Colonel Reginald Henry Phillimore, D.S.O., R.E.,
Director Geodetic Branch, Survey of India,
1927-28, 32-34.

Colonel Reginald Henry Phillimore, D.S.O.

Colonel R. H. Phillimore, whose portrait forms the frontispiece to this volume, was commissioned in the Royal Engineers in June 1898, joined the Survey of India in June 1903, and retired in June 1934 after serving continuously in the Department except for an interval of five years during the War.

Between 1903 and 1926 he served in topographical parties in Burma and the Eastern Circle, mostly in charge of No. 9 or No. 11 Party. During the War he was on active service in France and Salonica from 1915 to 1919, being four times mentioned in despatches and awarded the D. S. O., French Medaille d' honneur, and a brevet of Lieutenant-Colonel. After 1926 he was at different times Director of all the circles except the Southern, including periods as Director of the Geodetic Branch and as Director, Map Publication. Colonel Phillimore was the author of Chapters I, IV and XI of the Topographical Handbook (Introductory, Theodolite traversing, and Geographical maps).

He officiated as Surveyor General for 3 months in 1931. This period coincided with the financial crisis which led to drastic retrenchment in the Department, and Colonel Phillimore had to undertake the unpleasant duty of inaugurating it.

After his retirement Colonel Phillimore is maintaining his connection with the Survey of India by preparing a series of Record Volumes dealing with its early history. He deserves the gratitude of the Department for undertaking this valuable work, for which he is eminently fitted by his intimate knowledge of the Department and its traditions.

SURVEY OF INDIA

GEODETIC REPORT

1934

PUBLISHED BY ORDER OF
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Charts and Plates—(*concld.*)

INTRODUCTION

1. The year 1933–34 has been a satisfactory one for the Geodetic Branch of the Survey of India, and it has been found possible to undertake a large amount of geodetic work.

2. *Base-lines.*—(Chapter I). Three new base-lines have been measured and extended, one in Baluchistān, one at Poona and one in Assam. This completes the present programme of modern base-lines.

The invar wires were re-standardized at Dehra Dūn between the measurement of each base-line. In contrast to the previous year, they have maintained their lengths well. The 4-metre invar bar by which the wires are standardized has been recompared with the nickel and silica 1-metre standards, and has been found to have grown by 0·5 in 1,000,000 since 1930, a satisfactorily small amount (Chapter VII, para 66).

3. *Triangulation.*—(Chapter I, para 8). No triangulation has been carried out except the extensions of the base-lines, but a primary series to replace the Assam Valley secondary series has been reconnoitred. It is hoped to observe it in 1934–35, and to extend it through independent Nāga territory to longitude 96° in 1935–36, and thence south to join up with the Upper Irrawaddy and Mandalay Meridional series in Burma.

Chapter I, para 9 contains some discussion on the best time of day for the observation of horizontal angles. It is concluded that there is little to choose between the different times of day, except that the afternoon is to be avoided at stations in absolutely flat plains or where bad grazes occur for other reasons. It is of course best to observe at the greatest possible variety of times.

4. *Levelling.*—(Chapter II). The Burma levelling has been carried up to the Siamese frontier in latitude 21°, longitude 100°, and a new line has been run from Mandalay to Lashio and beyond, to check the triangulated heights of the Great Salween series. No progress has been made with the high precision level net in India, but the 1934–35 programme contains provision for two detachments on this work.

Secondary levelling was carried out in the area disturbed by the 1930 Pegu (Burma) earthquake, but no notable changes of level were found. A considerable amount of secondary and tertiary levelling was carried out in Bihār to record possible changes after the great earthquake of 15th Jan. All bench marks were found to have sunk, some by as much as 4 feet. This levelling, and the possible connection between the earthquake and the apparent changes of level found in this area in previous years, is discussed in Chapter II, para 14. Further levelling in this area will be carried out in 1934–35.

5. *Gravity*.—(Chapter III). The Pendulum detachment, after a long tour down the west coast of India, completed an extensive programme in Ceylon and then, thanks to facilities kindly afforded by Lt.-Colonel R. B. Seymour Sewell, C.I.E., F.R.S., leader of the John Murray Expedition, did a series of observations in the Maldive and Laccadive Islands.

Gravity results in Ceylon show a satisfactory agreement with the geology. They suggest however that the tilted syncline, which is the main feature of the geological structure of the island is not symmetrical, but has been distorted by a disturbance in the Adam's Peak region. It is hoped that geologists will investigate this.

In the Maldives gravity data cannot lead to a definite value for the thickness of the coral. The results are examined in the light of various assumptions, and lead to conclusions in agreement with the subsidence theory of coral island formation whether isostasy is accepted or not. If, however, the subsidence is due to isostatic adjustment then the subsidence has been nearly three times greater than that required if isostasy is not accepted.

Work at Minicoy leads to the interesting conclusion that the Laccadive Islands are tectonically distinct from the Maldive Islands. It must be admitted that this is based on very scanty data, but it appears to be supported by data on the west coast of India and by the topography of the islands.

In the field season of 1934–35 the programme of pendulum observations includes Cutch and part of Rājputāna.

6. *Deviation of the vertical*.—(Chapter IV). Two detachments were employed on tracing sections of the geoid by means of stations at close intervals. One detachment, observing both components of the deviation, worked from the Assam-Burma frontier through Bengal to Bihār. In 1934–35 it is hoped to extend this section to near Agra, and also to observe in Sind and Baluchistān. The whole section from Persia to Indo-China should be completed in 1935–36.

The second detachment, observing latitude only, worked between Cape Comorin and Hyderābād (Deccan). It is hoped to extend this section up to Agra in 1934–35. These observations considerably modify the form of the geoid in southern India as hitherto shown on our charts.

The observations of recent years in India and Burma, and also some communicated by the Siamese Survey Department, have been used to draw an extended chart of the geoid (Chapter IV, paras 47 and 48). The resulting figure shows remarkable departures from the curvature of the International spheroid, which cannot be remedied by any change in the arbitrary constants at the origin. Thus the radius of curvature of an east-to-west section 2,500 miles long is 700 feet greater than that of the spheroid, while the curvature of a 2,000-mile meridional section is 1,500 feet less than that of the spheroid. Also, the geoid in the south of Siam appears likely to be elevated 100 feet above any spheroid which at all closely fits these two arcs. It appears that these irregularities can only be caused by widespread departures from isostatic equilibrium. More latitude observations in Siam along meridian 99° or 100° would be of great value.

7. *Dehra Dūn Observatory.*—The Observatory took part in the international longitude project of October and November 1933, with three transits of different kinds operated in turn by four different observers (Chapter VI). The result, $5^h\ 12^m\ 11^s{\cdot}78$, agrees well with previous values, and the different observers agreed well among themselves when using the same instrument, but the three instruments show systematic discrepancies (a range of $0^s{\cdot}13$), and the probable error of the mean must be reckoned to be as much as $\pm\ 0^s{\cdot}03$. This is much larger than the figure usually quoted for observations of this extent, but it must be remarked that a very much smaller figure would probably have been given if only a single instrument had been in use.

Dr. de Graaff Hunter's new type of "shutter" transit has given promising results.

The regular longitude observations were carried on during the rest of the year, as also the usual magnetic, meteorological and seismographical observations. No progress has yet been made towards starting a latitude variation programme at Agra (Chapter VII, paras 66 to 70).

8. *Tide predictions.*—(Chapter V, paras 55 to 59). The Tide-Tables of the Indian Ocean for 1935 have been prepared as usual.

9. *Stokes' formula.*—(Chapter VIII). Stokes' formula relating the intensity of gravity and the shape of the geoid provides a means whereby the reference datums of disconnected geodetic surveys could be brought into terms with each other if sufficient gravity data were available. In Chapter VIII Mr. Gulatee discusses the precision with which this can be done. He concludes that the vertical separation between geoid and spheroid at the origin cannot be usefully determined, but that the deviation of the vertical could be determined within a second if it could be assumed that there exist no anomalies representable by low order harmonics (such as the 2nd, 3rd and 4th). The possibility of the existence of a second harmonic, however, with an amplitude of as much as 0·020 gal introduces doubt which may amount to several seconds in an extreme case.

10. *Non-departmental publications.*—Several papers relating to geodesy in India have been published in European and other periodicals. The Bihār earthquake, and the movements of ground level in Bengal recorded in Geodetic Report Vol. VI have led to some discussion(1) (2) (3). A paper on the computation of gravity anomalies by the late Mr. G. P. Rao, formerly a Geodetic Computer of the Survey of India has appeared in the Journal of the Indian Mathematical Society(4). Dr. W. Bowie has written a paper comparing isostatic conditions in India with America and Canada(5). A reply to this by Major Glennie will appear shortly in the same periodical. Mr. B. L. Gulatee has written an article on the deflection of the plumb-line in the Hydrographic Review(6).

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(1) *The Indian Earthquake (1934) Area*, by Dr. J. de Graaff Hunter, C. I. E. (*Nature* Vol. 133, Feb. 17/34).

(2) *Ground levels in Bihār in relation to the Earthquake of Jan. 15, 1934*, by Colonel Sir Sidney Burrard, F. R. S. (*Nature* Vol. 133, April 14/34).

(3) *Changing ground levels in Bengal*, by Dr. J. de Graaff Hunter. (*R. E. Journal* Vol. XLVIII, June/34).

(4) *On a method of Computing Gravity Anomalies*, by G. P. Rao, M. A. (*Journal of the Indian Math. Soc.* Vol. 20).

(5) *A comparison of Isostasy in India and in the United States and Southern Canada*, by Dr. W. Bowie. (*Gerlands Beiträge Zur Geophysik*, 41, Heft 2, 1934).

(6) *Deflection of the Plumb-Line*, by B. L. Gulatee, M. A. (*Hydrographic Review* Vol. X, No. 2., Nov. 1933).

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

PERSONNEL* OF THE GEODETIC BRANCH, 1933–34.

Director, Geodetic Branch

COLONEL R. H. PHILLIMORE, D.S.O., to 18th Feb. 1934
LT.-COLONEL C. G. LEWIS, O.B.E., R.E., from 19th Feb. to 21st June 1934
LT.-COLONEL C. M. THOMPSON, I.A., from 22nd June 1934

OFFICE OF THE DIRECTOR, GEODETIC BRANCH

Ministerial Service

Head Assistant

Mr. Diwan Chand

Assistants

Mr. Krishna Lal Sharma
20 Clerks.

COMPUTING AND TIDAL PARTY

(RECORDS AND RESEARCH)

Class I Service

Captain G. Bomford, R.E., in charge, to 7th Nov. 1933 and from 19th Mar. 1934.

LT.-Colonel C. G. Lewis, O.B.E., R.E., in charge, from 8th to 25th Nov. 1933.

(Charge was held by the Director, Geodetic Branch from 26th Nov. 1933 to 18th March 1934).

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

OBSERVATORY SECTION

Class II Service

Mr. R. B. Mathur, B.A. (Tidal Assistant to 30th Nov. 1933).

Magnetic Observer

Mr. Shyam Narain, B.SC.

Lower Subordinate Service

5 Computers.

TIDAL SECTION

Upper Subordinate Service

Mr. H. C. Banerjea, B.A. (Tidal Assistant from 1st Dec. 1933).

Lower Subordinate Service

9 Computers.

COMPUTING SECTION

Upper Subordinate Service

Mr. M. Chatterji (Head Computer).
Mr. H. C. Deva, B.A.
Mr. A. K. Maitra, B.A.
Mr. C. B. Madan, B.A.

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 from 7th June 1934.

Lower Subordinate Service

6 Draftsmen.

No. 14 PARTY (GEOPHYSICAL)

Class I Service

Major E. A. Glennie, D.S.O., R.E., in charge.

Class II Service

Mr. R. B. Mathur, B.A., from 1st Dec. 1933.

Lower Subordinate Service

5 Computers.

---

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

No. 15 PARTY (TRIANGULATION AND LEVELLING)

Class I Service

Captain G. Bomford, R.E., in charge.

Class II Service

Mr. N. N. Chuckerbutty, L.C.E.
Mr. M. N. A. Hashmie, B.A.

Upper Subordinate Service

Mr. A. A. S. Matlub Ahmad, from 15th Feb. to 6th June 1934.
Mr. J. N. Kohli, to 15th Aug. 1934.

Upper Subordinate Service—(contd.)

Mr. B. P. Rundev, from 3rd Mar. to 6th June 1934.
Mr. Mohd. Faizul Hasan.
Mr. P. K. Chowdhury, to 15th Aug. 1934.
Mr. I. D. Suri, from 27th Feb. to 6th June 1934.
Mr. L. R. Howard.
Mr. Mohd. Zafar Ali Qureshi.

Lower Subordinate Service

6 Computers and 2 Clerks. This excludes 13 Lower Subordinates temporarily employed on Bihār levelling.

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

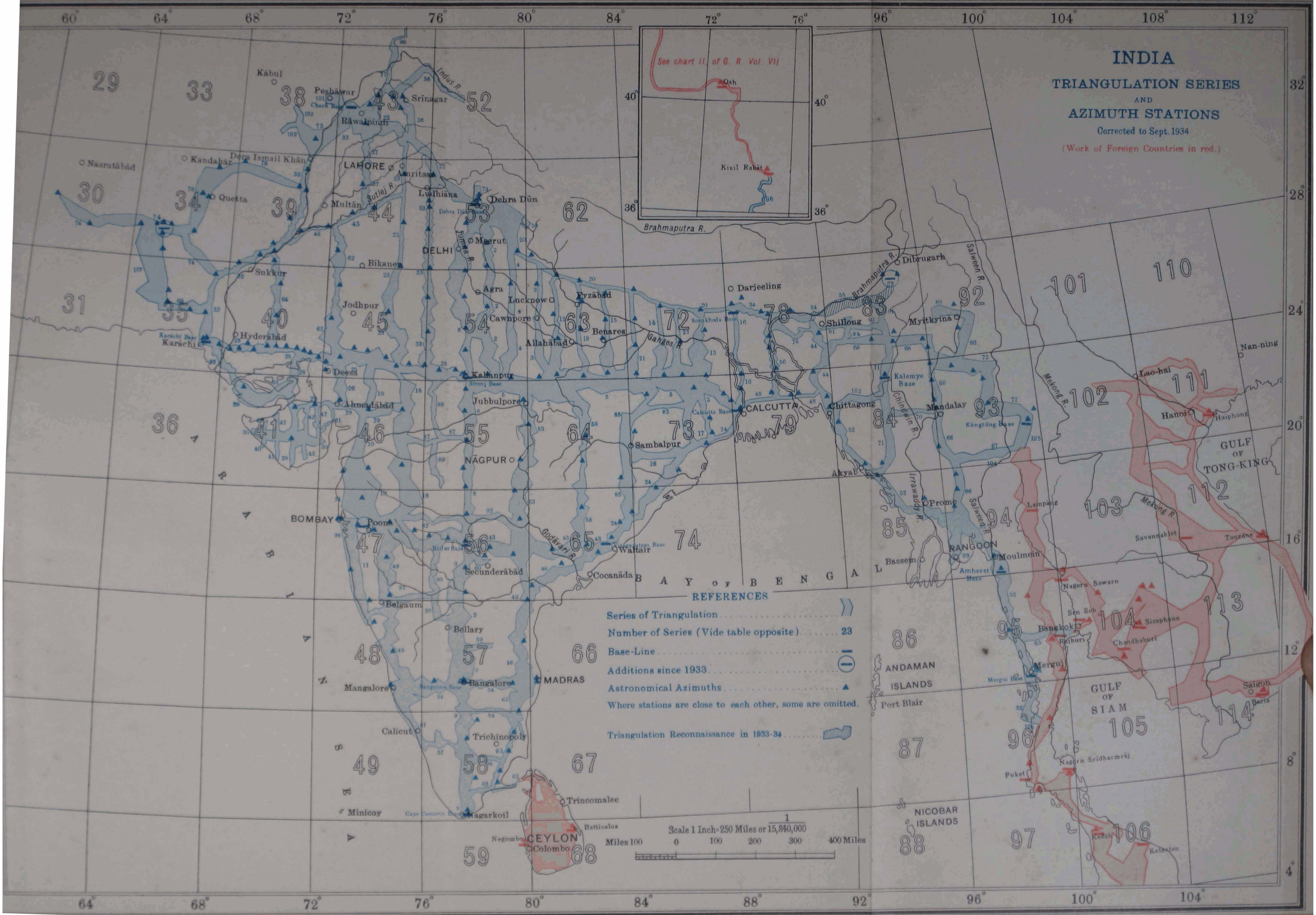
No.	Name of Series	Seasons	± *m*	± M
1	South Pārasnāth Mer. ...	1831-39	3·308	3·26
2	Budhon Meridional ...	1833-43	2·242	2·46
3	*Amūa Meridional* ...	1834-38	1·647	1·88
4	*Rangīr Meridional* ...	1834-64	1·643	1·79
5	*Calcutta Longitudinal* ...	1834-69	0·369	0·32
6	*Great Arc Meridional, Section 24°-30°* ...	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	0·806	0·87
39	(Cutch) Coast Line ...	1856-60	0·975	1·47
40	Kāthiāwār Meridional No. 1 ...	1858-59	0·930	1·51
41	Kāthiāwār Meridional No. 2 ...	1859-60	1·247	1·75
42	Kāthiāwār Meridional No. 3 ...	1859-60	0·969	1·48
43	*Bidar 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	0·96
60	Hyderābād ...	1871-72	1·405	1·56
61	Malabar Coast ...	1871,74,80	1·532	1·82
62	Jodhpur Meridional ...	1873-76	0·291	0·32
63	*South East Coast* ...	1875-79	0·522	0·65
64	Eastern Sind Mer. ...	1876-81	0·244	0·30
65	Siam Branch Triangulation ...	1878-81	3·711	4·34
66	Mandalay Meridional ...	1889-95	0·418	0·35
67	Mong Hsat * ...	1891-93	3·054	3·01
68	Manipur Longitudinal ...	1894-99	0·453	0·36
69	Makrān Longitudinal ...	1895-97	0·285	0·26
70	Mandalay Lon ...	1899-1909	1·696	1·96
71	Manipur Mer. ...	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	1·78
85	Sambalpur Meridional ...	1911-14	0·250	0·21
86	Indo-Russian Connection	1912-13	2·790	3·92
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	0·96
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.

Chart I


INDIA
TRIANGULATION SERIES
AND
AZIMUTH STATIONS
Corrected to Sept. 1934
(Work of Foreign Countries in red.)
See chart II. of G. R. Vol. VII
Osh
Kisil Rabat
REFERENCES
Series of Triangulation
Number of Series (Vide table opposite) 23
Base-Line
Additions since 1933
Astronomical Azimuths
Where stations are close to each other, some are omitted.
Triangulation Reconnaissance in 1933-34
Scale 1 Inch=250 Miles or 1/15,840,000
Miles 100 0 100 200 300 400 Miles
Kābul
Peshāwar
Srīnagar
Rāwalpindi
Indus R.
Nasratābād
Kandahār
Dera Ismail Khān
LAHORE
Amritsar
Quetta
Multān
Sutlej R.
Ludhiana
Dehra Dūn
Brahmaputra R.
Meerut
DELHI
Jumna R.
Bikaner
Sukkur
Agra
Lucknow
Fyzābād
Darjeeling
Dibrugarh
Salween R.
Jodhpur
Cawnpore
Benares
Shillong
Myitkyina
Hyderābād
Karachi
Allahābād
Ganges R.
Deesa
Kalianpur
Jubbulpore
Kalemyo Base
Ahmadābād
CALCUTTA
Chittagong
Mandalay
Mekong R.
Lao-hai
Hanoi
Haiphong
Nan-ning
NĀGPUR
Sambalpur
Chindwin R.
GULF OF TONG-KING
Akyab
Irrawaddy R.
Prome
BOMBAY
Poona
Godāvari R.
Waltair
RANGOON
Moulmein
Lampang
Savannakhet
Tourane
Secunderābād
Cocanāda
Bassein
Amherst Base
Nagorn Sawarn
BAY OF BENGAL
Belgaum
Bellary
Bangkok
Rajburi
Sisophone
Chandhaburi
ANDAMAN ISLANDS
Port Blair
Mergui
MADRAS
Mangalore
Bangalore
GULF OF SIAM
Saigon
Baria
Calicut
Trichinopoly
Nagorn Sridharmraj
Puket
Minicoy
Nagarkoil
Trincomalee
Batticaloa
NICOBAR ISLANDS
CEYLON
Colombo
Negombo
Kedah
Kelantan
ARABIAN SEA

CHAPTER I

TRIANGULATION AND BASE MEASUREMENT

BY CAPTAIN G. BOMFORD, R.E.

1. **Summary.**—The season's programme consisted of three base-lines with their extensions, and reconnaissance for a primary series to be observed next year in place of the existing Assam Valley secondary series. The base-lines are at Padag near Dālbandin in Baluchistān, at Poona, and at Namtiali near Sibsāgar in Assam. The invar wires were brought back to Dehra Dūn and re-standardized between each base-line. They held their lengths satisfactorily. (See Chapter VII).

Consideration has been given to the question of what is the best time of day for observing horizontal angles. The subject is discussed in para 9.

2. **Padag base-line.**—The base-line is 10 miles long lying across the side Pulchotau H.S.—Kopahdar H.S. of the Kalāt Longitudinal series (see Chart II). The easternmost 7 miles are on hard bare clay, and the remaining three miles are on gently sloping gravel. It is divided into two (unequal) halves by the centre station. The centre and two terminal stations are almost exactly in line, and are built up about 4 feet above the plain. At the west terminal the ground is 60 feet above the other two stations, so that the triangulation ray along the base is reasonably clear of the ground except during the midday minimum refraction.

In this base and the other two, the system of measurement was by invar wires in catenary, as in other recent base-lines. Wires Nos. 247 and 248 were used for the east-to-west measure, and 244 and 249 for the other. No. 252 was used as a daily standard of comparison, and 243 was used in addition every third or fourth day only.

Before measurement is started, the positions for the tripods are laid out by marks on pegs, or on slats nailed to pegs, accurately aligned and at approximately the right intervals. The spirit-levelling is carried along these pegs before and after the measurement. During measurement an assistant measures the heights of the tripods above the pegs, but when the rise or fall in a bay exceeds two feet this is checked by direct levelling between the tops of the tripods. Comparisons with the field standard have been made daily, some before and some after work, in such proportion as to make the mean temperature of comparison the same as the mean temperature at which the bases have been measured.

The Padag base-line was reconnoitred and laid out by Messrs. L. R. Howard and P. K. Chowdhury with about 20 *khalāsis* between 28th Nov. and 22nd Dec. The extension was observed by Captain Bomford between 12th and 22nd Dec. The measurement was done by Captain Bomford and Lieut. C. A. Biddle, R. E. assisted by Mr. Chowdhury, one recorder, and about 40 *khalāsis*, between 23rd Dec. and 4th Jan., the average out-turn being 110 bays a day. Temperature conditions were rather extreme, working temperatures varying from 27°C on 26th Dec. to – 6°C on 4th Jan., but conditions were otherwise good. Water was brought by train from Ahmedwal. The results are given in Table 1.

TABLE 1.—*Padag Base-line.*

Section No.	East to West		West to East		Mean value of each section	
	No. 248	No. 247	No. 244	No. 249		
1	1911·017	1911·018	1911·013	1911·015	1911·016	metres
2	1441·824	1441·825	1441·821	1441·825	1441·824	,,
3	1441·071	1441·072	1441·069	1441·069	1441·070	,,
Total E. Half	4793·912	4793·915	4793·903	4793·909	4793·910	,,
4	1442·623	1442·626	1442·623	1442·626	1442·625	,,
5	1442·779	1442·781	1442·779	1442·780	1442·780	,,
6	1442·454	1442·454	1442·451	1442·455	1442·453	,,
7	1442·464	1442·466	1442·464	1442·464	1442·464	,,
8	1466·653	1466·655	1466·652	1466·654	1466·654	,,
9	1442·445	1442·446	1442·445	1442·445	1442·445	,,
10	1105·870	1105·872	1105·870	1105·872	1105·871	,,
11	1131·606	1131·608	1131·606	1131·606	1131·607	,,
Total W. Half	10,916·894	10,916·908	10,916·890	10,916·902	10,916·899	,,
Length of Base	15,710·806	15,710·823	15,710·793	15,710·811	15,710·809	metres

Length of Base from East to West (Wires 248 and 247) = 15,710·815 metres.
Length of Base from West to East (Wires 244 and 249) = 15,710·802 metres.

The discrepancy between the east-to-west and west-to-east measures is 1 in 1,200,000. By direct measurement the log of the ratio of the two halves is 9·6425909 and by triangulation 9·6425912, which by chance is nearly identical.

The measured length of the base is reduced to Indian feet by the relations

1 standard yard = 0·914 399 20 metres

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

and is 51544·918 Indian feet.

The average spheroidal height of the Padag base is 2,817 feet, viz., 2,680 feet above sea-level *plus* 137 feet, the estimated height of the geoid above Everest's spheroid. Reduced to spheroid level, the length of the base is then 51537·980 Indian feet or 4·7121274 log feet.

The triangulated log length of the base-line in terms of the Kalāt Longitudinal series is 4·7121302, so that the discrepancy measured *minus* triangulated is −0·0000028.

In view of the early morning temperatures being so much lower than those at which the coefficients of expansion of the invar wires had been determined, a determination was made on 30th Dec. by the careful measurement of nine bays with all six wires during the cold of the morning and again in the afternoon. The results were as follows:—

Increases in mm. per 24 metres per °C under 10 kg. tension.

Wire Nos.	243	244	247	248	249	252
Previously accepted	+ ·0054	+ ·0058	− ·0009	− ·0028	− ·0044	− ·0050
December 1933	+ ·0040	+ ·0047	− ·0036	− ·0060	− ·0030	− ·0066

The day selected for the work had an unfortunately low range of temperature, and the mean difference between the morning and midday measures was only 9°C, whereas 15°C or 20°C had been hoped for. The results, however, agree well with the old values, and the latter have been accepted unchanged. The worst discrepancy (in No. 248) is only 1 in 1,000,000 per 8°C, and the mean of the four working wires differs by 1 in 1,000,000 per 17°C. The difference between the mean temperature of base measurement at Padag and of the two related standardizations at Dehra Dūn was 7°C, so the temperature coefficients are considered to be well enough determined. At other base-lines the temperature differences have been much less.

* See Supplement to Geodetic Report Vol. VI, page vi.

The base extension was carried out with 5½-inch Wild theodolite No. 59. Three face left or three face right measures were made on 28 zeros, the small increase on the usual programme being to allow of observations at four different times of day, as described in para 9. The average triangular error was 1″·11.

3. Poona base-line.—The base-line is 6½ miles long and is connected to the side Dighi H.S.—Māndvi H.S. of the Bombay Longitudinal series, through two new hill stations (see Chart II). The line is across undulating country, covered with grass and dry cultivation. It is divided into two halves by a centre station at which the two terminals subtend an angle of 175°. The ground falls quite steeply in front of the west and centre stations, which have been built up to a height of 4 feet, but a low crest in front of the east terminal necessitated the building of a tower 14 feet high, of the type described in the Geodetic Report for 1933.

In 1840 Lieut. W.S. Jacob of the Bombay Engineers prepared a base-line at Poona and connected its terminals by preliminary secondary triangulation, but it was never measured. The east terminal of the present base is identical with Jacob's station, but the west terminal is about 200 yards west of his, in what appears to be a rather better site.

The line and the new stations were prepared by Mr. Howard between 23rd Dec. and 18th Jan. The measurement was carried out by Captain Bomford and Mr. Chowdhury assisted by Mr. Howard between 19th and 27th Jan. and the extension was observed by Captain Bomford between 28th Jan. and 11th Feb. The system of work was the same as at the Padag base, but the rougher ground reduced the average daily out-turn to 100 bays a day. The results are given in Table 2.

The discrepancy between the east-to-west and west-to-east measures is 1 in 10,000,000. By direct measurement the log of the ratio of the two halves is 0·2647366, and by triangulation 0·2647320, a discrepancy of 1 in 100,000. The measured ratio is of course accepted.

The measured lengths of the two halves of the base in Indian feet are 22572·536 and 12270·038. The mean spheroidal heights of the two halves are 1,826 and 1,932 feet, viz., 1,871 and 1,977 feet above sea-level *minus* 45 feet, the estimated height of the geoid below Everest's spheroid. Reduced to spheroid level the lengths of the two halves of the base are 22570·565 and 12268·904 Indian feet, or 4·3535424 and 4·0888058 log feet.

The triangulated log lengths of the two halves, in terms of the Bombay Longitudinal series are 4·3535421 and 4·0888055, so that the discrepancy measured *minus* triangulated is +0·0000003. The smallness of this figure speaks well for the accuracy of our predecessors' work (1862–63), and also for their judgment in deciding that a base-line at Poona was not essential.

TABLE 2.—*Poona Base-line.*

Section No.	East to West No. 247	East to West No. 248	West to East No. 244	West to East No. 249	Mean value of each section	
1	1634·102	1634·101	1634·103	1634·104	1634·102	metres
2	1610·130	1610·129	1610·126	1610·128	1610·128	,,
3	1609·866	1609·866	1609·864	1609·868	1609·866	,,
4	2025·977	2025·979	2025·974	2025·977	2025·977	,,
Total E. Half	6880·075	6880·075	6880·067	6880·077	6880·073	,,
5	1921·039	1921·038	1921·038	1921·040	1921·039	,,
6	1818·849	1818·849	1818·849	1818·851	1818·849	,,
Total W. Half	3739·888	3739·887	3739·887	3739·891	3739·888	,,
Sum of two halves	10,619·963	10,619·962	10,619·954	10,619·968	10,619·961	metres

Sum of two halves from East to West (Wires 247 and 248) = 10,619·962 metres.
Sum of two halves from West to East (Wires 244 and 249) = 10,619·961 metres.

The base extension was carried out with 5½-inch Wild theodolite No. 59, on the same system as that at Padag. The average triangular error was 0″·72. At this base extension the small size of the hills and the freedom from any astronomical observations made it possible to adopt the following routine without interruption throughout the seven stations:—Leave first station in the morning: arrive next station that afternoon: observe four zeros (three measures FR or three FL on each) that evening and four that night: observe six zeros next morning, six in the afternoon, four that evening and four that night: march to the second station and start observations there next day. The weather was, of course, fine.

4. **Namtiali base-line.**—The base-line is 7 miles long, and is connected to four stations on the adjacent hills, of which two will form part of the new Assam Valley series which is to be observed in 1934–35 (see Chart II). The line lies in flat paddy fields. It is divided into two halves by a centre station at which the two terminals subtend an angle of 170°. The three stations are towers 10 or 12 feet high, of the type described in Geodetic Report 1933, Chapter I. Some difficulty was experienced in finding a line clear of village sites and bamboo jungle, and Rs. 600 was spent on compensation. The line is crossed by a few small streams, but it was not found necessary to use the 72-metre wire.

The line was cleared and the new stations built by Mr. M.N.A. Hashmie between 18th Oct. and 27th Nov., and Mr. Hashmie observed the extension between 28th Nov. and 25th Dec. Mr. Howard laid out the pegs between 6th and 24th Feb. The base was measured by Captain Bomford and Mr. Chowdhury assisted by Mr. Howard, between 25th Feb. and 4th March. The system of work was the same as at Padag and Poona, but the flat ground and an equable temperature raised the average out-turn to 120 bays a day. The results are given in Table 3.

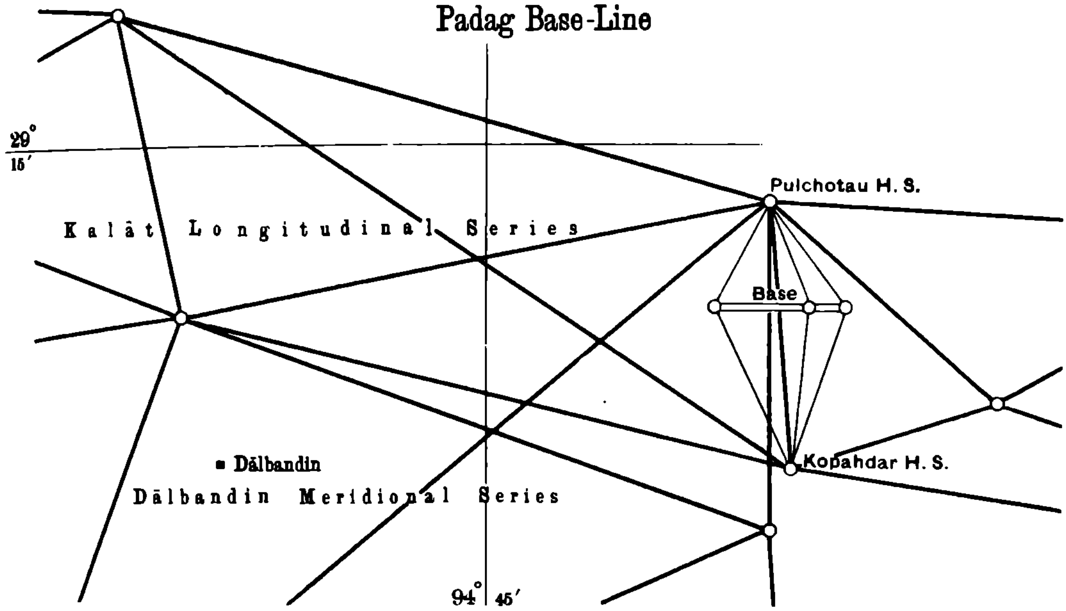
TABLE 3.—*Namtiali Base-line.*

Section No.	East to West		West to East		Mean value of each section	
	No. 248	No. 247	No. 244	No. 249		
1	1607·584	1607·586	1607·581	1607·586	1607·584	metres
2	1606·890	1606·891	1606·885	1606·889	1606·889	..
3	1606·684	1606·685	1606·683	1606·687	1606·685	..
4	1178·295	1178·296	1178·292	1178·296	1178·295	..
Total E. Half	5999·453	5999·458	5999·441	5999·458	5999·453	..
5	1604·784	1604·785	1604·781	1604·785	1604·784	..
6	1567·185	1567·186	1567·184	1567·188	1567·186	..
7	1632·176	1632·179	1632·174	1632·177	1632·176	..
8	771·308	771·309	771·307	771·309	771·308	..
Total W. Half	5575·453	5575·459	5575·446	5575·459	5575·454	..
Sum of two halves	11,574·906	11,574·917	11,574·887	11,574·917	11,574·907	metres

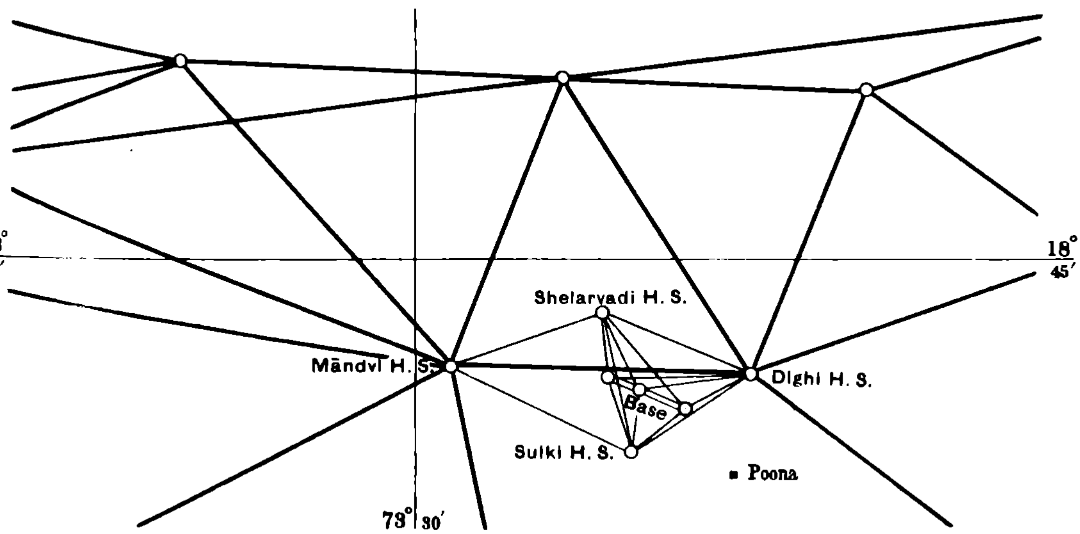
Sum of two halves from East to West (Wires 248 and 247) = 11,574·911 metres.
Sum of two halves from West to East (Wires 244 and 249) = 11,574·902 metres.

The discrepancy between the east-to-west and west-to-east measures is 1 in 1,300,000. By direct measurement the log of the ratio of the two halves is 9·9681686, and by triangulation 9·9681703, a discrepancy of 1 in 250,000.

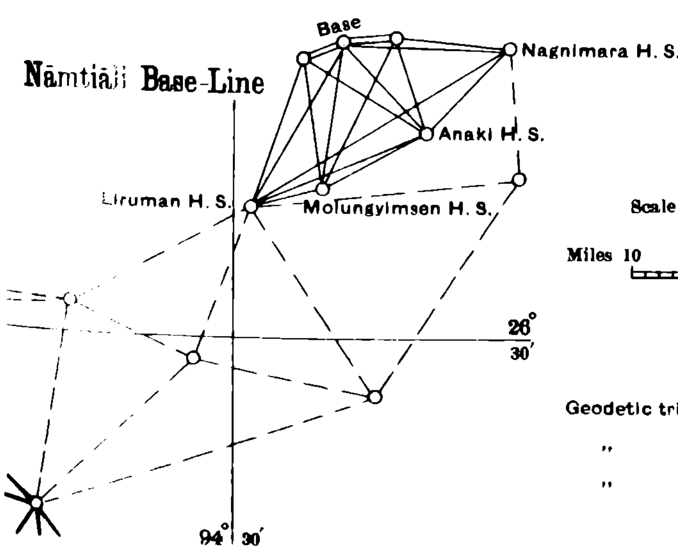
Padag Base-Line



Poona Base-Line



Nāmtiāli Base-Line



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

Miles 10 5 0 10 20 Miles

Geodetic triangulation of previous years

" " " 1933-34

" " for 1934-35

The measured lengths of the two halves in Indian feet are 19683·347 (east) and 18292·267 (west). The mean spheroidal heights of the two halves are 499 and 500 feet, viz., 324 and 325 feet above sea-level *plus* 175 feet, the estimated height* of the geoid above Everest's spheroid. Reduced to spheroid level the lengths of the two halves of the base are 19682·878 and 18291·830 Indian feet or 4·2940886 and 4·2622572 log feet. No comparison with triangulation is at present available.

The base extension was carried out with 5½-inch Wild theodolite No. 130, on 20 zeros (3 FL or 3 FR on each). The average triangular error was 0″·46, an exceptionally small figure.

5. **Accuracy.**—From the measures given by the four independent wires in Tables 1, 2 and 3, the probable errors of the base-lines might be deduced as:—

Padag	1:3,700,000
Poona	1:5,200,000
Namtiali	1:2,300,000.

Figures deduced in this way are, however, notoriously unreliable for they make no allowance for the error in the standard by which the lengths of the wires are determined, or for error in the triangulation which extends the base to a side of normal length. In Geodetic Report Vol. VII (page 20) it was concluded that the mean of the errors of standardization of the wires in 1930 was probably less than 1:1,000,000, but that it might be 1½:1,000,000. The standardizations described in Chapter VII of this report are rather more satisfactory, but the possibility of an error of 1:1,000,000 cannot be denied, and this possible error (or even something a little larger) is a better guide to the accuracy of the actual measurement than the probable errors given above. This figure of 1:1,000,000 is not well determined, but it is of little consequence, for the probable error of the extension is certainly larger, and is the ruling factor in the accuracy of the base as a whole.

The average corrections applied to the observed angles when grinding the three base extensions have been 0″·46, 0″·34 and 0″·50 at Padag, Poona and Namtiali respectively, which being multiplied by 0·845 give 0″·39, 0″·29 and 0″·42, for the probable errors of unadjusted angles at the three bases. Given the probable error of an unadjusted angle, the probable error of the ratio of

* Data are rather scanty, and this height may possibly be in error by 50 feet (1 in 400,000 of the earth's radius). The reduction to sea-level must be reconsidered when the azimuth observations of the new Assam Valley series have provided fuller information about the shape of the geoid in Assam.

any two sides is determinate, but in complicated figures the computation is very long*. The following discussion is not rigorous but is thought to be reasonably accurate.

For the probable errors of the adjusted angles a rough rule is

$$\text{Adjusted } p.e. = \text{unadjusted } p.e. \times \sqrt{\frac{t-n}{t}}$$

where t is the number of angles observed and n is the number of equations of condition †.

At the three bases, the fractions under the square root are 5/16, 9/30 and 9/27 respectively, so that the average probable errors of adjusted angles are 0″·22, 0″·16 and 0″·24. These probable errors apply to the rather small, partial, angles whose errors are determined by the grinding. The larger angles on which the extension primarily depends average about twice the size of the partial angles, and their probable error may reasonably be taken as $\sqrt{2}$ times as much.

Given the probable error of an adjusted angle, an approximate value for the probable error of the final side is easily obtained, (assuming the base-line itself to be errorless). At Padag, for instance, where the extension is very symmetrical, the error of the side Pulchotau–Kopahdar evidently depends only on the errors in the two angles West-Pulchotau-East and West-Kopahdar-East, and is easily expressed in terms of them. The other two figures are rather more complicated, but can be treated on similar lines and the results are:—

Probable error of final side at	Padag	= 1:650,000.
,, ,, ,, ,,	Poona	= 1:550,000.
,, ,, ,, ,,	Namtiali	= 1:580,000.

As remarked above, these figures are large compared with the probable errors of base measurement (being about twice the "possible errors"), and so approximately represent the total probable errors of measurement and extension combined.

6. **1930–33 Base-lines.**—The lengths of the three base-lines in Burma described in last year's report require reduction by one part in a million on account of the 4-metre invar standard bar having since been shown to have grown by a less amount since 1930 than had been expected. (See Chapter VII of this report, para 66 *d*). The lengths of these bases, and of the 1930–31 Kengtūng base, as reduced to spheroid level, require further modification now that the form of the geoid in Burma is better determined (see Chapter IV). The height of the geoid above Everest's spheroid at Kēngtūng, Mergui, Amherst and Kalemyo is now estimated to be

* See Dr. de Graaff Hunter in Geodetic Report Vol. VII, p. 144. At Poona a determinant of 22 rows would be involved.

† G.T. Vol. II. p. 195.

265, 305, 265 and 120 feet respectively in place of the previous estimates of 250, 300, 254 and 150 feet. Revised figures for these base-lines are given below :—

	Kēngtūng	Mergui	Amherst	Kalemyo (N. half)	Kalemyo (S. half)
Measured length (Indian feet) ...	38,463·99	16,290·22	44,561·23	19,802·33	14,748·36
Mean height above spheroid (feet)	2815	323	279	593	542
Reduced length (Indian feet) ...	38,458·79	16,289·97	44,560·63	19,801·77	14,747·98
Reduced length (log feet) ...	4·5849956	4·2119202	4·6489513	4·2967040	4·1687325
Discrepancy measured *minus* triangulated. (Burma grinding 1916)	−0·0000080 } * +0·0000063 }	+0·0000047	+0·0000075	+0·0000128 (N. and S. halves together)	

7. **Astronomical observations.**—Astronomical observations for azimuth and latitude were made at the stations of the Padag and Namtiali base-lines and their extensions, in order to calculate corrections to horizontal angles on account of the dislevelment of the theodolite. The largest correction was $1''\cdot21$. The resulting values of the deviation of the vertical are given in Chapter IV, Table 5. These observations were not made at Poona, as the small angles of elevation between the stations there would have caused the resulting corrections to have been much smaller.

Latitudes observed with Wild theodolite No. 59 again showed the persistent difference between north and south stars noticed in Geodetic Report Vol. VIII, page 69, in spite of the reflecting prism being used at the eyepiece, so the explanation there suggested (that the discrepancy is due to parallax) is not likely to be correct. The effect was not so noticeable in the observations made with No. 130.

8. **Assam Valley series.**—The existing Assam Valley series was weakly observed as a secondary series in 1867–78 ($m = 1\cdot69$), and in its eastern half where it leaves the hills, the triangles have very short sides. In 1934–35 it is proposed to reobserve the western half, where the triangles are of reasonable size, and to replace the eastern half by a primary series through the Nāga Hills which will connect with the Namtiali base, and which in 1935–36 it is hoped to extend through independent Nāga territory to longitude 96°, where it will turn south and eventually join the Upper Irrawaddy and Mandalay Meridional series in latitude 25°.

* In terms of the Mong Hsat and Great Salween series respectively.

In 1933–34 Mr. Hashmie, after completing the extension of the Namtiali base-line, built 6 new stations and visited, repaired and cleared 25 old ones in preparation for next year's observations (see Chart III). Work began in the Nāga Hills on 29th December, and was completed near Gauhāti on 1st March. Transport in the Nāga and Mīkīr Hills was by coolie, but motor transport was generally obtainable in the plains. Movement in the Nāga Hills was found to be easy, but the Mīkīr jungles are difficult and unhealthy.

Rain and cloud caused delay and annoyance during most months of the season, and from February there is apt to be thick haze.

9. **Best hour for horizontal angles.**—This subject was discussed in Geodetic Report Vol. V, Chapter I, where morning, evening* and night observations of four old triangulation series were separated out, and separate triangular errors were formed from each, from which was deduced the probable error of a single measure at different times of day. The results suggested that there was little to choose between night and evening observations, with a slight preference for the evening except in low rays over bare plains. Morning observations appeared to be good in jungle-covered hills, but bad in barren hills. No morning observations had been made in the low-lying series, and none in the heat of the afternoon in any of the series.

