAN ERRORS (Predicted – actual) E_1* H. W. Time (minutes) +	H. W. Time (minutes) −	H. W. Height (feet) +	H. W. Height (feet) −	L. W. Time (minutes) +	L. W. Time (minutes) −	L. W. Height (feet) +	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		4·1		0·2		5·2		0·2	8·5	0·3	8·5	0·2	0	1	0	0
16-31		2·8		0·2		4·4		0·3	9·1	0·3	9·1	0·3	2	1	0	0
Feb. 1-15		0·0		0·0		1·9	0·1		12·8	0·2	9·0	0·3	1	1	0	0
16-29		0·9		0·1		3·4		0·1	6·2	0·3	12·3	0·3	0	3	0	0
Mar. 1-15		4·2		0·3		8·8		0·3	6·1	0·5	10·7	0·3	0	1	0	0
16-31	2·4		0·0			6·1		0 2	8·2	0·2	14·1	0·4	1	3	0	0
April 1-15		3·1		0·3		3·3		0·1	8·6	0·3	9·6	0·4	0	1	0	0
16-30	0·7		0·1			4·3	0·0		7·5	0·2	9·4	0·4	0	0	0	0
May 1-15		1·8		0·4		3·8		0·2	6·2	0·4	9·4	0·4	0	2	0	0
16-31		6·2	0·3			7·8		0·0	11·2	0·4	10·7	0·3	2	2	1	0
June 1-15	4·3		0·0		6·7		0·1		7·2	0·2	7·9	0·2	0	0	0	0
16-30		0·9		0·0		5·7		0·0	5·9	0·2	8·8	0·2	0	0	0	0
July 1-15	0·0			0·2		4·4		0·2	3·9	0·4	7·5	0·2	0	0	2	0
16-31		3·2		0·2	3·3			0·4	14·3	0·4	9·5	0·4	3	1	0	0
Aug. 1-15		1·9		0·1	2·7			0·5	5·9	0·3	8·8	0·5	0	0	0	0
16-31		7·5	0·0		1·2			0·2	15·5	0·3	9·5	0·3	5	1	0	0
Sept. 1-15		2·1	0·2			1·7		0·3	7·2	0·3	8·9	0·4	0	1	0	0
16-30		8·5		0·0		0·8		0·3	14·6	0·3	15·9	0·3	1	2	0	0
Oct. 1-15	0·1			0·0		2·3		0·4	6·0	0·1	6·5	0·4	0	0	0	0
16-31		2·5		0·3		5·5		0·3	10·7	0·4	9·7	0·4	2	2	0	0
Nov. 1-15	2·2		0·2			5·9		0·0	6·4	0·3	6·8	0·1	0	0	1	0
16-30		2·7	0·0			2·4	0·1		7·1	0·3	5·7	0·2	0	0	0	0
Dec. 1-15	2·6		0·3			6·9	0·1		8·5	0·4	11·0	0·3	0	0	1	0
16-31		1·1	0·2			5·9	0·2		6·5	0·3	7·4	0·2	0	0	0	0
TOTALS ...	12·3	53·5	1·3	2·3	13·9	90·5	0·6	4·0	204·1	7·3	226·7	7·4	17	22	5	0
MEANS ...	− 1·7		− 0·0		− 3·2		− 0·1		8·5	0·3	9·4	0·3				

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

TABLE 8. *Mean errors E_1^* and E_2^* for 1932.*

COLOMBO

PERIOD 1932	MEAN ERRORS (Predicted – actual)												Number of errors exceeding			
	E_1^*								E_2^*				30 minutes of time		0·3 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	10·1			0·1	11·4		0·0		12·9	0·1	16·2	0·1	3	4	0	0
16-31	9·2			0·3	2·6			0·2	11·6	0·3	13·4	0·2	2	2	7	3
Feb. 1-15	24·2			0·2	12·0			0·0	24·6	0·2	17·6	0·1	7	3	1	0
16-29	13·3			0·1	17·0			0·0	13·4	0·2	18·7	0·1	2	4	1	0
Mar. 1-15	25·0			0·3	13·3			0·2	27·4	0·3	29·0	0·2	9	8	15	5
16-31	2·1			0·2		1·7		0·2	12·1	0·2	12·3	0·2	4	2	5	1
April 1-15	11·7			0·1	12·3		0·0		14·6	0·1	14·6	0·1	2	1	0	0
16-30		1·6		0·1	0·4		0·0		15·1	0·2	8·1	0·2	3	0	3	0
May 1-15	26·0			0·2	22·5			0·0	26·6	0·2	22·5	0·2	8	5	8	3
16-31	10·4		0·0		11·5		0·2		13·3	0·2	13·5	0·3	1	2	3	8
June 1-15	14·2		0·0		13·2		0·1		18·2	0·2	18·2	0·3	6	5	1	10
16-30	9·0			0·0	7·8		0·1		12·9	0·1	13·2	0·2	1	1	1	3
July 1-15	14·3			0·1	3·7		0·0		22·0	0·1	13·1	0·1	7	2	1	0
16-31	9·7			0·1	12·9		0·0		12·6	0·1	17·9	0·1	0	4	0	0
Aug. 1-15	15·8			0·3	13·5			0·2	15·8	0·3	15·4	0·2	2	1	7	2
16-31	19·8			0·6	16·5			0·4	26·0	0·6	17·6	0·4	7	2	27	20
Sept. 1-15	20·9			0·3	16·7			0·1	22·4	0·3	17·0	0·1	5	1	14	[illegible]
16-30	14·1			0·3	15·1			0·2	20·1	0·3	19·8	0·2	5	4	10	[illegible]
Oct. 1-15	20·8			0·3	17·4			0·1	23·2	0·3	28·5	0·2	6	8	13	[illegible]
16-31	23·2			0·1	19·5			0·1	24·6	0·1	20·0	0·1	7	3	0	[illegible]
Nov. 1-15	8·3		0·1		13·8		0·2		15·0	0·2	14·7	0·2	2	4	1	[illegible]
16-30	16·4			0·2	7·2			0·0	18·2	0·2	16·5	0·2	5	5	4	[illegible]
Dec. 1-15	10·7		0·1		13·5		0·3		14·6	0·2	15·1	0·3	3	3	5	[illegible]
16-31	10·8			0·2	6·0			0·1	17·0	0·2	17·7	0·2	4	2	5	[illegible]
TOTALS	340·0	1·6	0·2	4·1	279·8	1·7	0·9	1·8	434·2	5·2	410·6	4·5	101	76	132	[illegible]

TABLE 9. *Mean errors E_1* and E_2* for 1932.*

TRINCOMALEE

PERIOD 1932	MEAN ERRORS (Predicted−actual)												Number of errors exceeding			
	E_1 *								E_2 *				30 minutes of time		0·2 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	27·5			0·2	25·1			0·4	31·3	0·2	27·8	0·4	12	12	12	23
16-31	13·5			0·4	10·7			0·4	32·5	0·4	18·8	0·4	15	5	29	28
Feb. 1-15		3·0	0·0		1·1		0·0		22·8	0·2	24·3	0·1	6	11	10	1
16-29	17·7			0·5	9·2			0·1	27·7	0·5	17·0	0·2	15	5	23	8
Mar. 1-15	56·6			0·6	48·4			0·5	56·6	0·6	48·4	0·5	20	17	30	25
16-31		1·4		0·3	4·0			0·3	39·0	0·3	25·4	0·3	14	9	17	14
April 1-15		18·1		0·4		27·5		0·3	33·0	0·4	31·8	0·3	11	9	27	18
16-30		1·7		0·5	1·0			0·3	19·4	0·5	24·2	0·3	6	6	27	21
May 1-15	8·8			0·3	7·1			0·2	20·3	0·3	22·3	0·2	8	9	15	10
16-31	25·3			0·2	38·7			0·2	27·8	0·2	38·9	0·2	15	19	10	9
June 1-15	10·6			0·6	34·1			0·1	22·7	0·6	35·0	0·1	8	18	20	3
16-30	34·5			0·6	48·6			0·2	35·1	0·6	48·6	0·2	17	26	27	10
July 1-15	9·4			0·5	1·9			0·2	18·3	0·5	16·5	0·2	5	5	28	7
16-31	65·7			0·3	52·8			0·1	65·7	0·3	53·5	0·2	23	23	12	5
Aug. 1-15	2·3			0·3		1·0		0·2	25·3	0·4	19·5	0·2	12	5	18	6
16-31	17·9			0·5	10·8			0·2	29·9	0·5	32·3	0·2	14	16	30	13
Sept. 1-15		10·0		0·2		19·3		0·1	27·1	0·3	35·7	0·2	11	11	14	8
16-30	31·3			0·3	18·4			0·3	41·1	0·3	28·0	0·3	12	10	13	19
Oct. 1-15	24·4			0·5	12·7			0·2	30·2	0·5	22·2	0·2	10	6	29	15
16-31	10·4			0·1		0·5		0·2	41·1	0·2	30·3	0·2	12	10	3	13
Nov. 1-15		24·9		0·5		24·2		0·2	40·9	0·5	33·3	0·2	18	13	24	8
16-30	15·8			0·6	20·1			0·4	36·3	0·6	41·1	0·5	10	13	27	22
Dec. 1-15		20·5		0·2		4·4		0·4	42·7	0·4	37·7	0·4	12	10	14	21
16-31	24·4			0·4	37·2			0·2	26·6	0·4	42·3	0·3	12	21	23	15
TOTALS ...	396·1	79·6	0·0	9·0	381·9	76·9	0·0	5·7	793·4	9·7	754·9	6·3	298	289	482	322
MEANS ...	+ 13·2		− 0·4		+ 12·7		− 0·2		33·1	0·4	31·5	0·3				