When the Padag and Poona base extensions were being observed, observations at each station were grouped into four separate times of day, with a view to further investigation of the subject. In a base-net a large number of redundant angles are observed, so that the final grinding of the figure gives a very strong measure for each angle, not entirely dependent on its direct measurement. Thus in the Padag base extension there are 11 conditions among the 16 angles observed, and at Poona there are 21 conditions among 30 angles. The selected times of day were :—

(*a*) Morning.—Sunrise to about 10.00, before helios start to "jump".

(*b*) Afternoon.—13.30 to 16.00, at the worst time of day.

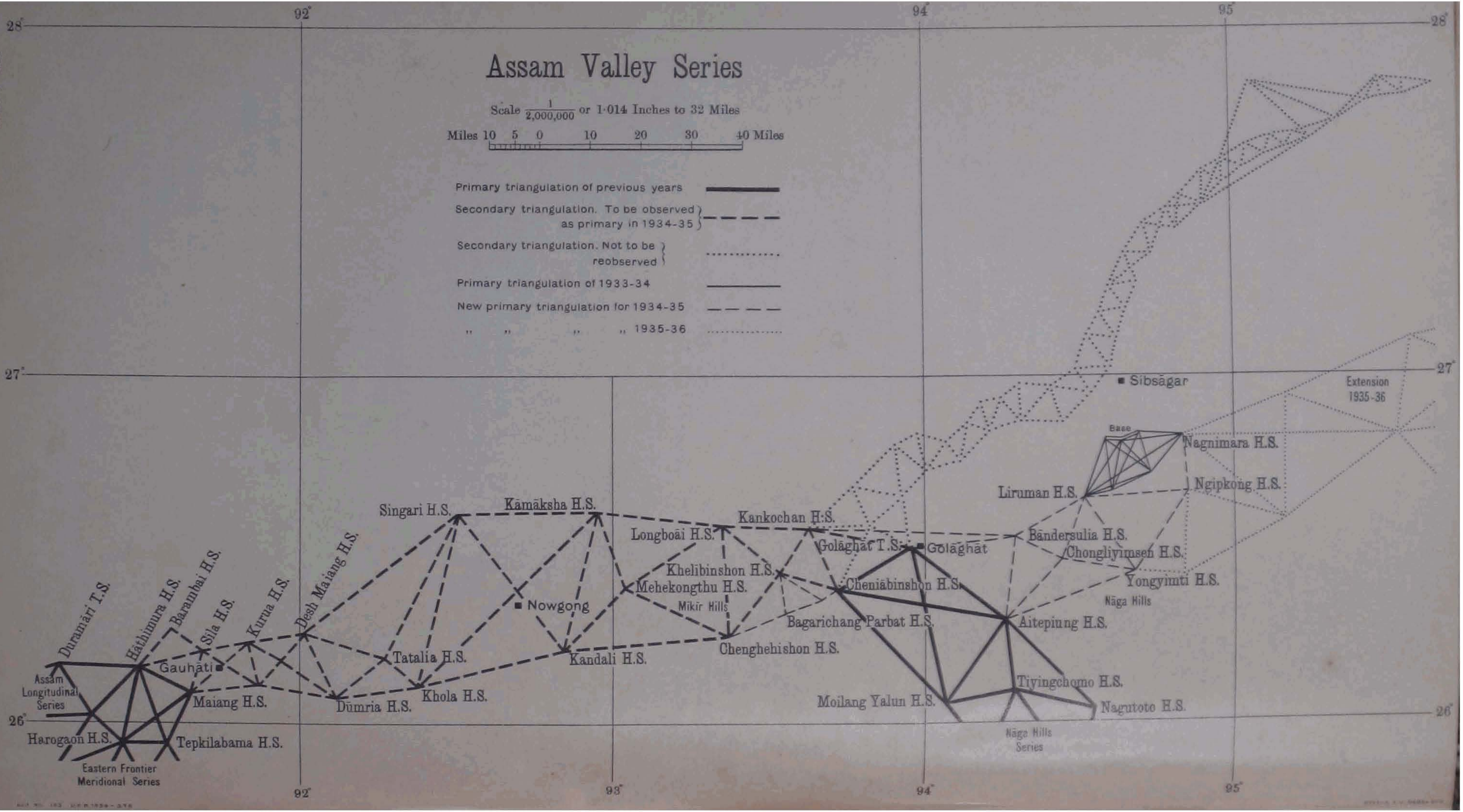
(*c*) Evening.—17.00 to sunset with helios fairly still.

(*d*) Night.—One to four hours after sunset.

At each time of day three measures of each angle were made on 6 or 8 zeros well distributed round the circle. Table 6 gives, for each angle, the observed morning, afternoon, evening and night means *minus* the general mean (spherical angle) derived from the grinding. In view of the strength of the ground figure and the

* Between 16.00 hours and sunset. This period was referred to as "afternoon" in Vol. V, but is now called "evening" to distinguish it from the period 13.30–16.00 hours which is called "afternoon" in the later part of this paragraph.

Chart III



Assam Valley Series
Scale 1/2,000,000 or 1·014 Inches to 32 Miles
Miles 10 5 0 10 20 30 40 Miles
Primary triangulation of previous years
Secondary triangulation. To be observed as primary in 1934-35
Secondary triangulation. Not to be reobserved
Primary triangulation of 1933-34
New primary triangulation for 1934-35
" " " " 1935-36
28°
92°
94°
95°
27°
26°
93°
Sibsāgar
Extension 1935-36
Base
Nagnimara H.S.
Ngipkong H.S.
Liruman H.S.
Singari H.S.
Kāmāksha H.S.
Kankochan H.S.
Longboāi H.S.
Golāghāt T.S.
Golāghāt
Bāndersulia H.S.
Chongliyimsen H.S.
Khelibinshon H.S.
Mehekongthu H.S.
Cheniābinshon H.S.
Yongyimti H.S.
Nāga Hills
Mikīr Hills
Nowgong
Bagarichang Parbat H.S.
Aitepinung H.S.
Chenghehishon H.S.
Kandali H.S.
Tatalia H.S.
Desh Maiang H.S.
Kurua H.S.
Sila H.S.
Barambai H.S.
Hāthimura H.S.
Duramāri T.S.
Gauhāti
Assam Longitudinal Series
Maiang H.S.
Dūmria H.S.
Khola H.S.
Tiyingchomo H.S.
Moilang Yalun H.S.
Nagutoto H.S.
Nāga Hills Series
Harogaon H.S.
Tepkilabama H.S.
Eastern Frontier Meridional Series

number of zeros used at each time of day, the entries in Table 6 are believed to give the error of each angle on account of horizontal refraction, with a probable error of about 0″·2 (see para 5). They consequently provide a basis for discussing the merits of different times of day in the type of country concerned.

At Padag, the East and Centre base stations are on absolutely flat bare ground. The West station is on bare ground slightly sloping from north to south. Pulchotau and Kopahdar are precipitous hills. At the three base stations the afternoon was obviously not a fit time of day for observations on account of the size and wide movement of the helio images. At Pulchotau and Kopahdar movement of the helio caused some annoyance in the afternoon, but was not bad.

At Poona, the West and Centre base stations are on quite sharp, grass-covered, rises. The East base station is on flat grass. Dighi H.S. is on a flat ridge with bad grazes in the direction of the other stations. Shelārvādi H.S. is on a rounded hill. Sulki and Māndvi are steep hills.

The last column of Table 6 shows the average * errors of the different angles at the four different times of day. Table 4 gives the mean of these average errors of all the angles at each of the twelve different stations, from which it is seen that the three Padag base stations and Dighi H.S. are notably worse than the others, as was expected except that Poona East end was expected to be bad too. This division into "good" and "bad" stations is necessary, for, as will be apparent later, at "bad" stations afternoon angles are very bad and must be avoided, while at "good" stations they are no worse than others.

TABLE 4.—*Average of errors at different stations.*

Padag Base		Poona Base	
Station	Average Error	Station	Average * Error
Centre Base ...	1″·12	Centre Base ...	0″·84
East Base ...	1″·02	East Base ...	0″·48
West Base ...	1″·37	West Base ...	0″·67
Kopahdar ..	0″·69	Dighi ...	1″·00
Pulchotau ...	0″·62	Shelārvādi ...	0″·75
		Sulki ...	0″·71
		Māndvi ...	0″·57

* The word "average" is used for the mean without regard to sign. The word "mean" is used for the mean with regard to sign, or for the mean of undirected numbers.

TABLE 5.—*Average errors at different times of the day.*

M = morning. A = afternoon. E = evening. N = night.

	No. of stations	M	A	E	N	Mean of M & A	M & E	M & N	A & E	A & N	E & N	M, A & E	M, A & N	M, E & N	A, E & N	M, A, E & N
		"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
Good stations at Padag ...	2	0·59	0·62	0·68	0·74	0·58	0·57	0·49	0·63	0·53	0·41	0·58	0·51	0·49	0·47	0·49
Good stations at Poona ...	6	0·60	0·75	0·66	0·74	0·52	0·51	0·54	0·64	0·55	0·55	0·52	0·47	0·48	0·53	0·47
Bad stations at Padag ...	3	0·77	1·90	1·02	0·98	1·17	0·75	0·75	1·39	1·13	0·73	1·05	0·93	0·67	1·01	0·90
Bad stations at Poona ...	1	0·72	1·91	0·75	0·62	0·77	0·70	0·54	0·86	0·78	0·56	0·55	0·40	0·58	0·44	0·35
Mean of two bases. Good stations		0·60	0·69	0·67	0·74	0·55	0·54	0·52	0·64	0·54	0·48	0·55	0·49	0·49	0·50	0·48
Mean of two bases. Bad stations		0·75	1·91	0·89	0·80	0·97	0·73	0·65	1·13	0·96	0·65	0·80	0·67	0·63	0·73	0·63

For the good and bad stations of each base Table 5 shows the average error at each of the four times of day, and the average errors of the 11 different combinations in which the different times may be meaned together. The last two lines show the mean of the two bases.

From the first four columns of Table 5, which give the time of day separately, it is seen that afternoon is very bad at the "bad" stations, but that otherwise there is not much to choose between the times of day. Rather surprisingly, night appears to be the next worst (confirming Geodetic Report Vol. V), but this does not mean that night observations are to be avoided, because the night errors tend to be of opposite sign to the day ones, and provide valuable cancellation.

Considering combinations of different times of day, it is seen that at "good" stations the mean of any two times, except perhaps afternoon and evening, gives practically as good a result as the mean of all four. At "bad" stations combinations of afternoon with any one other time are spoiled by the bad afternoon errors, which also have a similar effect on all other combinations, so that the mean of morning, evening and night, ignoring the afternoon angles, is the best combination.

There remains the question of how an observer is to distinguish between "good" and "bad" stations before completing his observations. Precipitous hills like Pulchotau and Kopahdar are obviously "good", and rays along a flat base-line are obviously "bad". At other stations a convenient rule will be that a ray is "bad" if at any time of day four consecutive careful intersections* of the mark will not generally come within a range of 5 seconds (i.e. apparently 2½ seconds on the 5½-inch Wild). At such stations observations should not be made at the worst time of day, but at other stations a more moderate unsteadiness of the mark has no ill effects, and observations may be made at any time of the day or night. At all stations, of course, the more variety the better, and for primary triangulation it is recommended that observations at any station should generally cover parts of at least two days and one night, or two nights and one day.

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* The telescope being moved off the mark by the slow-motion screw only.

TABLE 6.—*Errors in Horizontal Angles.*

The groups of three stations form triangles. The figures opposite each station relate to the angle at that station.

M = morning, A = afternoon, E = evening, N = night, m = final value from grinding.

Station	M − m	A − m	E − m	N − m	Average of preceding columns
Kopahdar ...	+0·19	−0·08	−0·04	+1·75	0·51
Pulehotau ...	+1·38	+0·77	+0·92	−0·10	0·79
Padag East ...	+2·23	+0·99	+1·49	+2·92	1·91
Kopahdar ...	−0·07	+0·12	+0·60	+0·88	0·42
Pulehotau ...	+0·13	+0·04	+0·94	−0·52	0·41
Padag Centre ...	−1·03	−0·64	−0·67	+0·72	0·77
Pulehotau ...	−0·97	−0·49	−1·34	+0·93	0·93
Kopahdar ...	+0·49	+1·40	+0·79	−0·49	0·79
Padag West ...	−0·92	+0·52	+0·16	−0·16	0·44
Kopahdar ...	+0·26	−0·20	−0·64	+0·87	0·49
Padag Centre ...	+1·13	+3·56	+2·89	+0·36	1·99
Padag East ...	+0·79	+0·63	+1·37	+0·25	0·76
Padag Centre ...	+0·23	−2·58	−1·69	−1·26	1·44
Pulehotau ...	+1·25	+0·73	−0·02	+0·42	0·61
Padag East ...	+1·14	+0·06	−0·18	+2·37	0·94
Pulehotau ...	−0·84	−0·45	−0·40	+0·11	0·52
Padag Centre ...	+0·11	+0·52	−0·21	−0·03	0·22
Padag West ...	−0·06	−3·17	−1·53	+0·87	1·41
Kopahdar ...	+0·42	+1·52	+1·39	+0·39	0·93
Padag Centre ...	−1·22	−1·24	−0·54	+0·67	0·92
Padag West ...	−0·66	+3·89	+1·89	−0·83	1·82
Padag West ...	−0·20	−5·17	−0·55	+0·90	1·71
Pulehotau ...	+0·41	+0·28	−0·42	+0·83	0·48
Padag East ...	+0·01	+0·69	+0·11	+0·82	0·41
Padag West ...	+0·14	+2·00	−0·98	−0·03	0·79
Padag East ...	+1·13	−0·63	−0·29	+1·55	0·90
Padag Centre ...	+0·34	−2·06	−1·90	−1·29	1·40
Padag West ...	−0·52	+5·89	+0·91	−0·86	2·05
Padag East ...	+1·92	−0·00	+1·08	+1·80	1·20
Kopahdar ...	+0·68	+1·32	+0·75	+1·26	1·00

(*Continued*)

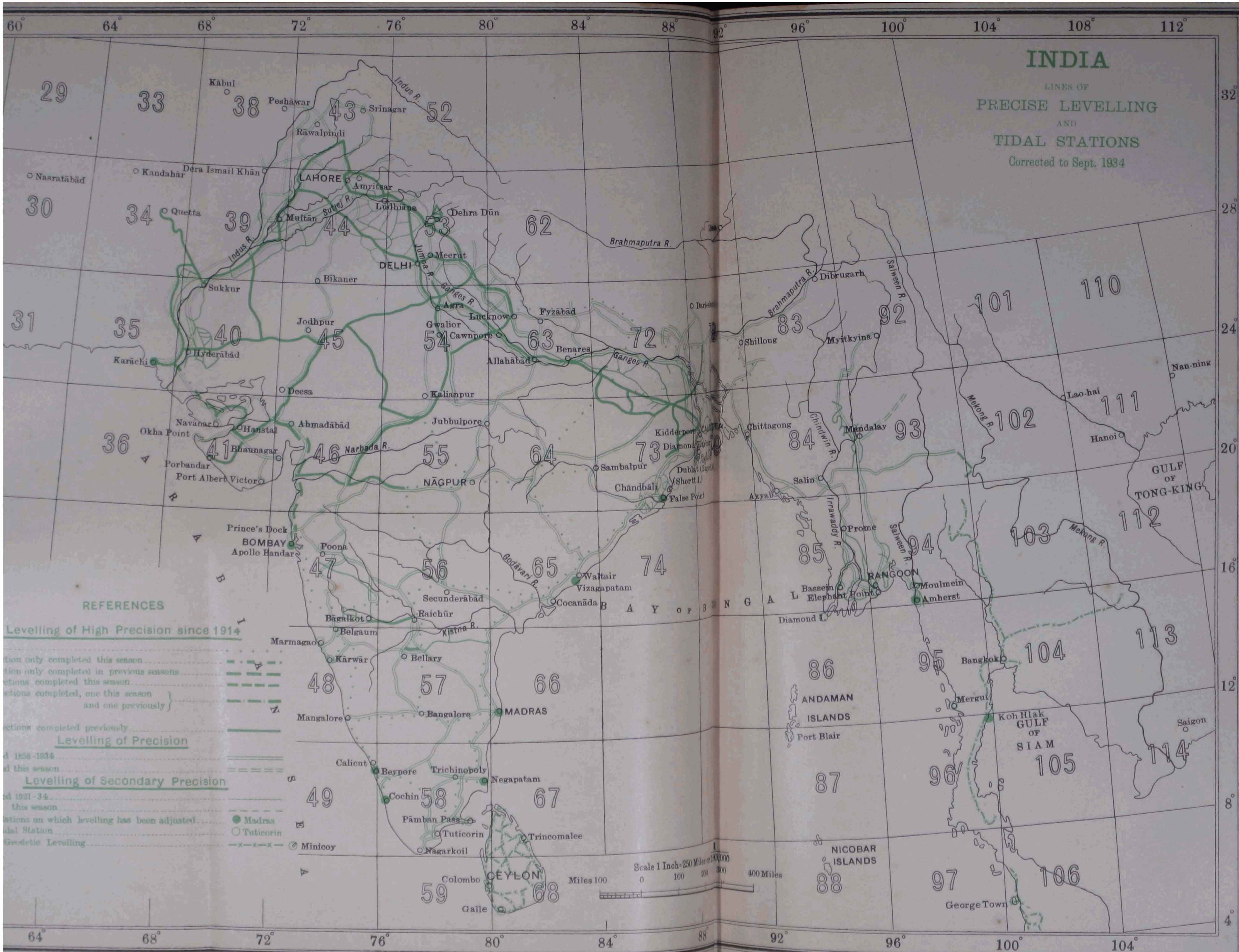
TABLE 6.—*Errors in Horizontal Angles*—(*contd.*)

Station		M − m	A − m	E − m	N − m	Average of preceding columns
Dighi	...	+0·68	−2·32	+0·23	−0·53	0·94
Māndvi	...	−0·53	−0·22	−0·15	−0·51	0·35
Shelārvādi	...	+1·45	+0·13	+0·57	+1·11	0·82
Māndvi	...	−0·67	+0·61	+0·62	−0·49	0·60
Dighi	...	−1·04	+0·25	−1·15	+0·51	0·74
Sulki	...	+1·38	−0·26	+0·48	+0·67	0·70
Dighi	...	−0·36	−2·07	−0·92	−0·02	0·84
Sulki	...	+0·48	+0·61	+1·57	+0·50	0·79
Shelārvādi	...	+0·77	+0·20	+1·15	+1·08	0·80
Sulki	...	+0·90	−0·87	−1·09	+0·17	0·76
Māndvi	...	−1·20	+0·39	+0·47	−1·00	0·77
Shelārvādi	...	+0·68	−0·07	−0·58	+0·03	0·34
Shelārvādi	...	+0·77	−0·48	−0·14	+0·75	0·54
Dighi	...	+0·66	−2·22	+0·01	−0·23	0·78
Poona East	...	+0·10	+0·10	−0·72	−0·08	0·25
Shelārvādi	...	−0·12	+1·67	+1·54	+1·66	1·25
Poona East	...	+0·61	+0·60	+0·24	−0·47	0·48
Poona West	...	+1·49	+0·78	+0·42	+0·59	0·82
Shelārvādi	...	+0·65	+1·19	+1·40	+2·41	1·41
Dighi	...	+0·59	−3·61	+0·86	+0·37	1·36
Poona West	...	+0·27	+0·60	+0·32	−0·41	0·40
Sulki	...	+0·51	−0·76	+0·91	+0·08	0·57
Shelārvādi	...	0·00	+0·68	+1·29	+0·33	0·58
Poona East	...	+1·09	−1·02	+0·25	−0·32	0·67
Sulki	...	+0·04	−1·36	−0·65	−0·41	0·62
Dighi	...	+1·01	−0·16	+0·92	−0·22	0·58
Poona East	...	+1·19	−0·92	−0·47	−0·40	0·75
Dighi	...	−0·95	+1·54	−1·78	−0·39	1·17
Sulki	...	+0·54	+1·18	+1·74	+0·09	0·89
Poona West	...	−0·42	−0·03	+0·22	−0·49	0·29
Poona East	...	+0·48	−1·62	+0·01	+0·15	0·57
Sulki	...	+0·58	−0·18	+1·09	−0·32	0·54
Poona West	...	−1·61	−0·21	+0·12	−1·49	0·87
Dighi	...	+0·06	+1·38	−0·86	−0·61	0·73
Poona East	...	+0·72	+0·71	−0·47	−0·54	0·61
Poona West	...	+1·22	+0·18	+0·10	+1·00	0·63

(*Continued*)

TABLE 6.—*Errors in Horizontal Angles*—(*concld.*)

Station	M − m	A − m	E − m	N − m	Average of preceding columns
Poona West ...	+0·75	−0·32	+0·38	+1·83	0·82
Dighi ...	+0·44	−0·70	−0·60	+0·81	0·64
Poona Centre ...	+0·51	+1·82	+0·68	+0·10	0·78
Sulki ...	+1·15	+0·71	+2·08	−0·75	1·17
Poona West ...	−1·17	+0·29	−0·16	−2·32	0·99
Poona Centre ...	−0·22	−2·92	−1·59	+0·46	1·30
Dighi ...	−1·39	+2·24	−1·18	−1·20	1·50
Sulki ...	−0·60	+0·48	−0·33	+0·85	0·57
Poona Centre ...	+0·34	+1·47	+1·01	−0·40	0·81
Dighi ...	−0·38	+2·08	−0·26	−1·42	1·04
Poona East ...	+0·79	+0·32	−0·58	−0·06	0·44
Poona Centre ...	+0·32	−0·65	−0·35	+0·91	0·56
Poona East ...	−0·08	+0·38	+0·10	−0·49	0·26
Poona West ...	+0·47	+0·50	−0·28	−0·83	0·52
Poona Centre ...	−0·20	−0·80	−0·23	−0·85	0·52
Shelārvādi ...	−0·12	+0·99	+0·25	+1·33	0·67
Sulki ...	+0·06	+0·57	+0·17	−0·41	0·30
Poona West ..	−0·15	+0·57	+0·54	−0·90	0·54
Sulki ...	+1·08	+0·13	+1·90	−0·35	0·87
Shelārvādi ...	−0·20	+0·45	+1·30	+0·62	0·64
Poona Centre ...	+0·17	−2·49	−1·13	−0·58	1·09
Shelārvādi ...	+0·20	+0·23	−0·01	−0·29	0·18
Poona East ...	+0·69	+0·22	+0·14	+0·02	0·27
Poona Centre ..	+0·44	+0·74	−0·13	+2·05	0·84
Poona Centre ...	+0·39	+0·43	+0·46	−1·04	0·58
Poona West ...	+1·01	+0·27	+0·69	+1·41	0·85
Shelārvādi ...	−0·32	+1·44	+1·55	+1·95	1·32
Shelārvādi ...	+0·97	−0·25	−0·15	+0·46	0·46
Dighi ...	+1·03	−4·31	+0·26	+1·18	1·70
Poona Centre ..	+0·13	+1·40	+0·23	+1·15	0·73
Sulki ...	−0·56	−0·88	−0·98	+0·44	0·72
Poona Centre ...	+0·02	+2·12	+1·36	−1·31	1·20
Poona East ...	+0·40	−1·24	+0·11	−0·34	0·52



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CHAPTER II

LEVELLING

BY CAPTAIN G. BOMFORD, R.E.

10. Summary.—The original programme of the party consisted of two detachments working in Burma, namely a single detachment carrying the Burma levelling up to the Siamese frontier south of Kēngtūng, and a double detachment relevelling the area of the Pegu (1930) earthquake and running a new line from Mandalay to Lashio in the Northern Shan States. This programme was completed, but three double detachments and eight single (tertiary) detachments were formed late in the season for levelling in the Bihār (1934) earthquake area.

The total out-turn of levelling was:—

High Precision 220 miles * (220 gross)†.
Precise levelling 284 miles (355 gross)†.
Secondary levelling 585 miles (675 gross) †.
Double tertiary levelling 271 miles.
Single tertiary levelling 1,272 miles.
Partal levelling (for check) 196 miles.

11. Kengtung-Siam.—No. 1 Detachment under Mr. J.N. Kohli carried out high precision levelling in both directions from Kēngtūng in the Southern Shan States to the Me-hsai bridge on the Siamese frontier, and left five bench marks in Siam. Details are given in Table 1. The Siamese survey department have not yet carried their levelling up to the frontier, but hope to do so shortly. The line follows the fair-weather motor road through Mong Hpayak and Mong Len, but the road was not open for motor transport until January. Permanent transport was necessary as there are few villages on the route, and carts were engaged until the road was good enough for a motor lorry to be substituted for them.

12. Pegu earthquake area.—After the earthquake of 5th May 1930, some local changes of level were reported, and the bench marks in this area have now been checked. Local subsidences may have occurred near tanks and canal banks, but few of the bench marks show any significant change.

The work was carried out by No. 2 Detachment under Mr. Faizul Hasan with Mr. Z. A. Qureshi as second leveller. The

* i.e., 110 miles in both directions.

† 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.

main lines from Rangoon to Pyinbongyi and from Pegu to Myitkyo were observed on the precise system, and the rest on the very similar secondary system. Details are given in Table 1. Table 3 shows the changes of height found. The only suggestion of a general change of ground level is that Pegu may have sunk three or four inches relative to the country 10 miles to the north, but this may not be real. There is a gap of 10 miles just north of Pegu, where no old bench marks were found, and where changes may possibly have occurred. The revised figures in Table 3 are based on Rangoon standard bench mark, and adjusted on to the embedded bench marks at Pyinbongyi and Myitkyo, on which the closing errors were +0·147 and +0·123 feet respectively.

13. **Mandalay-Lashio.**—On completion of work near Pegu, No. 2 Detachment undertook precise levelling of the line from Mandalay to Lashio. See Table 1. The main object of this work was to provide a spirit-levelled control for the heights of the trigonometrical stations of the Great Salween series, which were thought liable to appreciable error. (See Geodetic Report Vol. IV, Chart I). The line was therefore continued beyond Lashio to Loi Hsam-Hsip H.S., 6116 feet high. In point of fact, the triangulated heights were found to be good, being only 2 feet too low.

Up to the foot of the hill Loi Hsam-Hsip there is a good motorable road, but the last 1,500 feet are steep and levelling was difficult.

While passing through Calcutta on its return the detachment undertook 5 miles of secondary levelling to fix the new standard bench mark at St. George's Dock.

14. **Bihar earthquake area.**—The earthquake of 15th January 1934 caused visible changes of ground level in parts of Bihār, and it was feared that such general changes might have occurred as would lead to serious flooding and changes of river beds in the monsoon. A line of the old level net (1870–72) runs from Bagaha on the Gandak river, through Motihāri, Muzaffarpur and Darbhanga to Purnea, and a secondary line (1920–21) also runs from Bagaha through Raxaul and Sītāmarhi to Darbhanga. The relevelling of these two lines was sufficient to reveal any large general changes in the central area, but since the degree of disturbance was at first completely unknown it was also decided to run new lines of tertiary levelling 10 miles, 5 miles, and in places 1 mile apart, across two areas of about 2,500 and 2,100 square miles each, where disturbance was especially feared. Such lines could not of course show changes of a foot or two, but they would have revealed the existence of any large deeply depressed area which might have come into being.

Colonel R. H. Phillimore visited Patna in February, and arranged the programme with the local government. Mr. N. N. Chuckerbutty was placed in charge of the work, which was carried out by three secondary detachments under Messrs. A. A. S. Matlub

Ahmad, B. P. Rundev and J. N. Kohli, and eight tertiary levellers. The three secondary detachments were employed on relevelling the old lines, and the tertiary levellers on the new lines. **Each area** of new levelling was first surrounded by a circuit of double tertiary levelling, connected with the old lines, and then broken down by east and west lines of single levelling. The single tertiary lines were afterwards checked by north to south *partal* lines. These detachments arrived in Bihār on different dates between 23rd February and 15th March 1934. Field work was completed by 23rd May 1934, and the results (the ground heights of 23,000 points) were given to the Bihār government on 31st May. Details of this work are given in Table 1.

The changes in the old lines are shown in Table 4. The revised figures there given are based on Bagaha, but no other old bench marks are accepted as unchanged. The circuit Bagaha-Motihāri-Darbhanga-Sītāmarhi-Bagaha had a closing error of $+0 \cdot 696$ feet, which has been adjusted. The table shows a sinkage of $1\frac{1}{2}$ feet at Purnea, which so far as the accuracy of the levelling goes should not be error, but which may be due to the earthquake or to a slow rise at Bagaha during the 60 years since the old line was levelled. Elsewhere bench marks show sinkages of up to $4\frac{1}{2}$ feet, and it is noteworthy that there are only four cases of elevation, of which the largest is $0 \cdot 029$ feet. The largest sinkages occurred on structures which had presumably sunk into the ground, and the embedded bench marks generally show smaller changes, although one case of $2 \cdot 7$ feet occurs. Although they are never actually in contact with heavy structures, embedded bench marks are generally in towns, which are areas of accumulation and so liable to local sinkage if underlaid by running sand. Consequently even the embedded bench marks do not provide positive evidence that the country as a whole has sunk, although it seems very possible that it has.

In view of the small changes which have occurred, the new tertiary levelling lines provide little or no information. Contours based on them show the Kosi and Bāghmati rivers running on the crests of alluvial fans, and so liable to migrate, but this is a common state of affairs. As a result of the work, however, it was possible to reassure the local government that whatever flooding might result from choking of river beds or weakening of embankments, general changes of ground level were unlikely to aggravate the position.

15. **Secular changes in Bengal and Bihar.**—It is proper to consider what connection, if any, the earthquake has with the apparent changes of ground level during the last 70 years which have been discussed in the Geodetic Reports Vols. VI and 1933. Past levelling has suggested a steady rise, while the earthquake appears to have caused a sudden fall. Those who advocate the acceptance of the levelling results, and who would like to believe in the rise of

northern Bengal, would certainly prefer to have seen a rise as a result of the earthquake also, but the two opposite movements are not incompatible. Dr. de Graaff Hunter * has suggested the restoration of isostatic equilibrium as the cause of the steady rise, as is reasonable, but it is evident that this is unlikely to have caused the earthquake and the resultant depression.

It must, however, be admitted that until recently some force has been at work, which causes depression in this area, for it is filled with recent alluvium to a great depth. The force is presumably the north to south pressure which has created the Himālayas and the associated overthrust faults, and it may still be acting. If so, it is not unreasonable that this horizontal force should manifest itself in occasional earthquakes which suddenly deepen the depression, while the vertical forces of isostatic readjustment should act slowly and continuously to elevate it. Alternatively, and perhaps more probably, the depression during the earthquake may have no direct connection with tectonic forces, and may simply be due to consolidation of vigorously shaken alluvium. The great outpouring of water and sand supports this view.

Next season Purnea will be connected to less disturbed bench marks to the east to verify the sinkage there, and a line will be begun from Bagaha, through Benares and Allahābād to old 1880 levelling near Jhānsi, which should throw further light on this question.

16. Probable errors.—The probable errors of the high precision and precise lines levelled in 1933–34, calculated by the usual formulæ, are given below:—

Detachment	Line	Probable systematic error	Probable accidental error
		feet/miles	*feet/miles* $^{\frac{1}{2}}$
No. 1 Detachment	88 K Portion Kengtung-Me-hsai Bridge ...	±0·00073	±0·00237
No. 2 Detachment	89 G Mandalay-Lashio	...	±0·00345
do.	88 Rangoon-Pyinbongyi revision ...	...	±0·00265
do.	87 Pegu-Myitkyo revision ...	...	±0·00308
do.	88 G Thanatpin-Tongyi revision ...	...	±0·00293
do.	88 H Ohne-Thongwa-Ohne revision ...	...	±0·00332

* *Nature*, Vol. 133, page 236.

17. Progress of the new level net.—No levelling for the new level net (which excludes Burma) was carried out this year, so the figures given in Geodetic Report Vol. VII remain unchanged. Out of 15,800 miles the equivalent of 8,915 miles has been completed.

18. Protected bench marks.—The following bench marks have been added to the lists of Primary Protected bench marks published in Geodetic Report Vols. III and VIII.

Degree sheet	No. of bench mark	Degree sheet	No. of bench mark
35 P	115	84 D	3, 29
43 H	138	85 I	5
45 J	127 and not 125 as given in G.R. Vol. VIII.	93 B	43, 89
58 E	63 and not 36 as given in G.R. Vol. III.	93 E	38
		93 F	1, 53
58 M	50 and not 60 as given in G.R. Vol. III.	93 O	79
84 B	3	93 P	22, 29
84 C	21	102 D	17

TABLE 1.—*Tabular statement of out-turn of work, season 1933–34.*

Detachments and lines levelled	Months	Distance levelled: Main-line	Distance levelled: Extras and branch-lines	Distance levelled: Total	Total number of feet: Rises	Total number of feet: Falls	Mean number of stations at which the instruments were set up	Number of bench marks connected: Protected Primary: Rock-cut	Number of bench marks connected: Protected Primary: Others	Number of bench marks connected: Others
		Mls.	*Mls.*	*Mls.*	*feet*	*feet*				
No. 1 Detachment.										
Part of line 88K (Taunggyi-Me-hsai Bridge). Portion Kēng-tūng-Me-hsai Bridge (Fore)	Nov. to Dec. 33	110	...	110	6,315	7,723	3,064	1	3	102
Ditto (Back)	Dec. 33 to Feb. 34	110	...	110	7,638	6,220	2,932	1	3	99
No. 2 Detachment.										
Revision of Part of Line 88 (Elephant Point-Thazi). Portion Rangoon-Pyinbongyi	Oct. to Nov. 33	68	5	73	365	459	914	...	4*	93
Revision of Part of Line 87 (Pegu-Amherst). Portion Pegu-Myitkyo	Nov. 33	37	15	52	306	313	572	...	...	37
Revision of Secondary line 88 G Thanatpin-Tongyi	Nov. to Dec. 33	26	...	26	203	198	300	...	...	31
Revision of Secondary line 88 H Ohne-Thongwa-Ohne	Dec. 33	86	9	95	457	476	1,122	...		74
Line 89 G Mandalay-Lashio	Jan. to April 34	179	51	230	10,894	16,759	5,610	...	6†	209
Secondary line 74 L Hastings Bridge-Rājābāgān Ferry Station	April 34	5	...	5	30	45	98	.	...	8
Bihār Levelling Section										
Revision of Secondary line 71 A Bagaha-Darbhanga	Feb. to April 34	145	13	158	869	939	1,498	...	6*	198

* All old. † Includes one old. *(Continued)*

TABLE 1.—*Tabular statement of out-turn of work, season 1933–34—(concld.)*

Detachments and lines levelled	Months	Distance levelled			Total number of feet		Mean number of stations at which the instruments were set up	Number of bench marks connected		
		Main-line	Extras and branch-lines	Total	Rises	Falls		Protected Primary		Others
								Rock-cut	Others	
		Mls.	*Mls.*	*Mls.*	*feet*	*feet*				
Bihār Levelling Section—(concld.)										
Revision of Part of Line 71 (Gorakhpur-Purnea). Portion Bagaha-Darbhanga	March to April 34	166	31	197	1,090	1,205	1,724	...	9*	201
Revision of Part of Line 71 (Gorakhpur-Purnea). Portion Purnea-Darbhanga	March to May 34	157	37	194	1,186	1,132	1,936	...	3*	200
Double Tertiary Lines	March to April 34	271	...	271	1,640	1,352	2,630	...	...	250†
Single Tertiary Lines	April to May 34	1,272	...	1,272	...	...	10,642	...	...	1,140†
Partal Lines	May 34	196	.	196	774	907	1,390	...	...	48†

* All old. † *Pakka* points.

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 1933-34 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1933-34	
			miles		*feet*	*feet*	*feet*
At Kēngtūng on line 88 K.							
48(PP)	93 O	S.B.M. ...	0·0	1930-31	0·000	0·000	0·000
47	,,	Prism ...	0·0	,,	− 0·738	− 0·736	+ 0·002
46	,,	Prism ...	0·0	,,	− 0·753	− 0·753	0·000
45	,,	Iron bolt ...	0·0	,,	− 0·460	− 0·460	0·000
44	,,	Plinth ...	0·1	,,	+ 19·322	+ 19·316	− 0·006
42	,,	Flooring ...	0·2	,,	+ 27·653	+ 27·648	− 0·005
49	,,	Flooring ...	0·4	,,	− 80·278	− 80·265	+ 0·013
50	,,	Step ...	0·5	,,	− 81·010	− 80·998	+ 0·012
51	,,	Step ...	0·6	,,	− 79·156	− 79·147	+ 0·009
At Mandalay on line 89 G.							
2(PP)	93 B	S.B.M., Mandalay ...	0·0	1909-10	0·000	0·000	0·000
39 (*1*)	,,	Rock	0·0	1930-31	− 3·211	− 3·210	+ 0·001
40 (*38*)	,,	Culvert ...	0·9	,,	− 10·319	− 10·317	+ 0·002
41 (*5*)	,,	Culvert ...	1·1	,,	− 10·768	− 10·758	+ 0·010
168 (*54*)	,,	Plinth ...	2·6	,,	− 6·427	− 6·452	− 0·025
169	,,	Platform coping ...	3·2	,,	− 6·468	− 6·457	+ 0·011

TABLE 3.—*Revision levelling.*

Discrepancies between the old and new heights of bench marks.

Bench marks of the original levelling that were connected during the revisionary operations			Distance from starting bench mark	Difference between orthometric heights, above (+) or below (−) the starting bench mark			Difference (revision − original). The sign + denotes that the height was greater and the sign −, less in 1933-34 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1933-34	
			miles		*feet*	*feet*	*feet*
		Revision of Part of Line 88. (Rangoon–Pyinbongyi).					
32	94 D	S.B.M., Rangoon Cantonment ...	0·0	1909-10	0·000	0·000	0·000
129 (*31*)	,,	Stairs Shwedagon Pagoda ...	0·2	..	− 0·393	− 0·391	+0·002
130 (*54*)	,,	Parapet of drain ...	0·4	..	−51·274	−51·376	−0·102
131 (*30*)	,,	Parapet of drain ...	1·1	..	−67·646	−67·598	+0·048
132 (*29*)	,,	Plinth of railway office	1·2	..	−77·916	−77·951	−0·035
133 (*28*)	,,	E.B.M. at railway office	1·2	..	−79·139	−79·157	−0·018
134 (*27*)	,,	Step of Sule Pagoda	1·6	,,	−89·543	−89·560	−0·017
135 (*17*)	,,	S.B.M., Rangoon Custom House ...	2·1	,,	−89·387	−89·422	−0·035
137 (*22*)	,,	Stone block ...	2·7	,,	−92·240	−92·502	−0·262
138 (*24*)	,,	Stone block ...	2·7	,,	−91·918	−92·047	−0·129
140 (*18*)	,,	Graham Smith's B.M.	2·4	,,	−93·001	−93·003	−0·002
141 (*20*)	,,	Passengers' waiting room ...	2·5	,,	−91·842	−91·884	−0·042
142 (*19*)	,,	Passengers' waiting room ...	2·5	,,	−91·901	−91·909	−0·008
144 (*21*)	,,	Bed-plate of Tidal Observatory ...	2·5	,,	−88·826	−88·884	−0·058
150 (*34*)	,,	Ry. bridge No. 7 ...	3·5	..	−92·167	−92·286	−0·119
156 (*38*)	,,	E.B.M. at Togyaunggale R.S. ...	8·4	,,	−91·549	−92·207	−0·658
157 (*40*)	,,	Bridge No. 16 ...	10·1	,,	−91·087	−91·228	−0·141
158 (*41*)	,,	Bridge No. 17 ...	11·3	..	−90·370	−90·551	−0·181
163 (*46*)	,,	E.B.M. at Ledaunggan R.S. ...	17·2	,,	−88·534	−89·681	−1·147
166 (*49*)	,,	Bridge No. 25 ...	20·3	,,	−92·622	−92·956	−0·334
327 (2)	94 C	E.B.M. at Dabein R.S.	23·7	,,	−85·229	−85·540	−0·311
328 (*217*)	,,	Pillar at Dabein I.B.	23·7	1924-25	−90·166	−90·405	−0·239
331 (*5*)	,,	Culvert No. 30 ...	25·7	1909-10	−87·399	−87·676	−0·277
334 (*7*)	,,	Bridge No. 34 ...	28·8	,,	−86·930	−86·941	−0·011
336 (*9*)	,,	Bridge No. 36 ...	31·2	,,	−86·588	−86·630	−0·042
337 (*10*)	,,	E.B.M. at Tongyi ...	31·4	,,	−85·156	−85·283	−0·127
338 (*11*)	,,	Bridge No. 37 ...	31·6	,,	−86·418	−86·458	−0·040
344 (*16*)	,,	Bridge No. 48 ...	38·4	,,	−84·415	−84·396	+0·019
346 (*18*)	,,	E.B.M. at Tawa R.S.	39·3	,,	−83·462	−83·521	−0·059
350 (*21*)	,,	Bridge No. 53 ...	42·3	,,	−82·167	−82·024	+0·143
354 (*25*)	,,	Bridge No. 57 ...	45·5	,,	−76·668	−76·794	−0·126
356 (*27*)	,,	Platform coping, Pegu R.S. ...	47·5	,,	−74·829	−75·241	−0·412

(*Continued*)

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

Discrepancies between the old and new heights of bench marks.

Bench marks of the original levelling that were connected during the revisionary operations			Distance from starting bench mark	Difference between orthometric heights, above (+) or below (−) the starting bench mark			Difference (revision − original). The sign + denotes that the height was greater and the sign −, less in 1933-34 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1933-34	
			miles		*feet*	*feet*	*feet*
		Revision of Part of Line 88. (Rangoon–Pyinbongyi)—(concld.)					
357(*28*)	94 C	Platform coping, Pegu R.S. ...	47·6	1909-10	−74·693	−74·933	−0·240
358(*38*)	..	Platform coping, Pegu R.S. ...	47·7	..	−74·637	−74·939	−0·302
359(*31*)	..	□ at Pegu R.S. ...	47·7	..	−75·890	−76·222	−0·332
361(*32*)	..	S.B.M., Pegu ...	48·6	,,	−76·549	−76·800	−0·251
364(*40*)	..	Bridge No. 1 ...	50·1	..	−66·597	−66·990	−0·393
365(*41*)	..	Bridge No. 4 ...	52·0	,,	−67·639	−67·949	−0·310
376(*290*)	,,	Zinc plate ...	62·1	1928-29	−71·403	−71·425	−0·022
377(*291*)	..	Interred B. M. at Payagale R.S.	62·6	,,	−76·893	−76·881	+0·012
378(*284*)	..	Bridge No. 76 ...	62·7	,,	−75·203	−75·210	−0·007
379(*285*)	..	Bridge No. 79 ...	65·1	,,	−73·142	−73·160	−0·018
380(*286*)	..	Bridge No. 81 ...	66·1	..	−75·214	−75·214	0·000
381(*287*)	,,	Bridge No. 82 ...	66·6	..	−72·119	−72·174	−0·055
382(*288*)	..	Bridge No. 84 ...	67·4	,,	−72·657	−72·670	−0·013
289(*61*)	..	E.B.M. at Pyinbongyi R.S. ..	67·5	..	−69·656	−69·656	0·000*
		Revision of Part of Line 87. (Pegu–Myitkyo).					
361(*32*)	94 C	S.B.M., Pegu ...	48·6	1909-10	−76·549	−76·800	−0·251
383(*34*)	..	Iron bolt ...	49·8	,,	−52·548	−52·042	+0·506
387(*37*)	..	E.B.M. at P. W. D. office, Thanatpin ...	55·2	,,	−87·084	−87·262	−0·178
388(*36*)	..	Culvert ...	55·3	,,	−85·118	−85·464	−0·346
389(*101*)	..	E.B.M. at Thanatpin I.B. ...	55·4	1912-13	−89·971	−90·126	−0·155
390(*102*)	..	E.B.M. at Pagan-Nyoung-bin ...	57·3	,,	−84·537	−84·919	−0·382
391(*103*)	..	Abutment of sluice	57·3	..	−85·847	−86·123	−0·276
394(*104*)	..	Ta-wa lock ...	63·8	,,	−83·971	−83·429	+0·542
395(*105*)	..	E.B.M. at Ta-wa lock	63·8	,,	−82·555	−82·094	+0·461
346(*18*)	..	E.B.M. at Tawa R.S.	65·3	,,	−83·462	−83·521	−0·059
399(*106*)	..	E.B.M. at Minywa I.B.	61·6	,,	−82·072	−82·075	−0·003
400(*107*)	..	Zinc plate on wall...	61·6	,,	−87·557	−87·535	+0·022
404(*108*)	..	Bridge No. 21 ...	71·9	..	−76·005	−76·066	−0·061
407(*109*)	..	Wing-wall of Abya escape ...	75·1	,,	−83·162	−83·128	+0·034

* The old height of the E.B.M. at Pyinbongyi was accepted for adjustment. See page 24.

(Continued)

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

Discrepancies between the old and new heights of bench marks.