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

TABLE 10. *Mean errors E_1* and E_2* for 1932.*

MADRAS

PERIOD 1932	MEAN ERRORS (Predicted—actual) E_1* H. W. Time (minutes) +	H. W. Time (minutes) −	H. W. Height (feet) +	H. W. Height (feet) −	L. W. Time (minutes) +	L. W. Time (minutes) −	L. W. Height (feet) +	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.	0·4 feet of height H. W.	0·4 feet of height L. W.
Jan. 1-15	12·6			0·2	11·8			0·1	12·8	0·2	11·9	0·2	1	0	1	2
16-31	7·5			0·3	8·0			0·2	8·3	0·3	8·7	0·2	0	0	4	1
Feb. 1-15	9·0			0·1	4·9			0·0	9·3	0·1	5·9	0·1	0	0	0	0
16-29	4·3			0·4	4·7			0·3	6·2	0·4	7·7	0·3	0	0	14	4
Mar. 1-15	6·7			0·5	4·2			0·4	7·3	0·5	5·7	0·4	0	0	18	12
16-31	6·8			0·4	6·7			0·4	9·2	0·4	8·8	0·4	0	0	8	8
April 1-15	5·4			0·5	4·8			0·5	6·6	0·5	5·6	0·5	0	0	25	17
16-30	5·2			0·4	3·8			0·4	6·4	0·4	7·8	0·4	0	0	10	10
May 1-15	10·1			0·1	7·9			0·0	11·2	0·1	8·5	0·1	0	0	0	0
16-31	6·7			0·4	7·0			0·2	8·0	0·4	8·4	0·2	0	0	11	0
June 1-15	7·6			0·4	5·4			0·3	7·7	0·4	5·7	0·3	0	0	10	5
16-30	5·4			0·4	6·3			0·2	7·8	0·4	6·6	0·2	0	0	10	0
July 1-15	3·3			0·3	2·9			0·1	5·8	0·3	4·7	0·2	0	0	5	0
16-31	4·9			0·3	4·3			0·1	5·5	0·3	5·3	0·2	0	0	10	4
Aug. 1-15	5·9			0·1	5·6		0·1		6·7	0·1	7·1	0·1	0	0	0	0
16-31	2·4			0·2	1·7			0·2	4·6	0·2	5·2	0·2	0	0	0	0
Sept. 1-15	4·9			0·4	5·8			0·2	6·2	0·4	6·5	0·2	0	0	11	2
16-30	5·8			0·3	5·2			0·3	6·7	0·3	7·1	0·3	0	0	4	3
Oct. 1-15	3·9			0·2	3·1			0·0	5·3	0·2	5·4	0·1	0	0	0	0
16-31	5·6			0·0	4·3		0·1		6·9	0·2	5·3	0·1	1	0	0	0
Nov. 1-15	2·8			0·4	6·1			0·3	4·9	0·4	8·1	0·3	0	1	14	10
16-30	6·6			0·8	3·7			0·6	8·6	0·8	5·8	0·6	0	0	27	24
Dec. 1-15	4·3			0·4	5·0			0·4	5·6	0·4	7·6	0·4	0	0	15	12
16-31	5·6			0·2	3·7			0·2	5·8	0·3	4·5	0·3	0	0	3	1
TOTALS ...	143·3			7·7	126·9		0·2	5·4	173·4	8·0	163·9	6·3	2	1	200	115
MEANS ...	+ 6·0		− 0·3		+ 5·3		− 0·2		7·2	0·3	6·8	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 1932.*

KIDDERPORE (CALCUTTA)

PERIOD 1932	MEAN ERRORS (Predicted – actual)												Number of errors exceeding			
	E_1*								E_2*				30 minutes of time		1·0 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		3·5		0·3		1·9		0·2	8·5	0·3	8·3	0·5	0	2	0	0
16-31	6·7			0·5	1·5			0·0	10·2	0·5	12·3	0·4	0	3	3	0
Feb. 1-15		1·4		0·1	1·3		0·1		8·5	0·5	6·9	0·4	1	0	1	3
16-29		1·3		0·4		9·0	0·5		10·0	0·4	18·4	0·5	1	4	0	2
Mar. 1-15	The tide-gauge was dismantled and shifted to Garden Reach.															
17-31	2·0			0·4		2·3	0·4		9·3	0·4	11·3	0·5	1	1	1	2
April 1-15	2·9			0·5	12·7		0·2		8·0	0·5	14·1	0·4	0	3	5	4
16-30	2·9			0·7		5·8	0·2		10·0	0·7	11·5	0·4	1	0	3	0
May 1-15		2·8		0·1	7·9		0·1		7·8	0·4	10·8	0·3	0	0	0	0
16-31		3·8		0·3		5·4	0·4		9·5	0·6	14·9	0·6	1	0	2	6
June 1-15	4·0			0·5	9·2		0·1		9·9	0·5	14·7	0·2	0	1	0	0
16-30	0·5			0·4	3·3		0·0		7·9	0·4	8·3	0·2	0	0	2	0
July 1-15	3·1			0·3	1·7			0·2	11·5	0·4	7·7	0·6	0	0	1	0
16-31	10·4		0·0		22·0		0·5		14·6	0·3	22·7	0·5	2	6	0	1
Aug. 1-15		3·7		0·2		10·5	0·7		7·9	0·5	11·0	0·8	0	0	2	7
16-31		5·4	0·4			2·9	0·8		11·1	0·4	16·5	0·8	1	2	1	8
Sept. 1-15		7·5	0·3			3·8	1·6		9·9	0·4	10·2	1·6	0	0	0	26
16-30	9·2			0·6	18·1		0·6		12·2	0·7	24·6	0·7	2	7	7	8
Oct. 1-15		5·5	0·1			8·8	1·2		7·1	0·3	10·4	1·2	1	0	0	22
16-31	1·3			0·4	4·7		0·6		7·6	0·5	16·9	0·8	0	3	4	8
Nov. 1-15	2·2			1·2	6·3			0·5	6·2	1·2	11·2	0·5	0	3	16	2
16-30	2·8			1·0		1·8		0·2	8·6	1·0	16·9	0·5	0	3	11	0
Dec. 1-15		1·8		0·6	4·5			0·2	6·1	0·6	8·7	0·4	0	0	0	0
16-20		6·2		0·3		0·1		0·1	10·2	0·5	10·1	0·3	0	0	0	0
TOTALS ...	48·0	42·9	0·8	8·8	93·2	52·3	8·0	1·4	212·6	12·0	298·4	13·1	11	38	59	99
MEANS ...	+ 0·2		– 0·3		+ 1·8		+ 0·3		9·2	0·5	13·0	0·6				

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

TABLE 12. *Mean errors E_1* and E_2* for 1932.*

CHITTAGONG

PERIOD 1932	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	7·3			0·3	5·9			0·1	7·9	0·3	6·6	0·4	0	0	0	0
16-31	6·4			0·5	7·2			0·2	6·8	0·5	7·2	0·3	0	0	0	0
Feb. 1-15	5·7			0·4	6·7			0·1	6·7	0·5	7·2	0·4	0	0	2	0
16-29	4·6			0·1	5·5			0·0	5·9	0·3	6·9	0·4	0	0	0	1
Mar. 1-15	3·7			0·1	0·5		0·3		6·5	0·4	5·2	0·3	0	0	0	0
16-31	6·1		0·2		4·6		0·1		6·7	0·5	4·7	0·3	0	0	1	0
April 1-15		1·2		0·0		2·1	0·3		6·4	0·3	5·5	0·3	0	0	1	0
16-30	6·8			0·1	7·1			0·2	6·8	0·6	7·6	0·3	0	0	2	0
May 1-15	4·8			0·0	0·3		0·4		6·3	0·3	6·4	0·7	0	0	0	3
16-31	7·5		0·1		5·3		0·3		7·5	0·9	8·2	0·5	0	0	9	1
June 1-15	4·1			0·7	3·9			0·1	5·7	0·8	5·9	0·8	0	0	6	5
16-30	7·8			0·3	6·1		0·3		8·6	0·4	7·9	0·8	0	0	1	3
July 1-15	7·7			1·1	9·6		0·0		7·7	1·1	10·5	0·7	0	0	10	2
16-31	6·3			0·5	9·6		0·2		6·8	0·7	10·0	0·7	0	0	3	3
Aug. 1-15	6·9			0·6	6·1		0·7		7·0	0·6	7·7	0·7	0	0	1	1
16-31	7·6		0·2		5·8		1·0		7·8	0·2	6·1	1·0	0	0	0	7
Sept. 1-15	0·2			0·7	3·3		0·5		3·9	0·7	3·9	0·6	0	0	5	2
16-30	3·1			0·4	0·6		0·4		6·7	0·6	3·0	0·4	0	0	3	0
Oct. 1-15	3·7		0·7		3·9		0·7		5·5	0·7	6·2	0·7	0	0	5	5
16-31	3·6			0·4		1·0	0·2		5·1	0·5	3·8	0·4	0	0	2	1
Nov. 1-15	3·3			1·0		1·3		0·4	6·5	1·0	3·9	0·5	0	0	5	1
16-30		5·7		1·0		6·0		0·4	7·5	1·0	9·2	0·4	0	0	6	2
Dec. 1-15	3·2			0·5		0·9		0·1	6·5	0·6	7·3	0·3	0	0	4	0
16-31	6·6			0·3	1·7			0·1	7·4	0·6	4·1	0·3	0	0	0	0
TOTALS ...	117·0	6·9	1·2	9·0	93·7	11·3	5·4	1·7	160·2	14·1	155·0	12·2	0	0	66	37
MEANS ...	+ 4·6		– 0·3		+ 3·4		+ 0·2		6·7	0·6	6·5	0·5				

* E_1 is with regard to sign : E_2 is without regard to sign.
† Actual values are tide-pole readings during daylight only.

TABLE 13. *Mean errors E_1* and E_2* for 1932.*

AKYAB

PERIOD 1932	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 exceeding 30 minutes of time: H. W.	L. W.	0·8 feet of height: H. W.	L. W.
Jan. 1-15	5·1			0·1	4·1			0·1	5·1	0·1	4·1	0·2	0	0	0	0
16-31	4·8		0·1		5·2			0·2	4·8	0·1	5·2	0·4	0	0	0	2
Feb. 1-15	4·6			0·2	5·1		0·0		4·6	0·2	5·1	0·1	0	0	0	0
16-29	4·7			0·1	4·9			0·8	4·7	0·3	4·9	0·8	0	0	1	6
Mar. 1-15	5·3			0·2	4·9			0·0	5·3	0·5	4·9	0·2	0	0	3	0
16-31	4·9			0·2	4·9			0·4	4·9	0·2	4·9	0·6	0	0	0	4
April 1-15	4·8			0·3	4·9			0·1	4·8	0·4	4·9	0·2	0	0	0	0
16-30	4·9			0·4	5·5			0·3	4·9	0·4	5·5	0·3	0	0	2	1
May 1-15	4·6		0·1		4·9		0·3		4·6	0·2	4·9	0·4	0	0	0	1
16-31	4·9			0·3	4·9			0·2	4·9	0·5	4·9	0·2	0	0	2	0
June 1-15	5·1			0·3	5·0			0·3	5·1	0·3	5·0	0·4	0	0	0	2
16-30	5·3		0·0		5·1			0·1	5·3	0·3	5·1	0·3	0	0	1	0
July 1-15	4·5		0·0		4·9			0·1	4·5	0·2	4·9	0·2	0	0	0	0
16-31	4·8			0·2	5·1			0·1	4·8	0·4	5·1	0·3	0	0	3	1
Aug. 1-15	4·9			0·2	5·0			0·1	4·9	0·5	5·0	0·2	0	0	2	1
16-31	4·9		0·2		4·3		0·3		4·9	0·3	4·3	0·3	0	0	1	1
Sept. 1-15	5·1			0·1	5·1		0·2		5·1	0·2	5·1	0·2	0	0	0	0
16-30	4·3			0·0	4·9		0·0		4·3	0·4	4·9	0·2	0	0	0	0
Oct. 1-15	5·0		0·1		4·8		0·1		5·0	0·2	4·8	0·2	0	0	0	0
16-31	4·9			0·2	4·3		0·1		4·9	0·3	4·3	0·4	0	0	2	1
Nov. 1-15	4·3			0·4	5·0			0·1	4·3	0·4	5·0	0·2	0	0	2	1
16-30	4·5			0·2	4·5			0·1	4·5	0·3	4·5	0·2	0	0	2	0
Dec. 1-15	4·9			0·3	4·5			0·1	4·9	0·3	4·5	0·2	0	0	1	0
16-31	4·3			0·1	0·5		0·1		4·3	0·2	0·5	0·1	0	0	0	0
TOTALS ...	115·4		0·5	3·8	112·3		1·1	3·1	115·4	7·2	112·3	6·8	0	0	22	21
MEANS ...	+ 4·8		− 0·1		+ 4·7		− 0·1		4·8	0·3	4·7	0·3				

* E_1 is with regard to sign: E_2 is without regard to sign.
† Actual values are tide-pole readings during daylight only.

TABLE 14. *Mean errors E_1* and E_2* for 1932.*

RANGOON

PERIOD 1932	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	7·1		0·2			0·3	0·1		7·2	0·4	15·4	0·5	0	0	0	3
16-31	6·4		0·5		3·5		0·2		9·0	0·6	15·2	0·5	0	2	3	4
Feb. 1-15	5·2		0·3		7·4		0·4		12·0	0·4	15·2	0·5	2	1	1	2
16-29	8·9		0·3		5·0			0·1	12·1	0·5	15·6	0·5	1	2	2	0
Mar. 1-15	2·8		0·1		6·4		0·4		12·2	0·3	13·0	0·4	3	1	0	0
16-31	5·1		0·4		0·5			0·2	14·3	0·5	11·9	0·5	3	2	5	2
April 1-15	5·9			0·3	13·3		0·1		7·4	0·5	15·1	0·4	0	3	4	2
16-30	2·7		0·3			0·5		0·4	11·2	0·4	7·7	0·6	2	0	0	6
May. 1-15	6·3		0·1		8·9		0·4		8·9	0·2	11·0	0·6	1	3	0	6
16-31	4·2		0·2			4·6		0·6	8·5	0·4	11·7	0·7	0	1	0	8
June 1-15	8·7			0·6	10·7			0·7	9·9	0·6	13·3	0·8	0	6	2	7
16-30	8·0		0·3		2·7			0·1	8·4	0·5	11·0	0·5	0	0	2	3
July 1-15	8·2			0·3	4·0		0·1		9·8	0·4	11·3	0·5	0	0	0	2
16-31	9·6			0·3	9·5			0·4	12·2	0·4	15·3	0·5	0	3	1	2
Aug. 1-15	8·2			0·3		5·2		0·3	11·2	0·4	13·5	0·5	0	1	0	5
16-31	2·8		0·4		8·2		0·6		11·0	0·4	13·3	0·6	3	2	1	2
Sept. 1-15	1·4		0·2			1·1	0·3		11·0	0·4	7·2	0·5	1	0	0	1
16-30	8·7		0·0		11·5		0·6		12·1	0·4	14·9	0·6	3	5	0	3
Oct. 1-15		2·6	0·6			11·3	0·7		10·0	0·6	12·4	0·7	1	0	4	5
16-31	6·7		0·0		11·2		0·4		11·2	0·4	13·1	0·7	1	4	1	8
Nov. 1-15		0·2	0·1		1·8		0·3		8·0	0·3	9·6	0·4	0	0	0	2
16-30	11·9			0·1	5·4		0·2		12·0	0·4	11·7	0·6	3	3	2	6
Dec. 1-15	8·4			0·1	8·6		0·2		10·1	0·3	13·4	0·5	0	2	0	4
16-31	7·0		0·3			0·5	0·5		7·5	0·5	13·7	0·7	0	0	2	7
TOTALS ...	144·2	2·8	4·3	2·0	118·6	23·5	5·5	2·8	247·2	10·2	305·5	13·3	24	41	30	90
MEANS ...	+ 5·9		+ 0·1		+ 4·0		+ 0·1		10·3	0·4	12·7	0·6				

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

CHAPTER VII

RESEARCH AND TECHNICAL NOTES

1. Changes of level in Bengal

BY CAPTAIN G. BOMFORD, R.E.

Geodetic Report Volume VI, Chapter VII, contains a discussion of various levelling discrepancies which have been found in Bengal. The conclusion reached was that the plains in northern Bengal were rising at the rate of about 1 foot in 20 years. This conclusion has provoked a certain amount of criticism, especially from Colonel Sir Sidney Burrard*, formerly Surveyor General of India. The following paragraphs reply to various points of doubt or criticism which have been raised, but the Survey of India do not wish to be too dogmatic about the certainty of their conclusion. Levelling is notoriously susceptible to inexplicable systematic errors, and conclusions which might be considered well proved in other lines of investigation must be accepted with caution in spirit-levelling.

Many of the lines under consideration emanate from Howrah standard B.M. It has been suggested that this B.M. may have been sinking down into the ground, and so have caused the appearance of a rise at the further ends of these lines when they have been relevelled in later years. But precautions against such error have always been taken when new work is connected to old: several bench marks are always relevelled, and the connection is not accepted unless several give accordant results. The check-levelling at Howrah in 1913–14, a typical case, is given below:

Bench Mark		Height above No. 264 in 1882–83	Height above No. 264 in 1913–14
264	On veranda in Botanical Gardens ...	0·000	0·000
267	On platform, Burn's Workshop	+ 1·202	+ 1·224
326	On bridge over Bally Creek ...	+ 8·487	+ 8·486
327	On entrance to Library	+ 5·336	+ 5·413
328	Doorway of house	+ 7·860	+ 7·928
330	Embedded in floor of temple *ghāt* ...	+ 1·594	+ 1·713
334	Bridge parapet ...	+ 6·651	+ 6·795

* *The Royal Engineers Journal*, June 1933. Also in correspondence.

The above B.M's cover 10 miles of line, and it is unbelievable they could all have sunk into the ground more than an inch or two and still have maintained their relative heights so closely. Any greater changes in their level which may have occurred between 1882 and 1913 can only have been due to a general elevation or depression of the whole area covered by them.

Accepting the fact that the Calcutta B. M's have not been sinking into the ground, doubt may still be felt that north Bengal is rising rather than south Bengal sinking: a shrinkage of recent alluvium is such a natural thing to expect. But the tidal evidence given in Vol. VI seems conclusive on the point. The mean-water-level of the Hooghly is not a good levelling datum, but it was only 3 feet* above mean-sea-level in 1881, and it is unbelievable that it could be more than a foot lower now, since predictions of the times and heights of the tides, based on observations as old as 1881, are still accurate. The tidal data actually show that the land has risen 6 inches relative to the water in 1881, a figure which is quite consistent with the land having been stationary relative to M.S.L. in the open sea.