Bench marks of the original levelling that were connected during the revisionary operations			Distance from starting bench mark	Difference between orthometric heights, above (+) or below (−) the starting bench mark			Difference (revision − original). The sign + denotes that the height was greater and the sign −, less in 1933-34 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1933-34	
			miles		*feet*	*feet*	*feet*
Revision of Part of Line 87. (Pegu–Myitkyo)—(concld.)							
110	94 C	E.B M. at Abya I.B.	75·2	1912-13	−77·369	−77·369	0·000
409(*113*)	,,	Ry. bridge ...	79·1	,,	−75·954	−75·867	+0·087
410(*114*)	,,	Home signal ...	79·8	,,	−79·555	−79·510	+0·045
411(*115*)	,,	E.B.M. at Abya R.S.	80·1	,,	−88·052	−87·964	+0·088
415(*163*)	,,	E.B.M. at Myitkyo	84·3	1923-24	−82·992	−82·970	+0·022
416(*309*)(*112*)	,,	Myitkyo lock gate...	85·1	,,	−81·124	−81·101	+0·023
417(*310*)	,,	Myitkyo lock gate...	85·1	1928-29	−80·910	−80·890	+0·020
111	,,	E.B.M. at Myitkyo lock ...	85·1	1912-13	−79·423	−79·423	0·000*
Revision of Secondary line 88 G (Thanatpin–Tongyi).							
389(*101*)	94 C	E.B.M. at Thanatpin I.B. ...	55·4	1912-13	−89·971	−90·126	−0·155
418(*234*)	,,	E.B.M. at Thanatpin township office ...	55·8	1926-27	−88·657	−88·809	−0·152
419(*235*)	,,	Ry. bridge No. 17 ...	56·0	,,	−82·427	−82·610	−0·183
420(*236*)	,,	Ry. bridge No. 18 ...	56·2	,,	−79·412	−79·590	−0·178
421(*237*)	,,	Ry. culvert No. 20 ...	58·2	,,	−87·312	−87·447	−0·135
422(*238*)	,,	Ry. bridge No. 22 ...	59·0	,,	−85·156	−85·253	−0·097
423(*239*)	,,	Ry. bridge No. 23 ...	59·4	,,	−87·303	−87·413	−0·110
424(*240*)	,,	Ry. bridge No. 24 ...	59·8	,,	−80·412	−80·570	−0·158
425(*241*)	,,	Ry. bridge No. 25 ...	60·4	,,	−85·427	−85·483	−0·056
427(*243*)	,,	Ry. bridge No. 27 ...	61·6	,,	−86·776	−86·863	−0·087
428(*244*)	,,	Ry. bridge No. 28 ...	62·0	,,	−81·688	−81·799	−0·111
429(*245*)	,,	Ry. bridge No. 29 ...	62·8	,,	−86·651	−86·749	−0·098
430(*246*)	,,	Ry. bridge No. 30 ...	63·6	,,	−86·600	−86·700	−0·100
431(*247*)	,,	Ry. bridge No. 32 ...	63·9	,,	−79·342	−79·445	−0·103
432(*248*)	,,	Ry. bridge No. 33 ...	64·6	,,	−86·866	−86·982	−0·116
433(*249*)	,,	Ry. bridge No. 35 ...	65·0	,,	−81·444	−81·616	−0·172
434(*250*)	,,	Ry. bridge No. 36 ...	65·9	,,	−89·311	−89·487	−0·176
435(*251*)	,,	Ry. bridge No. 37 ...	66·4	,,	−86·346	−86·543	−0·197

* The old height of the E.B.M. at Myitkyo lock was accepted for adjustment. See page 24.

(*Continued*)

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

Discrepancies between the old and new heights of bench marks.

Bench marks of the original levelling that were connected during the revisionary operations: No.	Degree sheet	Description	Distance from starting bench mark (miles)	Difference between orthometric heights, above (+) or below (−) the starting bench mark: Date of original levelling	From published heights (feet)	From revision 1933-34 (feet)	Difference (revision − original). The sign + denotes that the height was greater and the sign − less in 1933-34 than when originally levelled (feet)
Revision of Secondary line 88 G (Thanatpin–Tongyi)—(concld.)							
437(*253*)	94 C	Ry. bridge No. 40 ...	67·6	1926-27	−75·187	−75·483	−0·296
438(*254*)	..	Ry. bridge No. 41 ...	68·4	..	−83·772	−83·996	−0·224
439(*255*)	..	Ry. bridge No. 42 ...	68·9	..	−87·881	−88·129	−0·248
440(*256*)	..	Ry. bridge No. 43 ...	69·2	..	−82·442	−82·710	−0·268
441(*257*)	..	E.B.M. at Ohne ...	70·8	..	−93·587	−93·923	−0·336
442(*258*)	..	E.B.M. at Ohne I.B.	71·4	..	−90·424	−90·781	−0·357
443(*259*)	..	Plinth of pagoda ...	71·7	..	−86·603	−87·102	−0·499
445(*261*)	..	Zinc plate on tree ...	74·0	..	−90·091	−90·400	−0·309
447(*262*)	..	Zinc plate on tree ...	77·7	..	−90·805	−90·550	+0·255
449(*264*)	..	Zinc plate on tree ...	80·0	..	−94·035	−95·323	−1·288
337(*10*)	..	E.B.M. at Tongyi R.S.	81·5	1909-10	−85·156	−85·283	−0·127
Revision of Secondary line 88H (Ohne–Thongwa–Ohne).							
441(*257*)	94 C	E.B.M. at Ohne ...	70·8	1926-27	−93·587	−93·923	−0·336
450(*268*)	..	Zinc plate on tree ...	73·0	..	−90·879	−91·175	−0·296
452(*270*)	..	E.B.M. at Thandin ...	75·9	..	−90·790	−91·045	−0·255
453(*271*)	..	E.B.M. at Kannyi-naung ...	81·3	..	−89·804	−89·985	−0·181
456(*272*)	..	E.B.M. at Thayetkon	85·9	..	−90·005	−90·233	−0·228
169(*81*)	94 D	E.B.M. at Emon ...	90·6	..	−91·713	−91·979	−0·266
171(*82*)	..	E.B.M. at Siminaing	95·8	..	−92·191	−92·498	−0·307
173(*83*)	..	E B.M. at Chaukindan	101·2	..	−94·106	−94·882	−0·776
174(*84*)	..	Zinc plate on tree ...	103·2	..	−87·725	−89·101	−1·376
176(*86*)	..	E.B M. at Kadon Baw	107·9	..	−93·767	−93·993	−0·226
177(*87*)	..	Iron plate on tree ...	109·8	..	−90·372	−90·612	−0·240
180(*90*)	..	E.B.M. at Kamakaya	112·2	..	−95·631	−95·890	−0·259
182(*92*)	..	Concrete pillar ...	114·8	..	−91·958	−92·239	−0·281
184(*94*)	..	E.B.M. at Wingyi ...	117·4	..	−98·254	−98·688	−0·434
185(*95*)	..	Concrete pillar ...	119·9	..	−93·486	−93·857	−0·371
187(*97*)	..	Zinc plate on tree ...	122·6	..	−97·584	−97·902	−0·318
188(*98*)	..	E.B.M. at Kadatpana	123·0	..	−98·184	−98·459	−0·275
189(*99*)	..	Platform of pagoda	124·1	..	−96·469	−97·004	−0·535
191(*101*)	..	Concrete pillar ...	125·8	..	−95·847	−96·086	−0·239
192(*102*)	..	Step of tank ...	128·0	..	−94·231	−94·443	−0·212
193(*103*)	..	Zinc plate on tree ...	128·1	..	−96·140	−96·252	−0·112
194(*104*)	..	E.B.M. at Thongwa	128·3	..	−99·268	−99·951	−0·683
195(*105*)	..	Masonry block ...	128·3	..	−96·358	−97·050	−0·692
196(*106*)	..	Masonry block ...	128·3	..	−96·426	−97·153	−0·727
200(*108*)	..	Step of pagoda ...	130·2	..	−91·987	−92·333	−0·346
202(*110*)	..	Concrete pillar ...	133·5	..	−91·387	−91·582	−0·195

(Continued)

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

Discrepancies between the old and new heights of bench marks.

Bench marks of the original levelling that were connected during the revisionary operations			Distance from starting bench mark	Difference between orthometric heights, above (+) or below (−) the starting bench mark			Difference (revision − original). The sign + denotes that the height was greater and the sign −, less in 1933-34 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1933-34	
			miles		*feet*	*feet*	*feet*
Revision of Secondary line 88 H (Ohne–Thongwa–Ohne)—(concld.)							
204(*112*)	94 D	E.B.M. at Zwedaw ..	134·9	1926-27	−93·466	−94·367	−0·901
209(*116*)	..	E.B.M. at Kayan ...	142·8	,,	−94·916	−95·122	−0·206
211(*118*)	,,	Stone pillar ...	143·0	..	−89·820	−90·127	−0·307
212(*117*)	..	E.B.M. at Kayan R.S.	143·0	..	−92·645	−92·898	−0·253
214(*120*)	..	Ry. bridge No. 63 ...	144·1	..	−85·587	−85·887	−0·300
219(*125*	..	Thetkegon R.S. ...	146·3	..	−90·849	−91·568	−0·719
220 *126*)	..	E.B.M. near Thetkegon R.S.	147·3	,,	−95·842	−96·345	−0·503
222(*128*)	..	Ry. bridge No. 55 ...	148·6	..	−89·664	−89·929	−0·265
457(*273*)	94 C	Ry. bridge No. 54 ...	149·3	,,	−86·406	−86·715	−0·309
458(*274*)	,,	Ry. bridge No. 53 ...	150·1	..	−87·674	−87·947	−0·273
459(*275*)	..	Ry. bridge No. 52 ...	150·4	,,	−82·598	−83·413	−0·815
460(*276*)	,,	Ry. bridge No. 51 ...	151·6	,,	−77·548	−78·850	−1·302
461(*277*)	..	E.B.M. at Muru village	152·4	..	−94·964	−95·276	−0·312
462(*278*)	..	Ry. bridge No. 50 ...	152·2	,,	−81·906	−82·448	−0·542
463(*279*)	,,	Ry. bridge No. 49 ...	152·9	..	−87·910	−88·410	−0·500
464(*280*)	..	Ry. bridge No. 48 ...	153·4	..	−87·912	−88·424	−0·512
465(*281*)	..	Ry. bridge No. 47 ...	153·9	..	−84·718	−85·147	−0·429
466(*282*)	..	Ry. bridge No. 46 ...	154·4	..	−87·776	−88·328	−0·552
467(*283*)	..	Ry. bridge No. 45 ...	155·1	..	−89·600	−90·012	−0·412
441(*257*)	..	E.B.M. at Ohne ..	156·3	..	−93·587	−93·923	−0·336

TABLE 4.—*Revision levelling.*

Discrepancies between the old and new heights of bench marks.

Bench marks of the original levelling that were connected during the revisionary operations			Distance from starting bench mark	Difference between orthometric heights, above (+) or below (−) the starting bench mark			Difference (revision − original). The sign + denotes that the height was greater and the sign −, less in 1934 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1934	
			miles		*feet*	*feet*	*feet*
		Revision of Part of Line 71. (Gorakhpur–Purnea).					
51	72 A	E.B.M. at Bagaha R.S. ...	0·0	1920-21	0·000	0·000	0·000
2	,,	Step of *shiwāla* ...	3·8	1870-72	+ 2·367	+ 2·165	−0·202
1	..	Step of well ...	4·6	,,	+ 2·321	+ 2·135	−0·186
5	,,	Bakwa T.S. ...	13·9	..	− 6·089	− 6·269	−0·180
4	72 B	Patjirwa T.S.	44·6	..	− 30·294	− 30·713	−0·419
9	,,	Step of *shiwāla* ...	42·2	,,	− 42·594	− 43·150	−0·556
16	..	Step of well ...	59·5	..	− 68·052	− 69·845	−1·793
15	..	Step of *shiwāla* ...	59·6	..	− 66·732	− 68·582	−1·850
26	..	Step of tank ...	74·9	..	− 74·223	− 78·345	−4·122
25	..	S.B.M., Motihāri ...	75·0	1909-10	− 72·876	− 74·509	−1·633
20	..	Step of church ...	76·4	1870-72	− 76·243	− 77·332	−1·089
18	..	Rūpdi T.S. ...	79·2	,,	− 77·105	− 81·692	−4·587
8	72 F	Harpur T.S. ...	131·5	..	−114·478	−115·205	−0·727
10	..	Step of tank ...	127·8	..	−117·607	−118·447	−0·840
11	..	Step of well ...	127·8	,,	−116·518	−117·289	−0·771
52	..	S.B.M., Muzaffarpur	128·0	1909-10	−115·589	−116·301	−0·712
13	..	Stone seat ...	128·6	1870-72	−111·244	−112·372	−1·128
14	..	Sāwajpur T.S.	138·0	..	−115·500	−117·848	−2·348
15	..	Step of tank ...	128·9	..	−114·577	−115·518	−0·941
16	..	Palādpur T.S.	134·3	..	−116·776	−118·644	−1·868
41	..	Step of *masjid* ...	163·5	..	−124·554	−125·889	−1·335
58	..	Bridge ...	164·7	1920-21	−129·205	−131·944	−2·739
57	..	Culvert ...	165·5	..	−130·317	−134·661	−4·344
56	..	E.B.M. at Darbhanga R.S. ...	166·3	..	−135·508	−137·436	−1·928
55	..	Bridge ...	168·7	..	−124·981	−126·042	−1·061
54	..	Bridge ...	168·9	..	−125·430	−126·674	−1·244
46	..	Veranda ...	171·2	1870-72	−129·631	−130·597	−0·966
53	..	Bridge ...	171·9	1920-21	−127·801	−129·071	−1·270
49	..	Chotaipati T.S.	170·5	1870-72	−135·978	−137·198	−1·220
3	72 J	Veranda ...	177·7	..	−123·279	−124·244	−0·965
11	..	Harpur T.S. ...	180·2	,,	−128·635	−130·714	−2·079
5	72 K	Step of *shiwāla* ..	232·1	..	−136·912	−141·426	−4·514
6	72 N	Well ...	290·8	..	−112·171	−114·108	−1·937
7	..	Step of *shiwāla* ...	299·3	..	−136·076	−137·333	−1·257
7	72 O	Well ...	308·5	..	−149·044	−150·558	−1·514
9	..	Veranda ...	313·9	,,	−154·961	−156·638	−1·677
11	..	Step of well ...	317·0	..	−161·753	−163·859	−2·106
302	,,	Step ...	322·6	1930-31	−168·292	−169·919	−1·627

(*Continued*)

TABLE 4.—*Revision levelling*—(*contd.*)

Discrepancies between the old and new heights of bench marks.

Bench marks of the original levelling that were connected during the revisionary operations			Distance from starting bench mark	Difference between orthometric heights, above (+) or below (−) the starting bench mark			Difference (revision − original). The sign + denotes that the height was greater and the sign −, less in 1934 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1934	
			miles		*feet*	*feet*	*feet*
		Revision of Part of Line 71. (Gorakhpur–Purnea)—(concld.)					
13	72 O	Stone B.M., Purnea...	322·6	1870-72	−171·968	−173·369	−1·401
169	,,	Bridge ...	319·3	1899-1900	−165·625	−166·971	−1·346
168	,,	E.B.M. at Purnea R.S.	319·6	,,	−165·076	−166·252	−1·176
80	,,	Purnea D.B. ...	321·9	1871-72	−170·011	−172·379	−2·368
177	,,	S.B.M., Purnea ...	323·0	1909-10	−169·378	−170·807	−1·429
		Revision of Secondary line 71A (Darbhanga–Bagaha).					
51	72 A	E.B.M. at Bagaha R.S.	0·0	1920-21	0·000	0·000	0·000
52	,,	Bridge over Gandak	0·9	,,	+ 12·383	+ 12·372	−0·011
50	,,	Culvert No. 65 ...	0·5	,,	+ 11·236	+ 11·243	+0·007
49	,,	Bridge No. 62 ...	1·7	,,	+ 8·988	+ 8·979	−0·009
48	,,	Bridge No. 59 ...	3·6	,,	+ 10·992	+ 10·977	−0·015
47	,,	Bridge No. 55 ...	5·3	,,	+ 14·068	+ 14·053	−0·015
46	,,	E.B.M. at Kharpokhra	5·5	,,	+ 5·728	+ 5·709	−0·019
45	,,	Bridge No. 54 ...	6·2	,,	+ 16·928	+ 16·898	−0·030
44	,,	Bridge No. 52 ...	7·5	,,	+ 26·214	+ 26·148	−0·066
43	,,	Bridge No. 48 ...	9·3	,,	+ 23·223	+ 23·152	−0·071
42	,,	Bridge No. 46 ...	10·7	,,	+ 28·018	+ 27·933	−0·085
41	,,	E.B.M. at Bhairoganj	10·8	,,	+ 18·517	+ 18·428	−0·089
40	,,	Bridge No. 44A ...	11·9	,,	+ 28·678	+ 28·595	−0·083
39	,,	Culvert No. 42 ...	13·3	,,	+ 22·586	+ 22·517	−0·069
38	,,	Bridge No. 41 ...	14·3	,,	+ 26·721	+ 26·706	−0·015
35	,,	E.B M. at Harinagar	16·1	,,	+ 13·227	+ 13·256	+0·029
34	,,	Bridge No. 39 ...	16·7	,,	+ 23·421	+ 23·435	+0·014
33	,,	Bridge No. 37 ...	17·5	,,	+ 21·092	+ 21·080	−0·012
32	,,	Bridge No. 34 ...	19·4	,,	+ 11·765	+ 11·707	−0·058
31	,,	Bridge No. 33 ...	20·5	,,	+ 4·432	+ 4·361	−0·071
30	,,	Bridge No. 32B ...	22·4	,,	− 2·316	− 2·447	−0·131
29	,,	Bridge No. 31 ...	23·7	,,	− 11·319	− 11·476	−0·157
28	,,	Bridge No. 29A ...	25·5	,,	− 15·747	− 15·944	−0·197
27	,,	E.B.M. at Narkatia-ganj ...	25·6	,,	− 21·065	− 21·262	−0·197
26	,,	Culvert No. 69 ...	26·3	,,	− 12·324	− 12·517	−0·193
25	,,	Bridge No. 68 ...	27·6	,,	− 18·828	− 19·021	−0·193
23	,,	Bridge No. 67A ...	29·0	,,	− 25·131	− 25·298	−0·167
22	,,	Bridge No. 67 ...	29·4	,,	− 15·983	− 16·139	−0·156

(*Continued*)

TABLE 4.—*Revision levelling*—(*contd.*)

Discrepancies between the old and new heights of bench marks.

Bench marks of the original levelling that were connected during the revisionary operations			Distance from starting bench mark	Difference between orthometric heights, above (+) or below (−) the starting bench mark			Difference (revision − original). The sign + denotes that the height was greater and the sign −, less in 1934 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1934	
			miles		feet	feet	feet
Revision of Secondary line 71A (Darbhanga–Bagaha)—(*contd.*)							
21	72 A	Bridge No. 65A ...	30·9	1920-21	−27·779	−27·890	−0·111
20	..	E.B.M. at Gokhula ...	31·3	..	−36·146	−36·274	−0·128
19	..	Bridge No. 64 ...	31·7	..	−25·367	−25·469	−0·102
18	..	Bridge No. 63A ...	32·2	..	−32·154	−32·314	−0·160
16	..	Bridge No. 62 ...	34·5	,,	−27·953	−28·102	−0·149
15	..	Bridge No. 60A ..	35·3	,,	−30·867	−31·029	−0·162
14	..	Bridge No. 59 ...	36·2	..	−31·220	−31·438	−0·218
13	..	Bridge No. 54C ...	38·6	,,	−32·382	−32·603	−0·221
12	..	Bridge No. 54 .	39·6	,,	−30·634	−30·928	−0·294
11	..	Bridge No. 53 ...	40·2	..	−33·206	−33·560	−0·354
9	..	E.B.M. at Sikta ...	40·4	,,	−41·169	−41·498	−0·329
10	..	Sikta T.S. ...	40·7	..	−27·386	−27·764	−0·378
8	..	Bridge No. 51 ...	42·0	..	−33·888	−34·168	−0·280
7	..	Bridge No. 49A ..	43·8	..	−33·399	−33·852	−0·453
6	..	Bridge No. 49 ...	44·4	..	−33·575	−33·908	−0·333
44	72 B	Bridge No. 48 .	45·7	..	−31·760	−31·957	−0·197
43	..	E.B.M. at Bhelwa .	46·7	,,	−39·987	−40·701	−0·714
40	..	Bridge No. 45 ...	49·5	,,	−30·488	−30·883	−0·395
38	..	Bridge No. 44 ...	50·4	..	−30·576	−30·855	−0·279
39	..	Harnāhi T.S.	54·9	,,	−45·021	−45·405	−0·384
37	..	E.B.M. at Raxaul ...	51·0	..	−35·334	−35·782	−0·448
35	..	Bridge No. 41 ...	53·9	,,	−35·114	−35·451	−0·337
34	..	Bridge No. 39 ..	55·9	..	−31·729	−32·120	−0·391
33	..	Bridge No. 37 ...	57·0	..	−34·828	−35·275	−0·447
32	.	Bridge No. 35 ...	58·3	,,	−34·812	−35·355	−0·543
31	..	E.B.M. at Adāpur ...	58·5	..	−47·486	−47·844	−0·358
30	..	Bridge No. 34 ...	59·2	..	−34·617	−35·228	−0·611
29	..	Bridge No. 33 ...	60·4	..	−39·488	−39·920	−0·432
28	..	Bridge No. 32 ..	61·5	..	−36·927	−37·394	−0·467
27	..	Bridge No. 31 ..	63·2	..	−45·771	−46·139	−0·368
144	72 F	Bridge No. 30 ..	65·7	,,	−44·016	−45·333	−1·317
143	..	E.B.M at Chauradāna	65·8	,,	−52·068	−53·004	−0·936
142	..	Bridge No. 29 ...	66·4	..	−42·030	−42·449	−0·419
141	..	Bridge No. 28 ...	67·8	..	−48·159	−49·192	−1·033
140	..	Bridge No. 27 ..	68·3	,,	−43·165	−43·603	−0·438
139	..	Bridge No. 23 ...	69·8	..	−48·134	−50·566	−2·432
138	.	Bridge No. 21 ...	70·5	..	−51·270	−51·612	−0·342
137	..	Bridge No. 20 ...	71·7	..	−43·986	−44·288	−0·302
136	..	Bridge ...	72·6	..	−37·224	−37·670	−0·446

(*Continued*)

TABLE 4.—*Revision levelling*—(*contd.*)

Discrepancies between the old and new heights of bench marks.

Bench marks of the original levelling that were connected during the revisionary operations			Distance from starting bench mark	Difference between orthometric heights, above (+) or below (−) the starting bench mark			Difference (revision − original). The sign + denotes that the height was greater and the sign −, less in 1934 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1934	
			miles		*feet*	*feet*	*feet*
Revision of Secondary line 71A (Darbhanga–Bagaha)—(contd).							
135	72 F	E.B.M. at Ghorāsahan	72·9	1920-21	− 44·816	− 45·476	−0·660
133	,,	Bridge No. 17 ...	74·6	,,	− 43·632	− 44·658	−1·026
132	,,	Bridge No. 15 ...	76·3	,,	− 51·126	− 51·806	−0·680
131	,,	Bridge No. 12 ...	77·9	,,	− 51·238	− 52·317	−1·079
130	,,	E.B.M. at Kundwa Chainpur ...	77·9	,,	− 59·013	− 59·239	−0·226
129	,,	Bridge No. 10 ...	79·1	,,	− 53·505	− 53·709	−0·204
128	,,	Bridge No. 8 ...	80·8	,,	− 54·252	− 54·801	−0·549
126	,,	Stone pillar at Goābāri ...	83·0	,,	− 54·775	− 55·631	−0·856
124	,,	Bridge No. 1 .	83·6	,,	− 53·319	− 54·893	−1·574
123	,,	E.B.M. at Bairagnia	84·4	,,	− 61·180	− 61·393	−0·213
122	,,	Platform coping ..	84·7	,,	− 53·554	− 55·158	−1·604
121	,,	Bridge No. 91 .	86·3	,,	− 48·995	− 50·575	−1·580
120	,,	Bridge over Bāghmati	87·8	,,	− 35·726	− 35·881	−0·155
119	,,	Bridge over Bāghmati	88·1	,,	− 35·870	− 35·862	+0·008
118	,,	Bridge No. 88 ...	89·3	,,	− 53·122	− 54·510	−1·388
117	,,	E.B.M. at Dhang ...	89·6	,,	− 63·933	− 64·259	−0·326
116	,,	Bridge No. 86 ...	90·1	,,	− 56·545	− 58·761	−2·216
115	,,	Bridge No. 85 ...	90·8	,,	− 58·158	− 58·729	−0·571
113	,,	Bridge No. 83	91·9	,,	− 61·031	− 63·004	−1·973
112	,,	Bridge No. 81 ...	93·5	,,	− 64·515	− 66·372	−1·857
110	,,	Bridge No. 78A ...	95·0	,,	− 68·470	− 69·679	−1·209
109	,,	Bridge No. 75 ...	96·4	,,	− 73·034	− 75·058	−2·024
108	,,	E.B.M. at Rīga R.S.	96·6	,,	− 78·456	− 78·970	−0·514
102	,,	E.B.M. at Sitāmarhi	102·2	.	− 88·675	− 90·576	−1·901
101	,,	Platform coping ...	102·5	,,	− 80·685	− 82·341	−1·656
100	,,	Bridge No. 62 ...	102·8	,,	− 82·587	− 85·772	−3·185
98	,,	Culvert No. 56 ...	105·6	,,	− 87·946	− 91·528	−3·582
96	,,	Bridge No. 51 ...	108·1	,,	− 91·455	− 94·995	−3·540
95	,,	Bridge No. 49 ...	109·1	,,	− 91·784	− 95·797	−4·013
94	,,	Bridge No. 48 ...	110·1	,,	− 96·224	− 97·854	−1·630
93	,,	E.B.M. at Bājpatti ...	110·6	,,	−101·221	−102·483	−1·262
92	,,	Bridge No. 46 ...	111·7	,,	− 98·965	−100·586	−1·621
91	,,	Bridge No. 44 ...	112·5	,,	−101·102	−101·941	−0·839
88	,,	Bridge No. 41 ...	114·6	,,	−104·387	−105·632	−1·245
85	,,	E.B.M. at Janakpur Road R.S.	117·8	,,	−111·188	−112·769	−1·581
84	,,	Veranda, Janakpur Road R.S.	118·0	,,	−104·751	−107·446	−2·695

(*Continued*)

TABLE 4.—*Revision levelling*—(*concld.*)

Discrepancies between the old and new heights of bench marks.

Bench marks of the original levelling that were connected during the revisionary operations			Distance from starting bench mark	Difference between orthometric heights, above (+) or below (−) the starting bench mark			Difference (revision − original). The sign + denotes that the height was greater and the sign −, less in 1934 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1934	
			miles		*feet*	*feet*	*feet*
Revision of Secondary line 71A (Darbhanga–Bagaha)—(concld.)							
83	72 F	Bridge No. 36 ...	119·1	1920-21	−106·825	−108·924	−2·099
82	,,	Bridge No. 34 ...	120·2	,,	−109·677	−113·522	−3·845
81	,,	Bridge No. 32 ...	121·1	,,	−109·612	−112·166	−2·554
79	,,	Bridge No. 30 ...	122·8	,,	−111·515	−114·454	−2·939
78	,,	E.B.M. at Jagiāra...	122·9	,,	−118·561	−121·315	−2·754
77	,,	Bridge No. 29 ...	123·6	,,	−112·856	−114·045	−1·189
75	,,	Bridge No. 26 ...	124·7	,,	−116·526	−118·219	−1·693
74	,,	Bridge No. 25 ...	125·2	,,	−116·754	−117·720	−0·966
73	,,	Bridge No. 24 ...	125·7	,,	−117·025	−119·363	−2·338
72	,,	Bridge No. 21 ...	126·9	,,	−118·268	−119·344	−1·076
61	,,	Bridge No. 15 ...	129·7	,,	−123·098	−125·111	−2·013
68	,,	E.B.M. at Kamtaul	129·9	,,	−131·943	−132·866	−0·923
67	,,	Bridge No. 12 ...	130·9	,,	−120·860	−122·004	−1·144
66	,,	Bridge No. 11 ...	131·6	,,	−121·162	−122·272	−1·110
65	,,	Bridge No. 8 ...	132·8	,,	−120·636	−121·877	−1·241
64	,,	Culvert	134·0	,,	−124·755	−126·895	−2·140
63	,,	Bridge No. 5 ...	136·1	,,	−121·228	−122·307	−1·079
61	,,	E.B.M. at Muhammadpur	137·3	,,	−132·280	−133·431	−1·151
60	,,	Platform coping ...	137·5	,,	−123·465	−125·049	−1·584
59	,,	Bridge	138·2	,,	−126·742	−127·998	−1·256
58	,,	Bridge	142·7	,,	−129·205	−131·944	−2·739
41	,,	Step of *masjid*, Darbhanga ...	143·9	1870-72	−124·554	−125·889	−1·335

TABLE 5.—*List of triangulation stations connected by spirit-levelling, season 1933–34.*

Name of station	Height above mean sea-level		Difference (Trian.—Lev.)	REMARKS
	Spirit-levelling	Trian-gulation		
	feet	*feet*	*feet*	
	Great Salween Series			
Loi Hsam-Hsip H.S.	6118·253	6116	−2	Upper mark-stone.
Lat. 23° 23′ 34″·216				
Long. 97 58 34·186				

Chapter III

GRAVITY

by Major E. A. Glennie, d.s.o., r.e.

19. Programme.—Field season 1933–34 was a remarkable one in many respects. Commencing in the last week of August the party did not return to Dehra Dūn until the following May having completed observations at seventy-one stations, of which 41 were in India, 21 in Ceylon, 8 in the Maldive Islands and one at Minicoy in the Laccadive Islands. The total mileage by road amounted to about 5,800 miles of which 1,700 miles were in Ceylon.

Two lorries were engaged for the whole season to carry the equipment and personnel. These were the same two lorries used in the field season 1931–32 and they were again under the able management of the owner, Mr. R. V. Knowles. Thanks to his efficient maintenance, there was no mechanical trouble of any sort throughout the long season.

The rafting across Cochin Harbour was nearly disastrous. On the Ernākulam side an accumulation of rain water in the boats surged to one end when the weight of the first lorry came on the raft and it was only prevented from sinking by the shallowness of the water. At the Cochin side the two back wheels of the second lorry slipped between the quay and the raft, and at one time there was danger of the whole lorry falling back into the harbour.

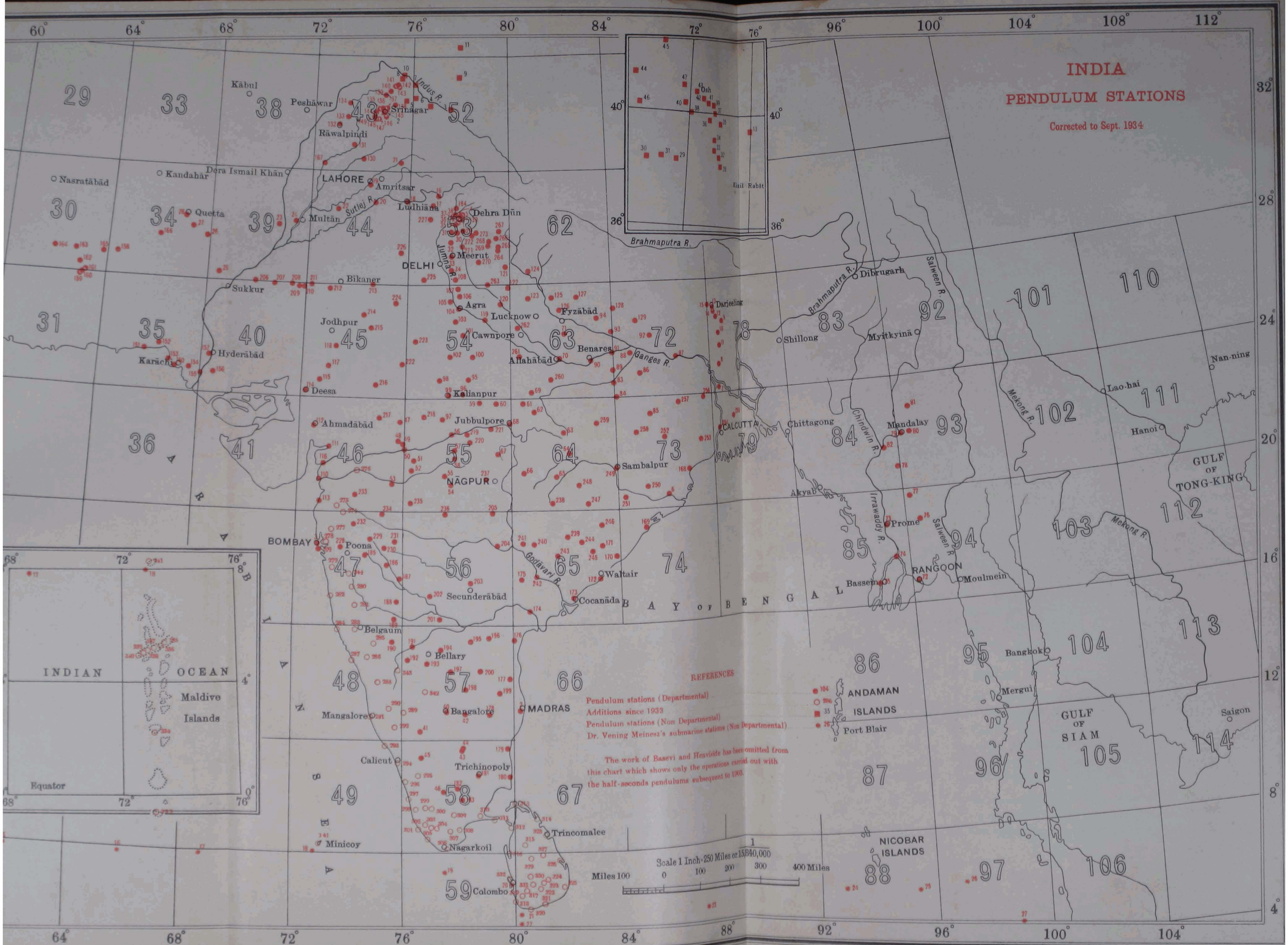
The field work commenced before the end of the monsoon and it was sheer luck that no delay occurred owing to floods. Starting at Nāsik, the party after observations at Peint proceeded north to the Tāpti river. While camped close to the edge of the left bank, the river rose seventy feet during the night, and in the morning was still rising rapidly. A hurried departure followed, but the observations had been completed. It was at this time that the city of Surat and all its neighbourhood was flooded.

Turning back south from the Tāpti river, the programme extended down the whole west coast of India to Cape Comorin, then round to Dhanushkodi, and so across to Ceylon.

Ceylon was reached during Christmas week. It had been anticipated that there would only be three weeks available for work in Ceylon. Actually the party was there two full months, and a much more extensive programme was possible.

While in Ceylon the party received much assistance and hospitality from the Ceylon Survey Department. In particular I am indebted to Mr. J. E. Jackson, Superintendent of the Trigonometrical

Chart V



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Office, for his co-operation and advice in arranging the programme, and to Dr. H. Jameson, Superintendent of Colombo Observatory, for kindly allowing the party to camp in the observatory grounds. Through the courtesy of the Surveyor General of Ceylon, a Government surveyor, Mr. V. T. Muttunayagampillai, was attached to the party. He assisted very greatly, arranging camping places, levelling from the Ceylon Survey bench marks, computing coincidences and carrying out other routine work.

On 17th March the equipment was loaded on H. E. M. S. *Mabahiss* for the cruise to the Maldives. During the ensuing four weeks the party was privileged to collaborate with the John Murray Oceanographic Expedition. The Expedition made all arrangements for the gravity programme, often, it is feared, at considerable inconvenience, and with some disorganization of their own scientific work. All members of No. 14 Party aboard were treated as guests, and are greatly indebted to Lt.-Colonel R. B. Seymour Sewell, C. I. E., F. R. S., the leader, and all the members of the Expedition for a most enjoyable and successful voyage.

Sailing south-west from Colombo the first gravity station was in Addu atoll south of the equator. The next station was $2\frac{1}{4}°$ north of the equator in Kolumadulu atoll. Then came a visit to Malé where Lt.-Colonel Sewell made arrangements for the main gravity programme with the Maldivian authorities. This consisted of a line of six stations running across the archipelago east and west about lat. 5° 15′. Two stations were in Fadiffolu atoll, and four stations in South Mālosmadulu atoll. This occupied eleven days, and during this time the party cruised in a small sailing craft engaged locally, while H. E. M. S. *Mabahiss* steamed away to the Horsburgh atoll for intensive research work there. During this period Lt.-Commander Farquharson, R.N. accompanied the party and carried out an arduous programme of magnetic observations while the gravity work proceeded. The Expedition next proceeded to Minicoy, where gravity observations were made, and then returned to Colombo where No. 14 Party disembarked on 13th April 1934. The party then travelled back through India making gravity observations at three stations *en route*, and entrained for Dehra Dūn on 3rd May. The last part of the journey was very hot.

Observations in India and Ceylon were usually made in rooms, and only occasionally in the large pendulum tent. In the Maldives and at Minicoy, a small double fly tent and a *shouldāri* were placed end to end. The use of the large pendulum tent would have caused delay and extra trouble, as the jungle on most of the islands was very dense, and a great deal of clearing would have been required.

A small prismatic astrolabe, made by Jobin, was taken into the field, and observations for astronomical latitude and longitude were made at three stations in India and at five stations in Ceylon.

This is the first time that this small pattern astrolabe has been used for field work in India. Only a short programme was possible, and in Ceylon the weather conditions were very bad, but results show that under better conditions and with a slightly longer programme this instrument can be relied on to give good results. The results of these observations are given in Table 5 of Chapter IV. No correction for personality has been applied to the astronomical longitudes, and this may be considerable.

20. Strength of the party.—The party which took the field consisted of Major E. A. Glennie, R.E., six *khalāsis*, two motor drivers, two cleaners and two private servants, thirteen in all. In addition, in Ceylon the party was joined by one Ceylon Government surveyor with his servant. The surveyor, however, had his own touring car, so the load on the lorries was not increased.

Owing to the very limited accommodation on H.E.M.S. *Mabahiss* the party was reduced to Major Glennie, one *khalāsi* and one private servant for work in the Maldives. The remainder stayed in Colombo in camp at the observatory.

The health of the party was excellent throughout except for a few cases of malaria contracted at Addalaichchenai in Ceylon. A course of plasmoquin and atebrin cured these promptly and there was no recurrence.

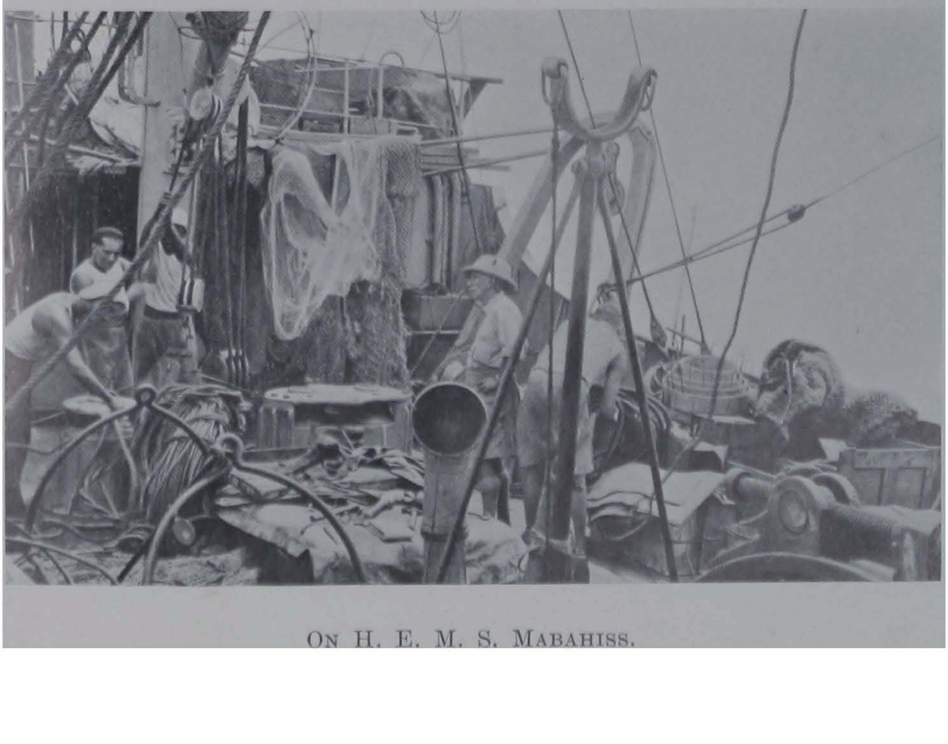
21. Method of observation.—In the three previous seasons the middle pendulum was omitted and the front and back pendulums were swung in optical combination. The results were satisfactory, but the method had the disadvantage that the values of the times of vibration for the difference between a pair of pendulums for any set of observations were not known. This difference is a valuable indication of the accuracy of the observations, and also shows the effect of ground motion. The use of a free middle pendulum also permits of correction for ground motion when this occurs. This season, therefore, observations were made with the middle pendulum in position and hanging free.

In order to save time, only one pair of pendulums was swung at each station, and risk of errors due to a change in length of a pendulum was obviated by changing the pairs in rotation at successive stations thus:—

STATION	PENDULUMS	
	front.	back.
274	A	C
275	C	B
276	B	A
277	A	C and so on.

The Marconi wireless set R.P. 11 with some of the original D E 3 b valves in use since 1926 was employed. These valves are now obsolete and are becoming less sensitive through age. The set

TURTLE HARPOONER, CEYLON.



ON H. E. M. S. MABAHISS.

LAGOON SHORE OF CORAL ISLAND, MALDIVES.

NATIVE CRAFT USED IN THE MALDIVES.

CORALS UNDER WATER, MALDIVES.

PENDULUM TENTS ON CORAL ISLAND.

is specially designed for the valves and requires extensive alterations to adapt it to modern valves throughout; the use, however, of a Phillips A 225 valve as a detector with the H.T. voltage of all valves reduced from 100 to 60 volts gives greatly improved reception. This improvement was introduced in January.

Wireless reception was good everywhere until the return to Dehra Dūn, where reception is always bad in April, May and June. Some trouble was experienced owing to the partial breakdown of insulation in a transformer. This was re-wound at Colombo.

Wireless rhythmic signals from Rugby, Bordeaux and Nauen were used. These are transmitted at the following hours:—

	Station	G.M.T. h	G.M.T. m
N_1	Nauen ...	00	01
B_1	Bordeaux ...	08	01
R_1	Rugby ...	09	55
N_2	Nauen ...	12	01
R_2	Rugby ...	17	55
B_2	Bordeaux ...	20	01

The normal programme of observation consisted of three sets of observations lasting 22 or 24 hours between signals as follows:—

Set 1 R_2-N_1 or R_1-R_2
Set 2 N_1-B_1 R_2-N_1
Set 3 B_1-R_2 N_1-B_1 or R_1

The Nauen signal after January was transmitted on a wave length of 13,000 metres and could not be received, and the normal programme became:—

Set 1	R_1-R_2 or in the Maldives	Set 1	R_2-B_2
Set 2 (*a*)	R_2-B_1	Set 2	B_2-B_1
Set 2 (*b*)	R_2-B_1	Set 3	B_1-R_1
Set 3	B_1-R_2	Set 4	R_1-R_2

If these sets are weighted according to the time intervals between signals, only the rate error due to the reception of the first and last signals at the station effects the mean results; there therefore appears to be no very serious objection to using time signals only two hours apart, so long as the whole series of observations at a station are consecutive and are spread over about 24 hours, though it is of course best to avoid observations with unequal weights.

For the same reason, pairing signals from different transmitting stations is not objectionable so long as the corrections applied to the first and last transmissions are taken from the same source, i.e., both from the Bulletin Horaire or both from the Admiralty list of wireless corrections. Since corrections for the N_1 signal do not appear in either of these lists, the N_1 signal should not be used as the first or the last signal at a station.

22. **Hayford computations.**—To facilitate the Hayford computations, a revised average height map of Ceylon was prepared in the field. As the area of Ceylon is comparatively small, the average heights of 10-minute squares were got out, instead of 30-minute squares as in the case of Average Height Map of India published in Geodetic Report Vol. V. The excellent 1 inch to 1 mile topographical sheets of the Ceylon Survey Department were used for the computation of the average heights.

The average height map was used for the outer zones of the Ceylon computations. Without the aid of these average height maps and the charts in Professional Paper No. 15, it would not have been possible to complete the isostatic reductions of seventy-one stations within the year.

The height estimations and Hayford computations for Dr. Vening Meinesz's sea station close to Minicoy were entirely redone; the final Hayford correction amounted to $+0 \cdot 0266$ gal as compared with $+0 \cdot 0260$ gal obtained by the United States Coast and Geodetic Survey, a close agreement which may be considered very stisfactory.

23. **Results.**—The times of vibration at Dehra Dūn are shown in Table 1. In Tables 2 and 3 are given the mean differences between the times of vibration for each pair of pendulums, the times of vibration, the deduced values of g and the probable errors at each field station.

Table 4 gives the details of theoretical and observed gravity and the Free Air, Bouguer, and Hayford or isostatic anomalies, with reference to Helmert's formula of 1901, and forms a third addendum to Table 2 of the Supplement to Geodetic Report Vol. VI. Table 5 gives values of $g-\gamma_F$ the crustal warp anomaly, and Table 6 gives values of $g-\gamma_{CI}$, the isostatic anomaly with reference to the International gravity formula of 1930. This last table is a first addendum to Table 6 in Geodetic Report Vol. VIII.

24. **Probable errors.**—The probable error of the deduced value of g is a combination of the probable errors at a field station and at Dehra Dūn of (a) the actual pendulum observations and (b) the clock rate correction. These are considered below:—

(a) *Probable error of pendulum observations.*—Assuming no ground motion and no change of length of pendulums, the difference, Δs, between the times of vibration of a pair of pendulums should be a constant quantity.