It has been pointed out that the present hypothesis rests largely on the old line from Howrah to Pirpainti, and that if a 3-foot error had occurred in that line, the evidence for change of level would be very heavily reduced. This is certainly the case: of the 6 items of evidence summarized in Vol. VI page 106, the first and the third, which are the most striking, depend on this line. It must, however, be noted that an error of 3 feet is very unlikely to have occurred anywhere in the old level net (the closing errors of 29 circuits averaged 0·4 feet), and that the line in question was contained in circuits whose errors were $+1\cdot4$ and $+0\cdot9$ feet†.

Modern secondary levelling is responsible for much of the evidence, and the word "secondary" suggests unreliability. It must be pointed out that the system of the modern secondary work is almost indistinguishable from the "precision" levelling of the old net. It is simultaneous double levelling with tolerances a little more lax than those allowed in the later stages of the old net, but similar to those under which much of the old work was done.

No hypothesis can be accepted without reasonable proof, but the amount of proof required depends on the inherent probability or improbability of the hypothesis. Reports of similar changes in other parts of the world are no evidence of changes in India, but they make it easier to accept such changes as possible. Attention is drawn to changes of level in Finland reported in the Travaux of the International Geodetic Association Tome 8, Chapter IV, and to

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* The figure 1½ feet was wrongly given in Vol. VI page 106, footnote.

† As mentioned in Vol. VI, these closing errors are much greater than the average, although they suggest no error of 3 feet. On the present hypothesis their comparatively large magnitude is explained by the suggested changes of level.

changes in Canada and the United States reported in "The Journal of Geology", Chicago, July–August 1933. The second of these is independent of spirit-levelling, being based on the levels of the Great Lakes.

It is thought that specific criticisms which have been made are adequately met in the above paragraphs, but the hypothesis has been weakened by an attempt to find confirmation from the west. A comparison of levelling between Benares and Agra (350 miles) in 1864–65 and 1925–27 reveals a change of only 0·030 feet. This suggests that the rock at Agra has been rising at identically the same rate as Benares, an improbable state of affairs. Further, extension to the sea coast at Karāchi, suggests that Agra actually sank by 0·817 feet between 1860 and 1925. From Karāchi to Agra is about 1,200 miles by one route and 700 by the other, and the levelling passes through an area where large misclosures have occurred*, so that the sinking is not proved, but a rise of several feet is certainly strongly negatived. Evidence of changes in north Bengal is clearly much better based on Calcutta (distant 200 miles) than on Karāchi (distant 1,700 miles), but a final opinion must be reserved until confirmation is obtained from other directions, and until the area affected by the rise is fully delineated.

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* Hyderābād, Sind. See Geodetic Report Vol. V, page 94.

II. The effect of Terrestrial Magnetism on Invar Pendulums

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

A review of the gravity work in India during the last few seasons is desirable in the light of recent investigations by Dr. E.C. Bullard on the effect of a magnetic field on invar pendulums*.

The high temperature correction factor of brass pendulums (about 50×10^{-7} sec. per °C) makes them rather unsuitable for use in the field where considerable fluctuations of temperature may be expected. Fused quartz was tried (temperature factor about 4×10^{-7} sec. per °C) but proved unsuitable because of its fragile nature, and also because of its low density, which involved an increase in the density correction factor and also a more rapid decrease in the arc of swing. Invar with a temperature coefficient about the same as fused quartz, and a suitable density, was at first suspect as a material for invariable pendulums on account of its magnetic properties; but subsequently it was decided that, owing to its low magnetic permeability and its small power of retaining permanent magnetism, pendulums of invar could be safely used for gravity determinations.

Dr. Bullard's investigations were made with invar pendulums of exactly the same design, as the Survey of India pendulums, so that his results can be directly applied to them.

An invar pendulum (without permanent magnetism) in the earth's field becomes a magnet by induction. The difference, δs seconds, in the time of swing of an invar pendulum of the same type as the Survey of India pendulums due to the *induced magnetic moment* is $\delta s = -0 \cdot 16 \times 10^{-7} aZ^2$,

where Z is the external field in gauss, and a is the induced magnetic moment.

a may be taken to be 310 C.G.S. units, as found by Dr. Bullard. (Actually in India it should be somewhat less, which is advantageous.) And $Z = 0 \cdot 35$ gauss at Dehra Dūn.

Then $\delta s = -6 \times 10^{-7}$ sec, and $\delta g = +0 \cdot 002$ cm/sec^2.

Proceeding south from Dehra Dūn, the earth's vertical magnetic field will vary from 0·35 gauss to 0·00 at the equator: northwards within the confines of India the range will be much less. Hence so

* "The effect of a magnetic field on relative gravity determinations with invar pendulums" by E.C. Bullard. Ph.D.—Proc. of the Cambridge Phil. Soc. Vol. XXIX. part 2, 10 May 1933.

long as the pendulums have no permanent magnetic moment, the effect on g due to the earth's field will only exceptionally reach $\delta g = \cdot 002$ cm/sec^2.

This is an amount which is not serious.

The effect of *permanent magnetization* is more serious. The formula for the error resulting from the interaction of permanent magnetism and the earth's field is $\delta s = -0 \cdot 37 \times 10^{-7} M_0 Z$, where M_0 is the permanent magnetic moment of the pendulum. At Cambridge where the earth's field is $0 \cdot 43$ gauss the maximum permanent moment taken up by the pendulum was ± 150 E.M.U., so at Dehra with a field of $0 \cdot 35$ gauss we might under adverse conditions get ± 120 E.M.U.

The corresponding effect on the value of gravity deduced from the swing of the pendulum is $\delta g = \pm \cdot 006$ cm/sec^2.

In the worst possible case with the pendulum fully magnetized when swung at Dehra Dūn, and at another place fully magnetized but with opposite polarity, the error in g would amount to $\cdot 012$ cm/sec^2. If the pendulums were fully magnetized when swung at Dehra Dūn and kept the same magnetization throughout the field season, then the greatest error in g would amount to $\delta g = \pm \cdot 006$ cm/sec^2. This is due to variation in the earth's field, and the error would be nil if the pendulums were screened from the earth's field. Since the ease with which pendulums can be magnetized by the earth's field varies very greatly in different pendulums*, the mean error due to two pendulums accidently magnetized and swung together will always tend to be less than that due to a single pendulum, and the error would be nil if the two pendulums happened to be equally magnetized but with opposite polarity.

It is evident therefore that without any precautions an error in g amounting to $\delta g = \cdot 012$ cm/sec^2 would be abnormal but might occur; normally the error would be less than $\cdot 006$ cm/sec^2. The possibility of such errors is unsatisfactory. Whether or not they have occurred in India is considered in a later paragraph.

As stated above, error due to the interaction of permanent magnetism with the earth's field is eliminated if the pendulum is screened, but it is also necessary to consider the interaction between the pendulum case and the permanent magnetism of the pendulums. This causes no error provided no change occurs in the permanent magnetism of the pendulums.

Dr. Bullard has found that a very slight tap may be sufficient to change this by 50 E.M.U. A tap sufficient to effect this change is most likely to occur when inserting the pendulum in the case preparatory to swinging it, or when removing it. It will then be at least partly screened, so the change is likely to be small. If however the pendulum is initially demagnetized, a similar tap while partly screened would result in far less change, if any. In addition it is

* Op. cit. p. 289.

easier to determine whether or not a pendulum has permanent magnetism than it is to determine the exact amount of the permanent magnetism present. The best method therefore of eliminating errors appears to be to keep the pendulums demagnetized, verifying that this is so at each station of observation.

Dr. Bullard finds that screening with Mu-metal,* ¼ mm thick, is sufficient to eliminate the effect of the earth's field: so that if both the vacuum case and the travelling case of the pendulums are so screened, the only risk of demagnetized pendulums taking up permanent magnetism is during transfer between the travelling case and the vacuum case. The pendulums should be tested for permanent magnetism at this stage and all shocks avoided, particularly outside the screened cases. If permanent magnetism is found, the pendulum should be demagnetized before observing. Permanent magnetism along the length of the pendulum will result in the bob being either a N. or a S. pole, although the stellite knife-head may acquire independently permanent magnetism at right angles to the length of the pendulum. The effect of the latter will be quite negligible, but on this account the test for magnetism parallel to the stem should be made at the bob end.

The test is made with a sensitive compass needle about one inch long. After removing two pendulums to a distance, the remaining pendulum is placed in the wooden travelling case, and aligned with the case along the magnetic meridian and the bob to the south; the compass is placed in the case close to the east side of the bob.

If there is no permanent magnetism the north point of the compass will be deflected about 40° towards the bob. This position is marked with ink on the glass above the compass needle. The case is then rotated through 180° and the south point of the compass will be found under the ink mark.

If there is permanent magnetism this will, in one position of the pendulum, oppose the earth's field and, in the other, reinforce it. Hence the position of the compass needle in the two positions will vary considerably. A fully magnetized pendulum would result in a change between the two positions of about 110°. One-fortieth of this would be detectable and for this the error in observed gravity would not exceed 0·0003 cm/sec^2.