If $\Delta s'$ be the difference for a single set for any observation then $\Delta s' - \Delta s$ is a measure of the accuracy of observation, which is independent of clock rate errors, and independent of the time interval between first and last series of coincidences, so long as this is reasonably long, say more than one and a half hours.

From all observations in field season 1933–34 we obtain in units of 10^{-7} sec.

Pendulums	A – C	C – B	B – A
Δs	– 3	– 14	+ 7
p.e.	± 0·4	± 0·6	± 0·6

There is an apparent inconsistency here, if we accept the condition $(A - C) + (C - B) + (B - A) = 0$; the failure of the condition must be due to small differences in the times of the individual pendulums depending on whether they are swung on the back or on the front pair of agates.

If $v = \Delta s' - \Delta s$, and n is the number of sets of observations at a station, then the probable error of the time of vibration of the mean pendulum (excluding errors due to clock rate) is:—

$$\epsilon_1 = \frac{0 \cdot 8453\,|v|}{2\,n\sqrt{n}}$$

Here Δs is accepted as the true value of the constant difference between a pair of pendulums, and ϵ_1 is the probable error resulting from errors in observation of pendulum coincidences and arc.

Temperature and pressure readings are taken to an accuracy which is ten times that actually required, so errors on that account may be considered to be negligible.

Errors due to faulty correction factors for temperature and density also will tend to cancel out, at least during the field season under consideration, as the conditions in the field and at Dehra Dūn were very similar.

(*b*) *Probable errors of clock rate corrections.*—Clock rate errors are due to two causes:—

(*i*) Errors in the wireless corrections to time signals issued from the observatory.

(*ii*) Errors of reception in the field and at Dehra Dūn.

The Admiralty Notices wireless corrections, and the Bulletin Horaire demi-definitive corrections give corrections to the same signal referred to the Greenwich and Paris observatory clocks respectively. The difference between the two corrections issued for the same signal is therefore a measure of the difference between the observatory clocks. Plotting these differences for the Rugby 10 a.m., the Nauen noon and Bordeaux 8 p.m. signals daily for the last half of August, we get lines which cross and re-cross at random in a narrow band.

Judged by this method the mean difference between the observatory clocks (Greenwich – Paris) is very closely $-0 \cdot 025$ sec. for the whole period, and so one can assume with sufficient accuracy that in any period of 24 hours at this time the difference between the two clocks remained constant, and that any departure from this value is due to error of reception.

We have therefore a number of independent observations for the difference between the two clocks, and the probable error of a single observation is found to be $\pm 0 \cdot 005$ sec., and, as this is a combination of two signals, the probable error of the rate for a given interval is the same.

Reception in the field cannot be so good as in observatories. Nevertheless signals are clear, and the method of observing coincidences by using the clock to interrupt the earphone circuit is a very accurate one. An estimate of the probable error in the field as amounting not more than four times that in the observatory is certainly on the safe side. This amounts to a probable error of one and a half coincidences, which is really unlikely under good conditions.

Hence we have for rate corrections:—

(*i*)	Probable error due to observatory	=	$\pm 0 \cdot 005$ sec.
(*ii*)	Probable error due to field reception	=	$\pm 0 \cdot 020$ sec.
	Combined probable error	=	$\pm 0 \cdot 021$ sec.

If a number of sets of observations are taken consecutively and are given weights according to the intervals between time signals, then errors due to the intermediate time signals cancel out and only the rate error due to the initial and final signals need be considered.

In the past field season three or four consecutive sets were always observed, the interval between beginning and ending signals usually being 16, 22, or 24 hours according to circumstances.

Hence the probable errors in rate and in rate corrections in these different cases are :—

Total interval	24 hours	22 hours	16 hours
p.e. of rate per 24 hours. ...	$\pm \cdot 021$ sec.	$\pm \cdot 023$ sec.	$\pm \cdot 032$ sec.
p.e. of rate correction to s, ϵ_2.	$\pm 1 \cdot 23 \times 10^{-7}$ sec.	$\pm 1 \cdot 35 \times 10^{-7}$ sec.	$\pm 1 \cdot 88 \times 10^{-7}$ sec.

These probable errors apply equally to the mean of a single pendulum or to the mean of the pair of pendulums at a station.

(*e*) *The probable error of the mean time of vibration* of a pair of pendulums at a station is $\epsilon_s = \sqrt{\epsilon^2_1 + \epsilon^2_2}$.

(*d*) *Probable errors at Dehra Dūn* $=\epsilon_D$.—These are derived in the same way and are shown below for each pair of pendulums:—

Pair	A C Sec. × 10^{-7}	C B Sec. × 10^{-7}	B A Sec. × 10^{-7}
ϵ_1	$\pm 0 \cdot 69$	$\pm 2 \cdot 03$	$\pm 2 \cdot 28$
ϵ_2	$\pm 1 \cdot 23$	$\pm 1 \cdot 23$	$\pm 1 \cdot 23$
ϵ_{D_1}	$\pm 1 \cdot 41$	$\pm 2 \cdot 37$	$\pm 2 \cdot 59$
ϵ_1	$\pm 1 \cdot 63$	$\pm 0 \cdot 73$	$\pm 0 \cdot 08$
ϵ_2	$\pm 1 \cdot 23$	$\pm 1 \cdot 23$	$\pm 1 \cdot 23$
ϵ_{D_2}	$\pm 2 \cdot 04$	$\pm 1 \cdot 43$	$\pm 1 \cdot 23$
ϵ_D	$\pm 1 \cdot 75$	$\pm 1 \cdot 96$	$\pm 2 \cdot 03$

ϵ_D is the p.e. of the mean of observations in August 1933 and May 1934 where $\epsilon_D = \sqrt{\dfrac{\epsilon^2_{D_1} + \epsilon^2_{D_2}}{2}}$.

(*e*) *Probable error of g*.—The probable error of the difference in time of vibration at a station and at Dehra Dūn is $\sqrt{\epsilon^2_S + \epsilon^2_D}$.

The probable error in the deduced value of g in milligals is $\epsilon_g = 0 \cdot 38\sqrt{\epsilon^2_S + \epsilon^2_D}$, where ϵ_S and ϵ_D are in units of 10^{-7} sec.

The probable error in g is shown in Table 3 for each station. The mean probable error in g is $\pm 1 \cdot 1$ milligals and only two stations have a probable error as high as ± 2 milligals.

This probable error in g is independent of any error in the adopted value of g at Dehra Dūn, viz. 978·063 gal.

This point is discussed in the next paragraph.

25. **Observations at Colombo.**—Within recent years three determinations of gravity have been made at Colombo. They are:—

Date	*Observer*	*Value*	*Height feet*
1929	Vening Meinesz	978·147	0
1932	Lejay	978·155	20
1934	Glennie	978·132	20

The 1934 value is based on 979·063 gal for Dehra Dūn. This is probably too low. A correction of + ·009 gal is required to bring it in terms of the value, 979·072 gal, obtained in 1927 with the Cambridge apparatus. A further correction of — ·003 gal is required to Vening Meinesz's determination, and of – ·001 gal to Lejay's, to correct them for change of height and latitude when referring them to Colombo Observatory, the site of the 1934 observations.

Applying these corrections, and adding the difference from Colombo to Dehra Dūn, +0·931 gal, obtained from the 1934 determination the following values at Dehra Dūn can be added to the list of Dehra Dūn values given in the Supplement to Geodetic Report Vol. VI, page xii;

Observer	*Deduced value of g at Dehra Dūn*
Lejay	979·085
Vening Meinesz	979·075

Father Lejay used elastic pendulums for his determination.

Evidence is therefore accumulating that the adopted value of *g* at Dehra Dūn, 979·063 gal, is too small. It is likely that 979·072 gal is near the truth, so that there is a discrepancy of only 3 milligals between the 1934 determination and that made by Vening Meinesz in 1929. In the discussions of results in India, Ceylon and the Maldive and Laccadive Islands which follow, the gravity anomalies are based on the old value of *g* at Dehra Dūn ; this is immaterial so long as data from external sources are not considered. These require a correction of *minus* 9 milligals to refer them to the Survey of India value at Dehra Dūn. This correction has therefore been applied to Dr. Vening Meinesz's determinations at sea, wherever use is made of them in this chapter.

26. Consideration of results.—In Chart VI of Geodetic Report Vol. V, a comparison of the geoid with gravity data was made. The agreement was very striking except in the extreme south of India. Here the geoid rose while gravity anomalies became increasingly negative. This season a revised geoidal section has been made for southern India (see Chapter IV), and in consequence the discrepancy between the gravity data and geoid has been very largely removed. The geoid is now found to be deeply depressed in southern India.

This striking depression of the geoid and the large area of negative gravity anomalies in south India requires explanation. It cannot be attributed to any apparent deficiency in the density of surface rocks. For this reason gravity work in Ceylon was considered especially important, as it might throw light on the conditions in the adjacent parts of India,—a hope which appears to have been justified.

Ceylon is a small and nearly detached continental block apparently fairly simple in its tectonic structure, and the explanation given for this structure appears to apply equally to southern India, and perhaps, indeed, to peninsular India as a whole. Similarly conditions on the west coast of India appear to throw light on those in the Maldives and Laccadives.

Hence in the discussion which follows, Ceylon will first be considered, then the Indian results and finally those in the Maldives and at Minicoy.

27. **The structure of Ceylon.**—The only account and map of the geological structure of Ceylon is that given by Dr. F. D. Adams in 1929 in the Canadian Journal of Research. He writes "The Island is thus a great syncline whose axis runs throughout its length in a general north to south direction, passing a short distance to the east of Kandy and of Nuwara Eliya. This syncline is closed on the south by the great sweep of the strata around the southern part of the Island here dipping everywhere inward, that is to the north, but it is open to the north where the strike of the gneiss before sinking beneath the low land covered by Tertiary deposits commences to open out, as has been mentioned, into a trumpet-like form. This great syncline of archean rocks which constitutes the Island of Ceylon thus plunges to the north and disappears beneath the Miocene strata which occupy the northern end of the Island".

The syncline is largely composed of gneiss, quartzites and limestone, and is evidently for the most part sedimentary in origin, but there are great intrusions of igneous rocks, particularly in the central highlands.

Turning now to the evidence from gravity data, Charts X and XI show gravity anomalies in Ceylon, and their relation to anomalies in India are shown in Charts XII and XIII. The *isostatic* anomalies $g-\gamma_C$ and the *crustal warp* anomalies, $g-\gamma_F$ both show increasing negative anomalies as one proceeds inland from the coast, except in the north. Interpreting the results according to the hypothesis of crustal warping, the $g-\gamma_F$ anomalies show that the island overlies a downwarp of the crust, which is deepest in the north, according well with the geological description quoted above.

Agreement with the superficial geological evidence, as pictured by Adams, is however not exact. From the north of the island down to about lat. 8° the deepest part of the downwarp runs centrally, but thereafter the gravity anomalies show that the centre of the trough curves eastwards passing near Bibile, and then swings back towards the centre at the south of the island.

South-west of Ratnapura too is a deep downwarp which at first sight appears to conflict with the geological evidence of an anticline in this neighbourhood. Agreement with geology is obtained, if a local positive or upwarping disturbance is assumed in the neighbourhood of Adam's Peak, pushing eastwards the deeper layers of the trough resulting in an asymmetrical syncline with an axial plane hading to the east. To the south-west the strata has been crushed both up and down between this local upwarp and the more general upwarp off the south-west coast.

Evidence in favour of local disturbance in the Peak region of Ceylon is afforded by Mr. E. R. Bartlam, Principal of the Ceylon Technical College, who from the available data considers that Adam's Peak represents the remains of a volcanic core. Gravity anomalies plainly show a positive tendency in that area. More gravity work is required to give a better picture of the structure at the extreme south of the island. The trough may extend seawards near Hambantota or may curve round ending in the crushed depression below the anticline discussed above.

On the whole the geological evidence favours a combination of the two; the seaward extension being shallow and soon terminating, and in the charts the anomaly contours are shown accordingly.

More gravity work is also required in the Adam's Peak area. It was intended to do this, but it was prevented by the arrival of the John Murray Expedition at Colombo bringing the Ceylon tour to an end.

The positive $g - \gamma_F$ anomalies on the east coast and the very small negative anomalies on the west coast indicate upwarps flanking these coasts. From a consideration both of the geological structure and the gravity anomalies, the conclusion is reached that originally there was a more or less symmetrical downwarp and that subsequently this was squeezed by the flanking upwarps and distorted by failure of the crust in the Peak region. An upwarp south of the island has closed the syncline there.

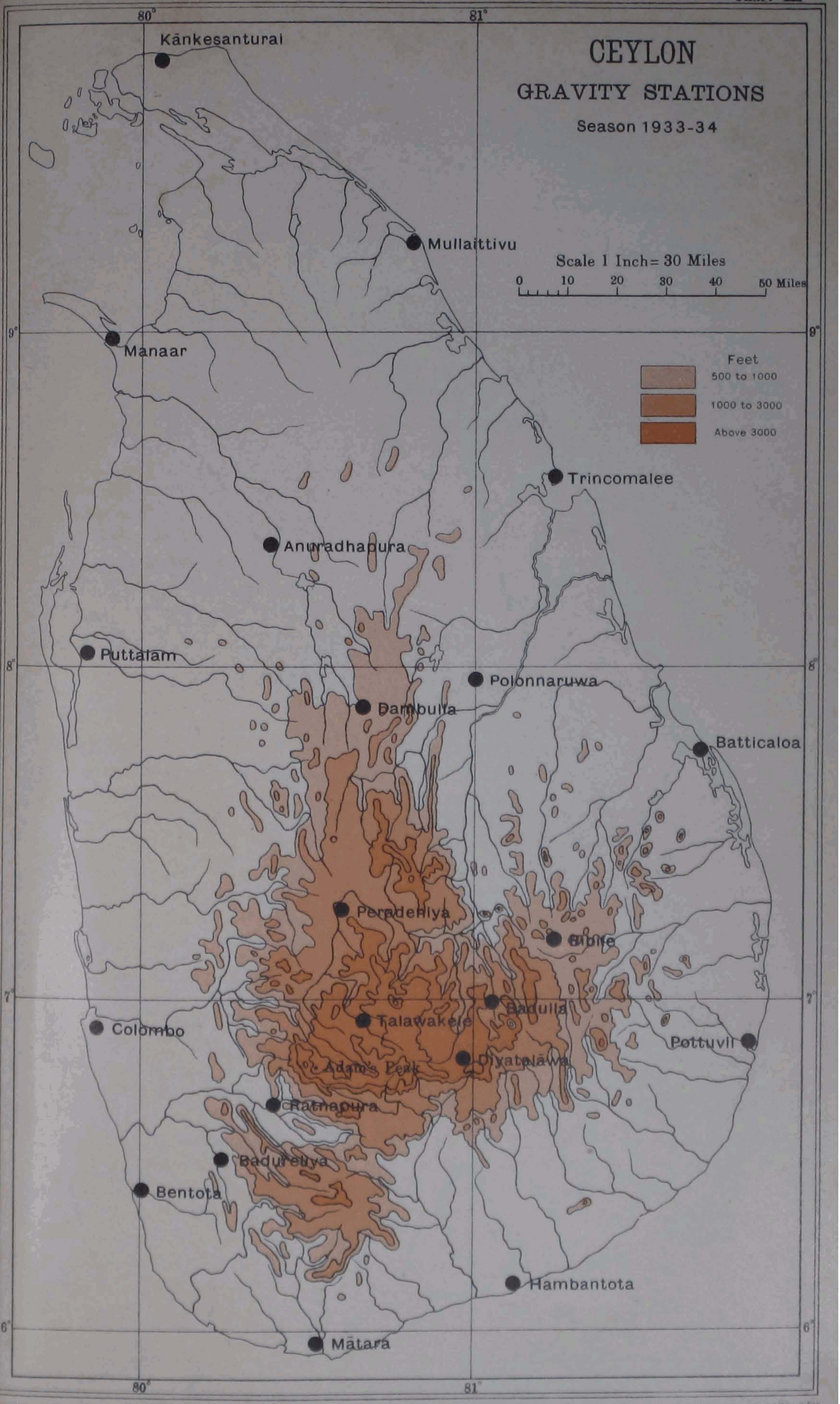
The evidence in fact is strongly in favour of lateral compression.

28. India.—The first stations in the field season were devoted to an attempt to delimit the north and west boundaries of the area of negative anomalies east of Bombay. There was a possibility, though an unlikely one, that this downwarp joined into the Vindhyan depression north of the Sātpura Range. From the small positive $g-\gamma_F$ anomaly (+3) and the $g-\gamma_{CH}$ anomaly (+15) obtained on the left bank of the Tāpti, it appears that these two downwarps are divided by an upwarp under the Sātpurās.

The remaining work in this area resulted in a shifting westward of the zero anomaly contours of both $g-\gamma_{CH}$ and $g-\gamma_F$ (see Charts XII and XIII). In consequence the rise to the large positive anomalies at Bombay is very abrupt.

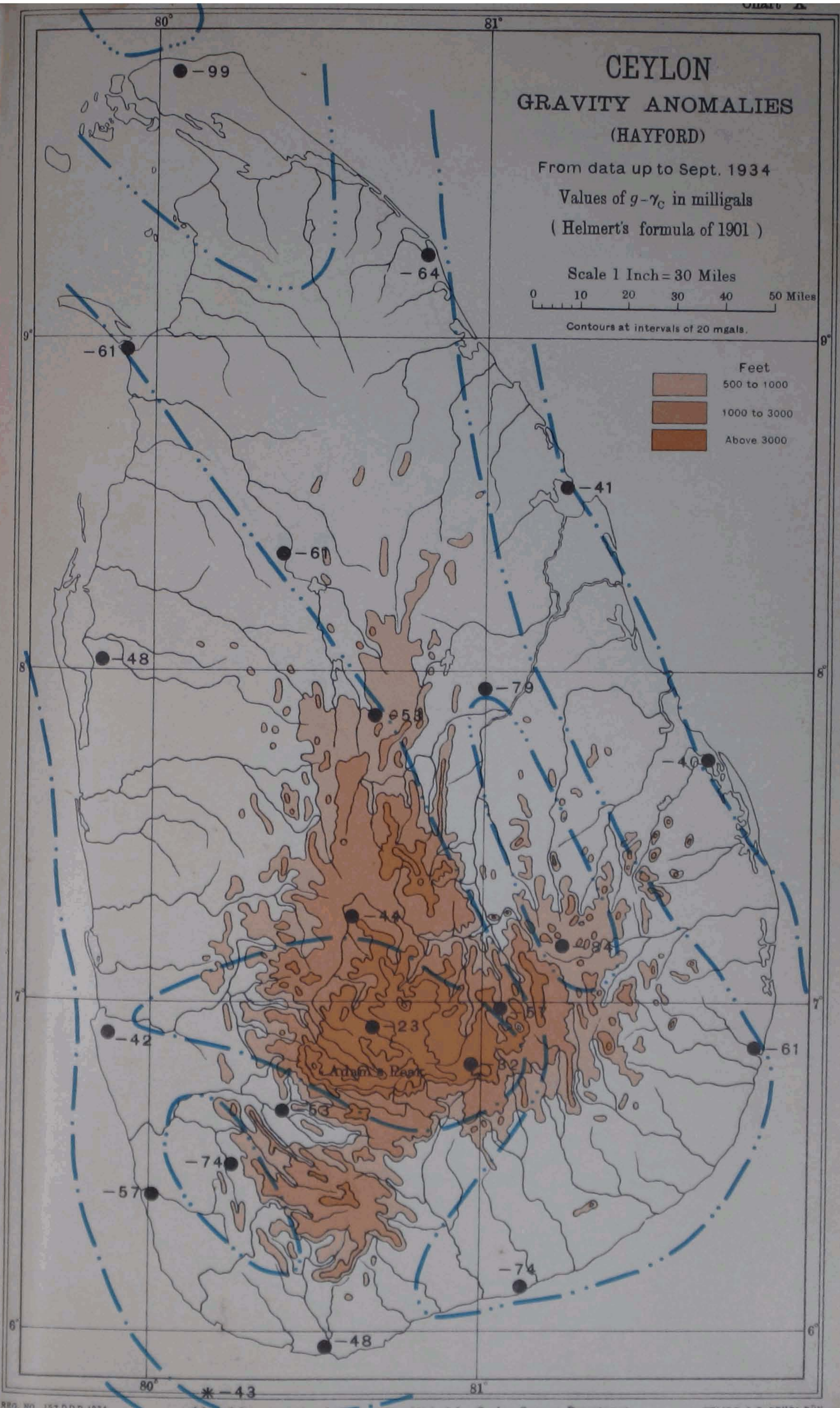
Between Panvel and Colāba, $g-\gamma_{CH}$ changes from −18 milligals to +63 milligals, that is a gradient of about 4 milligals per mile. There does not appear to be any other locality in India where the gradient markedly exceeds 3 milligals per mile. This result seems to confirm the statement already made in Professional Paper No. 27 that near Bombay is to be found the main source of upwelling of the Deccan trap. There must be a great dyke under the sea off the coast extending north from Bombay, and very high positive gravity anomalies are to be expected at sea over this.

South of Bombay the positive upwarp shown by the $g-\gamma_F$ anomalies on Chart XIII skirts the coast passing out to sea near Mangalore; inland, and paralleling this upwarp, is a downwarp which in its turn extends seawards south of Mangalore.

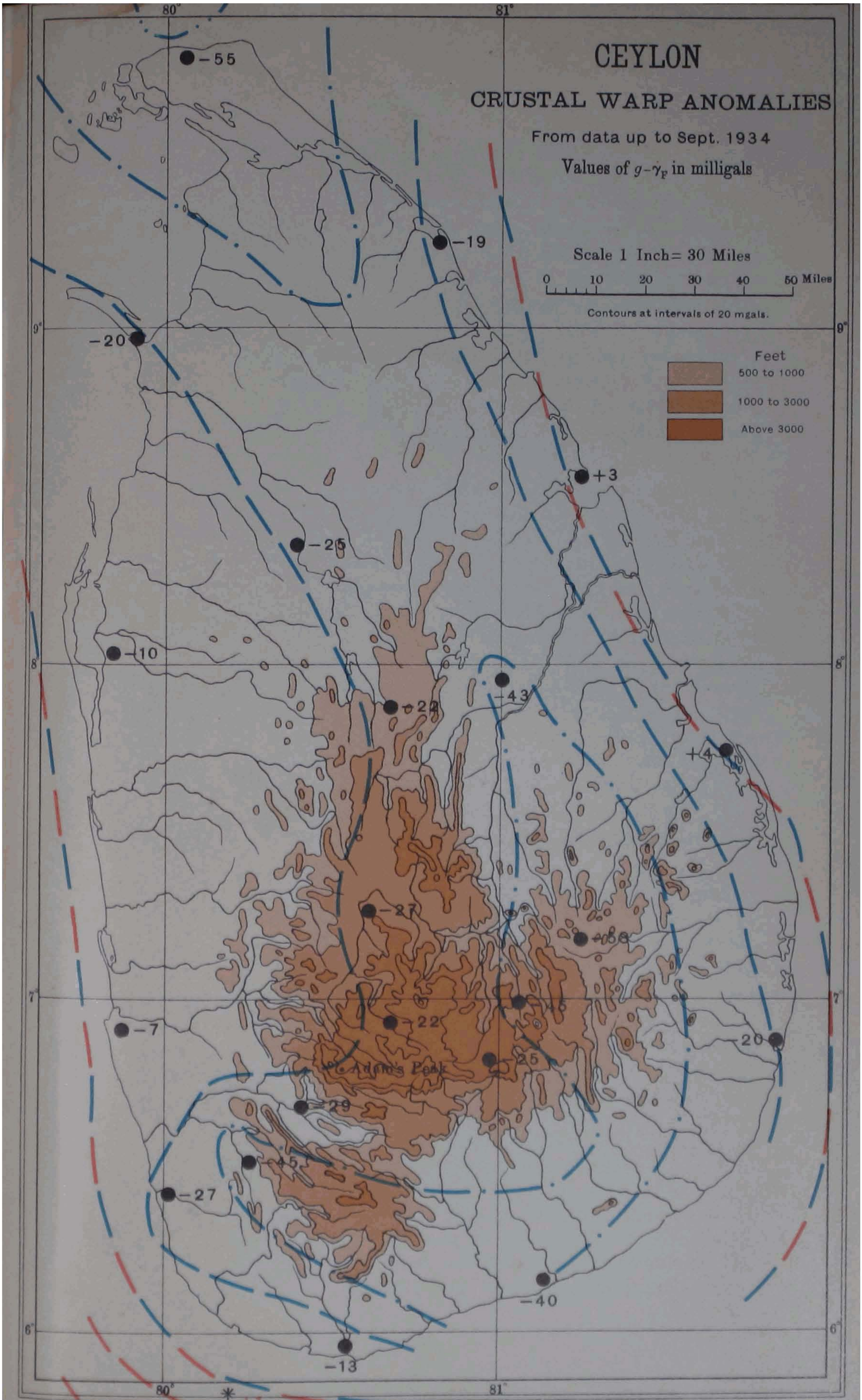


REG. NO. 156 D.D.D. 1934. Adapted by permission from a map published by Ceylon Survey Department HELIO S. I. O. DEHRA DŪN.

Chart X



REG. NO. 157 D.D.D. 1934. Adapted by permission from a map published by Ceylon Survey Department HELIO S. I. O. DEHRA DÚN.



REG. NO 158DDD 1934. Adapted by permission from a map published by Ceylon Survey Department HELIO S. I. O. DEHRA DUN.

Deflections of the plumb-line support this. Seaward deflections are found near the coast, especially large near Bombay and becoming smaller southwards. The extreme south of India, in the same way as Ceylon, appears to have been squeezed down between upwarps. These are the upwarps running from the Nīlgiris to the east coast south of Madras, and two upwarps to the south, one under the gulf of Manaar and another which approaches the west coast near Trivandrum.

Over these deep downwarpings in south India the geoid will be depressed. Superimposing on these the depression of the geoid over the trough south of the "Hidden Range", an explanation is found for the deep depression of the geoid and the negative gravity anomalies in southern India.

29. Maldive and Laccadive Islands.—The scientific equipment of the John Murray Expedition included an apparatus for continuous echo sounding. The depths obtained by this method in addition to those available in the latest Admiralty charts have been employed for the Hayford reductions. Special runs were made to obtain the profile of the bank on the east and west sides of the archipelago. These are shown in Plate XV. A smooth curve giving the average profile was drawn from these and employed where other depth data were not available. The sites of the gravity stations were always on the lagoon side of the island, so topographical changes in the nearer zones were small. In view of the very considerable amount of depth data available, the Hayford reduction work may be considered free from appreciable error.

Results on the Maldive Islands are shown in Plate XVI. The large negative anomalies and their increase towards the central meridian of the archipelago are noticeable.

At Minicoy in the Laccadive Islands in addition to the gravity station on land there is the submarine gravity station observed by Dr. Vening Meinesz out to sea on the west. The results at these two stations show a tectonic condition apparently opposite to that under the Maldives, since the crustal warp anomaly is positive over the land and negative out to sea.

From the gravity and deflection observations on the west coast of India it is known that a positive area flanks the coast as far south as Mangalore; if this is extended to Minicoy it is significant that a line drawn from Minicoy to Mangalore will skirt the southern margin of Kalpeni and Androth Islands, Ellicalpeni Bank, and other shallow soundings. It seems therefore a plausible deduction that the great positive upwarp off the Bombay coast runs south under the Laccadives to Minicoy, while the flanking depression of the crust on its east side continues out to sea south of Mangalore to the line of the Maldives, where a continental fragment of the crust has been crushed in the downwarp or submerged by it.

This conclusion is supported by Vening Meinesz's work in the Java sea. Sumatra and Java are flanked on the south and west by a great band of negative anomalies. This band persists whether its line is marked by islands or by deep sea. Over Sumatra and Java large positive gravity anomalies are found, but further east the high positive area underlies the deep Banda sea, while the negative band continues along the curve of the islands to Ceram.

Evidently the superficial conditions are incidental only. It is to the deeper warpings of the crust that the greater part of the anomalies must be referred.

The Admiralty charts also show a marked difference between the Laccadive Islands and the Maldive Islands. Instead of the striking linear arrangement of the Maldives with great atolls ten to twenty miles across, the Laccadives show a confused medley of small islands, reefs and banks.

Though the Laccadive Islands are believed to overlie an upwarped area of the crust, a small amount of recent submergence is not excluded. The original upwarp, if associated with the Arāvalli upheaval, may have occurred in geologically remote times, but any subsequent contrary movement has been much less than the original upwarp.

30. The formation of the Maldive Islands.—The formation of the Maldive Islands will be considered first with reference to the isostatic anomalies and secondly in the light of the crustal warp hypothesis.

(a) ISOSTATIC ANOMALIES

In Fadiffolu atoll the two stations Difuri and Kānifuri are at the extreme east and west margins of the atoll and there are no stations in the middle of the lagoon. In South Mālosmadulu atoll, Fonimagudu is on the eastern edge and Turādu on the western edge; while Māmādu and Mandu are in the lagoon. All the anomalies are negative and the largest anomalies are at the two stations in the lagoon.

In the Hayford corrections no allowance has been made for the low density of the coral rock, since its thickness is unknown, and it is at the stations in the lagoon that the error on this account would be greatest.

Considering only the four stations in South Mālosmadulu atoll, assume 3,000 feet thickness of coral rock, density 1·8, the deficiency in mass due to this low density being uncompensated.

Changing the topographical corrections accordingly the following results are obtained:—

Station	$g-\gamma_{CH}$ (uncorrected)	$g-\gamma_{CH}$ (corrected for coral 3,000 feet thick)
	mgal	*mgal*
Fonimagudu ..	−73	−47
Māmādu ...	−81	−49
Mandu ...	−77	−45
Turādu ...	−74	−45

The correction has therefore largely removed the discrepancy between the lagoon stations and the marginal stations.

The same assumptions applied to the Difuri and Kānifuri corrections give the following results:—

Station	$g-\gamma_{CH}$ (uncorrected)	$g-\gamma_{CH}$ (corrected)
	mgal	*mgal*
Difuri ...	−66	−36
Kānifuri ...	−71	−44

Kānifuri therefore falls into line fairly well, but Difuri is exceptional.

Considering the five accordant stations, the mean "corrected" anomaly is −46 mgals, and assuming that this anomaly is due to an additional thickness of coral, density 1·8, again with the defect uncompensated, four thousand feet additional thickness of coral is required. According to the usual explanation of the formation of the coral islands over a subsiding land mass, however, isostatic adjustment is given as the cause of subsidence. Defect of mass is therefore inadmissible, so compensation must be allowed for. With compensation of light coral rock an additional five thousand feet thickness is required.

The isostatic anomalies therefore, if solely due to the light coral rock, imply a thickness of 7,000 feet of coral *uncompensated* or 12,000 feet *compensated*. 12,000 feet thickness brings the coral deeper than the immediately surrounding ocean, a result which is only consistent with isostatic adjustment if the original land mass or bank on which the coral was formed was an upwarp of the ocean floor and not a continental relic of normal sial.

The density (1·8) which has been assumed for the coral is probably the lowest permissible, computations with higher densities would yield greater thicknesses of coral.

These calculations are based on the Helmert gravity formula of 1901; if the Bowie formula of the International gravity formula of 1930 were used, the computations would require very much greater thickness of coral. The formula based on the Survey of India spheroid which is used for the $g-\gamma_F$ anomalies, would give better results since it reduces the Helmert negative anomalies over the Maldives by 18 mgals. The total resulting thickness of coral (density 1·8) is then about 5,000 feet uncompensated or 9,000 feet compensated.

The employment of this same gravity formula in India without additional corrections would be unsatisfactory. The negative anomalies in south India would indeed be reduced, but the apparent advantage would be offset by a greatly increased area of very high positive anomalies in the northern part of the Peninsula. The use of this formula for the adjacent Maldive region without additional corrections is therefore hardly justified.

The conclusion therefore from this investigation of the isostatic anomalies is that, if the isostatic anomalies are due to local, superficial anomalies of density, the Maldive Islands mark the original site of an oceanic ridge, *not a continental block*, which has since sunk down under isostatic adjustment. Under Minicoy is part of the same ridge not yet isostatically adjusted.

(b) CRUSTAL WARPING

According to the hypothesis of crustal warping, gravity anomalies are mainly due to the up and down warpings of the lower layers of the crust. These tend to balance out, and over a very wide area equilibrium is reached very closely. This is a necessary result of the working of the ordinary laws of mechanics and of strength of materials *. Hence the Hayford method of computation provides an easy means of allowing for this general equilibrium. When computing the $g-\gamma_F$ anomaly Hayford compensation is assumed to be lacking over an area of about sixteen hundred square miles immediately surrounding the station. This anomaly is then assumed to give a measure of the underlying crustal warping, combined with the effect due to local departures of the superficial strata from normal density. In India there appears to be a general broad warping of the lower crustal layers superimposed on the more local warpings. In order to give prominence to the local warpings and so to bring out more clearly the local tectonic structure, a "Hidden Range" correction is applied to the crustal warp anomalies, which is intended to remove the effect of the general warping. In the

* See "The Hypothesis of Isostasy" by Dr. J. de G. Hunter. (Geophysical Supplement to Monthly Notices of the Royal Astronomical Society, Jan. 1932).

Maldive Islands there is no reason to assume any general warping of this nature, nor is it likely. The crustal warp anomalies therefore contain no "Hidden Range" correction.

If the underlying rock has a smooth level surface, which is not improbable, the argument used for the extra large isostatic anomalies at the two lagoon stations hold good also for the $g-\gamma_F$ anomalies. In the table below, is given (*i*) the isostatic anomaly, $g-\gamma_{CS}$, using the gravity formula on which the anomalies are based, (*ii*) the crustal warp anomaly, $g-\gamma_F$ and (*iii*) $g-\gamma_F$ corrected for the effect of 3,000 feet of coral density 1·8.

Station	$g-\gamma_{cs}$	$g-\gamma_F$	$g-\gamma_F$ corrected for 3,000 feet of coral
	mgals	*mgals*	*mgals*
Difuri ...	−48	−28	+ 2
Kānifuri ...	−53	−43	−15
Fonimagudu ...	−55	−48	−23
Māmādu ...	−63	−58	−26
Mandu ...	−59	−53	−21
Turādu ...	−56	−39	−10

Interpreted according to the previous explanation the $g-\gamma_F$ anomalies indicate a downwarp. It can be assumed that the coral has formed over the top of a block of sial of normal density which has foundered in this downwarp. The small outer anomalies show the effect of flanking upwarps. The greatest anomaly may be taken as indicating the amount of downwarp. Table III in Professional Paper No. 27 gives a means of computing the approximate depth of the downwarp.

The following assumptions may be made:—

(*i*) No thickness of coral.—An unreal assumption since there is no rock to be seen on the islands other than coral and the purely superficial beach or island sandstone.

(*ii*) Three thousand feet of coral.

(*iii*) Downwarping equal to the thickness of coral.—An interesting assumption, which implies that coral formation has kept pace with subsidence if the original land was nearly at sea-level.

Of course subsidence may not be quite the same as the downwarping; there might be a sagging of the block in the middle, or on the other hand a crushing upwards of the block. The table below gives results according to the above three assumptions:—

Computed depth of downwarping in feet

Assumed thickness of coral	Downwarping	
	Coral density 1·8	Coral density 2·2
Nil	17.000	17.000
3.000	7,500	Not computed
4.200	4,200	Not computed
6,500	Not computed	6,500

Plainly the crustal warp anomalies alone cannot yield a definite result for the thickness of the coral, but the conclusion drawn from them is that the Maldive Islands overlie an area where a block of sial has subsided as a result of the downwarping of the lower crustal layers. Whether this conclusion or that derived from the isostatic anomalies is to be preferred is a matter for argument in the light of the various theories of coral island formation, continental drift and so on.

31. **The tectonic structure lines.**—On the whole, the effect of this season has been to produce a simplified picture of the tectonic structure. This is shown in Chart XVII. Two great upwarps flank the coasts of the peninsula, another crosses it from the east at about lat. 25°. Between these the crust underlying the Indian peninsula has been wrinkled and squeezed up and down. Superimposed on all is the very gentle warp of the "Hidden Range" which is no doubt a more recent movement probably associated with the Himālayan uplift.

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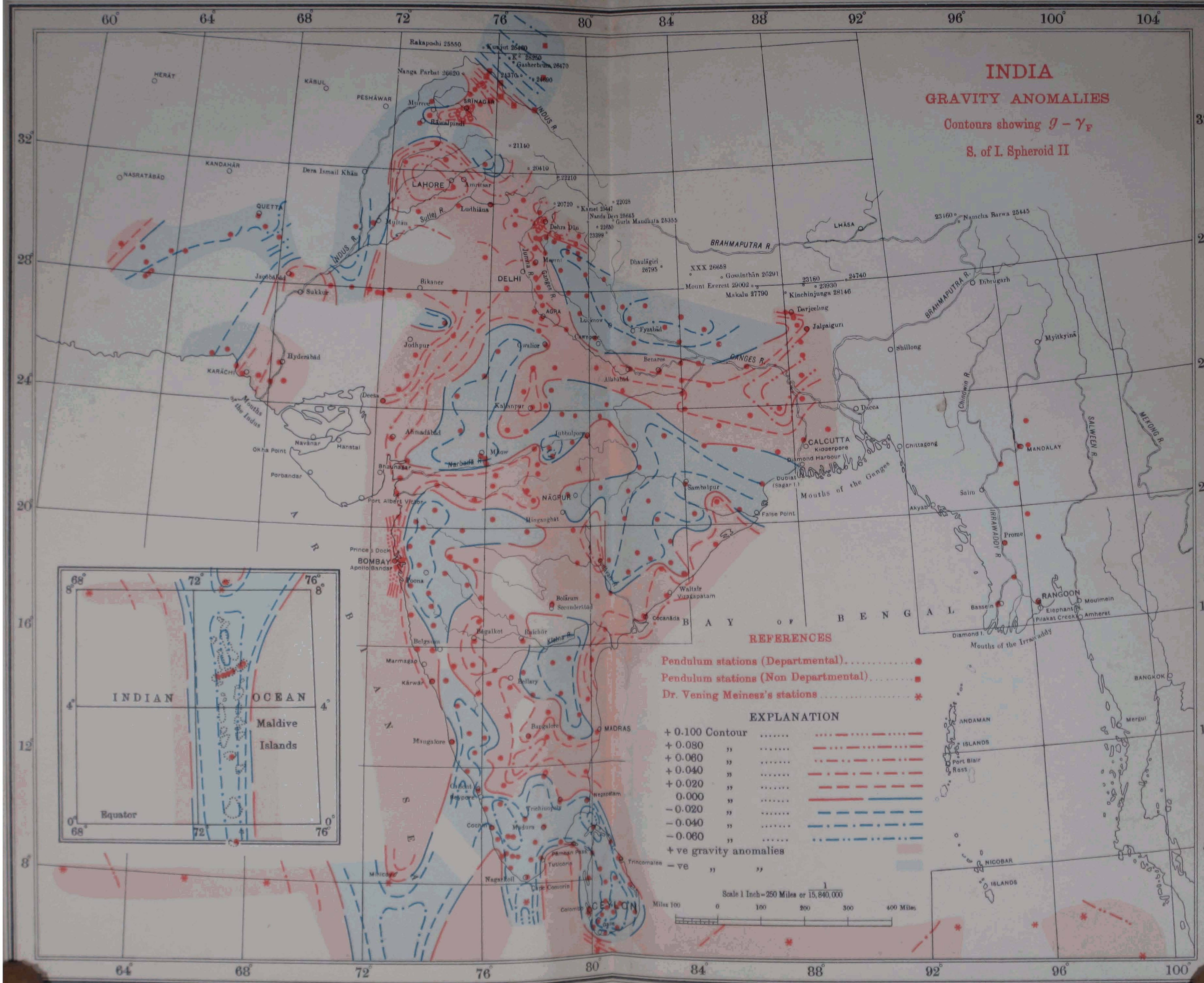
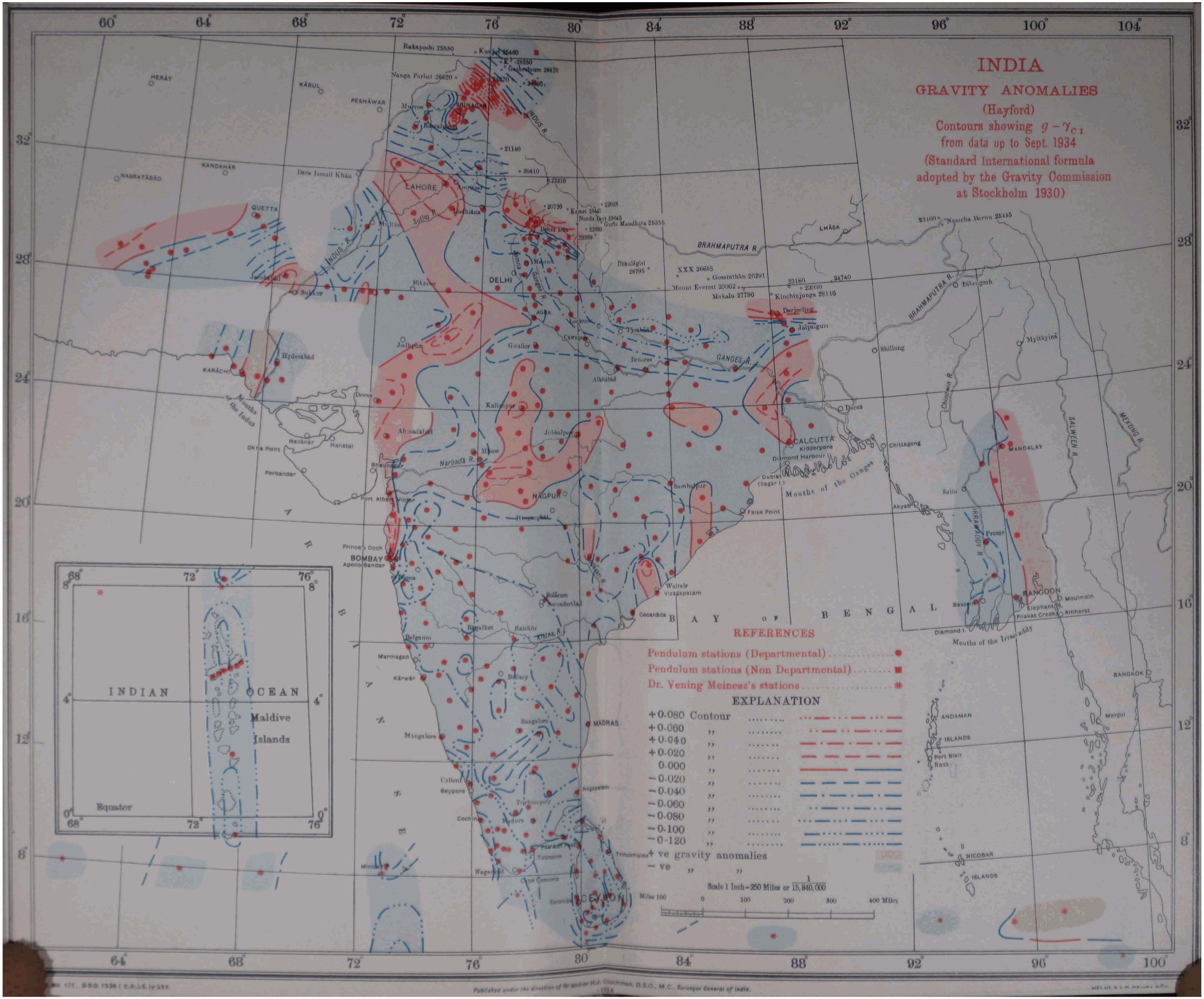
Chart XIII



INDIA
GRAVITY ANOMALIES
Contours showing $g - \gamma_F$
S. of I. Spheroid II
REFERENCES
Pendulum stations (Departmental)
Pendulum stations (Non Departmental)
Dr. Vening Meinesz's stations
EXPLANATION
+ 0.100 Contour
+ 0.080 ,,
+ 0.060 ,,
+ 0.040 ,,
+ 0.020 ,,
0.000 ,,
− 0.020 ,,
− 0.040 ,,
− 0.060 ,,
+ ve gravity anomalies
− ve ,, ,,
Scale 1 Inch = 250 Miles or $\frac{1}{15,840,000}$
Miles 100 0 100 200 300 400 Miles
INDIAN OCEAN
Maldive Islands
Equator
ARABIAN SEA
BAY OF BENGAL
BRAHMAPUTRA R.
GANGES R.
INDUS R.
Sutlej R.
Narbada R.
Mouths of the Ganges
Mouths of the Indus
Mouths of the Irrawaddy
IRRAWADDY R.
SALWEEN R.
MEKONG R.
Chindwin R.
CEYLON
ANDAMAN ISLANDS
NICOBAR ISLANDS
Rakaposhi 25550
Nanga Parbat 26620
Gasherbrum 26470
Kamet 25447
Nanda Devi 25645
Gurla Mandhata 25355
Dhaulagiri 26795
Mount Everest 29002
Makalu 27790
Gosainthān 26291
Kinchinjunga 28146
Namcha Barwa 25445
HERĀT
KĀBUL
PESHĀWAR
Murree
SRINAGAR
Rāwalpindi
KANDAHĀR
NASRATĀBĀD
Dera Ismail Khān
QUETTA
Multān
LAHORE
Amritsar
Ludhiāna
Dehra Dūn
Jacobābād
Sukkur
Bikaner
DELHI
Meerut
AGRA
Lucknow
Cawnpore
Fyzabād
Benares
Allahabad
Jodhpur
Gwalior
Hyderābād
KARĀCHI
Deesa
Kaliānpur
Jubbulpore
Ahmadābād
Mhow
Navānar
Hanstal
Okha Point
Porbandar
Bhaunagar
Port Albert Victor
NĀGPUR
Hinganghāt
Sambalpur
False Point
Darjeeling
Jalpaiguri
Shillong
Dacca
CALCUTTA
Kidderpore
Diamond Harbour
Chittagong
LHĀSA
Dibrugarh
Myitkyinā
MANDALAY
Akyab
Salin
Prome
Bassein
RANGOON
Moulmein
Amherst
Elephant Pt.
Diamond I.
BANGKOK
Mergui
Port Blair
Ross
Prince's Dock
BOMBAY
Apollo Bandar
Poona
Bolārum
Secunderābād
Waltair
Vizagapatam
Cocanāda
Belgaum
Bāgalkot
Raichūr
Marmagao
Kārwār
Bellary
Bangalore
MADRAS
Mangalore
Calicut
Beypore
Negapatam
Trichinopoly
Cochin
Madura
Minicoy
Pamban Pass
Tuticorin
Nagarkoil
Cape Comorin
Trincomalee
Colombo