Demagnetization by placing the pendulum in a solenoid round which an alternating current is passing, is unsatisfactory. Dr. Bullard shows that the last alternation of current is likely to leave the pendulum magnetized. Light tapping in a field opposed to the permanent magnetization is probably the best method, and has been employed in India. During the last field season (48 stations in all, including Dehra Dūn) the pendulums were tested for magnetism and always found to be demagnetized although no screening was used. During this season therefore errors will be due only to the

* A steel containing about 78°/₀ Ni, having a permeability up to 80,000.

effect of the earth's field on demagnetized pendulums and will not exceed ·001 cm/sec^2, as all the stations were between lats. 30° and 17° N.

The freedom of the pendulums from permanent magnetization without special precautions during the whole of a long and varied field season shows that there is at least a strong probability that they will not become permanently magnetized under normal conditions of use. That this has been so in the previous field seasons can be inferred from the fact that repeat observations with invar pendulums at stations previously observed with brass pendulums have given satisfactory results. These are tabulated below:

Station	Brass pendulum	Invar pendulum	Difference Brass *minus* invar
	cm/sec^2	*cm/sec*^{2}	*cm/sec*^{2}
No. 64 Bilāspur ...	978·682	978·681	+ ·001
,, 6 Cuttack ...	978·660	978·659	+ ·001
,, 2 Madras ...	978·282	978·279	+ ·003
,, 40 Bangalore	978·026	978·025	+ ·001

It is now proposed to equip both the vacuum case and the travelling case of the pendulums with Mu-metal screens during the recess season of 1934. Any possibility of adverse magnetic effects in future work will then be eliminated.

PUBLICATIONS

OF THE

SURVEY OF INDIA

(Corrected up to 31st December 1933)

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.

Sterling Prices of Publications. The prices to be charged for Survey of India publications in sterling equivalents in English money have been worked out under the rules given in letter No. A-401 dated the 17th January 1924 from the Under Secretary to the Government of India, Department of Industries and Labour, Delhi, to the Secretary to the High Commissioner for India, General Department, 42 Grosvenor Gardens, London, S.W. 1. These sterling prices are subject to fluctuation with the exchange rate and will be revised from time to time. The prices at the current rate of exchange are:

Price in Indian money		English equivalent		Price in Indian money		English equivalent	
Rupees	Annas	Shillings	Pence	Rupees	Annas	Shillings	Pence
0	2	0	3	4	8	7	6
0	4	0	5	5	0	8	3
0	8	0	10	5	8	9	0
0	12	1	3	6	0	9	9
1	0	1	9	6	8	10	6
1	2	1	11	7	0	11	6
1	8	2	6	7	8	12	0
1	12	3	0	8	0	13	6
2	0	3	6	8	8	14	6
2	8	4	6	9	0	15	0
3	0	5	3	9	8	16	0
3	8	6	0	10	0	16	6
4	0	6	9	10	8	17	6
4	4	7	3	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 published up till 1932, a coloured map 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.

Charts Nos. XIX & XX at the end of the Geodetic Report shew what triangulation pamphlets have been published.

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 and of certain selected secondary lines. 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 N.	Longitude E.	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	1929	Rs. 3-0-0
	Addendum to 53 ...	...	...	in the press.	
54	(Agra)	24-28	76-80	1930	Rs. 3-0-0
55	(Nāgpur)	20-24	76-80	1912	Rs. 2-0-0
56	(Hyderābād, Deccan) ...	16-20	76-80	1931	Rs. 2-0-0

Levelling Pamphlets—(*Continued*).

Pamphlet: Sheet	Pamphlet: Distinctive name of sheet	Latitude N.	Longitude E.	Published in	Price
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	1930	Rs. 2-0-0
73	(Cuttack)	20–24	84–88	1913	Rs. 2-0-0
	Addendum to 73 ...	...	...	1927	Rs. 2-0-0
74	(Puri)	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, printed by Gestetner at Dehra Dūn.

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

Levelling Pamphlets—(*Continued*).

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

Levelling Pamphlets—(*Continued*).

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

Levelling Pamphlets—(*Continued*).

Serial No.	Line number	Situated in degree sheets	Published in	Price
36	70K (Allahābād to Barākar) ...	63 G, K & O, 72 C, G, K&L and 73 I	1929	As. 14
37	70L (Mughal Sarāi to Hazāribāgh Road) ...	63 O & P and 72 D & H	"	As. 10
38	55N (Basti Maluk to Kabirwala)	39 N & O	1930	As. 6
39	55H (Abdul Hakīm to Garh Mahārāja) 55J (Damāmia to Ahar Bela)	39 N & 44 B	"	As. 6
40	29D (Gotūr to Kalādgi) ...	47 L & P	1931	As. 8
41	29B (Nīra to Jhālki) ...	47 J, K & O	1930	As. 6
42	64 I (Ghāziābād to Cawnpore) 64 J (Cawnpore to Allahābād)	53 H, 54 I, J & N and 63B, C & G	1930	Rs. 1/2
43	77 S (Khulna to Mādārīpur) 77 T (Mollāhāt to Barisāl) 77 U (Kachua to Alaipur)	79 E, F, I & J	1933	As. 10
44	88 G (Thanatpin to Tongyi) 88 H (Ohne to Thongwa and Ohne)	94 C & D	1933	As. 10
45	57 I (Khudiān to Lodhrān) 57 K (Bahāwalpur to Fāzilka)	39 N & O and 44 B, C, F, G & J	1932	As. 14
46	3 Branch-Lines between Hazāribāgh and Gomoh ...	72 H & L and 73 I	1933	As. 6
47	55 Q (Rohilānwāli to Leiah) ...	39 J, K & O	1933	As. 14
48	88 I (Bridge No. 74 to Myitkyo) 88 J (Panut to Penwegon)	94 B & C	1933	As. 6
49	70 S (Mānpur to Luckeesarai) 70 T (Patna to Gaya)	72 C, D, G, H & K	1933	As. 6

Levelling Pamphlets—(*Continued*).

Serial No.	Line number	Situated in degree sheets	Published in	Price
50	121 B (Toposi to Ondal) 121 C (Toposi to Gaurāngdih) 151 A (Pāndaveswar to Palāsthāli) 70 R (Ikrah to Sītārāmpur) 70 U (Pradhānkhunta to Pāthardīh) 70 V (Dhānbād to Jamuniātānr) 70 Q (Toposi to Bārābani)	73 I & M	1933	As. 10
51	56 I (Ferozepore to Jagraon) 61 I (Mahna to Head of Bhadaur distributary) 61 J (Badhni Kalān to Alamwāla)	44 I, J, M & N	1933	As. 14
52	57 O (Bhatinda to Dorāha) 57 P (Islāmwāla to Lambi)	44 J, K & N and 53 B	1933	As. 10
53	57 Q (Hanumāngarh to Hissār) 57 R (Hissār to Bālsamand)	44 K, O, P & 53 D	1933	As. 10
54	75 C (Muhammadnagar Patna to Bhadrakh) 75 D (Bhadrakh to Cuttack) 75 E (Cuttack to Pīr Hāt)	73 H, K, L & O	1933	As. 14
55	74 J (Saktigarh to Bally) 74 K (Seorāphuli to Tarakeswar) 74 L (Bāndel to Barharwa)	72 P, 73 M, 78 D and 79 A & B	1933	As. 10
56	74 M (Khāna to Kiul) (Portion Tinpahār to Pirpainti) 74 N (Nalhāti to Azimganj) 74 O (Tinpahār to Rājmahāl)	72 K, O & P, 73 M and 78 D	1933	As. 14
57	70 O (Jasidih to Baidyanāth Dhām) 70 P (Madhupur to Girīdih) 72 A (Bhāgalpur to Mandār hill)	72 K, L & P	1933	As. 6
58	74 I (Uttarpāra to Kālna) ...	79 A & B	1933	As. 6

Levelling Pamphlets—(*Concluded*).

Serial No.	Line number	Situated in degree sheets	Published in	Price
59	52 M (S.B.M. Sukkur to Barrage Road Bridge, Sukkur) ...	40 A	1933	As. 6
60	57 S (Bhiwāni to Bahādurgarh) 57 T (Hānsi to Bhatinda) 57 U (Mānsa to Sohūwāla)	44 J, K, N & O and 53 C, D & H	1933	As. 14
61	57 V (Badopāl to Narwāna) 57 W (Narwāna to Rājpura)	44 O and 53 B & C	1933	As. 10
62	61 K (Chandigarh to Dorāha) 57 X (Dorāha to Patiāla)	53 B	1933	As. 10
63	75 F (Chāribātia to Kendrāpāra) 75 G (Kiarbank to Puri) 39 B (Puri to Puri)	73 H, K, L & 74 E, I	1933	As. 10

NOTE. See also pamphlets of "Levelling of Precision in India and Burma" pages 91 and 92, for certain selected lines of Secondary Precision.

Tide-Tables.

From 1880 to 1922 tidal predictions based on the observations of the Survey of India were published annually by the India Office, London. From 1923 the prediction and publication have been undertaken at Dehra Dūn by the Survey of India, and until 1930 were published as follows :

(1) A single volume styled "**The Major Series**" *priced Rs. 8.*

(2) **Combined Pamphlets** varying in *price from Rs. 1-2 to Rs. 1-8 per copy.*

(3) **Separate Pamphlets** for individual ports *priced As. 12 per copy.* (For names of these ports see Geodetic Report Volume V, pages 31-33).

Commencing from 1931, a new form of publication styled "**Tide-Tables of the Indian Ocean**" has been introduced *priced Rs. 3 per copy.* This comprises full tide-tables for the 41 Indian ports predicted by the Survey of India, and 22 other standard ports in the Indian Ocean and Far East, also for 6 English and Mediterranean ports. In addition, it contains the non-harmonic tidal constants and tidal differences for about 470 ports and anchorages, and the harmonic tidal constants of about 170 important tidal stations, mainly in the Indian Ocean and Far East.

Separate Pamphlets of tide-tables have also been published for the following ports :

Bombay	...	*price As. 12*	*per copy*
Hooghly River	...	,, *Rs. 1-8*	,,
Rangoon River	...	,, *Rs. 1-2*	,,

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).

Vol. II **History and General Description of the Reduction of the Principal Triangulation.** Dehra Dūn, 1879. (Out of print).

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°, Rāhon, 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.*

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 Bidar 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.*

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

Gurwāni Meridional, Gora Meridional, Hurilāong 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.

G.T.S. Volumes—(*Concluded*).

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

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

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.*

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.*

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

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

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.*

Memoirs—(*Concluded*).

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.

Annual Reports of the **Revenue Branch.** 1851 to 1877. (1851 to 1870, out of print).

Ditto **Topographical Branch.** 1860 to 1877. (1863 to 1877, out of print).

Ditto **Trigonometrical Branch.** 1861 to 1878. (1861 to 1863, 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 to 1900. *Price Rs. 3 per volume.*
from 1900 to 1922. *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 then (*c*) "**Records of the Survey of India**" until 1921.

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, and Map Publication and Office work. Published annually. *From 1922 to 24 Price 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.

From 1933 inclusive, the General and Map Publication and Office work Reports have been combined into one report under the title of General Report. *Price Rs 1-8*, or *2s. 6d.*

The following fuller reports are available:

(*b*) **Extracts from Narrative Reports.**

1900-01. Recent Improvements in Photo-Zincography. G. T. Triangulation in Upper Burma. Experimental Base Measurement with Jäderin Apparatus. Topography in Upper Burma. Calcutta, 1903. (Out of print).

1901-02. G.T. Triangulation in Upper Burma. Topography in Upper Burma. Sind, Punjab. Calcutta, 1904. (Out of print).

1902-03. Principal Triangulation in Upper Burma. Topography in Upper Burma, Shan States. Survey of Sāmbhar Lake. 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. 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. Triangulation in Baluchistān. Survey Operations with the Somāliland Field Force. Calcutta, 1907. *Price Rs. 1-8.*

1905-06. Topography in Shan States. Calcutta, 1908. *Price Rs. 1-8.*

1906-07. Triangulation in Baluchistān. Topography in Shan States. Calcutta, 1909. *Price Rs. 1-8.*

1907-08. Topography in Shan States. Calcutta, 1910. *Price Rs. 1-8.*

1908-09. Calcutta, 1911. *Price Rs. 1-8.*

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

Vol. I **1909-10.** Calcutta, 1912. *Price Rs. 4.*

Vol. II **1910-11.** Calcutta, 1912. *Price Rs. 4.*

Vol. III **1911-12.** 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.** 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.** Note on Scales and cost rates of Town plans. Calcutta, 1915. *Price Rs. 4.*

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

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

Vol. IX **1914-15.** 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.** Mechanical Integrator for calculating Attractions (illustrated). Traverse Survey of the boundary of Imperial Delhi. Dehra Dūn, 1917. *Price Rs. 4.*

Vol. XI **1916-17.** Triangulation; use of high trestle for stations and 100-foot mast signals. Note on Basevi's Pendulum Operations at Morê. Photo-Litho Office; New method of preparing Layer plates; Developments and Improvements in preparing Tint-plates. Dehra Dūn, 1918. *Price Rs. 4.*

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

Annual Reports &c.—(*Continued*).

Vol. XIII **1917-18.** 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.** Levelling in Mesopotamia. Dehra Dūn, 1920. *Price Rs. 4.*

Vol. XV **1919-20.** Levelling; proposed new level net. 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.** High Climbs in the Himālaya prior to the Everest Expedition. Mt. Everest Survey Detachment, 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 Explorations, 1900-01, 1906-08, 1913-15. Dehra Dūn, 1923. *Price Rs. 12.*

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

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

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

Vol. XXI **1922-23-24.** I. Air Survey in the Irrawaddy Delta 1923-24, by Major C. G. Lewis, R.E., and II. Reconnaissance Survey in Bhutān 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.*

Vol. XXIII **1926-30.** Report on Sind Rectangulation, 1926-30, by Lt.-Colonel A. H. Gwyn, I. A. Dehra Dūn, 1932. *Price Rs. 1-8.*

Vol. XXIV **1901-29.** Riverain Surveys in the Punjab (at press).

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

Annual Reports &c.—(*Concluded*).

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

Vol. V **1928-29.** Computations and Publication of data. Observatories. Tides. Gravity and deviation of the vertical. Triangulation. Levelling. Research and Technical Notes. Dehra Dūn, 1930 *Price Rs. 3.*

Vol. VI **1929-30.** Computations and Publication of data. Observatories. Tides. Gravity. Triangulation. Levelling. Research and Technical Notes. Dehra Dūn, 1931. *Price Rs. 3.*

Vol. VII **1930-31.** Computations and Publication of data. Observatories. Tides. Deviation of the vertical. Gravity. Triangulation and Base Measurement. Levelling. The Magnetic Survey. Dehra Dūn, 1932. *Price Rs. 3.*

Vol. VIII **1931-32.** Computations and Publication of data. Observatories. Tides. Gravity. Triangulation. Levelling. Research and Technical Notes. Dehra Dūn, 1933. *Price Rs. 3.*

1933. Triangulation and Base Measurement. Levelling. Deviation of the Vertical. Computations and Publication of data. Observatories. Tides. Research and Technical Notes. Dehra Dūn, 1934. *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.**	861
2.	**Circular Orders (Administrative).**	431
3.	**Circular Orders (Professional).**	196
4.	**Departmental Orders** (appointments, promotions, transfers etc.)	

These are numbered serially and had reached the above numbers by September 1933. *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 Handbooks. 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.
   - „ „ 1904-1908. Calcutta, 1909. (Out of print).
   - „ „ 1909-1913. Calcutta, 1915.
   - „ „ 1914-1918. Calcutta, 1920.
   - „ „ 1919-1924. Dehra Dūn 1929.

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Departmental Orders.—(*Concluded*).

2. *Circular Orders (Administrative) 1878-1903. Calcutta, 1904.
   " " 1904-1908. Calcutta, 1909.
   " " 1909-1913. Calcutta, 1915.
   " " 1914-1918. Calcutta, 1920.
   " " 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.

Catalogues and Lists.

1. **Catalogue** of Maps published by the Survey of India. Calcutta, 1931. *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 Cantonments and Military stations. Dehra Dūn, 1927. *Price As. 8.*

3. **Catalogue** of Books in the headquarters Library, Calcutta, 1901. (Out of print).

4. **Catalogue** of Scientific Books and Subjects in the Library of the Trigonometrical Survey Office. Dehra Dūn, 1908. *Price Re. 1.*

5. **Catalogue** of books in the Library of the Great Trigonometrical Survey. Dehra Dūn, 1911.

6. Classified **Catalogue** of the Trigonometrical Survey Library. Dehra Dūn, 1921. *Gratis.*

7. **Green Lists.** Part I List of Officers in the Survey of India (annually to date 1st January. Supplementary Edition dated 1st July 1932). Calcutta. *Price Rs. 1-2.*
   Part II History of Services of Officers in the Survey of India (annually up to 1st July 1931. 1932 Edition not published. Biennially to date 1st July, from 1933 inclusive), Calcutta. *Price Rs. 1-2.*

8. **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. 1932 Edition published on 1st July). Calcutta. *Price Rs. 6-6.*
   Part II Circles and parties (published annually to date 1st January. 1932 Edition published on 1st July). Calcutta. *Price Rs. 8-10.*

9. **List of the Publications of the Survey of India** (published annually) Dehra Dūn. *Gratis.*

10. **Price List of Mathematical Instrument Office.** Corrected up to 1st September 1927. Calcutta, 1928. *Gratis.*

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* For Departmental use only.

Tables and Star Charts.

1. **Auxiliary Tables.** To facilitate the computations of a Trigonometrical Survey, and the projection of maps for India, by Radhanath Sickdhar. Calcutta, 1851.

2. **Auxiliary Tables.** To facilitate the calculations of the Survey Department of India, by J.B.N. Hennessey, F.R.A.S. Dehra Dūn, 1868.

3. **Auxiliary Tables.** To facilitate the calculations of the Survey of India. Third edition, by Colonel C.T. Haig, R.E. Dehra Dūn 1887. *Price Rs. 2.*

4. **Auxiliary Tables.** To facilitate the calculations of the Survey of India. Fourth Edition, by Lt.-Colonel S. G. Burrard, R.E., F.R.S. Dehra Dūn, 1906. *Price Rs. 2.*

5. **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, 1931. *Price Rs. 2*

Part III Topographical Survey Tables, (reprinted with additions). Dehra Dūn, 1928. *Price Rs. 3.*

Part IV Geodetic Tables, (A) Triangulation Tables. Dehra Dūn. 1931. *Price Re 1.*

6. Tables for Graticules of Maps. Extracts for the use of **Explorers.** Dehra Dūn, 1918. *Price As. 4.*

7. * Metric Weights and Measures and other tables. Photo-Litho Office. Calcutta, 1889.