INDIA
GRAVITY ANOMALIES
(Hayford)
Contours showing $g - \gamma_{C\,I}$
from data up to Sept. 1934
(Standard International formula
adopted by the Gravity Commission
at Stockholm 1930)
REFERENCES
Pendulum stations (Departmental)
Pendulum stations (Non Departmental)
Dr. Vening Meinesz's stations
EXPLANATION
+0.080 Contour
+0.060 ,,
+0.040 ,,
+0.020 ,,
0.000 ,,
−0.020 ,,
−0.040 ,,
−0.060 ,,
−0.080 ,,
−0.100 ,,
−0.120 ,,
+ ve gravity anomalies
− ve ,, ,,
Scale 1 Inch = 250 Miles or $\frac{1}{15,840,000}$
Miles 100 0 100 200 300 400 Miles
INDIAN OCEAN
Maldive Islands
Equator
ARABIAN SEA
BAY OF BENGAL
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CEYLON
QUETTA
KARĀCHI
KANDAHĀR
KĀBUL
HERĀT
PESHĀWAR
SRINAGAR
LHĀSA
BRAHMAPUTRA R.
GANGES R.
INDUS R.
Narbada R.
Kistna R.
IRRAWADDY R.
SALWEEN R.
MEKONG R.
Chindwin R.
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Gosainthān 26291
Namcha Barwa 25445
ANDAMAN ISLANDS
NICOBAR ISLANDS
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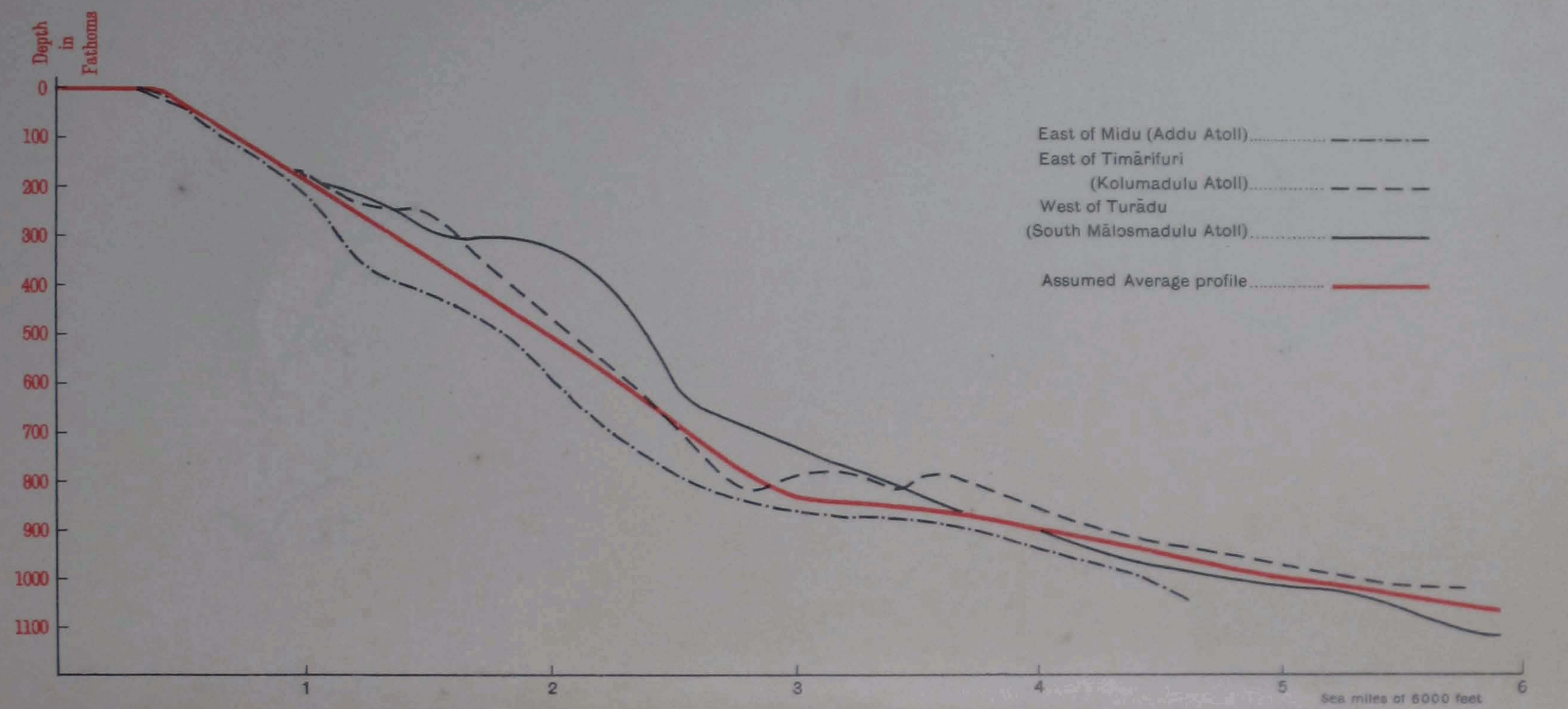
BANGKOK
Mergui
Moulmein
Akyab
Chittagong
Dacca
Shillong
Darjeeling
Jalpaiguri
Dibrugarh
Myitkyinā
Hyderābād
Jodhpur
Ahmadābād
Gwalior
Agra
Lucknow
Cawnpore
Benares
Allahābād
Jubbulpore
Kalianpur
Sambalpur
Waltair
Vizagapatam
Cocanāda
False Point
Mangalore
Bangalore
Bellary
Belgaum
Karwār
Marmagao
Calicut
Beypore
Cochin
Madura
Trichinopoly
Tuticorin
Cape Comorin
Colombo
Trincomalee
Nagapatam
Published under the direction of Brigadier H.J. Couchman, D.S.O., M.C., Surveyor General of India.
1934

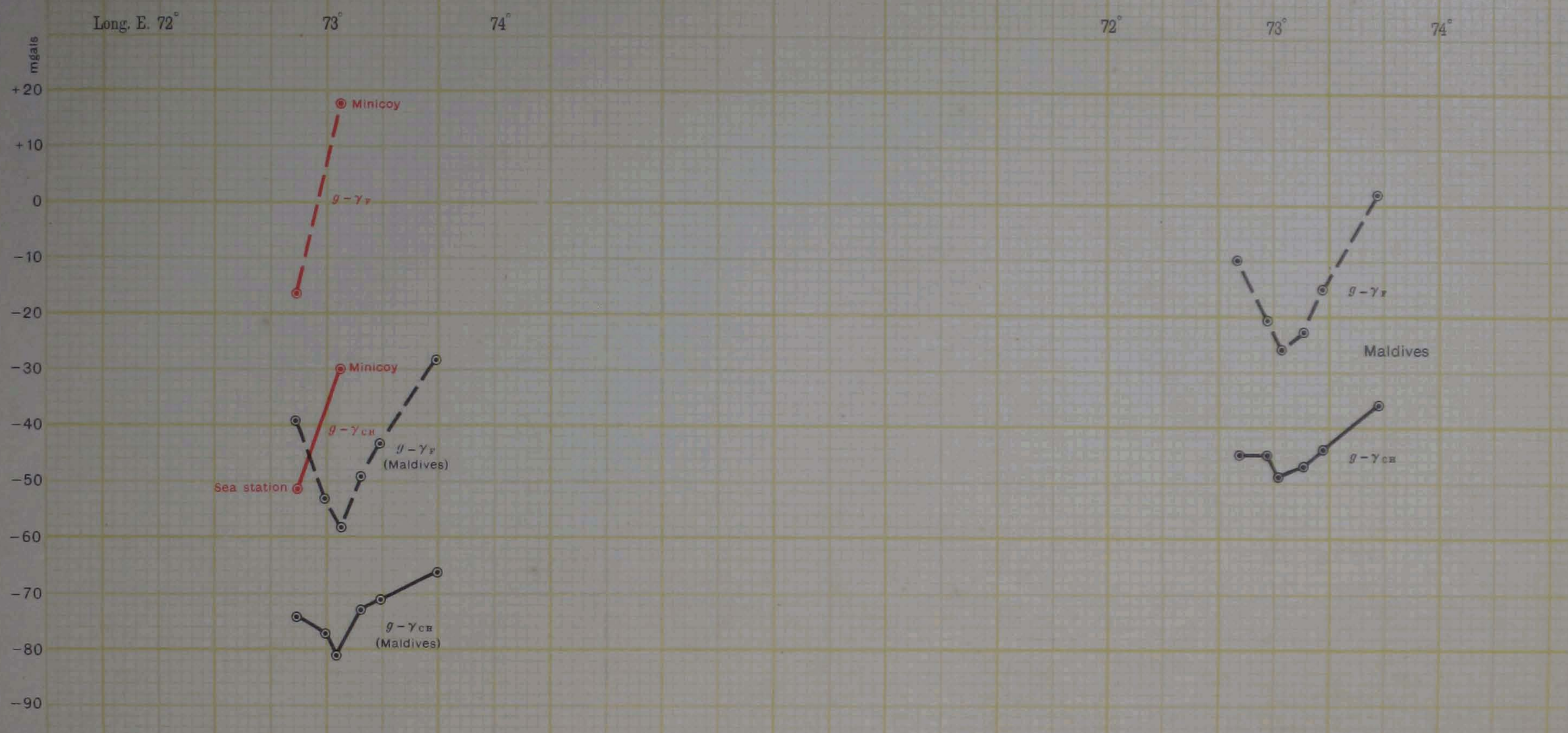
Seaward Profile of Atolls
Maldive Archipelago

Vertical scale twice Horizontal scale



REG. No.147D.D.D. 1934-390

Plate XVI



A

Gravity Anomalies
Minicoy and Maldive
Sections
assuming normal rock density (2·67).

B

Gravity Anomalies
Maldive Section
assuming 3000 feet coral (1·8)
and normal density below.

REG. No. 1490 D.O. 1934 - 390

Helio S. I. O. Dehra Dún

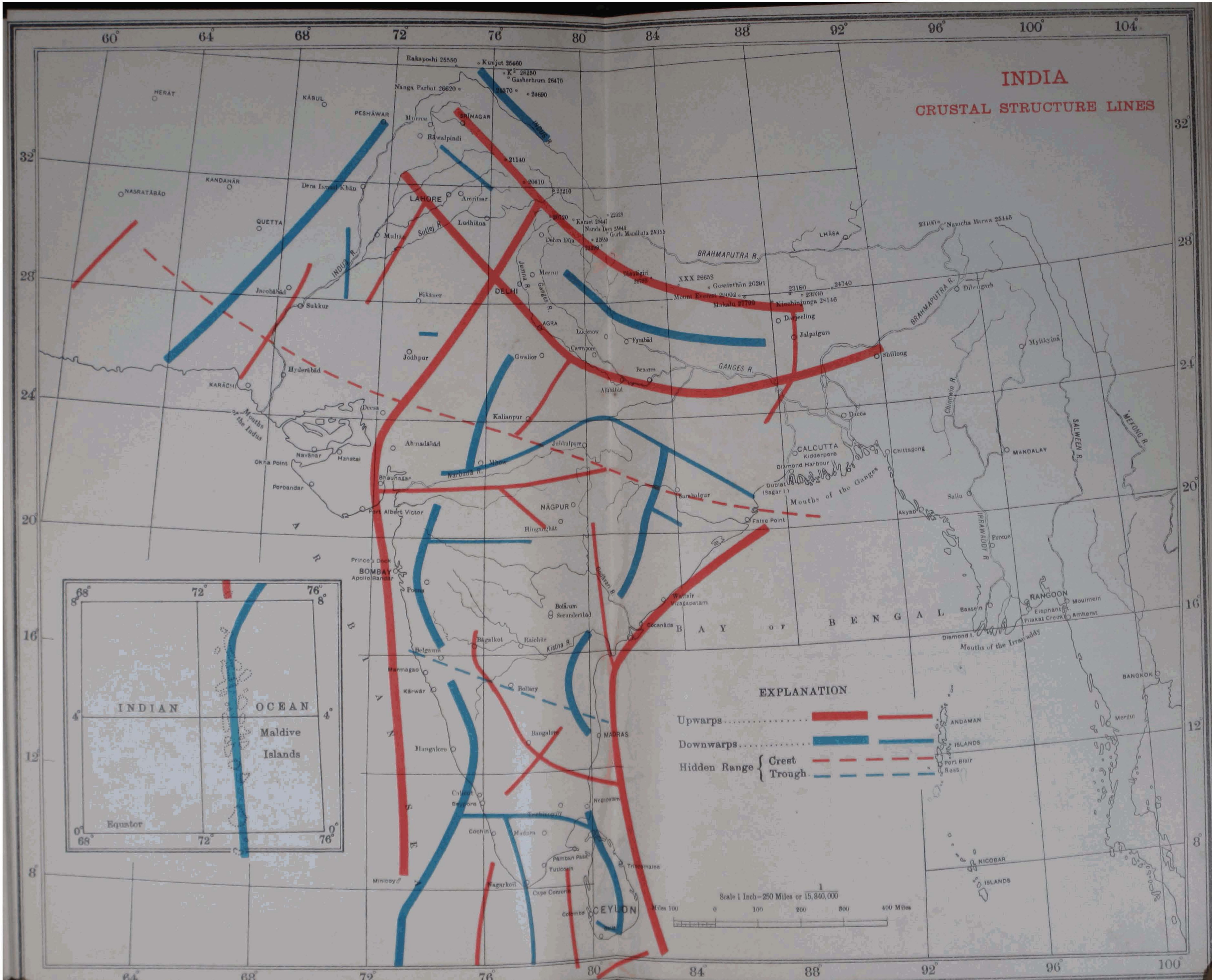


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TABLE 1.—*Times of vibration at Dehra Dūn, season 1933–34.*

Date		A	Weight	B	Weight	C	Weight
1933		s		s		s	
August 12th	...	0·507 9506	8			0·507 9509	8
,, 12	...	9494	6			9497	6
,, 13	...	9517	12			9513	12
,, 13	...	9492	6			9489	6
,, 14	...			0·507 9512	10	9491	10
,, 14	...			9504	6	9497	6
,, 15	...			9516	8	9513	8
,, 15	...	9512	8	9531	8		
,, 15	...	9510	6	9523	6		
,, 16	...	9475	8	9492	8		
Weighted mean	...	0·507 9502		0·507 9513		0·507 9502	

Date		A	Weight	B	Weight	C	Weight
1934		s		s		s	
May 7th	...	0·507 9497	6			0·507 9504	6
,, 7	...	9508	$7\frac{1}{2}$			9503	$7\frac{1}{2}$
,, 8	...	9505	$7\frac{1}{2}$			9516	$7\frac{1}{2}$
,, 8	...			0·507 9508	6	9495	6
,, 8	...			9509	9	9489	9
,, 9	...			9504	5	9488	5
,, 9	...	9508	6	9516	6		
,, 9	...	9514	$9\frac{1}{2}$	9521	$9\frac{1}{2}$		
,, 10	...	9492	4	9499	4		
,, 10	...	9524	5	9511	5		
Weighted mean	...	0·507 9508		0·507 9511		0·507 9500	

Adopted mean times of vibration.

	A	B	C
General mean	s 0·507 9505	s 0·507 9512	s 0·507 9501

TABLE 2.—*Mean differences of pairs of pendulums, season 1933–34.*
(The unit is 10^{-7} sec.)

Station No.	A–C	v	Station No.	C–B	v	Station No.	B–A	v
274	− 0·7	+ 2·5	275	+ 5·3	+ 19·6	276	+ 15·1	+ 8·4
277	− 9·0	− 5·8	278	− 19·3	− 5·0	279	+ 8·7	+ 2·0
280	− 2·0	+ 1·2	281	− 17·7	− 3·4	282	− 1·5	− 8·2
283	− 2·3	+ 0·9	284	− 8·7	+ 5·6	285	+ 6·7	0·0
286	− 1·3	+ 1·9	287	− 16·7	− 2·4	288	+ 7·7	+ 1·0
289	− 0·3	+ 2·9	290	− 13·3	+ 1·0	291	+ 15·3	+ 8·6
292	+ 4·3	+ 7·5	293	− 13·0	+ 1·3	294	+ 7·7	+ 1·0
295	− 2·3	+ 0·9	296	− 14·3	0·0	297	− 2·0	− 8·7
298	− 1·7	− 1·5	299	− 10·3	+ 4·0	300	− 4·3	− 11·0
301	− 3·3	− 0·1	302	− 16·7	− 2·4	303	+ 14·3	+ 7·6
304	− 0·7	+ 2·5	305	+ 4·3	+ 18·6	306	+ 11·0	+ 4·3
307	− 1·7	+ 1·5	308	− 17·0	− 2·7	309	+ 8·0	+ 1·3
310	− 3·0	+ 0·2	311	− 15·0	− 0·7	312	+ 10·3	+ 3·6
313	− 6·0	− 2·8	314	− 20·3	− 6·0	315	+ 9·7	+ 3·0
316	− 6·0	− 2·8	317	− 8·7	+ 5·6	318	+ 2·7	− 4·0
319	− 4·7	− 1·5	320	− 13·0	+ 1·3	321	− 0·7	− 7·4
322	− 5·7	− 2·5	323	− 19·7	− 5·4	324	+ 5·7	− 1·0
325	− 7·0	− 3·8	326	− 17·3	− 3·0	327	+ 0·7	− 6·0
328	− 4·8	− 1·6	329	− 18·5	− 4·2	330	− 2·0	− 8·7
331	− 0·7	+ 2·5	332	− 12·2	+ 2·1	—		
333	− 6·5	− 3·3	334	− 34·0	− 19·7	335	+ 13·7	+ 7·0
336	+ 1·5	+ 4·7	337	− 23·5	− 9·2	338	+ 16·8	+ 9·1
339	− 7·0	− 3·8	340	− 17·8	− 3·5	341	+ 2·0	− 4·7
342	− 8·3	− 5·1	343	− 11·0	+ 3·3	344	+ 0·3	− 6·4

TABLE 3.—*Mean times of vibration, deduced values of g and probable errors, season 1933–34.*

Station No.		Pendulums A	Pendulums B	Pendulums C	Mean	Probable error of Mean
274	s	0·508 1070		0·508 1071	0·508 1071	± 1·62
	g	978·459		978·458	978·459	0·9
275	s		0·508 1033	0·508 1038	0·508 1036	4·88
	g		978·477	978·470	978·474	2·0
276	s	0·508 0485	0·508 0501		0·508 0493	2·37
	g	978·685	978·682		978·684	1·2
277	s	0·508 0894		0·508 0902	0·508 0898	2·60
	g	978·528		978·523	978·526	1·2
278	s		0·508 0860	0·508 0841	0·508 0851	1·79
	g		978·543	978·546	978·545	1·0
279	s	0·508 1112	0·508 1120		0·508 1116	1·30
	g	978·444	978·443		978·444	0·9
280	s	0·508 1533		0·508 1535	0·508 1534	1·73
	g	978·281		978·279	978·280	0·9
281	s		0·508 1579	0·508 1552	0·508 1566	3·10
	g		978·266	978·272	978·269	1·4
282	s	0·508 1144	0·508 1143		0·508 1144	2·17
	g	978·431	978·434		978·433	1·1
283	s	0·508 1689		0·508 1691	0·508 1690	1·89
	g	978·221		978·219	978·220	1·0
284	s		0·508 1299	0·508 1291	0·508 1295	2·50
	g		978·374	978·373	978·374	1·2
285	s	0·508 1788	0·508 1795		0·508 1792	1·36
	g	978·183	978·183		978·183	0·9
286	s	0·508 1763		0·508 1764	0·508 1764	1·72
	g	978·193		978·191	978·192	0·9
287	s		0·508 1448	0·508 1432	0·508 1440	2·08
	g		978·317	978·319	978·318	1·1
288	s	0·508 1949	0·508 1957		0·508 1953	1·39
	g	978·121	978·120		978·121	0·9
289	s	0·508 2254		0·508 2254	0·508 2254	1·50
	g	978·003		978·002	978·003	0·9
290	s		0·508 2261	0·508 2247	0·508 2254	1·39
	g		978·003	978·004	978·004	0·9
291	s	0·508 1644	0·508 1658		0·508 1651	2·04
	g	978·238	978·236		978·237	1·1
292	s	0·508 2311		0·508 2307	0·508 2309	2·32
	g	977·981		977·981	977·981	1·1
293	s		0·508 1828	0·508 1815	0·508 1822	1·53
	g		978·170	978·171	978·171	0·9
294	s	0·508 1778	0·508 1785		0·508 1782	1·47
	g	978·187	978·187		978·187	1·0
295	s	0·508 1980		0·508 1983	0·508 1982	1·44
	g	978·109		978·106	978·108	0·9
296	s		0·508 1911	0·508 1896	0·508 1904	1·30
	g		978·138	978·140	978·139	0·9
297	s	0·508 1843	0·508 1852		0·508 1848	2·95
	g	978·162	978·161		978·162	1·4

(Continued)

TABLE 3.—*Mean times of vibration, deduced values of g and probable errors, season 1933–34*—(*contd.*)

Station No.		Pendulums A	Pendulums B	Pendulums C	Mean	Probable error of Mean
298	s	0·508 1902		0·508 1904	0·508 1903	± 1·32
	g	978·139		978·137	978·138	0·8
299	s		0·508 2560	0·508 2549	0·508 2555	1·62
	g		977·888	977·888	977·888	1·0
300	s	0·508 2482	0·508 2487		0·508 2485	3·07
	g	977·915	977·916		977·916	1·4
301	s	0·508 1867		0·508 1871	0·508 1869	1·41
	g	978·152		978·150	978·151	0·9
302	s		0·508 1995	0·508 1979	0·508 1987	1·39
	g		978·106	978·108	978·107	0·9
303	s	0·508 2082	0·508 2096		0·508 2089	2·17
	g	978·070	978·067		978·069	1·1
304	s	0·508 2082		0·508 2083	0·508 2083	1·36
	g	978·070		978·068	978·069	0·8
305	s		0·508 1981	0·508 1982	0·508 1982	4·64
	g		978·111	978·107	978·109	1·9
306	s	0·508 1982	0·508 1992		0·508 1987	1·67
	g	978·108	978·107		978·108	1·0
307	s	0·508 1998		0·508 2000	0·508 1999	1·57
	g	978·102		978·100	978·101	0·9
308	s		0·508 1878	0·508 1862	0·508 1870	2·29
	g		978·151	978·153	978·152	1·1
309	s	0·508 1971	0·508 1985		0·508 1978	2·19
	g	978·112	978·110		978·111	1·1
310	s	0·508 1934		0·508 1937	0·508 1936	1·44
	g	978·127		978·124	978·126	0·9
311	s		0·508 1863	0·508 1847	0·508 1855	1·46
	g		978·157	978·159	978·158	0·9
312	s	0·508 1908	0·508 1918		0·508 1913	1·57
	g	978·137	978·136		978·137	1·0
313	s	0·508 1937		0·508 1943	0·508 1940	1·53
	g	978·125		978·122	978·124	0·9
314	s		0·508 1825	0·508 1806	0·508 1816	1·97
	g		978·171	978·174	978·173	1·1
315	s	0·508 1990	0·508 2000		0·508 1995	1·50
	g	978·105	978·104		978·105	1·0
316	s	0·508 1909		0·508 1915	0·508 1912	1·43
	g	978·136		978·133	978·135	0·9
317	s		0·508 2041	0·508 2033	0·508 2037	1·87
	g		978·088	978·087	978·088	1·0
318	s	0·508 1955	0·508 1959		0·508 1957	2·14
	g	978·119	978·120		978·120	1·1
319	s	0·508 2027		0·508 2032	0·508 2030	1·65
	g	978·091		978·087	978·089	0·9
320	s		0·508 1900	0·508 1888	0·508 1894	1·41
	g		978·143	978·143	978·143	0·9
321	s	0·508 1979	0·508 1977		0·508 1978	2·87
	g	978·109	978·113		978·111	1·3

(*Continued*)

TABLE 3.—*Mean times of vibration, deduced values of g and probable errors, season 1933–34*—(*concld.*)

Station No.		Pendulums A	B	C	Mean	Probable error of Mean
322	s	0·508 2687		0·508 2694	0·508 2691	± 1·50
	g	977·836		977·832	977·834	0·9
323	s		0·508 2394	0·508 2374	0·508 2384	1·93
	g		977·952	977·956	977·954	1·1
324	s	0·508 2187	0·508 2188		0·508 2188	1·00
	g	978·029	978·031		978·030	0·9
325	s	0·508 1870		0·508 1874	0·508 1872	3·24
	g	978·151		978·148	978·150	1·4
326	s		0·508 1813	0·508 1796	0·508 1805	1·24
	g		978·176	978·178	978·177	0·9
327	s	0·508 2032	0·508 2032		0·508 2032	1·80
	g	978·089	978·092		978·091	1·0
328	s	0·508 1791		0·508 1797	0·508 1794	1·30
	g	978·182		978·178	978·180	0·8
329	s		0·508 2046	0·508 2028	0·508 2037	1·83
	g		978·086	978·089	978·088	1·0
330	s	0·508 2259	0·508 2260		0·508 2260	2·86
	g	978·001	978·004		978·003	1·3
331	s	0·508 2651		0·508 2652	0·508 2652	1·10
	g	977·850		977·848	977·849	0·8
332	s		0·508 1928	0·508 1915	0·508 1922	0·93
	g		978·132	978·132	978·132	0·8
333	s	0·508 1988		0·508 1993	0·508 1991	1·49
	g	978·106		978·102	978·104	0·9
334	s		0·508 2045	0·508 2013	0·508 2029	5·23
	g		978·087	978·095	978·091	2·1
335	s	0·508 1942	0·508 1956		0·508 1949	2·96
	g	978·125	978·121		978·123	1·4
336	s	0·508 1982		0·508 1984	0·508 1983	2·72
	g	978·108		978·106	978·107	1·2
337	s		0·508 2007	0·508 1985	0·508 1996	2·36
	g		978·101	978·105	978·103	1·2
338	s	0·508 2012	0·508 2027		0·508 2020	2·39
	g	978·096	978·094		978·095	1·2
339	s	0·508 1995		0·508 2001	0·508 1998	2·12
	g	978·103		978·099	978·101	1·0
340	s		0·508 1988	0·508 1972	0·508 1980	1·58
	g		978·108	978·110	978·109	1·0
341	s	0·508 1688	0·508 1696		0·508 1692	1·80
	g	978·221	978·221		978·221	1·0
342	s	0·508 1936		0·508 1941	0·508 1939	2·58
	g	978·126		978·122	978·124	1·2
343	s		0·508 1861	0·508 1853	0·508 1857	1·55
	g		978·157	978·156	978·157	1·0
344	s	0·508 1522	0·508 1522		0·508 1522	1·89
	g	978·285	978·288		978·287	1·1

TABLE 4.—*Modern gravity observations in India.*
(Additions in field season 1933–34).

No.	Sheet No.	Station	Date	Height	Latitude N.	Longitude E.	g	$g-\gamma_A$	$g-\gamma_B$	$g-\gamma_C$
				feet	° ′ ″	° ′ ″	*cm/sec*^{2}	*cm/sec*^{2}	*cm/sec*^{2}	*cm/sec*^{2}
274	47 E	Nāsik ...	9 9 33	1937	19 59 42	73 46 28	978·459	+ ·006	− ·059	− ·022
275	46 H	Peint ...	11 9 33	2035	20 15 15	73 30 05	978·474	+ ·016	− ·050	− ·024
276	46 K	Tāpti ..	14 9 33	377	21 31 14	74 12 53	978·684	− ·006	− ·019	·005
277	47 E	Shāhāpur ...	19 9 33	192	19 27 14	73 19 48	978·526	− ·059	− ·065	− ·049
278	47 F	Panvel ...	21 9 33	40	18 58 38	73 07 06	978·545	− ·027	− ·028	− ·018
279	47 F	Mahād ...	23 9 33	35	18 04 32	73 25 29	978·444	− ·080	− ·080	− ·063
280	47 K	Umbraj ...	25 9 33	1938	17 24 26	74 06 07	978·280	− ·030	− ·095	− ·056
281	47 L	Kolhāpur ...	27 9 33	1842	16 42 33	74 14 43	978·269	− ·015	− ·077	− ·043
282	47 G	Ratnāgiri ...	30 9 33	10	17 01 14	73 16 43	978·433	− ·038	− ·038	− ·039
283	48 I	Tambulvadi ...	6 10 33	2294	15 55 05	74 17 21	978·220	+ ·017	− ·060	− ·030
284	48 E	Vengurla ...	7 10 33	58	15 51 40	73 39 12	978·374	− ·036	− ·037	− ·043
285	48 M	Dhārwār ...	10 10 33	2390	15 27 39	75 00 09	978·183	+ ·010	− ·071	− ·027
286	48 J	Yellāpur ...	12 10 33	1777	14 57 56	74 42 56	978·192	− ·015	− ·075	− ·051
287	48 J	Kārwār ...	14 10 33	23	14 47 27	74 06 41	978·318	− ·046	− ·046	− ·050
288	48 N	Anantapur ...	17 10 33	2081	14 03 54	75 12 47	978·121	− ·019	− ·089	− ·056
289	57 C	Hassan ...	19 10 33	3095	13 00 09	76 06 06	978·003	+ ·002	− ·102	− ·050
290	48 O	Mudgere ...	21 10 33	3211	13 08 13	75 38 34	978·004	+ ·007	− ·099	− ·057
291	48 L	Mangalore ...	23 10 33	135	12 52 41	74 51 28	978·237	− ·036	− ·050	− ·046
292	48 P	Mercāra ...	29 10 33	3723	12 25 44	75 43 50	977·981	+ ·061	− ·063	− ·025
293	49 M	Cannanore ...	31 10 33	40	11 51 42	75 21 24	978·171	− ·073	− ·074	− ·083
294	49 M	Calicut ...	3 11 33	23	11 15 01	75 46 40	978·187	− ·037	− ·038	− ·045
295	58 B	Pālghāt ..	5 11 33	304	10 46 13	76 39 09	978·108	− ·073	− ·083	− ·072
296	58 B	Trichūr ...	7 11 33	38	10 30 48	76 13 07	978·139	− ·059	− ·060	− ·072
297	58 C	Cochin ...	13 11 33	11	9 57 59	76 14 41	978·162	− ·022	− ·023	− ·043
298	58 C	Kottayam ...	16 11 33	83	9 34 52	76 31 27	978·138	+ ·043	− ·030	− ·051
299	58 C	Pīrmed ...	18 11 33	3322	9 34 34	76 58 20	977·888	+ ·026	− ·079	− ·072
300	58 G	Thekkadi ..	20 11 33	2897	9 35 35	77 10 32	977·916	+ ·014	− ·082	− ·068
301	58 D	Quilon ...	24 11 33	36	8 53 08	76 35 30	978·151	+ ·001	− ·000	− ·035
302	58 C	Punalūr ...	26 11 33	111	9 01 01	76 55 48	978·107	− ·040	− ·043	− ·064
303	58 H	Tenmalai ...	28 11 33	527	8 57 57	77 04 19	978·069	− ·037	− ·053	− ·067
304	58 H	Shencottah ...	30 11 33	562	8 58 26	77 15 00	978·069	− ·034	− ·052	− ·065
305	58 D	Trivandrum ...	2 12 33	24	8 29 05	76 57 08	978·109	− ·031	− ·032	− ·067
306	58 H	Cape Comorin	6 12 33	108	8 04 44	77 32 47	978·108	− ·014	− ·017	− ·063
307	58 H	Pālamcottah ...	8 12 33	141	8 43 00	77 44 04	978·101	− ·035	− ·040	− ·067
308	58 L	Tuticorin ...	11 12 33	5	8 47 31	78 09 32	978·152	+ ·001	+ ·001	− ·027
309	58 G	Sāttūr ..	15 12 33	209	9 21 34	77 55 29	978·111	− ·036	− ·043	− ·058
310	58 K	Rāmnad ...	21 12 33	20	9 21 30	78 50 28	978·126	− ·038	− ·039	− ·068
311	58 O	Dhanushkodi ...	25 12 33	4	9 10 29	79 25 16	978·158	− ·003	− ·003	− ·041
312	58 P	Manaar ...	28 12 33	7	8 58 33	79 54 57	978·137	− ·018	− ·018	− ·061
313	67 C	Kānkesanturai	31 12 33	11	9 48 58	80 02 52	978·124	− ·055	− ·055	− ·099
314	67 C	Mullaittivu ...	3 1 34	13	9 16 02	80 48 50	978·173	+ ·010	+ ·012	− ·064
315	67 D	Anuradhapura	7 1 34	288	8 20 55	80 23 24	978·105	− ·007	− ·016	− ·061
316	58 P	Puttalam ...	9 1 34	5	8 01 39	79 49 52	978·135	+ ·005	+ ·005	− ·048
317	68 B	Ratnapura ...	19 1 34	177	6 41 01	80 24 13	978·088	+ ·005	+ ·001	− ·053
318	59 N	Bentota ...	21 1 34	26	6 25 25	79 59 50	978·120	+ ·027	+ ·028	− ·057
319	68 B	Badureliya ...	22 1 34	51	6 30 55	80 14 42	978·089	− ·003	− ·003	− ·074
320	68 C	Mātara ...	24 1 34	10	5 56 36	80 32 52	978·143	+ ·059	+ ·062	− ·048
321	68 F	Hambantota ..	25 1 34	61	6 07 13	81 07 38	978·111	+ ·028	+ ·029	− ·074

(*Continued*)

TABLE 4.—*Modern gravity observations in India.*
(Additions in field season 1933–34)—(*concld.*)

No.	Sheet No.	Station	Date	Height	Latitude N.	Longitude E.	g	$g-\gamma_A$	$g-\gamma_B$	$g-\gamma_C$
				feet	° ′ ″	° ′ ″	*cm/sec*^{2}	*cm/sec*^{2}	*cm/sec*^{2}	*cm/sec*^{2}
322	68 B	Diyatalāwa ...	28 1 34	4103	6 49 01	80 57 37	977·834	+ ·115	− ·019	− ·032
323	68 F	Badulla ...	31 1 34	2193	6 59 23	81 03 30	977·954	+ ·053	− ·057	− ·057
324	68 E	Bibile ...	2 2 34	796	7 09 35	81 13 36	978·030	− ·005	− ·031	− ·084
325	68 F	Pottuvil ...	4 2 34	17	6 51 27	81 49 56	978·150	+ ·048	+ ·051	− ·061
326	68 E	Batticaloa ...	9 2 34	6	7 45 17	81 41 02	978·177	+ ·054	+ ·057	− ·040
327	68 A	Polonnaruwa ...	13 2 34	212	7 57 22	80 59 55	978·091	− ·018	− ·025	− ·079
328	67 H	Trincomalee ...	15 2 34	17	8 33 17	81 13 47	978·180	+ ·038	+ ·040	− ·041
329	68 A	Dambulla ..	17 2 34	534	7 51 37	80 39 10	978·088	+ ·011	− ·006	− ·053
330	68 A	Peradeniya ...	20 2 34	1587	7 16 04	80 35 52	978·003	+ ·039	− ·014	− ·044
331	68 B	Talawakele ...	22 2 34	3967	6 56 20	80 39 46	977·849	+ ·116	− ·014	− ·023
332	59 N	Colombo ...	25 2 34	20	6 54 18	79 52 13	978·132	+ ·029	+ ·030	− ·042
333	...	Midu ...	22 3 34	5	0 35 54	73 10 45	978·104	+ ·073	+ ·085	− ·087
334	...	Timārifuri ...	24 3 34	4	2 13 12	73 09 18	978·091	+ ·054	+ ·065	− ·076
335	50 G	Difuri ...	29 3 34	4	5 23 36	73 38 00	978·123	+ ·047	+ ·057	− ·066
336	50 G	Kānifuri ...	31 3 34	4	5 22 12	73 19 12	978·107	+ ·032	+ ·038	− ·071
337	50 G	Fonimagudu ...	2 4 34	4	5 15 54	73 10 24	978·103	+ ·029	+ ·033	− ·073
338	50 G	Māmādu ...	4 4 34	4	5 13 30	73 03 36	978·095	+ ·022	+ ·024	− ·081
339	50 C	Mandu ...	5 4 34	4	5 11 30	72 58 00	978·101	+ ·029	+ ·031	− ·077
340	50 C	Turādu ...	7 4 34	5	5 02 42	72 48 42	978·109	+ ·040	+ ·048	− ·074
341	49 H	Minicoy ...	10 4 34	6	8 19 03	73 03 51	978·221	+ ·084	+ ·115	− ·029
342	57 C	Sira ...	22 4 34	2178	13 44 48	76 53 56	978·124	+ ·007	− ·066	− ·018
343	48 N	Dāvangere ...	24 4 34	1938	14 27 59	75 55 11	978·157	− ·013	− ·078	− ·036
344	47 K	Surul ...	29 4 34	2542	17 57 54	74 01 38	978·287	+ ·004	− ·081	− ·038

NOTE:—This table is the third addendum to the list of gravity stations given in the Supplement to Geodetic Report Vol. VI.

TABLE 5.—*Values of* $g-\gamma_F$.

(The unit is 10^{-7} sec.)

Station No.	Corrections to $g-\gamma_{CH}$: Compen-sation	Hidden Range	Spheroid S. of I. II	$g-\gamma_F$	Station No.	Corrections to $g-\gamma_{CH}$: Compen-sation	Hidden Range	Spheroid S. of I. II	$g-\gamma_F$
274	−19	− 4	+24	−21	310	0	+22	+19	−27
275	−13	− 6	+24	−20	311	+ 1	+22	+19	+ 1
276	− 7	−20	+25	+ 3	312	0	+22	+19	−20
277	− 5	0	+24	−30	313	0	+25	+19	−55
278	− 3	+11	+24	+14	314	+ 2	+24	+19	−19
279	− 8	+22	+23	−26	315	− 3	+21	+18	−25
280	−20	+26	+23	−27	316	+ 1	+19	+18	−10
281	−18	+31	+22	− 9	317	−10	+16	+18	−29
282	− 2	+31	+22	+12	318	0	+12	+18	−27
283	−19	+36	+22	+ 9	319	− 4	+15	+18	−45
284	− 2	+36	+22	+13	320	+ 6	+11	+18	−13
285	−20	+36	+21	+ 3	321	+ 1	+15	+18	−40
286	−15	+34	+21	−11	322	−28	+17	+18	−25
287	− 2	+34	+21	+ 3	323	−24	+18	+18	−45
288	−19	+33	+21	−22	324	−11	+19	+18	−58
289	−28	+30	+20	−29	325	+ 5	+18	+18	−20
290	−27	+30	+20	−35	326	+ 5	+21	+18	+ 4
291	− 1	+29	+20	+ 2	327	− 2	+20	+18	−43
292	−27	+28	+20	− 5	328	+ 4	+22	+18	+ 3
293	− 1	+26	+20	−39	329	− 6	+19	+18	−22
294	− 2	+25	+19	− 3	330	−19	+18	+18	−27
295	− 8	+24	+19	−48	331	−34	+17	+18	−22
296	− 2	+23	+19	−32	332	+ 1	+16	+18	− 7
297	0	+22	+19	− 3	333	+24	0	+17	−46
298	− 1	+21	+19	−12	334	+18	0	+17	−41
299	−19	+21	+19	−51	335	+20	0	+18	−28
300	−26	+21	+19	−54	336	+10	0	+18	−43
301	0	+19	+19	+ 3	337	+ 7	0	+18	−48
302	− 5	+19	+19	−31	338	+ 5	0	+18	−58
303	− 9	+19	+19	−38	339	+ 6	0	+18	−53
304	−11	+19	+19	−38	340	+ 7	0	+18	−39
305	− 1	+17	+18	−33	341	+31	0	+18	+19
306	0	+17	+18	−28	342	−21	+33	+21	+15
307	− 2	+19	+18	−32	343	−18	+34	+21	+ 1
308	0	+20	+19	+12	344	−24	+21	+23	−18
309	− 3	+21	+19	−21					

TABLE 6.—*Values of* $g-\gamma_{CI}$.
(The unit is 10^{-7} sec.)

Station No.	$g-\gamma_{CI}$	Station No.	$g-\gamma_{CI}$	Station No.	$g-\gamma_{CI}$	Station No.	$g-\gamma_{CI}$
274	−40	292	− 44	310	− 87	328	− 60
275	−42	293	−102	311	− 60	329	− 72
276	−13	294	− 64	312	− 80	330	− 63
277	−67	295	− 91	313	−118	331	− 42
278	−36	296	− 91	314	− 83	332	− 61
279	−81	297	− 62	315	− 80	333	−106
280	−74	298	− 70	316	− 67	334	− 95
281	−61	299	− 91	317	− 72	335	− 85
282	−57	300	− 87	318	− 76	336	− 90
283	−48	301	− 54	319	− 93	337	− 92
284	−61	302	− 83	320	− 67	338	−100
285	−45	303	− 86	321	− 93	339	− 96
286	−69	304	− 84	322	− 51	340	− 93
287	−68	305	− 86	323	− 76	341	− 48
288	−74	306	− 82	324	−103	342	− 36
289	−69	307	− 86	325	− 80	343	− 54
290	−76	308	− 46	326	− 59	344	− 56
291	−65	309	− 77	327	− 98		

CHAPTER IV

DEVIATION OF THE VERTICAL

BY CAPTAIN G. BOMFORD, R.E.

32. Summary.—A detachment under Mr. R. B. Mathur, B. A. measured both components of the deviation of the vertical at 35 stations along a line from the Burma frontier through Bengal to near Rānchi in Orissa. This work extends the section across Burma reported in Geodetic Report 1933, Chapter III, and connects it to that part of the Indian geoid whose form is fairly well known. During the next two years it is hoped to extend this section across India to the Persian frontier.

A detachment under Computer J. B. Mathur measured the meridional component of the deviation of the vertical at 36 stations along a north-and-south line from Cape Comorin to near Hyderābād, Deccan. It is hoped to extend this section to near Agra in 1934–35, where a short length of the east-and-west line will connect it to the Ajmer–Ladākh geoidal section described in Geodetic Report Vol. VII., Chapter IV.

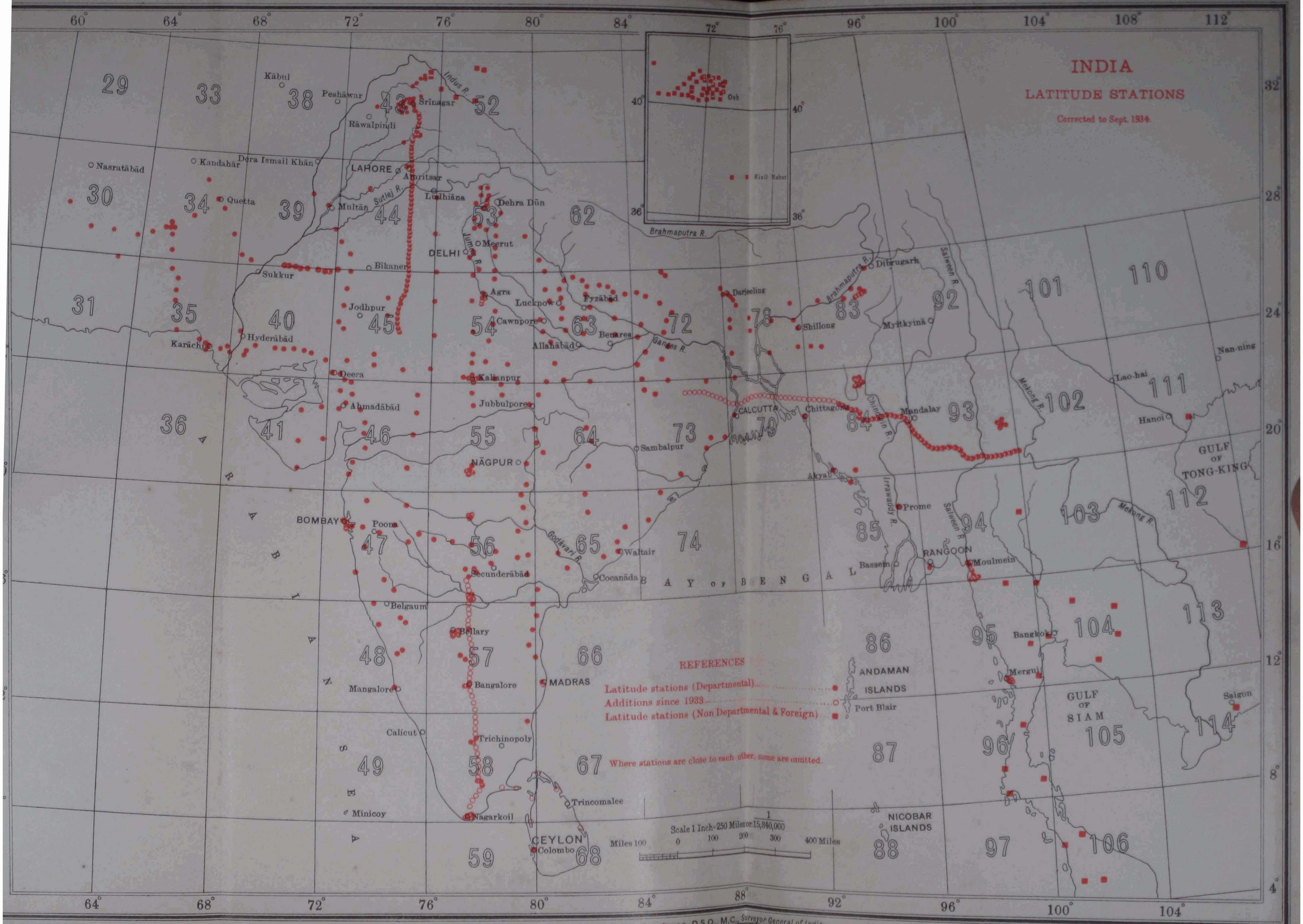
As a result of the last two seasons' work it is now possible to draw provisional geoidal contours in Burma, to which Siamese observations also contribute. The result shows a very remarkable geoidal rise to the south. Data in Lower Burma and Siam are at present regrettably scant, but the rise appears to be real, and agrees with results obtained from Stokes' formula by R. A. Hirvonen* (see para 48).

While making pendulum observations, Major E. A. Glennie observed 7 latitude and longitude stations in south India and Ceylon (see Chapter III). A few astronomical latitudes and azimuths were also observed in connection with the Padag (Baluchistān) and Namtiali (Assam) base-lines. These, together with all the observations described above, are tabulated in Table 5 (pages 80 to 87) which constitutes the fourth addendum to the list of deflection stations included in the Supplement to Geodetic Report Vol. VI.

LATITUDE AND LONGITUDE OBSERVATIONS IN BENGAL

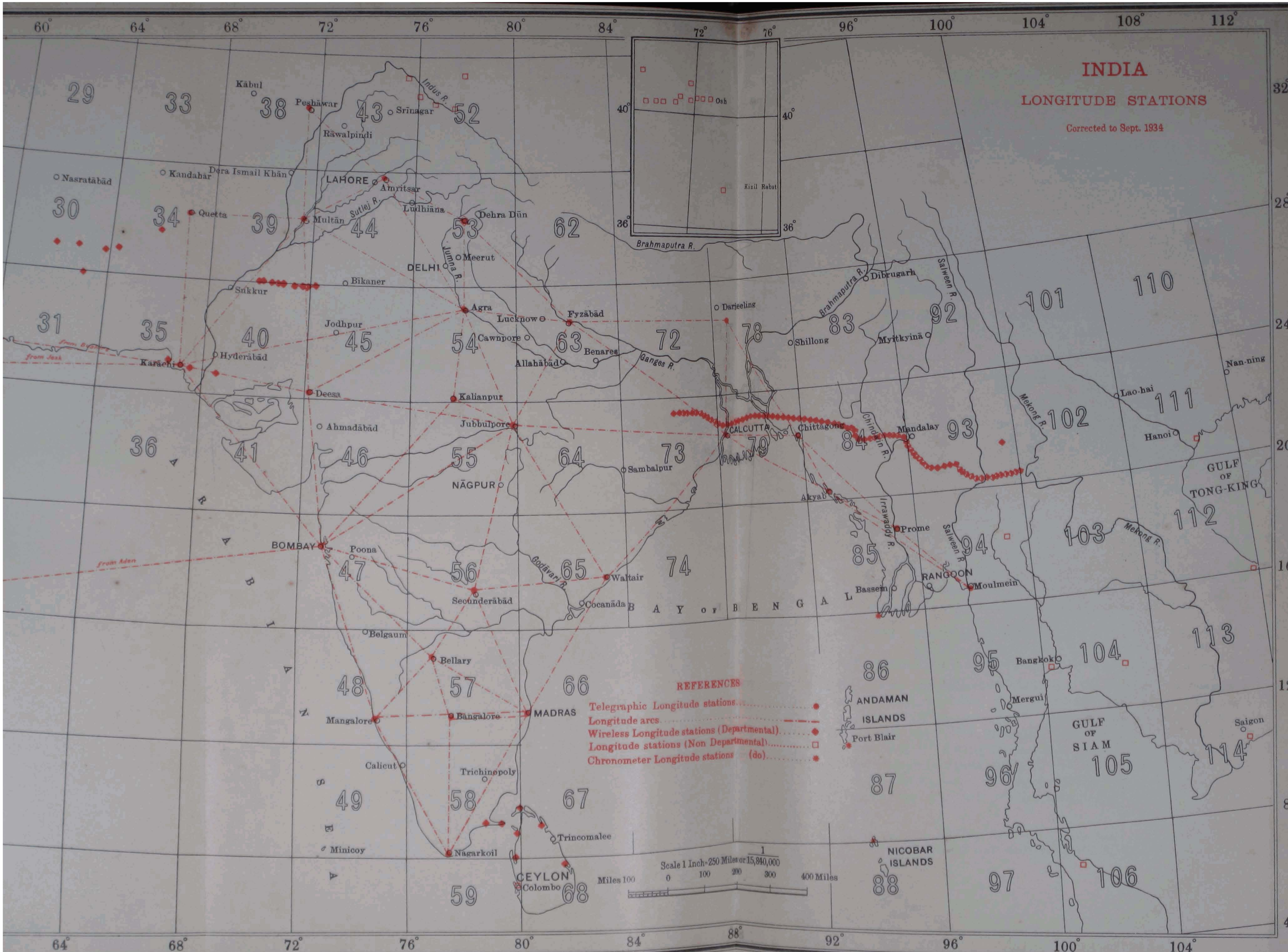
33. Astronomical observations.—The instruments and system of work were the same as those used the previous year (Geodetic Report 1933, pages 16 and 17). At all stations observations were made for one night with the prismatic astrolabe (large model), which was checked by comparative observations with the bent transit at about every fourth station. A series of four nights'

* "The Continental Undulations of the Geoid" by R.A. Hirvonen, Helsinki 1934.



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

Heliozincographed at the Survey of India Offices, Dehra Dūn.



94.D.D.D.1934(C.O)S.I-380.
Published under the direction of Brigadier H.J. Couchman, D.S.O., M.C., Surveyor General of India.
Heliozincographed at the Survey of India Offices, Dehra Dūn.

observations to determine personal equation was made with both instruments at Dehra Dūn both before and after the field season.

During the first part of the season the longitudes were based on the Rugby 10.00 and 18.00 G.M.T. signals, but later it became impossible to receive the former, and use was made of the Bordeaux 20.01 G.M.T. and 18.00 Rugby signals. On many nights only one signal was received and the rate of the clock was then determined by two distinct series of astronomical observations. This procedure involves no loss of accuracy, but is tiring for the observer. In 1931–32 Major Glennie found wireless reception (15000–18000 metres) difficult in the neighbourhood of Calcutta, and this appears to be a permanent characteristic of the place.

34. **Personal equation.**—The personal equation of transit and astrolabe was determined at Dehra Dūn as follows :—

Date	Longitude by Transit	Longitude by Astrolabe
Nov. 27	$5^h12^m11^s{\cdot}74$	$5^h12^m11^s{\cdot}74$*
28	11 ·75*	11 ·68*
29	11 ·54	11 ·59
30	11 ·65	11 ·63*
Dec. 6	11 ·65*	11 ·63
7	11 ·71	—
Weighted Mean	11 ·67	11 ·63
April 20	11 ·66	11 ·77
21	11 ·75	11 ·86
25	11 ·71	11 ·76
26	11 ·79	11 ·72
Mean	11 ·73	11 ·78

The accepted longitude of Dehra Dūn is $5^h\ 12^m\ 11^s{\cdot}77$, so the corrections to the transit and astrolabe are $+0^s{\cdot}10$ and $+0^s{\cdot}14$ before the field season, and $+0^s{\cdot}04$ and $-0^s{\cdot}01$ after the season.

Table 1 shows the differences between the transit and astrolabe at the field stations where they were both used. According to the transit, corrected in accordance with the Dehra Dūn observations, the proper correction to the astrolabe is $+0^s{\cdot}05$ during the first half and $+0^s{\cdot}09$ during the second. The Dehra Dūn observations of the astrolabe itself suggest $+0^s{\cdot}09$ for the first half and $+0^s{\cdot}02$ for the second. The values which have been accepted are $+0^s{\cdot}06$ for the first half of the season and $+0^s{\cdot}05$ for the second.

* Low weight on account of clock comparisons being insufficient.

TABLE 1.—*Personal equation of the Astrolabe.*

Date (1)	Interpolated correction to Transit (2)	Observed Transit *minus* Astrolabe (3)	Astrolabe correcton (2) + (3) = corrected Transit *minus* Astrolabe (4)	Means (5)	Directly interpolated correction to Astrolabe (6)	Means (7)
	s	s	s	s	s	s
Dehra Nov. & Dec.	+0·10				+0·14	
Dec. 24	+0·10	−0·05	+0·05		+0·12	
Jan. 4	+0·09	−0·18	−0·09		+0·10	
19	+0·09	+0·01	+0·10	+0·05	+0·09	+0·09
27	+0·08	+0·15	+0·23		+0·08	
Feb. 6	+0·08	−0·01	+0·07		+0·07	
16	+0·07	−0·09	−0·02		+0·06	
Mar. 2	+0·07	0·00	+0·07		+0·05	
12	+0·06	+0·02	+0·08		+0·04	
20	+0·06	+0·01	+0·07		+0·03	
27	+0·05	+0·09	+0·14	+0·09	+0·02	+0·02
April 5	+0·05	−0·03	+0·02		+0·01	
11	+0·04	+0·11	+0·15		+0·00	
Dehra April	+0·04				−0·01	

35. **Geodetic positions.**—All except four of the observations were made at previously fixed trigonometrical stations. The remaining four were fixed by resection from points recently fixed by topographical triangulation.

36. **Probable errors.**—The mean probable error of the determination of latitude at each station was $\pm 0''\cdot 43$: of local time by the astrolabe $\pm 0^s\cdot 022$: and of local time by the transit $\pm 0^s\cdot 023$. The average probable error of the time-keeping of the "mean clock" between stars and wireless was $\pm 0^s\cdot 015$. These figures are all satisfactorily low but they are of little importance in determining the probable error of geoidal height between the ends of the section. This depends almost entirely on systematic error in the personal equation, and as the latter is based on two short groups of observations at Dehra, it cannot be taken as less than $0^s\cdot 02$ (as in Geodetic Report 1933). The resulting probable error of geoidal height in a section 430 miles long is then $\pm 3\cdot 3$ feet, or say ± 4 feet to allow for other sources of error.

If this ± 4 feet is combined with the $\pm 4\cdot 6$ feet found for the probable error of the Burma section (1933), the probable error in geoidal height in the 900 miles between Orissa and Indo-China is $6\cdot 1$ feet, so the accuracy attained is certainly sufficient to record the main features of the geoid.

37. **Narrative of season's work.**—The detachment, consisting of Mr. R.B. Mathur, one computer, and 35 *khalāsis,* left Dehra

Dūn on 9th Dec. Leaving Chittagong on 16th Dec and observing one station *en route* they reached the Burma frontier on 30th Dec, and then worked back through Fenny, Jessore and Bānkura to Jhalida (40 miles east of Rānchi), where work closed on 13th April.

Transport in the Chittagong Hill Tracts and the Lushai Hills was by coolies, of whom 70 were semi-permanently engaged. Transport across the Bengal delta, by carts, coolies and boats, was difficult on account of the frequent changes necessary. In one march of 15 miles it was necessary to make 5 changes of transport. From Jessore onwards transport was generally by cart or rail. The health of the detachment was good until the end of February, but there was a good deal of fever as the weather got hot.

38. **Computations.**—Field computations were carried out as in the previous year. The times of emission of the wireless signals have been corrected in accordance with the "definitive" lists of the Bulletin Horaire. Geodetic positions are in terms of current G.T. values, i.e., those published in the triangulation pamphlets.

39. **The geoidal section.**—Chart XX shows the stations observed and the detailed geoidal contours which result from them in combination with a few older stations. Plate XXI shows sections of the geoid and compensated geoid with reference to the International spheroid. It also shows a section of the geoid as hitherto given in Survey of India charts. The old section differs considerably from the new in showing a rise from the Ganges delta towards the west. The new section is of course correct, as the old one was based only on a few azimuth observations (see next para). The old and the new lie fairly parallel between longitudes 86° and 88°, and the datum of the new section has been chosen to make them agree there.

40. **Laplace stations.**—Several longitude stations are at or near old azimuth stations, and more or less accurate Laplace equations can consequently be formed. Table 2 shows the deflections at these places deduced from longitude and azimuth observations respectively, and the azimuth error of the triangulation which is consequently inferred. The deflections are with respect to Everest's spheroid. Where the azimuth and longitude stations are not identical, two or three of the latter have been meaned together.

The comparisons with Chittagong and Calcutta longitude stations show that there is nothing seriously wrong with the new work: differences of deflection of $1''\cdot 7$ and $0''\cdot 0$ may well occur between stations 40 miles apart in even the flatest country. The astronomical azimuth observations appear to have been carefully made (in 1863–69), and it can only be concluded that the East Calcutta triangulation series, to which most of the azimuth stations belong, is of exceptionally low quality.

TABLE 2.—*Laplace equations.*

Longitude station	Azimuth station	Distance between 1 & 2	P.V. deflection (Everest) by longitude at 1	P.V. deflection* by azimuth at 2	Deduced error in triangulation
1	2	3	4	5	6
		miles	"	"	"
Pokimura, Maji Tān, Betagee ...	Chittagong Laplace	40	− 9·7	− 8·0	For comparison
Pokimura, Maji Tān, Betagee ...	Semu Tān H.S.	12	− 9·7	− 4·0	− 2·2
Haripur, Mālgaon ...	Gangapur T.S.	15	−10·2	− 0·2	− 4·2
Bāshakpur, Haripur ...	Lakhinagar T.S.	12	− 8·5	+12·0	− 8·7
Daulatpur ...	Daulatpur T.S.	0	−11·8	+ 4·7	− 6·9
Simahāt, Satten ...	Calcutta Laplace	35	− 7·5	− 7·5	For comparison
Madhpur ...	Madhpur T.S.	0	− 0·1	+ 8·4	− 3·6
Tilabani ...	Tilabani H.S.	0	− 5·0	+ 0·9	− 2·5

The errors in this triangulation, and in the deflections deduced from its azimuth stations, account for the errors in the old geoid referred to in para 39. It can be said with some confidence that most of the Indian triangulation is free from errors of this size (after adjustment on Laplace stations), but the present case emphasizes the fact that little reliance can be placed on geoidal features whose existence has been deduced solely from azimuth stations. This fact has of course been realized since Dr. de Graaff Hunter first started to draw the Indian geoid, but until recently few longitude stations have been available as an alternative to azimuths, and some years must still elapse before sufficient will be available to verify all the main features of the geoid. It is a fortunate fact that the most striking geoidal features in India run more or less east and west, and their form is consequently based on meridional deflections, whose accuracy cannot be doubted.

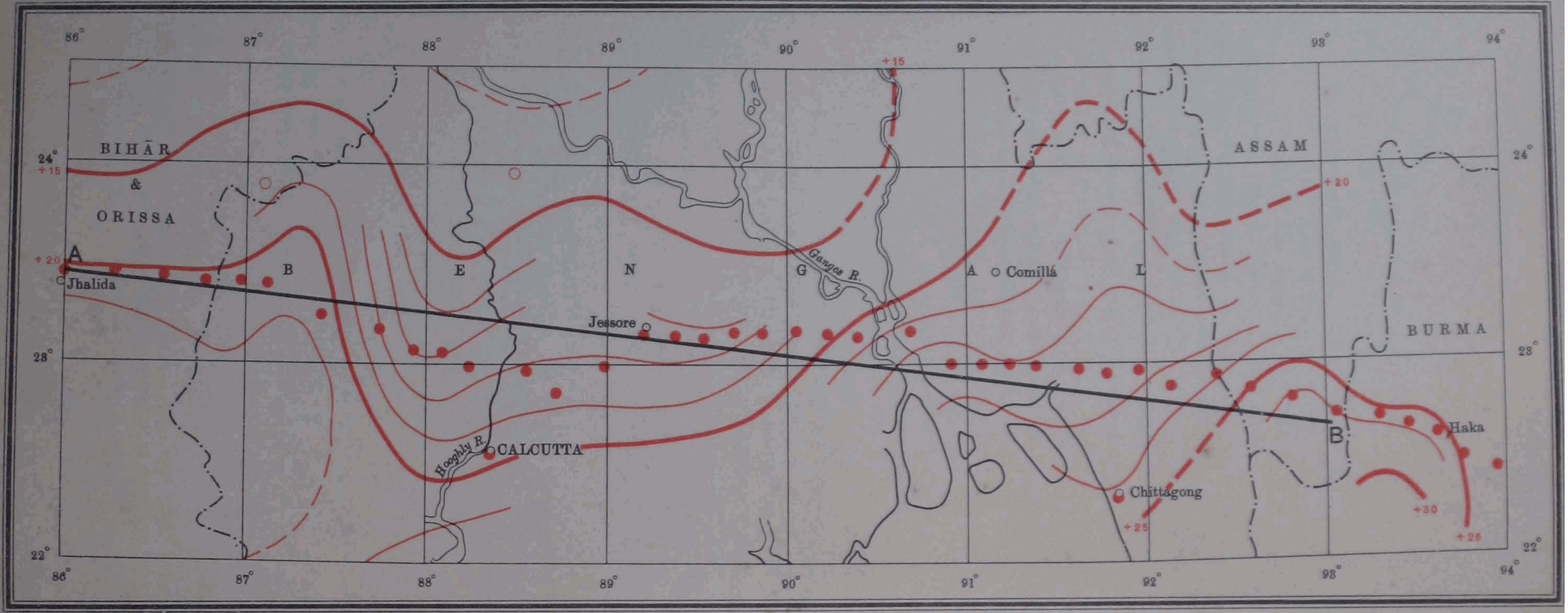
LATITUDE OBSERVATIONS IN SOUTH INDIA

41. **Programme.**—The instrument used was the small Zenith Telescope on a portable iron stand (see Geodetic Report Vol. VII, page 50). About 10 pairs of latitude stars, 2 deviation stars, and an occasional collimation star, were observed at each station, on one night only. Apart from the reduction from two nights to one, the system of work was the same as that described in Vol. VII. The average probable error of the astronomical latitudes was $\pm 0''\cdot 25$.

* Corrected for the known azimuth errors at old Laplace stations, assuming error at intermediate stations to have accumulated evenly. See Professional Paper No. 16. Table XCIV.

THE GEOID IN BENGAL

Referred to the International Spheroid



REG. No. 178 D.D.D.-1535.380

Latitude and Longitude stations .... ●

Latitude stations only .... ○

Scale 1/3,801,600 or 1 Inch to 60 Miles

Miles 20 10 0 20 40 60 80 Miles

Helio S. I. O. Dehra Dun

Geoidal contours at 1-foot intervals.

A-B is the line on which Plate XXI gives Sections.

To avoid doubt in the geodetic value of the latitude, the observations were always made at or in the immediate neighbourhood of an existing triangulation station or intersected point. Since only the meridional component of the deflection was observed, the stations were placed as nearly as possible on a north-and-south alignment.

42. **Narrative of season's work.**—The detachment, consisting of Computer J. B. Mathur, one computer and 10 *khalāsis*, left Dehra Dūn on 4th Dec and started work at the south end of the section. Transport was by country carts, but coolies frequently had to be engaged to carry the camp up to the trigonometrically fixed hill-tops. Work closed on 26th March.

Cloud caused some delay and annoyance in December and January. The health of the detachment was good.

This season Computer J. B. Mathur was doing work which has hitherto been done by officers some grades senior to himself, and he deserves credit for his satisfactory out-turn of thoroughly reliable work.

43. **The geoidal section.**—Plate XXI shows sections of the geoid and compensated geoid with reference to the international spheroid, and also the geoidal section as previously determined. Between latitudes 17° and 13° the old and new sections agree well*, but between latitudes 13° and 11° paucity of data in the old section has resulted in a sharp drop of 20 feet being completely missed. The comparatively high geoid which has been supposed to exist in the extreme south of India has caused some surprise when contrasted with the low values of gravity found there, and it is satisfactory to find that no discrepancy really occurs. The rise in the compensated geoid under the Mysore plateau (latitude 13°) finds its counterpart in the relatively positive Hayford gravity anomalies there (see Chart XII in Chapter III), although the most positive gravity anomalies seem to occur (near latitude 12°) rather south of the crest of the geoidal rise. The explanation probably is that a narrow belt of intense gravity anomaly can result from masses which are too local to have much effect on the geoid.

THE GEOID IN INDIA, BURMA AND SIAM

44. **Siamese data.**—The geoidal section given in Plate XXI gives the form of the geoid along the northern frontier of Siam, so that values of the meridional component of the deflection in Siam and Lower Burma will suffice to determine its form approximately in that country. Unfortunately, not many stations are available, but they agree among themselves so closely in giving a fairly uniform southerly deflection, that a very large geoidal rise to the south can be fairly confidently predicted from them.

* The old value in latitude 17° has been used as datum.

The Director of the Royal Siamese Survey has kindly communicated the information given in the first four columns of Table 3. The geodetic latitudes require careful consideration. They are computed on a spheroid with Everest's axes, but with a centre which is not coincident with that of the Indian Everest spheroid. They can, however, be readily brought into Indian terms by applying the discrepancies at the three Indo-Siamese junction points as given in Geodetic Report Vol. VII, page 5*. Geodetic latitudes relative to Everest's spheroid are next converted to the Indian international spheroid in the usual way by means of Chart XI S of the Supplement to Geodetic Report Vol. VI, and the results are given in column 6. A further point which must be considered is that the Indian triangulation has never been adjusted on to its Laplace stations †. The resulting error generally has little effect on geodetic latitudes and longitudes, but in Burma the azimuth errors are large, the country is far east of the origin, and all geodetic latitudes are wrong by an appreciable amount. They have to be increased by about $0''\cdot 9$ in long 92°, $1''\cdot 5$ in 96°, and $2''\cdot 1$ in 99°. The corrections are important because of the large meridional extent of the country which is being considered. They are applied in the 7th column of Table 3, and the last column gives the final values for the deflection.

45. The geoid in Burma and Siam.—The data available south of the main cross-section are the 9 latitude stations in Siam given in Table 3, and 15 in Burma. Several of the latter are grouped close together, and for practical purposes the deflection is only known at 6 places. These are shown in Table 4 and Chart XVIII.

There are also three longitude stations where the deflection in the prime vertical is known, and 12 azimuth stations. Azimuth stations in low latitudes are useless, however, and at present nothing can be done beyond a rough determination of the rise of the geoid from north to south.

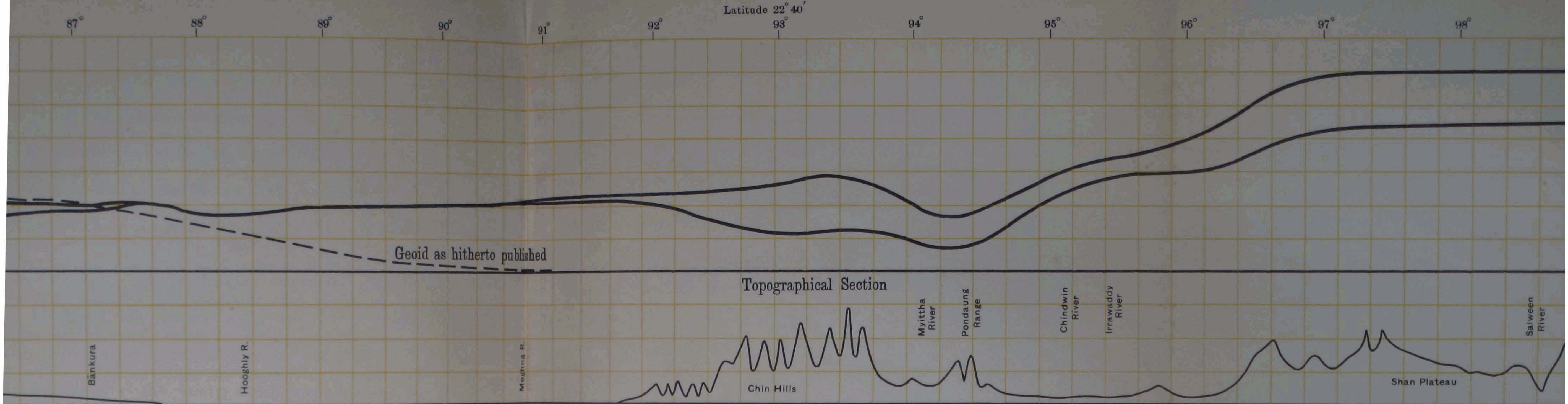
Although 15 stations and groups in Burma and Siam are not much, they are evenly distributed, and the constancy of their deflections is remarkable. Only one station or group, that near Akyab, has a northerly deflection, and that is fully accounted for by the local topography. It is also far west of the general line of stations which is being considered. The mean southerly deflection of the 15 groups is $+3''\cdot 4$, and 13 of them lie between $+2''\cdot 9$ and $+5''\cdot 5$. It may also be noted that of the 44 latitude stations in the main section line from east to west, 42 have southerly deflections.

* This rough adjustment will eventually have to be replaced by a regular "simultaneous adjustment" of all the triangulation in Siam and Lower Burma. This is not practicable at present, but the results are not likely to differ by more than $1''$ in latitude from those now arrived at.

† Except the geodetic azimuths when required for deducing A–G at astronomical azimuth stations.

THE GEOID IN BENGAL & BURMA

Section on Line A-B of Chart XX and of Chart XI of G.R. 1933



THE GEOID IN SOUTH INDIA

Section on Longitude 77° 45′ E.

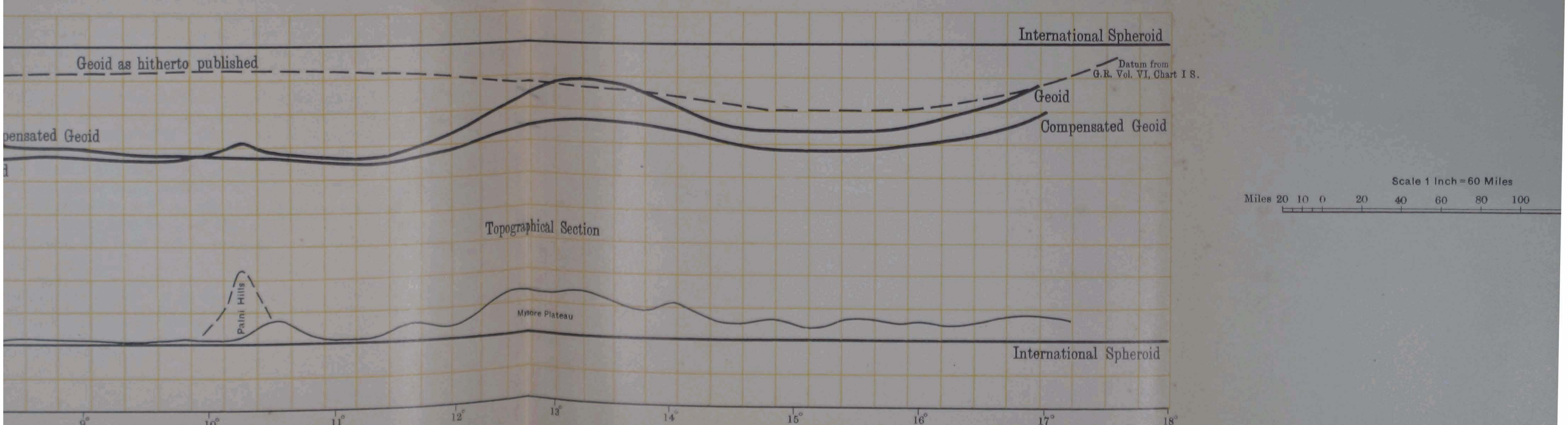


TABLE 3.—*Siamese Latitude Stations.*

NAME (1)	Longitude (2)	Astronomical Latitude (3)	Geodetic Latitude (Siamese terms) (4)	Geodetic Latitude (Indian terms. Everest) (5)	Geodetic Latitude (International) (6)	Geodetic Latitude (International, corrected for Laplace adjustment) (7)	A – G (3) – (7)
	° ′	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	″
Koh Yāo-yai	98 36	7 58 32·09	7 58 21·11	7 58 21·11	7 58 25·31	7 58 27·31	+ 4·8
Base N. Nagorn Srīdharmrāj ...	99 58	8 28 47·64	8 28 37·04	8 28 37·04	8 28 41·24	8 28 43·24	+ 4·4
Khao Pākglōhng Bāngphakbie ...	98 16	9 00 15·98	9 00 07·00	9 00 07·00	9 00 10·70	9 00 12·70	+ 3·3
Khao Gūang	99 56	12 27 38·18	12 27 30·00	12 27 28·75	12 27 31·45	12 27 33·45	+ 4·7
Khao Srabāp	102 13	12 33 06·05	12 32 58·18	12 32 56·93	12 32 59·93	12 33 01·93	+ 4·1
Base S. Rājburi	99 50	13 33 18·51	13 33 11·51	13 33 09·91	13 33 12·21	13 33 14·21	+ 4·3
Khao Bhrik	101 33	14 54 05·89	14 53 58·18	14 53 56·43	14 53 58·43	14 54 00·43	+ 5·5
Base E. Nagorn Sawarn ...	100 11	15 23 10·86	15 23 06·01	15 23 04·21	15 23 05·91	15 23 07·91	+ 2·9
Khao Kungkang	99 04	15 28 26·10	15 28 23·67	15 28 21·87	15 28 23·47	15 28 25·47	+ 0·6

TABLE 4.—*Latitude stations and groups in Lower Burma.*

Station or group	Latitude	Longitude	Number in group	A – G (International)	A – G (International, corrected for Laplace adjustment)
	° ′	° ′		″	″
Akyab	20 08	92 54	3	– 0·7	– 1·8
Prome	18 49	95 13	1	+ 4·2	+ 2·9
Rangoon (Syriam) ...	16 44	96 17	1	+ 5·1	+ 3·6
Moulmein ...	16 30	97 38	3	+ 6·2	+ 4·4
Amherst	16 04	97 42	5	+ 5·4	+ 3·7
Mergui	12 22	98 45	4	+ 5·9	+ 3·9

If the deflections at the 15 groups are integrated up as if they all stood in the same longitude, there results a fairly uniform rise of about 70 feet between latitudes 20° and 8°N. As the geoid in latitude 20° is already 65 feet above the Indian International spheroid, the abnormality in the south of Siam amounts to the large figure of 135 feet. This is discussed in para 48.

It must be emphasized that the form of the geoid in Burma is not yet at all well determined (except along the one section line). Apart from the broad fact that there is a great rise towards the south, no details are known.

The geoid contours are shown in Chart XXII, and those of the compensated geoid in Chart XXIII.

46. Dr. Vening Meinesz's trough of negative anomaly.— Dr. Vening Meinesz has discovered a trough of intense negative anomalies along the south side of the East Indies*. It is of interest to speculate whether this connects with the Indian Gangetic trough. Major Glennie considered this point in Geodetic Report Vol. VIII (page 57) and concluded that the probable line of extension was through the Andaman Islands, Arakan Yoma and Chin Hills. Plate XXI shows clearly that no negative trough passes up through the Ganges delta, but shows a wide depression of the compensated geoid across the Chin Hills, with its deepest point under the small Pondaung Range. This supports Major Glennie's conclusion, although strong southerly deflections rather suggest that the basin is closed towards the south as shown in Charts XXII and XXIII in latitude 22°. The broken contours

* "*Relevé Gravimetrique Maritime de l'Archipel Indien*", Delft 1931; and in the Journal of the Royal Geographical Society, April 1931.

drawn in these charts between latitudes 16° and 22° must not be taken as an expression of opinion whether this trough or others extend to the south or not, and the point can only be settled by further gravity or deflection observations there.

47. The Indian geoid.—Charts XXII and XXIII show revised contours of the geoid and compensated geoid* in India relative to the International spheroid†.

The new data which have been incorporated are:—

(*a*) The section from Orissa to Indo-China. See Geodetic Report 1933, Chapter III, and para 39 of this report.

(*b*) The section from Ladākh to Ajmer. See Geodetic Report Vol. VII, Chapter IV.

(*c*) The section from Cape Comorin to Hyderābād. See para 43.

(*d*) The section across the Bīkaner Desert. See Geodetic Report Vol. VII, Chapter IV.

(*e*) The longitude observations in south India. See Chapter III, para 19.

(*f*) Data in Baluchistān. See Geodetic Report Vol. VIII, Chapter V.

(*g*) Advance results of the 1934–35 programme in Baluchistān and Sind, comprising a line of 37 new stations from near Sukkur to the Persian frontier. This section considerably modifies item (*f*).

Of the above, items (*a*) (*b*) (*c*) (*d*) and (*g*), are part of the two main section lines which it is hoped to complete in 1935–36. Item (*e*) is of interest in that it revises some old values of the deflection (based on azimuth observations) which made an apparent rise of the geoid towards north Ceylon. This is now abolished and the geoid follows expectations in falling towards the area of intense negative gravity anomalies situated there.

48. Conclusions.—The spheroid on which Charts XXII and XXIII are based has an arbitrarily placed centre, and would have to be tilted and raised or lowered by unknown amounts to make it identical with the spheroid used by any other survey. Nevertheless, three things are quite clear, namely:—

(*a*) The average radius of curvature of the geoid along a line 2,500 miles long roughly east and west in about latitude 26°

* It may be repeated that the compensated geoid is a figure which lies below the geoid by an amount equal to the geoidal rise caused by the actual topography and Hayford compensation. It is an equipotential surface of the solid uniform spheroid and the Hayford anomalies. It is related to $g-\gamma_c$ in the same way as the geoid itself is related to $g-\gamma_A$.

† This figure has International axes, and the minor axis is parallel to that of the earth. Its centre is so chosen as to make it fit the Indian compensated geoid (1927).

is 1,000 feet greater than that of the international spheroid. Plate XXIV shows a section along this line, and the blue curve (which fits the section well) has a radius of curvature 1,000 feet greater than the spheroid. Part of this 1,000 feet may be due to the mountains which terminate the end of the section. If these mountains are compensated on Hayford's system, their effect is avoided by considering the compensated geoid. Its radius of curvature is 700 feet greater than that of the spheroid.

(*b*) The average radius of curvature of the meridian, on the other hand, along a line 2,000 miles long is less than that of the spheroid, as shown in Plate XXV. No blue curve has been drawn to fit the geoid itself as it is abnormally distorted by the great mass of the Himālaya, whose effect must be removed before a useful result can be obtained. The compensated geoid is fitted by a radius of curvature 1,780* feet less than that of the international spheroid †.

(*c*) The geoid (and compensated geoid) in the south of Siam will be elevated about 100 feet above any spheroid which at all closely fits the geoid (or compensated geoid) in India and northern Burma.

It is important to consider whether these points can be attributed to errors of observation, but it can be said with confidence that they cannot, except possibly in the case of (*c*). Thus:—

(*i*) An error in the fundamental standard of length cannot explain both (*a*) and (*b*): nor can it explain (*c*).

(*ii*) 700 feet, the smallest figure quoted in items (*a*) and (*b*) amounts to 1 in 30,000 of the earth's radius, while 1,780 feet amounts to 1 in 12,000. It is not possible that arcs of the Indian triangulation should be in error by such fractions as these. The simultaneous adjustment was based on 10 base-lines on which the average closing error‡ (before adjustment) was 1 : 100,000 §.

(*iii*) Items (*a*) and (*b*) are not affected by possible azimuth error. Item (*c*) is sensitive to azimuth error in the long east-and-west line from the origin to northern Siam, but it

* Field-work in progress while this report is at press shows that the difference of geoidal height along this section between latitudes 17° and 24° is about 20 feet less than that shown on Charts XXII, XXIII and XXV. The difference arises from comparative paucity of astronomical stations in the old arc. The figure of 1,780 feet given above will be reduced to about 1,500 feet on this account.

† Two arcs at right-angles suffice to determine a spheroid. The figure which results from these two arcs (2,500 and 2,000 miles long) has a semi-major axis of 6,378,568 metres (180 metres greater than the International spheroid) and a flattening of 1/290·5. These figures are not of course put forward as the probable dimensions of the earth's figure, but simply to illustrate the extent to which its shape in India differs from that spheroid which best fits the earth as a whole.

‡ Without regard to sign.

§ Professional Paper No. 16, Table LII.

No. 174 D.D.D. 1935 (C.O.181)-383
Published under the direction of Brigadier H.J. Couchman, D.S.O., M.C., Surveyor General of India.
HELIO. S.I.O. DEHRA DUN

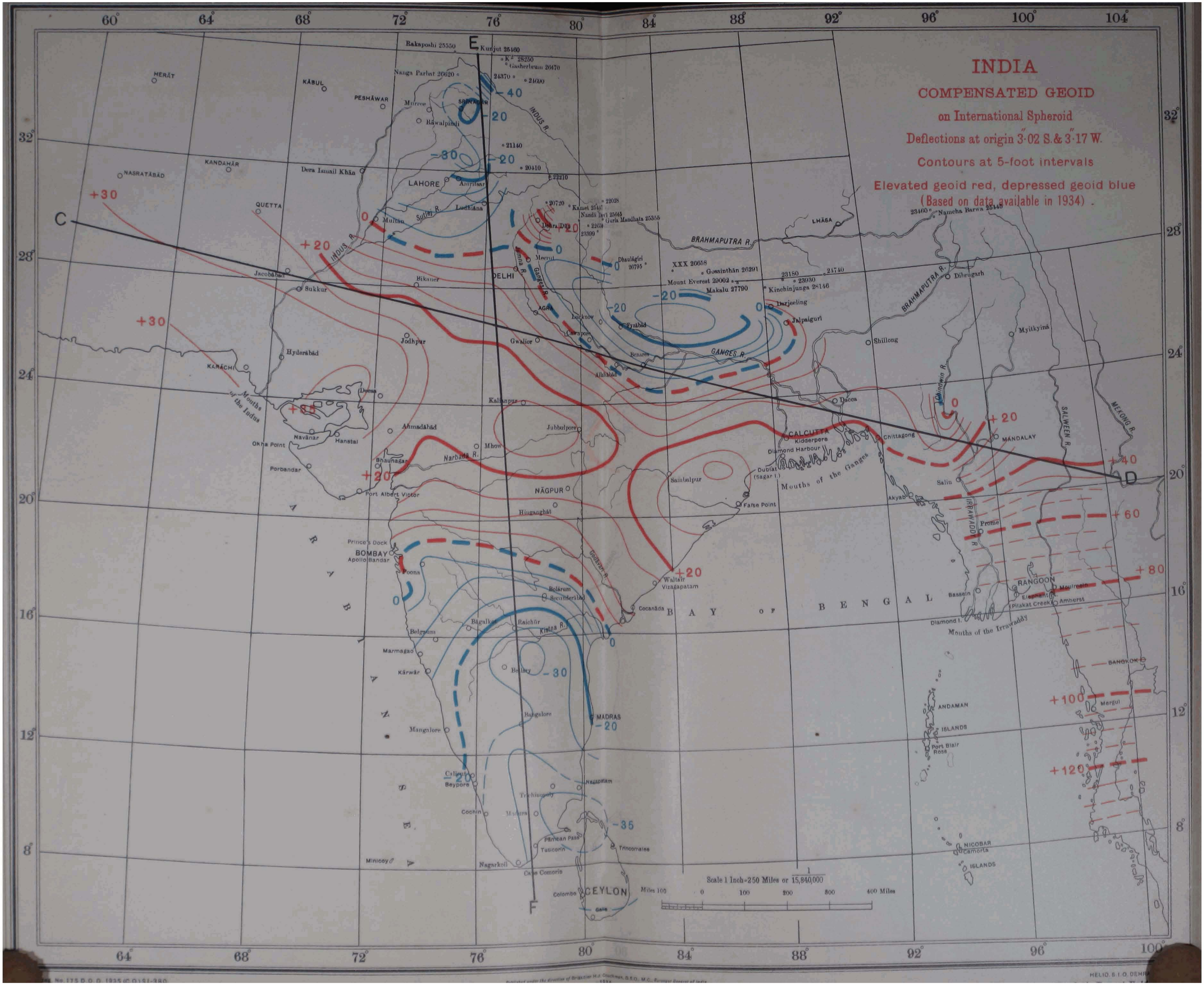

INDIA
COMPENSATED GEOID
on International Spheroid
Deflections at origin 3″·02 S. & 3″·17 W.
Contours at 5-foot intervals
Elevated geoid red, depressed geoid blue
(Based on data available in 1934).
ARABIAN SEA
BAY OF BENGAL
CEYLON
ANDAMAN ISLANDS
NICOBAR ISLANDS
Mouths of the Indus
Mouths of the Ganges
Mouths of the Irrawaddy
BRAHMAPUTRA R.
GANGES R.
INDUS R.
SALWEEN R.
MEKONG R.
IRRAWADDY R.
Narbada R.
Kistna R.
Godavari R.
HERĀT
KĀBUL
PESHĀWAR
KANDAHĀR
QUETTA
NASRATĀBĀD
LAHORE
DELHI
BOMBAY
CALCUTTA
MADRAS
RANGOON
MANDALAY
NĀGPUR
LHĀSA
BANGKOK
KARĀCHI
Mount Everest 29002
Makalu 27790
Kinchinjunga 28146
Rakaposhi 25550
Nanga Parbat 26620
Scale 1 Inch = 250 Miles or 1/15,840,000
Miles 100 0 100 200 300 400 Miles
C
D
E
F

Plate XXIV

Sections on line C-D of Chart XXIII

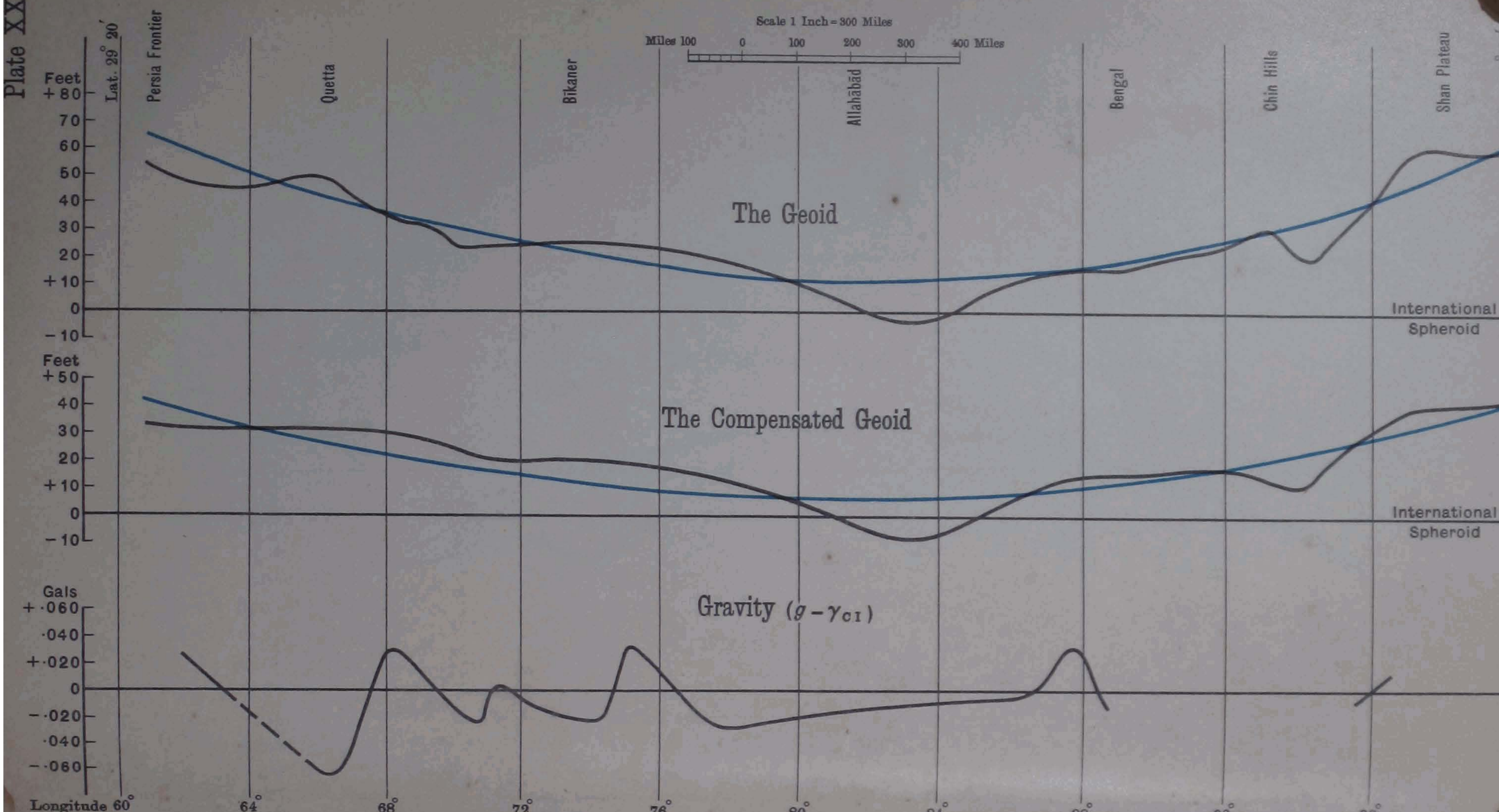


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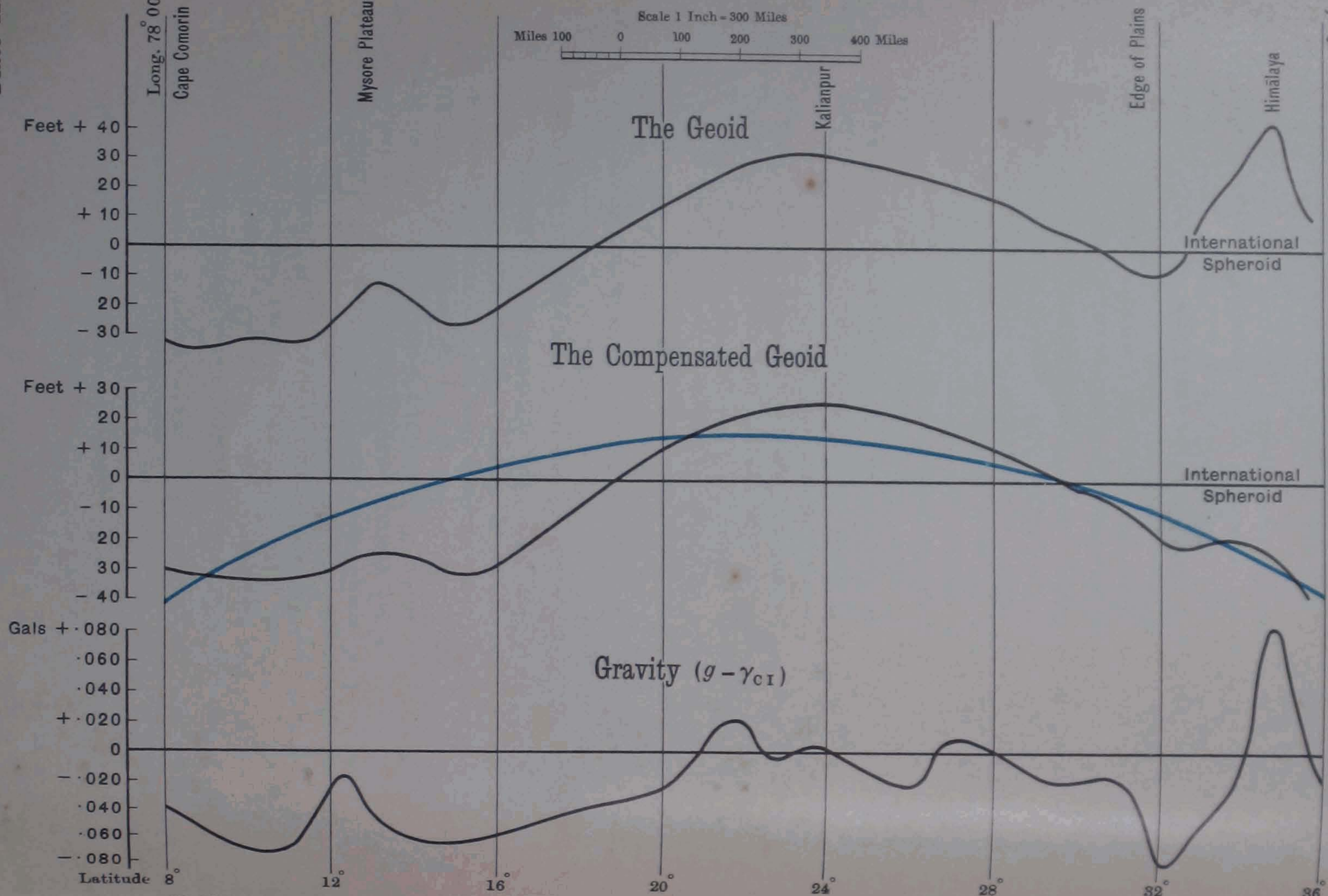
Plate XXV

Sections on line E-F of Chart XXIII



REG. NO. 177 D.D.D. 1835.380.