8. Logarithmic Sines and Cosines to 5 places of decimals. Dehra Dūn, 1886. *Price As. 4.*

9. Logarithmic Sines, Cosines, Tangents and Cotangents to 5 places of decimals. Dehra Dūn. 1915. (Out of print)

10. Common Logarithms to 5 places of decimals, 1885. (Out of print).

11. Table for determining Heights in Traversing. Dehra Dūn, 1898. *Price As. 8.*

12. Tables of distances in Chains and Links corresponding to a subtense of 20 feet. Dehra Dūn, 1889. *Price As. 4.*

13. * ,, ,, 10 feet. Calcutta, 1915.

14. * ,, ,, 8 feet. ,,

15. Field Traverse Tables. First Edition. Calcutta, 1928. *Price As. 8.*

16. Star Charts for latitude 20° N., by Colonel J. R. Hobday, I.S.C. Calcutta, 1904. *Price Rs. 1-8.*

17. Star Charts for latitude 30° N., by Lt.-Colonel S. G. Burrard, R.E., F.R.S. Dehra Dūn, 1906. *Price Rs. 1-8.*

18. Star Charts for latitude 15° N. Dehra Dūn, 1928. *Price Rs. 2.*

19. Star Charts for latitude 30° N. Dehra Dūn, 1928. *Price Rs. 2.*

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

21. * Rainfall, maximum and minimum temperatures, from 1868 to 1927, recorded at the Survey Office Observatory, Dehra Dūn, 1928.

22. * Booklet of conventional signs for use on Plane-table Sections. Second Edition, 1928.

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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.

2. Ditto Second Edition. London, 1855.

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.-Col. R. Smyth. Third Edition, revised and enlarged. Calcutta, 1875.

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 I Geodetic Triangulation. First Edition. Dehra Dūn 1931. *Price Rs. 2-8.*

   Part V The Tides. First Edition, revised, Dehra Dūn, 1926. *Price Rs. 2.*

   Part VI Levelling. Second 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. Fifth Edition 1932. *Price As. 8.*

   „ II Constitution and Organization of a Survey Party, reprinted with additions, 1923. *Price As. 8.*

   „ III Triangulation and its Computation, revised 1930. *Price Re. 1.*

   „ IV Theodolite Traversing. Third Edition, 1927. *Price Re. 1.*

   „ V Plane-tabling. Third Edition, 1926. *Price Re. 1.*

   „ VI Fair Mapping, reprinted with additions and revised, (Sixth Edition) 1928. *Price Re. 1.*

   „ VII Trans-Frontier Reconnaissance. Third Edition, 1924. *Price As. 8.*

   „ VIII Surveys in War. Second Edition, 1930. *Price Re. 1.*

   „ IX Forest Surveys and Maps. 1925. *Price As. 8.*

   „ X Map Reproduction. Third Edition, 1928. *Price As. 8.*

   „ XI Geographical Maps. Second Edition, 1926. *Price As. 8.*

   „ XII Air Surveys (Provisional Edition). *At press.*

6. ***Photo-Litho Office,** Notes on Organization, Methods and Processes, by Major W. C. Hedley, R.E. Third Edition. Calcutta, 1924.

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

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.*

9. **Survey of India Copy Book of Hand Printing.** Calcutta.

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. *Notes on some of the Methods of Map Reproduction suitable for the Field with appendix—Suggested Equipment Tables for the Light Field Litho Press (experimental), by Lieut. A. A. Chase, R.E. Calcutta, 1911.

5. *Report on a trial of the equipment of the 1st (Prince of Wales' Own) Sappers and Miners, for reproducing maps in the field, by Lieut. A. A. Chase, R.E. Calcutta, 1912. (Out of print).

Base Lines and Magnetic.

6. *Notes on use of the Jäderin Base line Apparatus. Dehra Dūn, 1904. (Out of print).

7. *Miscellaneous Papers relating to the Measurement of Geodetic Bases by Jäderin Invar Apparatus. Dehra Dūn, 1912.

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

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

10. ***For Explorers.** Notes on the use of Thermometers, Barometers and Hypsometers with Tables for the Computation of Heights, by J. de Graaff Hunter, M.A. Dehra Dūn, 1911. (Out of print).

11. Instructions for Topographical Surveying, by Lt-Colonel Sir A. Scott Waugh, F.R.S., F.R.G.S. &c. Roorkee, 1861.

12. Notes on the Aneroid barometer for the use of travellers in determining heights of peaks in Southern India, by Major Branfill, R.E. 1871.

13. Curriculum of the course of instruction for Probationers of the Provincial Service of the Survey of India. Dehra Dūn, 1913.

14. Notes on the spelling of Turki, Tibetan and Chinese place names, by Colonel R. A. Wauhope, C.B., C.M.G., C.I.E., R.E. Dehra Dūn, 1912. *Price As. 8.*

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

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Notes and Instructions.—(*Concluded*)

16. *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.

17. **Accounts Pamphlet.** Notes on accounts for field units. Dehra Dūn, 1928. *Price Re. 1.*

18. Specimens of papers set at Examinations for the Class II Service. Dehra Dūn, 1927, 1929 & 1933. *Price Re. 1 per year.*

19. Specimens of drawing on blue prints, etc.

20. Specimens of hand printing.

21. How to correct proofs.

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., (later Sir Henry Hayden, Kt., C.S.I., C.I.E.,) Supdt., Geological Survey of India. Revised by Colonel Sir Sidney Burrard, K.C.S.I., F.R.S., and A. M. Heron, D.Sc., F.G.S., F.R.G.S., F.R.S.E., Supdt., Geological Survey of India. (Second Edition) Delhi 1933.

Part	I	The High Peaks of Asia.	*Price Rs. 3-6, or 5s. 9d.*
,,	II	The Principal Mountain Ranges of Asia.	*Price Rs. 3, or 5s. 3d.*
,,	III	The Glaciers and Rivers of the Himālaya and Tibet.	Second Edition at press
,,	IV	The Geology of the Himālaya.	Second Edition at press

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., Second Edition, Calcutta, 1929. *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).

5. Report on the Trans-Himālayan Explorations in Eastern Tibet during 1878, and in South-Eastern Tibet during 1875-76, by Major-General J. T. Walker, C.B., R.E., F.R.S. Dehra Dūn, 1879. *Price Re. 1.*

6. Report on Explorations in Nepāl and Tibet, by Explorer M-H, season 1885-86, prepared by Mr. C. Wood. Dehra Dūn, 1887. *Price Re. 1.*

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Unclassified Papers.—(*Continued*)

7. Report on the explorations in Sikkim Bhutan and Tibet, 1856-86, by Lt-Colonel G. Strahan, R.E. Dehra Dūn, 1889. *Price Rs. 1-8.*

8. Report on the Explorations in Great Tibet and Mongolia made by A-K in 1879-82: prepared by J. B. N. Hennessey M.A., F.R.S. Dehra Dūn, 1891. *Price Rs. 3.*

9. Reports on an Exploration on the North-East Frontier, 1913 by Captain F.M. Bailey, I.A., Political Department and Captain H.T. Morshead, R.E., Survey of India. Simla, 1914.

10. Alphabetical index showing the Geographical positions of all names appearing on Sheet No. 72. Dehra Dūn, 1914. *Price As. 6.*

11. The "Where Is It". Reference index showing geographical position of all important localities in INDIA and adjacent countries, in four parts. Calcutta, 1928.

Part I	Place names. Cities, towns, and other sites.	*Price As. 12.*
„ II	Railway stations. Complete list, 1928.	
„ III	Localities. Districts, States, Tribes etc.	
„ IV	Physical. Ranges, passes, peaks, glaciers, rivers, canals, lakes, bays, capes, islands etc.	

12. Glossary of Vernacular Terms used in Survey of India Maps. Calcutta, 1931. *Price As. 5.*

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.

6. *Report on the Trigonometrical Results of the Earthquake in Assam, by Captain S. G. Burrard, R.E. Calcutta, 1898. (Out of print).

7. *Notes on the Topographical Survey of the 1/50,000 Sheets of Algeria by the Topographical Section of the "Service Geographique de l'Armée", by Captain W. M. Coldstream, R.E. Calcutta, 1906.

8. *The Simla Estates Boundary Survey on the scale of 50 feet to 1 inch, by Captain E. A. Tandy, R.E. Calcutta, 1906.

9. *A note on the stage reached by the Geodetic Operations of the Survey of India in 1920, by Lt.-Colonel H. McC. Cowie, R.E. The Magnetic Survey of India, by Major R. H. Thomas, D.S.O., R.E. and a note on the present levelling policy, by Major K. Mason, M.C., R.E. Dehra Dūn, 1922. (Out of print).

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Unclassified Papers.—(*Concluded*).

10. Report on the Levelling operations in connection with the selection of the site of the new Capital at Delhi, 1911-12. Simla, 1912.

11. The International Longitude Project, Oct.-Nov., 1926. Dehra Dūn, 1928.

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.*

Projections.

1. On the projection used for the General Maps of India. Dehra Dūn, 1903.

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.

Mapping.

1. Memorandum on the compilation of map of a portion of Tibet explored by Captain H. H. P. Deasy in 1896. Dehra Dūn, 1897.

2. The reproduction of Maps and drawings by Mr. T. A. Pope. Calcutta, 1905.

3. *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.

4. *A Note on the representation of hills, by Major C. L. Robertson, C.M.G., R.E. Dehra Dūn, 1912.

5. *A Note on the representation of hills on the Maps of India, by Major F. W. Pirrie, I.A. Dehra Dūn, 1912.

6. *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 Présentés par Divers. Savants à l' Académie 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).

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Professional Papers.—(*Continued*).