HELIO S. I. O. DEHRA DUN

requires an accumulated error of 300 feet in latitude to account for it. It may be remarked that the allowance that has been made for Laplace closures has reduced the geoidal rise by about 40 feet. To account for the rise between latitudes 20° and 8° it would be necessary to suppose that additional errors of 10″ or 20″ in azimuth had occurred and had not been detected by the fairly numerous Laplace stations which are available. This is impossible.

(*iv*) The provision of further astronomical stations will modify the figures in items (*a*) and (*b*), (see footnote to page 78), but it can safely be said that error or paucity of astronomical observations cannot account for these two items. At the ends of the sections the angles between the International spheroid and the blue curves in Plate XXI are about 3″, which cannot possibly be the mean error of the very large number of astronomical stations available at the ends of each arc. Item (*c*) is of course more weakly determined in this respect, but the two arcs of items (*a*) and (*b*) are probably better supplied with astronomical stations than any arcs which have ever been measured.

Item (*c*), the great rise of the geoid towards southern Siam, receives confirmation from the work which R. A. Hirvonen* has based on Stokes' formula. Hirvonen has collected together all available values of *g*, and has calculated the undulations of the geoid which result from them. He finds a depression of 68† metres in lat 10° N long 80° E, and of 11 metres in lat 10° long 100°. The difference between −68 and −11 metres is 57 metres or 187 feet, which compares very well with the 160 feet shown on Chart XXII. Hirvonen's work goes some way towards providing the confirmation which this geoidal feature is in need of.

The present geoid charts, being drawn with an arbitrary datum, do not conform with Hirvonen in showing the whole of India and Burma as a depressed area. This omission is not significant, and very great extensions of the geoidal survey will be necessary before it includes a sufficient area of more elevated geoid to show up the fact that India as a whole is depressed. Gravity observations, however, are already sufficient to indicate that this is the case, as is shown in Chart XIV (Chapter III) where gravity anomalies relative to the International formula are very predominantly negative.

The three geoidal abnormalities listed as (*a*), (*b*) and (*c*) above represent departures from the spheroidal state after making allowance for the effects of topography and Hayford compensation. In wide-spread features of this nature the exact type of compensation (Hayford or Airy, local or regional) is a matter of little consequence, and these abnormalities must probably be attributed to departures from hydrostatic equilibrium.

* "The Continental Undulations of the Geoid" by R. A. Hirvonen. Publications of the Finnish Geodetic Institute, No. 19, Helsinki 1934.

† His Table 11 modified by his page 70.

TABLE 5

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.
				"	"	"	"	"	"
686	56 H	Dorapalli h.s.	2031	− 6·0					
687	H	Impagat H.S.	2329	− 7·1					
688	H	Jaganpalli rock	1201	− 7·3					
689	H	Induvāsi h.s.	1512	− 5·0					
690	57 E	Kĕre Bĕlagal H.S.	1415	− 4·0					
691	E	Palakurti rock	1379	− 0·2					
692	E	Pulikŏnda H.S.	1797	+ 0·9					
693	E	Koilkŏnda h.s.	1943	− 2·6					
694	F	Kanampalli rock peak	1510	+ 4·2					
695	F	Devarakŏnda H.S.	1836	+ 3·8					
696	F	Gollapalle h.s.	1516	+ 4·3					
697	F	Urakŏnda H.S.	2189	+ 5·9					
698	F	Pĕnukŏnda h.s.	3058	+ 5·7					
699	G	Konduru white ridge	2347	+ 6·9					
700	G	Gudem hill staff	2435	+ 5·6					
701	G	Kālkote h.s.	3370	+ 3·3					
702	G	Halasūrbetta H.S.	3335	− 3·0					
703	H	Bannergatta H.S.	3269	− 7·2					
704	H	Devarabĕtta H.S.	3365	− 5·2					
705	H	Mariyālam H.S.	3446	− 7·9					
706	H	Pĕnnagaram II h.s.	1760	− 7·0					
707	58 E	Vellakaradu h.s.	892	− 6·2					
708	E	Pakkanadu h.s.	1115	− 9·0					
709	E	Palakapalayam hill temple	1023	− 3·7					
710	E	Molsi white temple	524	− 0·3					

DEFLECTIONS 1933–34

EVEREST'S SPHEROID							
Latitude		Longitude	Azimuth	Name of station observed for Azimuth	Deflections		Serial No.
					Meridian	P.V.	
	° ′ ″	° ′ ″	° ′ ″		″	″	
A	16 53 56·2				− 6·0		686
G	16 54 02·2	G 77 40 08·0					
A	16 42 25·32				− 7·0		687
G	16 42 32·29	G 77 39 12·99					
A	16 27 14·7				− 7·2		688
G	16 27 21·9	G 77 38 30·2					
A	16 02 23·1				− 4·7		689
G	16 02 27·8	G 77 30 43·5					
A	15 48 39·37				− 3·6		690
G	15 48 42·94	G 77 40 59·20					
A	15 37 40·3				+ 0·3		691
G	15 37 40·0	G 77 34 15·7					
A	15 28 10·01				+ 1·4		692
G	15 28 08·62	G 77 35 56·47					
A	15 19 11·5				− 2·0		693
G	15 19 13·6	G 77 36 36·2					
A	14 52 23·9				+ 4·9		694
G	14 52 19·0	G 77 37 45·9					
A	14 40 34·00				+ 4·6		695
G	14 40 29·41	G 77 38 57·31					
A	14 31 21·1				+ 5·1		696
G	14 31 16·0	G 77 38 18·9					
A	14 15 50·73				+ 6·8		697
G	14 15 43·94	G 77 36 29·63					
A	14 04 09·1				+ 6·7		698
G	14 04 02·4	G 77 35 01·5					
A	13 50 43·3				+ 7·9		699
G	13 50 35·4	G 77 37 09·8					
A	13 38 38·7				+ 6·7		700
G	13 38 32·0	G 77 35 50·0					
A	13 25 15·0				+ 4·5		701
G	13 25 10·5	G 77 36 05·1					
A	13 09 36·47				− 1·8		702
G	13 09 38·27	G 77 37 13·35					
A	12 48 32·61				− 5·8		703
G	12 48 38·37	G 77 34 33·55					
A	12 37 23·51				− 3·7		704
G	12 37 27·24	G 77 37 37·37					
A	12 22 33·99				− 6·3		705
G	12 22 40·32	G 77 42 21·09					
A	12 07 45·1				− 5·4		706
G	12 07 50·5	G 77 52 48·6					
A	11 55 09·7				− 4·5		707
G	11 55 14·2	G 77 50 49·4					
A	11 40 23·9				− 7·3		708
G	11 40 31·1	G 77 47 33·2					
A	11 27 10·2				− 1·8		709
G	11 27 12·0	G 77 46 15·9					
A	11 15 34·6				+ 1·7		710
G	11 15 33·0	G 77 51 05·2					

NOTE:—*Minus* sign denotes N. or E. deflection of the plumb-line.

TABLE 5

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.
				″	″	″	″	″	″
711	58 F	Nallichinam-patti temple	558	− 1·6					
712	F	Veriyapur h.s.	1793	+ 6·5					
713	F	Kamapillae conical hill	1237	+ 0·3					
714	F	Karadupatti red mound	746	− 5·0					
715	G	Perumalai h.s.	626	− 2·6					
716	G	Maiyittanpatti road s.	416	− 0·8					
717	K	Kutipārai H.S.	354	− 0·5					
718	G	Mīnākshi H.S.	330	− 0·1					
719	G	Melpārai Patti h.s.	401	− 0·3					
720	H	Melpatnam hill temple	519	+ 1·2					
721	H	Kanimārpōttai H.S.	685	+ 0·5					
722	K	Rāmnād ...	20	+ 4·2	+ 2·4				
723	O	Dhanushkodi ...	4		+ 8·9				
724	P	Manaar ...	7	+ 5	− 6				
725	P	Puttalam ...	5						
726	67 C	Kānkesanturai	11						
727	C	Mullaittivu ...	13						
728	68 E	Batticaloa ...	6						
729	59 N	Colombo clock tower	20	+ 2	− 7				
730	84 F	Sangao h.s.	4530	+ 6·2	+ 4·0				
731	B	Sairep ...	5000*	+ 1·4	− 3·4				
732	B	Lungsin I.B. ...	1937	+ 0·8	− 3·2				
733	B	Baro Harina ...	500*	+ 7	+ 0				
734	B	Thothingmura h.s.	1261	+ 2·9	− 3·2				
735	79 N	Pokimura ...	1300*		+ 0				

* Approximate.

DEFLECTIONS 1933-34—(*Contd.*)

EVEREST'S SPHEROID						
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections Meridian	Deflections P.V.	Serial No.
° ′ ″	° ′ ″	° ′ ″		″	″	
A 10 47 08·8				+ 0·5		711
G 10 47 08·3	*G* 77 52 27·6					
A 10 31 03·6				+ 8·7		712
G 10 30 54·9	*G* 77 47 53·0					
A 10 15 48·5				+ 2·6		713
G 10 15 45·9	*G* 77 53 06·6					
A 10 05 01·3				− 2·6		714
G 10 05 03·9	*G* 77 55 30·4					
A 9 53 22·7				− 0·1		715
G 9 53 22·9	*G* 77 58 21·8					
A 9 39 57·6				+ 1·7		716
G 9 39 55·9	*G* 77 58 02·5					
A 9 28 46·92				+ 2·1		717
G 9 28 44·87	*G* 78 00 37·76					
A 9 12 33·89				+ 2·6		718
G 9 12 31·34	*G* 77 58 48·91					
A 9 02 17·6				+ 2·4		719
G 9 02 15·2	*G* 77 51 13·4					
A 8 45 27·5				+ 3·9		720
G 8 45 23·6	*G* 77 46 20·9					
A 8 30 22·72				+ 3·4		721
G 8 30 19·37	*G* 77 37 25·16					
A 9 21 37·1	*A* 78 50 27·2			+ 6·8	+ 1·4	722
G 9 21 30·3	*G* 78 50 28·9					
	A 79 25 20·9				+ 7·6	723
G 9 10 28·5	*G* 79 25 16·4					
A 8 58 35·4	*A* 79 54 56·4			+ 8	− 8	724
G 8 58 27 *	*G* 79 55 07 *					
A 8 01 49	*A* 79 49 53					725
G 8 02 †	*G* 79 50 †					
A 9 48 58	*A* 80 02 56					726
G 9 49 †	*G* 80 03 †					
A 9 16 16	*A* 80 48 55					727
G 9 16 †	*G* 80 49 †					
A 7 45 20	*A* 81 41 08					728
G 7 45 †	*G* 81 41 †					
A 6 56 03·80	*A* 79 50 26·48			+ 5	− 9	729
G 6 55 59 *	*G* 79 50 38 *					
A 22 44 34·0	*A* 93 03 35·3			+ 4·7	− 5·8	730
G 22 44 29·3	*G* 93 03 44·6					
A 22 49 04·0	*A* 92 49 10·4			− 0·2	−13·0	731
G 22 49 04·2	*G* 92 49 27·6					
A 22 52 45·1	*A* 92 35 08·1			− 0·8	−12·6	732
G 22 52 45·9	*G* 92 35 25·0					
A 22 55 27	*A* 92 23 00			+ 5	−10	733
G 22 55 21	*G* 92 23 14					
A 22 53 22·8	*A* 92 08 27·0			+ 1·2	−12·5	734
G 22 53 21·6	*G* 92 08 43·7					
A 22 56 28	*A* 91 58 27				− 9	735
G 22 56	*G* 91 58 40					

NOTE:—*Minus* sign denotes N. or E. deflection of the plumb-line.

* Reduced to Indian terms vide Geodetic Report 1933, page 33. Observations are not of 1933-34.

† Not yet available.

TABLE 5

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.
				"	"	"	"	"	"
736	79 N	Maji Tān H.S.	291	+ 1·1	−1·5				
737	N	Betagee ...	200*	+ 1	−0				
738	N	Bijar Singh T.S.	49	+ 1·0	−0·8				
739	M	Kadra T.S.	23	+ 1·4	+0·3				
740	M	Mātabi T.S.	24	+ 2·1	+0·8				
741	I	Bāshakpur T.S.	23	+ 2·3	+1·0				
742	I	Haripur T.S.	16	+ 4·3	−1·4				
743	I	Mālgaon T.S.	14	+ 3·8	−2·7				
744	I	Jhaudi T.S.	15	+ 3·6	−3·3				
745	I	Kandia T.S.	17	+ 4·9	−0·9				
746	E	Hatiāra T.S.	16	+ 4·7	−2·8				
747	E	Daulatpur T.S.	17	+ 5·0	−4·1				
748	E	Bāliakāndi T.S.	16	+ 3·1	+0·4				
749	E	Basantia T.S.	21	+ 2·7	−0·3				
750	E	Bhāturia T.S.	20	+ 2·5	+1·3				
751	B	Piprāgāchhi T.S.	27	+ 2·2	−0·9				
752	B	Berghom T.S.	24	+ 2·6	+0·1				
753	B	Simahāt T.S.	30	+ 1·3	+0·5				
754	B	Satten T.S.	36	+ 4·7	−1·7				
755	A	Dastanpur T.S.	60	+ 3·3	−1·6				
756	73 M	Hākistāpur T.S.	76	+ 2·6	+2·2				
757	M	Madhpur T.S.	131	+ 0·5	+6·4				
758	M	Karāsoli H.S.	328	+ 1·0	+3·6				
759	M	Kola h.s.	199	+ 1·2	−1·9				
760	I	Sūsinia H.S.	1442	+ 2·5	−1·1				

* Approximate.

DEFLECTIONS 1933–34—(*Contd.*)

EVEREST'S SPHEROID							Serial No.
Latitude	Longitude	Azimuth	Name of Station observed for Azimuth	Deflections			
				Meridian	P.V.		
° ′ ″	° ′ ″	° ′ ″		″	″		
A 22 56 51·72	*A* 91 46 37·47			− 0·6	−10·4		736
G 22 56 52·30	*G* 91 46 51·90						
A 22 58 29·6	*A* 91 38 22			− 1	− 9		737
G 22 58 30·5	*G* 91 38 35						
A 22 59 58·60	*A* 91 22 46·25			− 0·7	− 9·5		738
G 22 59 59·30	*G* 91 22 59·71						
A 23 00 29·41	*A* 91 13 59·34			− 0·3	− 8·3		739
G 23 00 29·68	*G* 91 14 11·54						
A 23 00 37·00	*A* 91 05 22·05			+ 0·5	− 7·7		740
G 23 00 36·55	*G* 91 05 33·70						
A 23 00 48·42	*A* 90 54 57·27			+ 0·6	− 7·4		741
G 23 00 47·78	*G* 90 55 08·49						
A 23 08 47·18	*A* 90 40 34·74			+ 2·5	− 9·7		742
G 23 08 44·70	*G* 90 40 48·48						
A 23 07 49·79	*A* 90 22 22·12			+ 2·0	−10·8		743
G 23 07 47·84	*G* 90 22 37·07						
A 23 08 37·06	*A* 90 12 53·68			+ 1·8	−11·3		744
G 23 08 35·23	*G* 90 13 09·18						
A 23 09 46·34	*A* 90 02 53·74			+ 3·1	− 8·8		745
G 23 09 43·25	*G* 90 03 06·69						
A 23 09 32·63	*A* 89 52 04·98			+ 2·8	−10·6		746
G 23 09 29·86	*G* 89 52 19·68						
A 23 08 46·85	*A* 89 42 41·73			+ 3·1	−11·8		747
G 23 08 43·76	*G* 89 42 57·76						
A 23 08 07·13	*A* 89 31 36·45			+ 1·2	− 7·2		748
G 23 08 05·90	*G* 89 31 47·48						
A 23 07 54·64	*A* 89 22 25·95			+ 0·8	− 7·8		749
G 23 07 53·84	*G* 89 22 37·63						
A 23 07 52·90	*A* 89 11 32·86			+ 0·6	− 6·1		750
G 23 07 52·30	*G* 89 11 42·66						
A 22 58 49·40	*A* 88 59 14·33			+ 0·3	− 8·2		751
G 22 58 49·07	*G* 88 59 26·49						
A 22 52 13·68	*A* 88 42 37·80			+ 0·8	− 7·0		752
G 22 52 12·88	*G* 88 42 48·60						
A 22 57 33·65	*A* 88 32 52·20			− 0·6	− 6·5		753
G 22 57 34·23	*G* 88 33 02·43						
A 22 58 37·77	*A* 88 14 13·56			+ 2·8	− 8·6		754
G 22 58 35·02	*G* 88 14 26·07						
A 23 02 54·93	*A* 88 05 31·38			+ 1·3	− 8·4		755
G 23 02 53·63	*G* 88 05 43·76						
A 23 04 07·77	*A* 87 56 19·13			+ 0·6	− 4·5		756
G 23 04 07·19	*G* 87 56 27·15						
A 23 09 51·45	*A* 87 44 34·04			− 1·6	− 0·1		757
G 23 09 53·06	*G* 87 44 37·29						
A 23 14 13·93	*A* 87 25 04·40			− 1·2	− 2·7		758
G 23 14 15·12	*G* 87 25 10·47						
A 23 23 18·6	*A* 87 06 58·7			− 1·1	− 8·1		759
G 23 23 19·7	*G* 87 07 10·7						
A 23 23 43·13	*A* 86 59 02·23			+ 0·2	− 7·1		760
G 23 23 42·97	*G* 86 59 13·13						

NOTE:—*Minus* sign denotes N. or E. deflection of the plumb-line.

TABLE 5

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.
				"	"	"	"	"	"
761	73 I	Gorangdih h.s.	740	+ 1·7	− 0·0				
762	I	Tilabani H.S.	1327	+ 3·7	+ 0·8				
763	I	Bawa h.s.	1048	+ 6·3	− 0·7				
764	I	Trijunction No. 3 s.	1112	+ 4·6	+ 2·1				
765	34 G	Padag Base West S.	2740	+ 8·2	+ 2·0				
766	G	Padag Base Centre S.	2678	+ 18·7	− 8·1				
767	G	Padag Base East S.	2676	+ 13·0	− 4·2				
768	H	Kopahdar H.S.	6790	+ 23·7	− 6·8				
769	83 J	Namtiali Base East S.	322	+ 15·0					
770	J	Naginimara H.S.	1821	+ 22·8					
771	J	Namtiali Base Centre S.	328	+ 14·7					
772	J	Namtiali Base West S.	322	+ 13·6					
773	J	Anaki H.S.	2947	+ 29·3					
774	J	Molungyimsen H.S.	2517	+ 25·7					
775	J	Lirumen H.S.	2667	+ 19·9					
		Non-Departmental Observations							
776	95 M	Khao Kung-kang *		+ 2·6					
777	O	Base S. Rājburi*		+ 6·3					
778	P	Khao Gūang *		+ 6·7					
779	96 K	Khao Pākglōhng Bāngphakbie *		+ 5·3					
780	P	Base N. Nagorn Srīdharmrāj *		+ 6·4					
781	97 I	Koh Yāo-yai *		+ 6·8					
782	104 A	Base E. Nagorn Sawarn *		+ 5·0					
783	F	Khao Bhrik *		+ 7·5					
784	L	Khao Srabāp *		+ 6·2					

* Reduced to Indian terms (vide Geodetic Report 1934, Chapter IV), but without correction for Laplace adjustment. Observations are not of 1933–34.

DEFLECTIONS 1933-34—(*Concld.*)

EVEREST'S SPHEROID						
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections		Serial No.
				Meridian	P.V.	
° ′ ″	° ′ ″	° ′ ″		″	″	
A 23 24 16·5 G 23 24 17·1	*A* 86 46 36·3 *G* 86 46 46·0			− 0·6	− 5·9	761
A 23 25 01·22 G 23 24 59·87	*A* 86 33 06·06 *G* 86 33 14·64			+ 1·4	− 5·0	762
A 23 26 45·2 G 23 26 41·2	*A* 86 16 08·2 *G* 86 16 18·4			+ 4·0	− 6·4	763
A 23 26 01·8 G 23 25 59·5	*A* 85 59 59·8 *G* 86 00 06·7			+ 2·3	− 3·4	764
A 29 04 52·5 G 29 04 48·7	*G* 65 01 46	A 209 17 22·7 G 209 17 17·4	Pulchotau H.S.	+ 3·8	+ 9·5	765
A 29 04 57·4 G 29 04 43·1	*G* 65 08 30	A 159 41 49·2 G 159 41 49·6	Pulchotau H.S.	+ 14·3	− 0·7	766
A 29 04 49·1 G 29 04 40·5	*G* 65 11 27	A 142 24 38·7 G 142 24 36·9	Pulchotau H.S.	+ 8·6	+ 3·2	767
A 28 54 05·7 G 28 53 46·42	*G* 65 06 36·28	A 177 39 26·1 G 177 39 25·7	Pulchotau H.S.	+ 19·3	+ 0·7	768
A 26 49 32·0 G 26 49 20·0	*G* 94 41 56·0	A 272 57 34·7 G 272 58 *	Naginimara H.S.	+ 12·0		769
A 26 49 17·2 G 26 48 57·3	*G* 94 50 0·9	A 44 16 15·5 G 44 16 *	Anaki H.S.	+ 19·9		770
A 26 48 46·2 G 26 48 34·5	*G* 94 38 24·7	A 267 52 04·8 G 267 52 *	Naginimara H.S.	+ 11·7		771
A 26 48 32·9 G 26 48 22·3	*G* 94 35 03·3	A 266 06 57·2 G 266 07 *	Namtiali Centre S.	+ 10·6		772
A 26 43 52·7 G 26 43 26·3	*G* 94 44 01·7	A 224 13 30·8 G 224 14 *	Naginimara H.S.	+ 26·4		773
A 26 40 20·8 G 26 39 58·0	*G* 94 36 18·3	A 243 22 40·1 G 243 23 *	Anaki H.S.	+ 22·8		774
A 26 39 23·4 G 26 39 06·3	*G* 94 31 05·9	A 259 32 26·2 G 259 32 *	Molungyimsen H.S.	+ 17·1		775
Siam						
A 15 28 26·1 G 15 28 21·9	*G* 99 04			+ 4·2		776
A 13 33 18·5 G 13 33 09·9	*G* 99 50			+ 8·6		777
A 12 27 38·2 G 12 27 28·8	*G* 99 56			+ 9·4		778
A 9 00 16·0 G 9 00 07·0	*G* 98 16			+ 9·0		779
A 8 28 47·6 G 8 28 37·0	*G* 99 58			+ 10·6		780
A 7 58 32·1 G 7 58 21·1	*G* 98 36			+ 11·0		781
A 15 23 10·9 G 15 23 04·2	*G* 100 11			+ 6·7		782
A 14 54 05·9 G 14 53 56·4	*G* 101 33			+ 9·5		783
A 12 33 06·1 G 12 32 56·9	*G* 102 13			+ 9·2		784

NOTE:—*Minus* sign denotes N. or E. deflection of the plumb-line.
* Not yet available.

CHAPTER V

COMPUTING OFFICE AND TIDAL SECTION

BY CAPTAIN G. BOMFORD, R.E.

49. **Summary.**—The Computing Office has largely been employed on work which is described in other sections of this report, especially that in Chapters I and IV. It has also, as usual, dealt with a large number of small cases of which no mention can be made in an annual report. The Tidal Section has followed its usual routine.

COMPUTING OFFICE

50. **Geodetic triangulation.**—The grinding of the Poona and Namtiali base extension nets (see Chapter 1, paras 3 and 4), with 21 and 18 condition equations respectively, has provided experience in a type of work which has not been called for in India for the last 20 years, and many unforeseen difficulties resulted. Clearer rules have been drafted for inclusion in the Handbook.

51. **Minor triangulation.**—The adjustment of minor triangulation in 1/M sheet 35 has been completed, and sheets 29 and 30 are in hand. Adjustment and computation in parts of sheets 45 and 54, where No. 1 Topographical Party is now working, have also been undertaken.

52. **Lambert grid.**—During the year comparatively little progress has been made with the conversion of triangulation data on the N. W. Frontier into terms of the Lambert grid, as the office has been busy with the computation of field work. Only 1,000 points have been converted and 1,500 classified according to quality. Five grid triangulation pamphlets have been printed, and four more sent to press.

53. **Publications.**—The data for four Persian degree sheets have been compiled. Two Persian triangulation pamphlets, one Indian pamphlet, and addendum pages for seven Indian degree sheets have been printed. Five Indian pamphlets have been reprinted.

An addendum to levelling pamphlet No. 53 (Delhi) has been printed, and No. 40 (Hyderābād, Sind) has been reprinted. The data of about 200 miles of precise levelling have been printed and issued as addenda to existing pamphlets, and three secondary levelling pamphlets with about 600 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 1933.

(*b*) Record Volume No. XXIV. *Riverain Surveys in the Punjab.*

(*c*) Record Volume No. XXV. *Surveys in Swāt, Chitrāl & Gilgit* by Lt.-Colonel C. G. Lewis, O.B.E., R.E.

(*d*) Handbook of Topography, Chapter XII, *Air Surveys.*

(*e*) Handbook of Topography, Chapter VII, *Trans-frontier Reconnaissance.*

54. **Chart Section.**—The Chart Section has completed the following work:—

(*a*) Charts for 4 grid triangulation pamphlets.

(*b*) 17 charts and plates for Geodetic Report 1933.

(*c*) 10 charts and plates for Geodetic Report 1934.

(*d*) 8 forms and diagrams for Handbook of Topography, Chapter VII.

(*e*) About 170 other miscellaneous charts and diagrams.

TIDAL SECTION

55. **Tidal observations.**—Registrations with automatic gauges were continued by the port authorities at Aden, Karāchi, Bombay, Calcutta and Rangoon, and daylight observations on tide-poles were made at Bhāvnagar, Chittagong, Akyab and Chāndbāli. The Calcutta Port Commissioners also started a Kent's pneumatic gauge at Dublat on 1st April 1933. The Ceylon Survey Department completed their 5-year series of observations at Colombo and Trincomalee on 15th January 1934. The gauge at Colombo is still working under the control of the port authorities, but that at Trincomalee has been dismantled.

A list of Indian tidal stations is given in Geodetic Report Volume V, pages 31 to 33.

56. **Inspections.**—The port officials inspected the tidal observatory at Karāchi in February, at Rangoon in May and at Bombay in May and July. The gauges have all worked exceptionally well, the only break being one of a single day at Bombay.

57. **Corrections to predictions.**—Empirical corrections have been applied to the predicted tides at Kidderpore, Rangoon, Chittagong and Chāndbāli on the same lines as those tabulated in previous reports.

58. **Tide-tables.**—The Tide-tables of the Indian Ocean for 1934, and the separate pamphlets for Bombay, the Hooghly River and the Rangoon River, have been prepared and issued as usual.

Advance predictions for 1935 have been sent on the usual exchange basis 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 1934 was Rs. 3,445/10/-, exclusive of agents' commission.

59. **Accuracy of predictions.**—The greatest errors recorded in the height of low water during 1933 at the ports mentioned in para 55 are given in Table 1. Tables 2 to 14 give detailed results of comparisons between the predictions and the times and heights actually recorded at these ports. The quality of the predictions is the same as in previous years except for some deterioration at Kidderpore, to meet which a revised correction table has been introduced. Predictions at the new port of Chāndbāli are satisfactory, although its riverain character prevents its predictions attaining any high degree of accuracy.

TABLE 1.—*Greatest differences between predicted and actual heights of low water during 1933.*

Port	Predicted *minus* Actual	Date	REMARKS
	feet		
Aden ...	−0·5 / +0·5	March 12, 27, 29, Apl. 26, 27, May 10, 11, June 28, Oct. 21 and Nov. 17.	
Karachi ...	−0·9	Dec. 11.	
Bhāvnagar ...	−3·3	Feb. 25 and Aug. 5.	
Bombay (Apollo Bandar)	−1·7	May 17, 18.	
Colombo ...	−0·5	May 18, June 16, Aug. 25 and Nov. 23.	
Trincomalee ...	−1·6	Oct. 31	
Madras ...	−0·9	March 25.	
Chāndbāli ...	−6·8	Aug. 9.	Riverain port
Dublat ...	−2·6	Aug. 4.	Do.
Kidderpore (Calcutta)...	−3·0	July 16.	Do.
Chittagong ...	+1·7	April 5 and July 23.	Do.
Akyab ...	−1·6	June 6.	
Rangoon ...	+2·3	Aug. 26.	Riverain port

TABLE 2.—*Mean errors E_1* and E_2* for 1933.*

ADEN

PERIOD 1933	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		3·2		0·1	3·5			0·2	8·3	0·2	10·5	0·2	1	0	0	0
16-31		1·0		0·0	3·5			0·1	5·4	0·1	9·6	0·2	0	0	0	0
Feb. 1-15		1·4		0·1	8·2			0·2	2·9	0·1	12·4	0·2	0	1	0	0
16-28		1·5		0·0	6·8			0·1	4·6	0·1	10·8	0·2	0	1	0	0
Mar. 1-15		1·0		0·1	2·9			0·2	5·8	0·1	9·3	0·2	0	2	0	0
16-31		7·8		0·1	3·5			0·2	7·8	0·1	8·3	0·2	1	0	0	0
April 1-15	2·6			0·1	5·7			0·1	7·5	0·1	7·4	0·2	2	0	0	0
16-30		3·3		0·2	4·7			0·2	5·8	0·2	6·1	0·2	0	0	0	0
May 1-15		3·3		0·1	3·1			0·1	8·4	0·1	6·9	0·2	1	0	0	0
16-31		1·4		0·0		1·6		0·1	5·6	0·1	4·4	0·1	0	0	0	0
June 1-15		4·6		0·0		3·1		0·1	8·4	0·2	5·3	0·2	0	0	0	0
16-30		8·2		0·2	0·0			0·3	9·1	0·2	4·3	0·3	2	0	0	0
July 1-15		9·0		0·1		1·1		0·1	10·3	0·1	6·1	0·2	2	0	0	0
16-31		10·1	0·0			4·1		0·1	10·5	0·1	5·0	0·1	0	0	0	0
Aug. 1-15		24·8	0·1			13·4		0·1	24·8	0·2	14·8	0·1	8	0	0	0
16-31		24·9	0·0			13·8		0·1	25·0	0·1	15·1	0·2	12	1	0	0
Sept. 1-15	3·8			0·0	11·4		0·0		6·7	0·1	14·5	0·1	0	0	0	0
16-30	7·4			0·0	16·8		0·0		8·2	0·1	16·9	0·1	0	5	0	0
Oct. 1-15	5·8			0·1	15·9			0·2	6·2	0·1	16·7	0·2	0	4	0	0
16-31	8·2			0·1	10·1			0·1	8·6	0·1	10·6	0·1	0	0	0	0
Nov. 1-15	3·7		0·2		12·1		0·1		5·7	0·2	13·9	0·1	1	5	0	0
16-30	2·2		0·2		6·6		0·1		5·0	0·2	10·6	0·2	0	1	0	0
Dec. 1-15	0·8		0·2		12·8		0·1		5·0	0·2	13·0	0·1	0	0	0	0
16-31		1·7	0·1		1·3		0·1		5·6	0·2	8·4	0·1	0	0	0	0
TOTALS ...	34·5	107·2	0·8	1·3	128·9	37·1	0·4	2·6	201·2	3·3	240·9	4·0	30	20	0	0
MEANS ...	− 3·0		− 0·0		+ 3·8		− 0·1		8·4	0·1	10·0	0·2				

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

TABLE 3.—*Mean errors E_1* and E_2* for 1933.*

KARĀCHI

PERIOD 1933	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.	0·9 feet of height H. W.	L. W.
Jan 1-15		5·9		0·2		0·4		0·0	14·8	0·2	6·9	0·2	3	0	0	0
16-31	2·4			0·3	7·4		0·0		7·5	0·4	13·9	0·2	0	1	1	0
Feb. 1-15	0·4			0·4		1·4		0·1	16·3	0·4	12·7	0·2	2	2	0	0
16-28		1·6		0·3	3·6			0·0	9·0	0·3	11·3	0·2	2	2	0	0
Mar. 1-15		2·7		0·4	3·4			0·2	11·7	0·4	12·9	0·2	2	3	0	0
16-31	0·1			0·5	1·3			0·2	9·4	0·5	8·6	0·2	1	0	0	0
April 1-15	3·5			0·5	10·6			0·2	5·9	0·5	14·2	0·2	0	2	0	0
16-30		1·4		0·2	4·8		0·1		7·9	0·2	8·4	0·2	0	1	0	0
May 1-15	3·7			0·1	6·2		0·2		6·3	0·2	11·8	0·2	0	2	0	0
16-31	0·8			0·3	5·1			0·0	7·9	0·4	10·6	0·3	0	2	0	0
June 1-15	2·3			0·2	6·1		0·0		5·5	0·3	10·3	0·2	0	1	0	0
16-30	5·4			0·7	5·9			0·3	10·3	0·7	11·0	0·3	0	0	3	0
July 1-15	2·4			0·0	0·6		0·2		8·8	0·3	10·6	0·3	0	2	0	0
16-31	1·1			0·1	3·6		0·2		11·4	0·2	13·0	0·3	3	2	0	0
Aug. 1-15		4·3		0·1		6·2	0·2		11·1	0·1	12·5	0·2	1	2	0	0
16-31		1·5		0·2	0·4		0·0		9·3	0·2	9·9	0·1	0	0	0	0
Sept. 1-15		0·8		0·3		0·8	0·1		8·9	0·3	8·9	0·3	0	1	0	0
16-30	2·1			0·4	9·7			0·0	8·3	0·4	11·1	0·2	1	2	1	0
Oct. 1-15		0·6		0·3	9·1			0·0	6·6	0·3	11·2	0·2	1	3	0	0
16-31		0·2		0·4	9·3		0·0		6·2	0·4	11·9	0·3	0	0	1	0
Nov. 1-15		4·4		0·4	7·7			0·2	8·5	0·4	11·0	0·3	0	2	0	0
16-30		1·1		0·3	3·9			0·0	6·7	0·3	8·5	0·2	0	0	0	0
Dec. 1-15		3·7		0·6	7·9			0·3	8·4	0·6	13·2	0·4	0	4	4	0
16-31		7·4		0·3		3·8		0·0	13·7	0·3	7·8	0·2	2	0	0	0
TOTALS	24·2	35·6		7·5	106·6	12·6	1·0	1·5	220·4	8·3	262·2	5·6	18	34	10	0
MEANS	− 0·5		− 0·3		+ 3·9		− 0·0		9·2	0·3	10·9	0·2				

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

TABLE 4.—*Mean errors E_1* and E_2* for 1933.*

BHĀVNAGAR

PERIOD 1933	MEAN ERRORS (Predicted – Actual †)												Number of errors exceeding			
	E_1*								E_2*				30 minutes of time		1·0 feet of height	
	H. W. Time		H. W. Height		L. W. Time		L. W. Height		H. W. Time	H. W. Ht.	L. W. Time	L. W. Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	–	+	–	+	–	+	–								
Jan. 1-15	5·4		0·3			17·0	0·1		8·7	0·6	20·3	0·5	0	4	4	2
16-31	8·3		0·0			35·4		0·5	13·8	0·5	38·9	1·4	0	10	2	10
Feb. 1-15	7·7		0·9			11·1	0·2		8·8	0·9	24·9	0·6	0	7	5	3
16-28	15·2			0·1		30·5		0·7	15·2	0·3	34·6	1·8	0	7	0	10
Mar. 1-15	7·8		0·6			15·2		0·4	9·0	0·6	28·0	0·9	0	7	0	4
16-31	9·7			0·1		27·8		0·6	9·7	0·5	30·1	1·3	0	8	1	8
April 1-15	6·5		0·2			14·5		0·5	10·3	0·6	25·5	1·1	0	6	2	6
16-30	8·7			0·3		17·3	0·1		8·7	0·7	24·5	0·3	0	5	4	0
May 1-15	6·1		0·1			21·9		0·4	13·8	0·8	30·6	1·0	0	7	4	6
16-31	11·3			0·2		0·8	0·4		11·3	0·6	5·8	1·0	0	0	2	7
June 1-15	11·2			0·2		25·5	0·1		17·1	0·5	25·9	0·9	0	6	3	8
16-30	7·1		0·0			0·9	1·3		7·1	0·2	4·9	1·3	0	0	0	9
July 1-15	9·2		0·2			29·9	1·3		14·8	0·5	30·1	1·4	0	6	1	9
16-31	11·2		0·2			1·3	1·1		11·2	0·3	10·6	1·4	0	0	0	11
Aug. 1-15	8·2			0·3		24·3		0·5	13·8	0·4	29·1	2·0	0	8	2	12
16-31	10·3			0·1		11·5	0·8		10·3	0·3	19·9	1·1	0	5	0	9
Sept. 1-15	8·3		0·0			24·5	0·3		9·9	0·5	28·0	1·0	0	7	1	7
16-30	2·9			0·6		17·3	1·0		7·2	0·6	20·8	1·1	0	4	4	7
Oct. 1-15	8·5			0·1		13·4	0·4		10·1	0·5	25·8	0·7	0	6	0	4
16-31	7·1		0·7			22·9	1·1		11·8	0·8	23·6	1·3	0	6	3	8
Nov. 1-15	5·1		0·7			8·8	1·9		13·6	0·9	15·1	1·9	1	3	6	12
16-30	8·9		0·7			22·7	0·9		13·7	0·8	22·7	1·0	0	5	4	7
Dec. 1-15	13·7		0·5		0·0		1·6		13·7	0·8	6·4	1·6	0	0	6	13
16-31	9·4		0·9			22·6	0·6		13·4	1·0	28·9	1·0	0	8	7	9
TOTALS...	207·8		6·0	2·0	0·0	417·1	13·2	3·6	277·0	14·2	555·0	27·6	1	125	61	181
MEANS ...	+ 8·7		+ 0·2		– 17·4		+ 0·4		11·5	0·6	23·1	1·2				

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

† Actual values are tide-pole readings during daylight only.

NOTE:—The mean range of the greatest ordinary spring-tides for this port is more than 31 feet.

TABLE 5.—*Mean errors E_1* and E_2* for 1933.*

BOMBAY (APOLLO BANDAR)

PERIOD 1933	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		9·6		0·1		18·1		0·2	11·3	0·3	18·1	0·2	1	3	0	0
16-31		2·9	0·0			8·2	0·1		6·3	0·3	10·6	0·3	0	1	0	0
Feb. 1-15		9·0		0·1		14·1		0·1	12·3	0·2	17·2	0·2	2	3	0	0
16-28		1·9		0·0		5·4		0·0	8·1	0·2	7·8	0·3	0	0	0	0
Mar. 1-15		8·3		0·2		5·1		0·2	11·6	0·3	11·4	0·3	0	0	0	0
16-31		5·6		0·4		10·2		0·2	10·3	0·5	10·6	0·3	0	0	0	0
April 1-15		6·5		0·5		0·7		0·4	12·2	0·5	12·5	0·4	1	1	2	0
16-30	3·6			0·3		5·7		0·2	7·7	0·4	8·9	0·3	1	0	0	0
May 1-15		4·4		0·2		10·2		0·3	12·7	0·3	13·5	0·4	0	0	0	1
16-31		7·0		0·3		11·2		0·3	12·6	0·4	13·8	0·6	2	1	0	6
June 1-15		7·2		0·2		1·3		0·4	8·9	0·3	5·5	0·4	1	0	0	0
16-30		6·0		0·7	1·1			0·7	7·9	0·7	7·7	0·7	0	0	1	3
July 1-15		11·1	0·2			6·5	0·1		12·0	0·5	10·2	0·2	0	0	2	0
16-31		8·3		0·1		7·7		0·3	13·8	0·4	13·1	0·3	2	3	0	0
Aug. 1-15		7·1		0·2	0·0			0·4	12·7	0·4	14·6	0·4	2	3	0	1
16-31	5·1			0·0	5·6			0·3	9·3	0·4	9·1	0·3	2	1	0	0
Sept. 1-15		6·6		0·2		1·8		0·3	13·0	0·3	10·1	0·3	2	0	0	1
16-30		6·4		0·0		6·0		0·5	10·1	0·3	11·1	0·5	0	0	0	5
Oct. 1-15		13·2		0·2		0·8		0·2	14·2	0·3	10·4	0·3	1	0	0	1
16-31		4·9		0·2		0·3		0·5	7·0	0·4	4·9	0·5	1	0	0	7
Nov. 1-15		7·6		0·5		5·2		0·3	9·9	0·5	9·4	0·3	1	0	0	0
16-30		1·3		0·1		7·5		0·4	10·4	0·3	10·9	0·4	1	1	0	0
Dec. 1-15		2·2		0·6		6·2		0·5	11·5	0·6	9·6	0·5	1	2	0	3
16-31		6·3		0·1		12·5		0·2	8·1	0·3	12·7	0·2	1	1	0	0
TOTALS	8·7	143·4	0·2	5·2	6·7	144·7	0·2	6·9	253·9	9·1	263·7	8·6	22	20	5	28
MEANS	– 5·6		– 0·2		– 5·8		– 0·3		10·6	0·4	11·0	0·4				

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

TABLE 6.—*Mean errors E_1* and E_2* for 1933.*

COLOMBO

PERIOD 1933	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.	0·3 feet of height H. W.	0·3 feet of height L. W.
Jan. 1-15	20·3			0·2	18·0			0·1	22·3	0·2	19·1	0·1	4	5	4	0
16-31	20·6			0·2	16·0			0·1	20·6	0·2	20·5	0·1	3	6	3	1
Feb. 1-15	8·5			0·1	13·0		0·0		15·9	0·1	16·5	0·1	1	4	1	0
16-28	16·5			0·2	13·6			0·1	19·3	0·2	16·0	0·1	3	1	2	0
Mar. 1-15	19·2			0·2	15·5			0·1	19·3	0·2	15·7	0·1	6	4	3	0
16-31	17·2			0·3	15·1			0·1	22·9	0·3	19·1	0·1	6	3	8	0
April 1-15	13·0			0·2	20·1			0·1	18·4	0·2	21·1	0·1	3	7	6	0
16-30	9·7			0·0	4·4		0·1		20·1	0·1	16·0	0·2	4	3	0	0
May 1-15	14·6			0·1	1·9			0·0	18·3	0·2	14·8	0·1	3	3	3	1
16-31	5·2			0·1	6·3			0·1	20·8	0·2	13·4	0·2	9	3	8	3
June 1-15	6·6			0·1		0·5		0·0	17·3	0·2	15·0	0·1	5	2	3	2
16-30		0·3		0·3	0·3			0·2	17·5	0·3	8·8	0·2	5	1	13	2
July 1-15	6·8			0·1	2·9		0·1		17·7	0·1	11·2	0·1	6	1	0	2
16-31	1·5			0·2	6·8			0·0	18·4	0·2	11·7	0·1	7	1	5	0
Aug. 1-15	23·1			0·3	19·6			0·0	30·4	0·3	23·3	0·2	8	7	11	0
16-31	7·7			0·4	24·1			0·2	18·2	0·4	25·7	0·2	3	9	19	6
Sept. 1-15	13·6			0·2	11·0			0·0	14·7	0·2	14·8	0·1	5	4	7	0
16-30	11·8			0·1	14·8		0·1		12·4	0·1	15·3	0·1	3	5	0	0
Oct. 1-15	5·0			0·2	11·2			0·0	15·2	0·2	14·9	0·1	5	2	6	0
16-31	10·6			0·1	9·9		0·1		15·9	0·1	13·6	0·1	3	2	1	1
Nov. 1-15	12·9			0·4	0·3			0·2	20·2	0·4	18·8	0·2	6	4	10	5
16-30	2·2			0·3	10·9			0·2	13·3	0·3	15·7	0·2	2	2	9	5
Dec. 1-15	16·7			0·3	1·3			0·2	20·8	0·3	12·5	0·2	8	3	13	3
16-31	5·8			0·3	16·9			0·2	12·0	0·3	25·5	0·2	2	12	9	5
Totals ..	269·1	0·3		4·9	253·9	0·5	0·4	1·9	441·9	5·3	399·0	3·3	110	94	144	36
Means ...	+11·2		−0·2		+10·6		−0·1		18·4	0·2	16·6	0·1				

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

Note:—The mean range of the greatest ordinary spring-tides for this port is 2½ feet.