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. *Price Re. 1.*

No. 7. ***Miscellaneous.** Calcutta, 1903. *Price Re. 1.*

(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.*

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. *Price Re. 1.*

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. *Price Re. 1.*

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. *Price Re. 1.*

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.*

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Professional Papers.—(*Concluded*).

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.*

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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).

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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).

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7. ||Identification of Peaks in the Himālaya with notes, by Colonel Sir S. G. Burrard, K.C.S.I., R.E., F.R.S. (Geographical Journal, September 1918).

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39. **The De Filippi Expedition to the Eastern Kara-koram, by B.B.D. and Colonel Sir G. P. Lenox-Conyngham, R.E., F.R.S., M.A. (Nature, 13th February 1926).

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51. * Note on Sir Francis Younghusband's Urdok Glacier, by Major Kenneth Mason, M.C., R.E. (Geographical Journal, March 1928).

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54. * The Kara-koram: Correspondence regarding the proper nomenclature of the Kara-koram Himālaya, by Colonel Sir S. G. Burrard, K.C.S.I., R.E., F.R.S., Dr. T.G. Longstaff and Major Kenneth Mason, M.C., R.E. (Geographical Journal, September 1929 and January 1930).

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62. ‡, §The Hypothesis of Isostasy, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. (The Observatory, Dec. 1931 and Geophysical Supplement to Monthly Notices of the Royal Astronomical Society, Jan. 1932).

63. *Review of Captain Hotine's "Survey from the Air Photographs", by J. de Graaff Hunter, M.A., SC.D., F. INST. P. (Empire Survey Review No. 3, Vol. I, Jan. 1932, pages 134-137).

64 ||Stokes's Formula in Geodesy, by B. L. Gulatee, M.A. (Cantab) (Nature, 20th February 1932).

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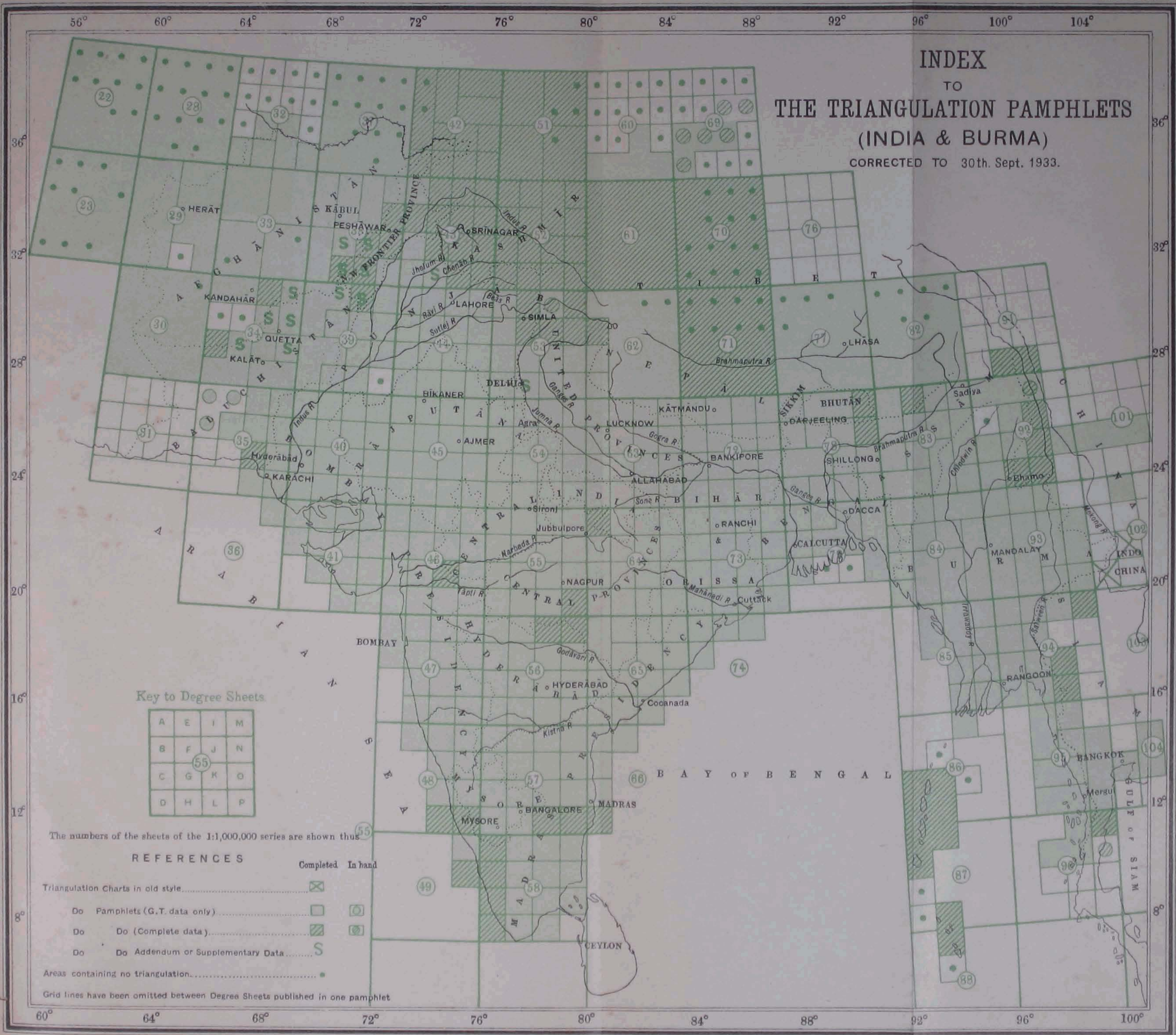

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Miles 100 50 0 100 200 300 400 500 Miles

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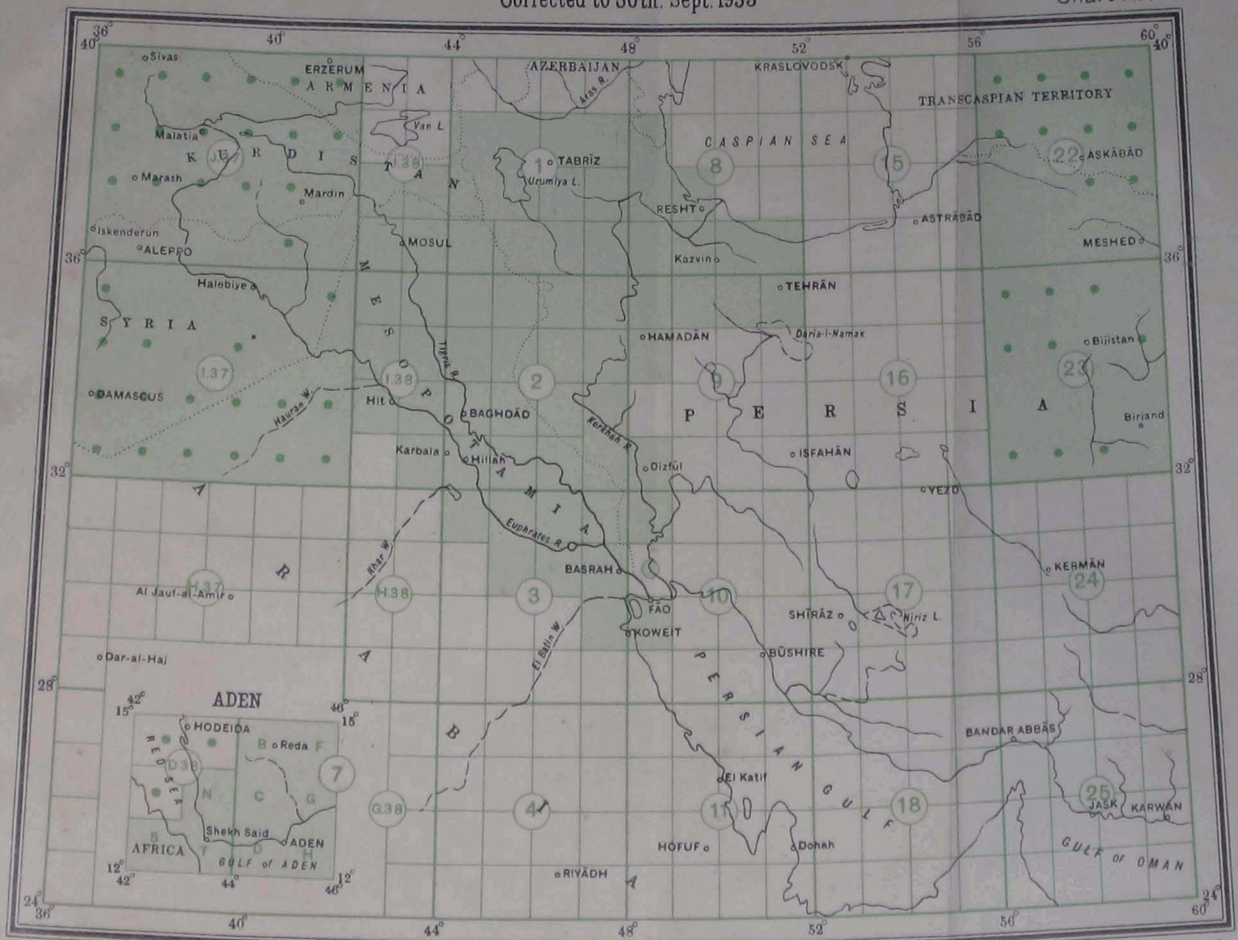
To accompany Geodetic Report 1933

INDEX TO THE TRIANGULATION PAMPHLETS
IRĀQ, PERSIA & ADEN
Corrected to 30th. Sept. 1933

Chart XX



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