TABLE 7.—*Mean errors* E_1* *and* E_2* *for 1933.*

TRINCOMALEE

PERIOD 1933	MEAN ERRORS (Predicted – Actual) E₁* H. W. Time minutes +	−	H. W. Height feet +	−	L. W. Time minutes +	−	L. W. Height feet +	−	E₂* H. W. Time minutes	H. W. Ht. feet	L. W. Time minutes	L. W. Ht. feet	Number of errors exceeding 30 minutes of time H. W.	L. W.	0·2 feet of height H. W.	L. W.
Jan. 1-15	26·6			0·5	35·2			0·1	28·6	0·5	38·5	0·3	12	13	27	12
16-31	34·2			0·5	32·6			0·4	34·3	0·5	35·7	0·4	15	12	23	25
Feb. 1-15	27·6			0·6	26·7			0·2	39·0	0·6	33·7	0·2	14	10	29	9
16-28	6·4			0·7	16·9			0·3	25·0	0·7	33·8	0·3	5	16	25	14
Mar. 1-15	37·7			0·5	17·3			0·5	38·0	0·5	32·8	0·5	15	13	28	24
16-31	18·6			0·6	26·5			0·4	31·2	0·6	32·1	0·4	13	14	31	29
April 1-15	46·0			0·4	40·0			0·3	48·9	0·4	40·0	0·3	15	10	19	19
16-30	23·9			0·4	15·8			0·2	32·8	0·4	28·8	0·2	13	12	22	14
May 1-15	14·0			0·5	20·6			0·4	21·9	0·5	36·9	0·4	4	13	23	22
16-31	37·5			0·5	19·6			0·4	37·7	0·5	25·2	0·4	19	10	25	21
June 1-15	25·1			0·3	35·8			0·1	28·4	0·3	35·8	0·1	15	19	23	5
16-30	23·3			0·3	8·9			0·2	29·3	0·3	25·7	0·2	13	9	14	9
July 1-15	1·1			0·1	19·2			0·1	23·0	0·2	34·7	0·2	4	18	12	9
16-31	27·8			0·2	30·7			0·2	59·2	0·2	48·7	0·2	27	24	15	7
Aug. 1-15		13·6		0·5		16·1		0·4	29·0	0·5	35·9	0·4	10	15	25	18
16-31		7·4		0·7		14·1		0·3	21·0	0·7	25·7	0·3	7	11	29	17
Sept. 1-15	11·8			0·4	9·7			0·3	41·2	0·4	36·1	0·3	21	18	18	15
16-30		14·3		0·5		17·6		0·0	41·0	0·5	34·1	0·3	14	9	22	19
Oct. 1-15	35·6			0·5	25·5			0·3	46·1	0·5	42·3	0·4	15	15	20	17
16-31	18·2			0·6	25·7			0·4	35·1	0·6	41·9	0·5	8	13	21	13
Nov. 1-15	62·1			1·0	49·1			0·6	62·2	1·0	53·4	0·6	13	13	16	12
16-30	11·5			0·6	17·5			0·3	52·1	0·6	56·9	0·4	16	17	19	11
Dec. 1-15	34·7			0·6	22·8			0·5	42·6	0·6	34·6	0·5	15	11	28	22
16-31	16·5			0·3	34·4		0·0		46·0	0·3	43·0	0·1	17	16	16	5
TOTALS ...	540·2	35·3		11·8	530·5	47·8	0·0	6·9	893·6	11·9	886·6	7·9	320	331	530	368
MEANS ...	+ 21·0		− 0·5		+ 20·1		− 0·3		37·2	0·5	36·9	0·3				

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

NOTE.—The mean range of the greatest ordinary spring-tides for this port is 2 feet.

TABLE 8.—*Mean errors E_1* and E_2* for 1933.*

MADRAS

PERIOD 1933	MEAN ERRORS (Predicted – Actual)												Number of errors exceeding			
	E_1*								E_2*				30 minutes of time		0·4 feet of height	
	H. W. Time (minutes)		H. W. Height (feet)		L. W. Time (minutes)		L. W. Height (feet)		H. W. Time (minutes)	H. W. Ht. (feet)	L. W. Time (minutes)	L. W. Ht. (feet)	H. W.	L. W.	H. W.	L. W.
	+	–	+	–	+	–	+	–								
Jan. 1-15		0·3		0·0	0·7			0·0	5·0	0·1	6·1	0·1	0	0	0	0
16-31	4·2			0·4	1·5			0·3	6·4	0·4	5·6	0·3	0	0	12	6
Feb. 1-15		1·3		0·3	0·0			0·3	7·0	0·3	5·4	0·3	0	0	9	5
16-28	5·0			0·6	4·4			0·5	5·7	0·6	4·9	0·5	0	0	21	14
Mar. 1-15	9·2			0·5	7·2			0·5	9·9	0·5	9·8	0·5	0	0	20	18
16-31	3·0			0·6	3·3			0·5	4·8	0·6	5·1	0·5	0	0	25	21
April 1-15	9·7			0·4	7·8			0·3	10·3	0·4	9·1	0·3	0	0	6	4
16-30	5·4			0·3	5·1			0·2	6·9	0·3	8·2	0·2	0	0	1	0
May 1-15	3·0			0·3	3·3			0·1	4·7	0·3	5·5	0·2	0	0	2	0
16-31	6·6			0·6	6·0			0·4	7·7	0·6	7·0	0·4	0	0	27	14
June 1-15	4·5			0·3	3·2			0·3	6·4	0·3	5·6	0·3	0	0	10	8
16-30	4·9			0·4	5·1			0·2	6·5	0·4	5·5	0·2	0	0	7	5
July 1-15	7·1			0·3	7·2			0·2	8·0	0·3	7·4	0·2	0	0	5	1
16-31	11·0			0·2	10·0			0·1	11·5	0·2	10·9	0·1	2	2	1	0
Aug. 1-15	5·0			0·5	5·7			0·3	6·3	0·5	7·0	0·3	0	0	17	9
16-31	1·1			0·5	1·3			0·3	4·5	0·5	4·7	0·3	0	0	21	5
Sept. 1-15																
16-30																
Oct. 1-15																
16-31																
Nov. 1-15																
16-30																
Dec. 1-15																
16-31																
TOTALS ...	79·7	1·6		6·2	71·8			4·5	111·6	6·3	107·8	4·7	2	2	184	110
MEANS ...	+ 4·9		– 0·4		+ 4·5		– 0·3		7·0	0·4	6·7	0·3				

Observatory closed from 1st September 1933.

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

TABLE 9.—*Mean errors E_1* and E_2* for 1933.*

(CHĀNDBĀLI)

PERIOD 1933	MEAN ERRORS (Predicted − Actual†) E₁* H. W. Time (minutes) +	−	H. W. Height (feet) +	−	L. W. Time (minutes) +	−	L. W. Height (feet) +	−	E₂* H. W. Time (minutes)	H. W. Ht. (feet)	L. W. Time (minutes)	L. W. Ht. (feet)	Number of errors exceeding 30 minutes of time H. W.	L. W.	1·0 feet of height H. W.	L. W.
Jan. 1-15	Actual values are only available from the 1st April 1933.																	
16-31																		
Feb. 1-15																		
16-28																		
Mar. 1-15																		
16-31																		
April 1-15		28·1		0·2		39·5	0·5		31·8	0·7	51·0	0·5	6	12	1	1
16-30		26·1		0·1		34·4	0·5		26·1	0·3	34·4	0·5	5	10	0	0
May 1-15		19·0		0·5		26·3	0·4		19·0	0·6	30·7	0·4	1	7	2	0
16-31		18·2		0·6		25·5	0·1		18·2	0·6	26·1	0·3	0	8	4	0
June 1-15		5·4		1·1		10·0	0·1		12·5	1·1	16·0	0·5	1	1	9	2
16-30	5·5			0·8		20·7		0·4	9·9	0·8	21·2	0·4	0	4	2	2
July 1-15	12·1			0·7		26·9	0·1		20·7	0·7	27·0	0·6	3	5	0	0
16-31	26·3			0·8		20·9		3·1	30·8	0·9	38·9	3·1	8	9	6	15
Aug. 1-15	22·9			1·2	2·7			4·1	26·2	1·2	23·9	4·1	5	3	10	15
16-31	5·5		0·7			53·6	0·6		24·9	0·7	55·8	0·7	5	13	2	5
Sept. 1-15	12·5		0·3			34·2		0·2	19·5	0·5	39·9	0·5	3	9	0	1
16-30	10·0			0·0		33·7		1·1	13·2	0·3	40·7	1·1	2	10	0	7
Oct. 1-15	3·5		0·7			40·3	0·4		16·7	0·7	41·7	0·8	3	9	3	5
16-31		2·1		0·2		42·5		0·6	15·3	0·3	42·5	0·9	0	13	0	5
Nov. 1-15		11·5	0·3			30·9	0·6		11·8	0·4	30·9	0·7	0	7	0	2
16-30		23·3		0·3		26·6	0·3		23·3	0·5	26·6	0·3	3	4	0	0
Dec. 1-15		17·1		0·2		27·7	0·3		19·4	0·3	28·1	0·4	4	7	0	0
16-31		16·8		0·5		25·4	0·1		20·7	0·5	28·6	0·1	3	6	3	0
TOTALS	98·3	167·6	2·0	7·2	2·7	519·1	4·0	9·5	360·0	11·1	604·0	15·9	52	137	42	60
MEANS	−3·9		−0·3		−28·7		−0·3		20·0	0·6	33·6	0·9				

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

† Actual values are tide-pole readings during daylight only.

NOTE:—Predictions were not published in the 1933 Tide-Tables. They have been included in 1934.

TABLE 10.—*Mean errors E_1* and E_2* for 1933.*

DUBLAT

PERIOD 1933	MEAN ERRORS (Predicted – Actual) E_1* H. W. Time (minutes) +	−	H. W. Height (feet) +	−	L. W. Time (minutes) +	−	L. W. Height (feet) +	−	E_2* H. W. Time (minutes)	H. W. Ht. (feet)	L. W. Time (minutes)	L. W. Ht. (feet)	Number of errors exceeding 30 minutes of time H. W.	L. W.	1·0 feet of height H. W.	L. W.
Jan. 1-15	The tide-gauge was started from the 1st April 1933.															
16-31																
Feb. 1-15																
16-28																
Mar. 1-15																
16-31																
April 1-15		4·6		0·4		12·2	0·1		14·2	0·5	19·0	0·3	2	2	0	0
16-30		4·3		0·3		16·0	0·1		7·7	0·3	16·3	0·4	0	3	0	0
May 1-15		7·9		0·1		26·9		0·1	9·7	0·2	26·9	0·3	1	7	0	0
16-31		1·3		0·6		9·2		0·3	8·2	0·8	15·0	0·3	0	2	12	0
June 1-15	7·8			0·4		9·2		0·6	11·1	0·4	11·0	0·6	1	1	0	5
16-30	11·9			0·2	2·5			0·1	18·3	0·3	13·6	0·7	4	0	0	3
July 1-15		8·4	0·1			13·4		0·6	9·6	0·3	18·7	0·6	0	4	1	2
16-31	16·3			0·6	10·4			0·3	17·2	0·6	13·7	0·7	4	2	6	7
Aug. 1-15	6·1			0·8	5·3			0·8	10·0	0·8	12·6	1·0	1	2	9	12
16-31		8·5		0·0		14·9	0·1		11·2	0·3	15·5	0·4	0	3	0	0
Sept. 1-15		4·4		0·8		3·1		0·7	13·8	0·8	17·6	0·8	2	4	12	12
16-30		9·7		0·8		9·7		0·5	9·8	0·8	12·5	0·5	0	2	7	4
Oct. 1-15		9·8		0·4		5·6		0·1	18·7	0·5	20·1	0·3	3	3	1	0
16-31		25·3		0·4		30·2		0·8	25·4	0·4	30·2	0·8	11	11	4	6
Nov. 1-15		18·3		0·2		18·4		0·0	18·9	0·3	20·3	0·3	4	4	0	0
16-30		24·3		0·1		29·8		0·4	24·3	0·3	29·8	0·4	7	13	0	1
Dec. 1-15		17·4		0·2		20·1		0·0	17·4	0·2	20·5	0·4	0	2	0	0
16-31		12·0	0·0			18·7		0·3	12·4	0·4	18·7	0·4	0	2	0	0
TOTALS ...	42·1	156·2	0·1	6·3	18·2	237·4	0·3	5·6	257·9	8·2	332·0	9·2	40	67	52	52
MEANS ...	− 6·3		− 0·3		−12·2		− 0·3		14·3	0·5	18·4	0·5				

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

TABLE 11.—*Mean errors E_1* and E_2* for 1933.*

KIDDERPORE (CALCUTTA)

PERIOD 1933	MEAN ERRORS (Predicted – Actual) E_1* H. W. Time (minutes) +	H. W. Time −	H. W. Height (feet) +	H. W. Height −	L. W. Time (minutes) +	L. W. Time −	L. W. Height (feet) +	L. W. Height −	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		1·5		0·4		11·0	0·3	11·1	0·6	1	0	1	5
16-31		8·9	0·3			13·0	0·3		11·8	0·4	14·4	0·4	0	2	1	3
Feb. 1-15	3·3			0·4	13·4		0·2		11·2	0·4	16·3	0·4	2	5	3	2
16-28	1·8			0·4		0·2		0·1	5·9	0·5	7·4	0·4	0	1	2	0
Mar. 1-15	2·1			0·6	13·5		0·1		10·1	0·6	16·9	0·4	2	4	5	0
16-31		5·4		0·4		3·6	0·2		9·7	0·6	8·2	0·4	0	0	5	0
April 1-15	1·1			0·5	5·7		0·4		12·9	0·6	17·6	0·6	3	5	4	3
16-30		3·3	0·0			0·8	0·3		10·2	0·3	11·4	0·4	0	0	0	0
May 1-15		2·4	0·1			7·6	0·8		11·3	0·3	19·0	0·8	0	3	0	6
16-31		1·5		0·2	7·9		0·1		12·5	0·6	15·5	0·3	1	4	6	0
June 1-15	4·5			0·7		3·3		0·0	7·9	0·7	10·1	0·3	0	0	5	0
16-30	2·3			0·7	9·8			0·2	8·0	0·7	12·1	0·4	0	1	5	0
July 1-15	6·1			1·6		7·6		0·8	9·6	1·6	12·9	0·8	0	1	21	10
16-31	12·3			2·2	17·0			0·8	13·3	2·2	18·1	1·0	3	6	30	8
Aug. 1-15	8·1			1·2	7·8			0·4	10·6	1·2	14·2	0·5	1	3	14	5
16-31		1·7		1·0		6·3		0·7	7·1	1·0	15·8	0·7	0	4	14	5
Sept. 1-15	12·8			1·6	9·1			1·3	15·1	1·6	23·8	1·3	3	7	28	22
16-30	12·0			1·5	1·6			0·9	12·8	1·5	9·7	0·9	0	0	23	13
Oct. 1-15	20·5			1·3	14·8			1·0	21·3	1·3	21·7	1·0	8	7	19	14
16-31	11·0			1·1		0·2		1·1	16·5	1·1	9·9	1·1	3	0	15	20
Nov. 1-15	11·2			1·0	11·8			1·1	13·5	1·0	16·9	1·1	3	3	9	15
16-30	3·1			0·6		4·7		0·4	9·4	0·7	8·0	0·5	1	0	6	1
Dec. 1-15		3·9		0·6	2·9			0·4	11·6	0·6	10·4	0·5	2	0	2	0
16-31	2·5			0·4	1·6			0·1	9·3	0·4	13·5	0·4	0	0	0	0
TOTALS ..	114·7	31·5	0·6	18·0	118·4	47·3	2·8	9·3	272·6	20·2	334·9	15·2	33	56	218	132
MEANS	+ 3·5		− 0·7		+ 3·0		− 0·3		11·4	0·8	14·0	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 1933.*

CHITTAGONG

PERIOD 1933	MEAN ERRORS (Predicted – Actual†) E₁* 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) −	E₂* H. W. Time (minutes)	E₂* H. W. Ht. (feet)	E₂* L. W. Time (minutes)	E₂* 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	4·8			0·0	1·4		0·4		6·1	0·3	4·7	0·5	0	0	0	0
16-31	2·6		0·2		1·8		0·3		5·3	0·4	5·3	0·4	0	0	0	0
Feb. 1-15		0·3		0·1	1·3		0·2		7·0	0·4	5·5	0·3	0	0	0	0
16-28	1·8			0·1	0·3		0·0		5·5	0·5	4·8	0·3	0	0	1	0
Mar. 1-15	1·3		0·2		0·7		0·3		3·9	0·3	5·1	0·4	0	0	0	0
16-31		1·0	0·5		1·8		0·3		6·3	0·7	4·5	0·4	0	0	4	0
April 1-15	1·1		0·3		2·5		0·4		5·9	0·8	4·1	0·4	0	0	5	2
16-30	1·1		0·7			0·5	0·3		5·3	0·9	6·8	0·4	0	0	6	2
May 1-15	3·0		1·0		5·9		0·3		8·1	1·0	6·3	0·3	0	0	6	1
16-31	5·2			0·1	3·3		0·1		6·4	0·4	5·8	0·3	0	0	0	0
June 1-15	8·7		0·5		5·2		0·3		8·7	0·5	6·5	0·4	0	0	1	0
16-30	1·8		0·3			0·9	0·8		7·7	0·4	7·1	0·8	0	0	0	5
July 1-15	6·4		0·4		3·9		0·3		6·5	0·8	6·6	0·4	0	0	4	0
16-31	0·7		0·1		2·6		0·8		4·8	0·3	4·3	0·8	0	0	0	5
Aug. 1-15	1·7			0·0	3·3		0·6		4·7	0·5	7·7	0·6	0	0	1	3
16-31	0·9		0·1			1·0	0·1		6·1	0·4	9·0	0·4	0	1	0	0
Sept. 1-15	0·2			0·7		2·3		0·2	3·5	0·7	6·7	0·4	0	0	3	0
16-30		8·2		0·4		7·0		0·1	14·2	0·6	8·3	0·4	1	0	3	2
Oct. 1-15		4·7		0·2		1·5	0·1		6·5	0·5	3·5	0·2	0	0	3	0
16-31	1·9			0·0	4·4		0·1		5·3	0·2	7·0	0·2	0	0	0	0
Nov. 1-15	2·9			0·0	3·7		0·2		3·3	0·2	4·8	0·2	0	0	0	0
16-30	6·4		0·1		4·5			0·1	6·5	0·4	5·3	0·1	0	0	1	0
Dec. 1-15	1·8			0·5	2·7		0·2		4·9	0·5	4·1	0·2	0	0	3	0
16-31	3·5			0·2	6·3			0·2	7·1	0·3	6·3	0·2	0	0	0	0
TOTALS...	57·8	14·2	4·4	2·3	55·6	13·2	6·1	0·6	149·6	12·0	140·1	9·0	1	1	41	20
MEANS...	+ 1·8		+ 0·1		+ 1·8		+ 0·2		6·2	0·5	5·8	0·4				

* 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 1933.*

AKYAB

PERIOD 1933	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.	0·8 feet of height H. W.	L. W.
Jan. 1-15	4·9		0·2		5·1		0·3		4·9	0·2	5·1	0·3	0	0	0	0
16-31	4·6			0·1	4·8		0·0		4·6	0·1	4·8	0·3	0	0	0	0
Feb. 1-15	4·5			0·4	4·7			0·2	4·5	0·4	4·7	0·4	0	0	3	2
16-28	5·2			0·1	4·5			0·3	5·2	0·2	4·5	0·3	0	0	0	1
Mar. 1-15	5·1			0·0	4·5			0·2	5·1	0·2	4·5	0·4	0	0	0	3
16-31	4·4			0·1	4·9		0·1		4·4	0·1	4·9	0·2	0	0	0	0
April 1-15	4·7			0·2	4·2			0·1	4·7	0·3	4·3	0·2	0	0	1	0
16-30	5·3			0·2	5·1			0·0	5·3	0·3	5·1	0·3	0	0	0	1
May 1-15	4·4			0·1	4·6		0·2		4·4	0·2	4·6	0·2	0	0	0	0
16-31	4·9			0·3	4·9		0·0		4·9	0·6	4·9	0·2	0	0	5	0
June 1-15	4·7			0·3	5·2			0·5	4·7	0·3	5·2	0·6	0	0	0	5
16-30	4·6		0·0		4·8		0·3		4·6	0·3	4·8	0·4	0	0	0	2
July 1-15	4·8		0·3		4·3		0·0		4·8	0·3	4·3	0·2	0	0	0	0
16-31	4·9		0·1		4·7			0·2	4·9	0·4	4·7	0·4	0	0	0	2
Aug. 1-15	4·5			0·2	4·8			0·7	4·5	0·3	4·8	0·7	0	0	0	5
16-31	5·3		0·4		5·2		0·4		5·3	0·4	5·2	0·4	0	0	0	0
Sept. 1-15	4·1			0·4	4·6		0·1		4·1	0·4	4·6	0·3	0	0	2	0
16-30	4·9			0·4	5·3			0·5	4·9	0·4	5·3	0·7	0	0	3	6
Oct. 1-15	5·1			0·0	4·9			0·0	5·1	0·1	4·9	0·1	0	0	0	0
16-31	4·6			0·1	5·6			0·0	4·6	0·2	5·6	0·1	0	0	0	0
Nov. 1-15	4·3			0·3	5·3			0·2	4·3	0·3	5·3	0·3	0	0	0	1
16-30	4·9			0·3	4·3			0·2	4·9	0·4	4·3	0·2	0	0	1	0
Dec. 1-15	5·0			0·5	5·0			0·2	5·0	0·5	5·0	0·3	0	0	2	2
16-31	5·0			0·1	5·1		0·1		5·0	0·2	5·1	0·1	0	0	0	0
TOTALS	114·7		1·0	4·1	116·4		1·5	3·3	114·7	7·1	116·5	7·6	0	0	17	30
MEANS	+ 4·8		– 0·1		+ 4·9		– 0·1		4·8	0·3	4·9	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 1933.*

RANGOON

PERIOD 1933	MEAN ERRORS (Predicted – Actual)												Number of errors exceeding			
	E_1*								E_2*				30 *minutes* of time		1·0 *feet* of height	
	H. W. Time		H. W. Height		L. W. Time		L. W. Height		H. W. Time	H. W. Ht.	L. W. Time	L. W. Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	−	+	−	+	−	+	−								
Jan. 1-15	2·7		0·3		6·7		0·6		8·4	0·5	16·3	0·6	0	2	1	5
16-31	5·9		0·3			2·5	0·2		7·9	0·4	13·2	0·5	0	0	1	0
Feb. 1-15	9·6			0·1	12·0		0·1		12·2	0·4	16·1	0·5	3	4	0	2
16-28		1·3		0·0		3·8		0·0	7·1	0·4	9·2	0·3	0	0	0	0
Mar. 1-15	7·8			0·0	8·9			0·1	13·7	0·3	12·9	0·4	5	3	0	2
16-31	4·3		0·1			0·8	0·2		9·3	0·4	8·8	0·4	1	1	0	1
April 1-15	7·0		0·2		2·6			0·1	14·7	0·4	12·8	0·5	2	2	1	3
16-30	1·0		0·1		0·7		0·4		8·2	0·3	10·3	0·5	1	2	0	3
May 1-15	8·7		0·4		0·9		0·1		10·9	0·4	12·7	0·6	0	3	0	5
16-31	7·6			0·4	5·8			0·3	10·8	1·0	15·6	0·6	0	4	7	6
June 1-15	14·5			0·4		3·3		0·8	15·9	0·4	10·2	0·8	0	0	1	9
16-30	8·0			0·2	8·6			0·0	8·9	0·3	13·9	0·7	0	2	0	8
July 1-15	11·6		0·2			5·5		0·2	12·1	0·3	11·5	0·4	1	0	0	2
16-31	4·3			0·1	11·5			0·0	11·4	0·4	13·9	0·4	0	3	2	3
Aug. 1-15	13·4			0·2	2·5			0·7	15·5	0·5	14·7	0·7	0	2	2	8
16-31		4·3	0·4			0·6	1·1		8·4	0·5	8·6	1·1	0	0	3	17
Sept. 1-15	3·7		0·1		9·4		0·3		13·0	0·4	16·8	0·4	3	6	1	0
16-30	7·3			0·0	1·2		0·4		12·1	0·4	7·7	0·6	0	0	2	5
Oct. 1-15	8·0		0·2		12·7		0·9		11·2	0·3	16·4	0·9	2	7	0	13
16-31		0·4	0·3			1·5	0·7		6·9	0·4	5·3	0·7	1	0	0	7
Nov. 1-15	11·2		0·2		11·1		0·8		12·0	0·5	13·3	0·8	0	5	0	9
16-30	2·0		0·4			3·2	0·4		6·2	0·5	11·0	0·6	0	0	0	2
Dec. 1-15	7·4		0·1		8·3		0·7		7·7	0·3	14·2	0·7	0	0	0	6
16-31	3·3		0·3		1·1		0·1		5·8	0·4	14·1	0·5	0	5	0	3
TOTALS ...	149·3	6·0	3·6	1·4	101·0	21·2	7·0	2·2	250·3	10·1	299·5	14·2	19	51	21	119
MEANS ...	+ 6·0		+ 0·1		+ 3·5		+ 0·2		10·4	0·4	12·5	0·6				

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

CHAPTER VI

THE INTERNATIONAL LONGITUDE PROJECT

BY CAPTAIN G. BOMFORD, R.E.

60. Summary.—The Dehra Dūn observatory took part in the International Longitude Project of October and November 1933, with four observers taking turns on three different types of transit telescope. The results from all observatories taking part are being collected and reduced by the Bureau International de l'heure at Paris, but a provisional value for the longitude of Dehra Dūn has been obtained using the Bulletin Horaire "temps definitive" for the times of emission of the wireless signals. The result, which is unlikely to differ by more than $0^s{\cdot}01$ or $0^s{\cdot}02$ from the final value, is $5^h\ 12^m\ 11^s{\cdot}78 \pm 0^s{\cdot}03$.

The high probable error results from the use of three different instruments. On each instrument the four observers agreed with each other well, but the three instruments show systematic differences.

This value of $11^s{\cdot}78$ agrees fairly well with $11^s{\cdot}75$* obtained in 1926, and very well with $11^s{\cdot}77$, the electro-telegraphic value of 1894–96. It is probably nearer the truth than its probable error suggests.

61. Equipment.—The three transit telescopes are:—

(*a*) The motor transit. A reversible instrument of $3\frac{7}{16}$–inch aperture and 36–inch focal length, made by Troughton & Simms in 1894. It has previously been known as the North Transit. It has a self-registering moving wire micrometer, which has recently been fitted with an electric drive (see Geodetic Report 1933, page 43 and Plate XVI).

(*b*) The shutter transit. Identical with the motor transit, except that instead of the moving wire micrometer and electric drive it is fitted with Dr. de Graaff Hunter's new moving shutter, which is briefly described in Geodetic Report Vol. VIII, page 7.

(*c*) The bent transit. A reversible instrument of $2\frac{1}{2}$–inch aperture and 20–inch focal length, made by Troughton & Simms in 1907. It has previously been known as the South Transit. It has a hand-driven moving wire micrometer.

* Given as $11^s{\cdot}79$ in Geodetic Report Vol. III, but reduced to $11^s{\cdot}75$ in Geodetic Report 1933 after re-reading the chronograph sheets.

Of the above, (*a*) and (*b*) were used (with fixed wires) for the electro-telegraphic longitude of 1894–96, and (*c*) and (*a*) (without electric drive) were used in the international project of 1926. On all three occasions these transits were set up on the same meridian within 150 feet of each other.

The wireless receiver used was a Marconi R. P. 11 with an 80-foot vertical aerial, but without the phasing unit. Automatic registration was not employed.

The observatory clock is Shortt No. 34, with Riefler No. 450 as second clock. Both work at a controlled temperature of 80° F.

62. Programme.—The four observers were Mr. B. L. Gulatee, M.A., Mr. R. B. Mathur, B.A., Mr. H. C. Banerjea, B.A., and Computer J. B. Mathur. Except for Sundays and four wet nights, two of the three instruments were in use each night from 2nd October to 25th November *.

The nightly programme of each instrument consisted of ten time stars within 10° of the zenith and two azimuth stars, and observations generally extended from 7 to 10 p.m. All stars were observed in both positions of the instrument, and the bubble was read before and after each star. Observations for the lost motion of the screw were made, but were inconsistent and have been ignored. It was in any case too small to explain the difference between the bent transit and the other two. No special observations were made for irregularity of the circular pivots (transit axis bearings), but in addition to computing the longitude with all the stars observed, it has been computed using time stars within 3° of the zenith only. Such stars are comparatively free from pivot error, and the agreement between the two solutions (see para 63) shows that no serious pivot error was present.

No special observations for personal equation were made. It was hoped that the twelve different combinations of observer and instrument would thoroughly eliminate it.

On the average, eight of the ten time stars were taken from the list circulated in the Bulletin Geodesique No. 38, of which one was generally from the equatorial list. In the case of the equatorial stars the 10° limit of zenith distance was increased to 15°.

The following five wireless signals were received daily, except on Sundays:

(*a*)	Bordeaux	8:01	G.M.T.	
(*b*)	Rugby	9:55	„	
(*c*)	Saigon	11:00	„	(from 9th Oct.)
(*d*)	Rugby	17:55	„	
(*e*)	Saigon	19:00	„	

The method of reception was the "extinction method", which is considered to be more free from systematic error than automatic registration. Four or five coincidences were generally observed.

* Observations were continued until 30th November, but on the last few days the wireless signals were received by comparison with a portable chronometer in preparation for work in the field. The results were not satisfactory, and have been ignored.

63. Computation of the longitude.—Immediately on completion of the observations, the clock error according to each star observed, and the clock time of reception of each wireless signal, was sent to the Bureau de l'heure at Paris, by whom the results of all observatories are being co-ordinated. Table 4 summarizes these figures. The longitude of Dehra Dūn has, however, been obtained with almost complete finality by accepting the Bulletin Horaire, "temps definitive" for the Rugby and Bordeaux signals, and discussion of the performance of the instruments need not be postponed until the publication of the finally co-ordinated results. The Saigon signals have not been employed, as their emission is considerably less regular than the other two, and all corrections are not yet available.

Plate XXVI shows the error of the Shortt clock according to the observations of the three transits. The smoothed curves give the values which have been accepted.

Table 1 gives mean values of the longitude according to different observers and instruments, as deduced from the three Rugby and Bordeaux signals. Each entry is the mean of 4 to 6 days' work except those with an asterisk which are 10 to 12 days'. The velocity of propagation has been taken as 186,000 miles per second. The correction to the time of emission has been the mean of the definitive corrections to the first and last signals, since the 4 or 5 coincidence signals with which comparison was actually made are evenly spaced throughout the 306 dots of each wireless signal. Star places have mostly been taken from the Nautical Almanac and American Ephemeris. Short period terms have been included.

Tables 2 and 3 give mean results by each wireless signal and each instrument. In these tables the results are given (*a*) using all the stars observed and (*b*) using only those time stars which are within 3° of the zenith.

The most striking table is that which shows the mean by different instruments, which shows up the weakness of the result. The other tables wrongly suggest a high standard of accuracy. The acceptance of only close zenith stars slightly increases the discrepancies, and the mean of all stars gives the result which is accepted, viz:—$5^h\ 12^m\ 11^s{\cdot}78$.

TABLE 1.—*Longitude of Dehra Dūn by different observers.*

Observer	Motor	Shutter	Bent	Mean
	h m s	*s*	*s*	*s*
B.L.G.	5 12 11·82 *	11·80	11·67	11·76
R.B.M.	11·86	11·79	11·72*	11·79
H.C.B.	11·85	11·82*	11·68	11·78
J.B.M.	11·80	11·77*	11·72	11·76

NOTE:—For this table all three Rugby and Bordeaux wireless signals have been used and all time stars. Each observer did one week with each instrument, except that an asterisk (*) denotes two weeks.

TABLE 2.—*Longitude of Dehra Dūn by different signals.*

Signal		Mean Longitude					
		All time stars			Close zenith stars only		
		h	*m*	*s*	*h*	*m*	*s*
Bordeaux	8:01 G.M.T.	5	12	11·78	5	12	11·78
Rugby	9:55 G.M.T.			11·78			11·77
Rugby	17:55 G.M.T.			11·77			11·76
Mean	...	5	12	11·78	5	12	11·77

TABLE 3.—*Longitude of Dehra Dūn by different instruments.*

Instrument	Mean Longitude					
	All time stars			Close zenith stars only		
	h	*m*	*s*	*h*	*m*	*s*
Motor transit	5	12	11·83	5	12	11·84
Shutter transit			11·80			11·80
Bent transit			11·70			11·68
Mean ...	5	12	11·78	5	12	11·77

64. **Performance of the instruments.**—The wide range of variation between the three instruments calls for explanation, but none is forthcoming. The comparatively close accordance between the motor and shutter transits suggests that the bent transit is in error, and it was certainly the least regular of the three, as is shown in Plate XXVI. But the bent transit gives a value as near to the 1926 value as any of the three, and regularity is little guide when liability to systematic error is in question. It is therefore considered that there is no cause for rejecting the bent transit, and the mean of all three has been accepted. That the difference between the instruments is not due to personal equation of the observer, in the ordinary sense, is shown by Table 1. Each of the four observers gets similar results on any one instrument. Nor can it be due to lateral refraction or other peculiarity of the site, for the three instruments were very close together, and the bent transit was moved during the observations to test this point.

The performance of Dr. Hunter's new shutter transit has been very satisfactory. Plate XXVI shows that it was the most steady of the three in giving small departures from a smooth clock rate, and the mean value of the longitude derived from it is probably nearer the truth than that obtained from the other two. Four different observers have agreed within a range of $0^s \cdot 05$ which is quite satisfactory, although it must be noted that the other instruments have done no worse, so that this is no proof of the absence of systematic error. It appears that a final proof of the excellence of the new type of instrument will not be available until two or three, set up together, give accordant results. Dr. Hunter who is now in England, is making an improved model, and when this is received at Dehra it will be possible to compare it with the existing one.

65. **The longitude of Dehra Dun.**—The figures $11^s \cdot 77$ in 1894, $11^s \cdot 75$ in 1926 and $11^s \cdot 78$ in 1933 suggest no progressive change. Nor would it be suggested if the bent transit in 1933 was rejected, and the 1933 value increased to 11·82. It is accordingly concluded that the differences are due solely to instrumental error, and that the 1894 value of $11^s \cdot 77$ is still well applicable.

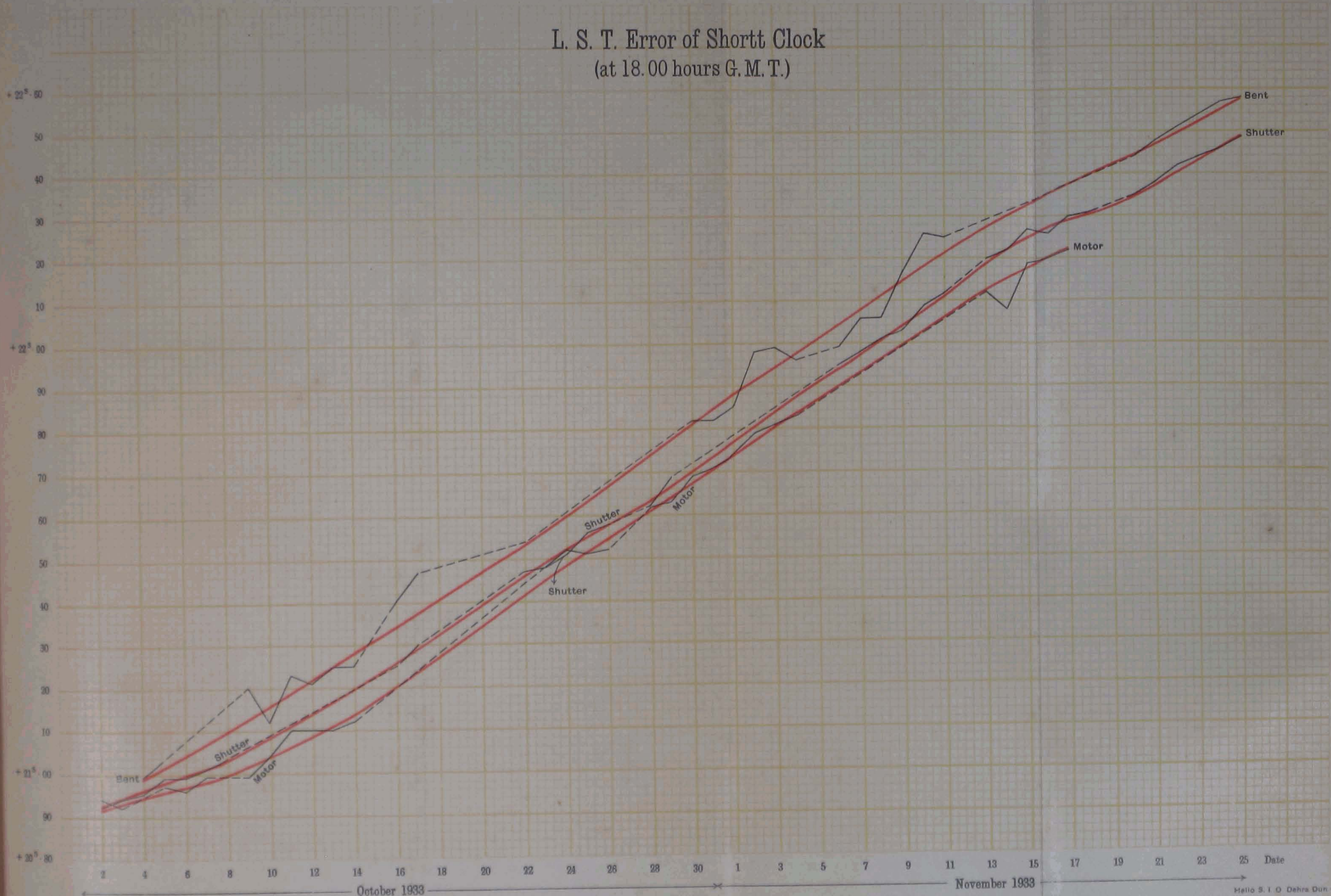

L. S. T. Error of Shortt Clock
(at 18.00 hours G.M.T.)
Bent
Shutter
Motor
Bent
Shutter
Motor
Shutter
Shutter
Motor
+22s·60
50
40
30
20
10
+22s·00
90
80
70
60
50
40
30
20
10
+21s·00
90
+20s·80
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 1 3 5 7 9 11 13 15 17 19 21 23 25 Date
October 1933
November 1933

TABLE 4.—*Time of reception of Wireless Signals.*

1933	Clock time of 1st Signal					Dehra L.S.T. error of clock at 18.00 G.M.T.		
	Bordeaux $8^h\ 01^m$	Rugby $9^h\ 55^m$	Saigon $11^h\ 00^m$	Rugby $17^h\ 55^m$	Saigon $19^h\ 00^m$	By Motor	By Shutter	By Bent
	h m s	h m s	h m s	h m s	h m s	m s	m s	m s
Oct. 2	13 55 54·29	15 50 13·06	...	23 51 31·89	00 56 42·60	+00 20·92 (a)	+00 20·92 (d)	...
3	13 59 50·88	54 09·67	...	55 28·47	01 00 39·04	20·93 (a)	20·94 (d)	...
4	14 03 47·44	15 58 06·19	...	23 59 25·06	04 35·81	...	20·96 (d)	+00 20·99 (a)
5	07 44·03	16 02 02·82	...	00 03 21·62	08 32·37	20·96 (a)	20·98 (d)	...
6	11 40·58	05 59·33	...	07 18·22	...	20·97 (a)	20·99 (d)	...
7	15 37·15	09 55·93	...	11 14·78	16 25·51	20·98 (a)	21·01 (d)	...
9	23 30·33	17 49·11	17 22 59·30	19 07·95	24 18·55	21·02 (c)	...	21·13 (b)
10	27 26·93	21 45·69	26 56·51	23 04·52	28 15·10	21·04 (c)	...	21·16 (b)
11	31 23·55	25 42·26	30 52·78	27 01·08	32 11·84	21·07 (c)	...	21·19 (b)
12	35 20·12	29 38·80	34 49·49	30 57·66	36 08·32	21·09 (c)	...	21·22 (b)
13	39 16·67	33 35·38	38 46·07	34 54·23	40 04·95	21·11 (c)	...	21·25 (b)
14	43 13·23	37 31·97	42 42·49	38 50·82	44 01·43	21·14 (c)	...	21·28 (b)
16	51 06·38	45 25·16	50 35·00	46 44·00	51 54·67	...	21·26 (a)	21·35 (d)
17	55 02·97	49 21·75	54 33·33	50 40·59	55 51·14	...	21·29 (a)	21·38 (d)
18	14 58 59·60	53 18·32	17 58 29·04	00 54 37·16	01 59 47·75	...	...	...
19	15 02 56·21	16 57 14·90	18 02 24·55	...	...	...	...	...
20	06 52·81	17 01 11·51	06 23·03	...	...	...	...	...
21	10 49·41	05 08·11	10 18·75	...	...	...	...	...
22	14 46·00	09 04·71	14 15·19	01 10 23·58	02 15 34·16	...	21·46 (a)	21·53 (d)
23	18 42·63	13 01·33	18 11·67	14 20·19	19 30·73	21·45 (b)	21·49 (c)	...
24	22 39·19	16 57·90	22 09·43	18 16·77	23 27·80	21·48 (b)	21·52 (c)	...
25	26 35·78	20 54·49	26 05·15	22 13·34	27 23·78	21·52 (b)	21·55 (c)	...
26	30 32·34	24 51·07	30 01·38	26 09·95	31 20·71	21·55 (b)	21·58 (c)	...
27	34 28·90	28 47·64	33 58·52	...	...	...	...	...
28	38 25·48	32 44·23	...	34 03·07	39 13·63	21·61 (b)	21·63 (c)	...
29	42 22·10	36 40·81	41 51·55	37 59·67	...	21·64 (b)	+00 21·67 (c)	...
30	46 18·69	40 37·38	45 48·01	41 56·21	47 07·77	21·68 (d)	...	21·81 (a)
31	15 50 15·29	17 44 33·97	18 49 43·22	01 45 52·80	02 51 03·40	+00 21·71 (d)	...	+00 21·85 (a)

NOTE:—1. (a) Signifies observer B.L.G., (b) R.B.M., (c) H.C.B. and (d) J.B.M.
2. Although recorded as time of reception of 1st signal, the times are derived from the recording of several rythmic dots throughout the series. See para 63.
3. These figures are times of reception. No allowance has been made for velocity of propagation.
4. Clock errors have been taken from the smooth curves of Plate XXVI.
5. + error indicates that clock is fast.

(Continued)

TABLE 4.—*Time of reception of Wireless Signals*—(*concluded*).

1933	Clock time of 1st Signal: Bordeaux 8^h 01^m	Clock time of 1st Signal: Rugby 9^h 55^m	Clock time of 1st Signal: Saigon 11^h 00^m	Clock time of 1st Signal: Rugby 17^h 55^m	Clock time of 1st Signal: Saigon 19^h 00^m	Dehra L.S.T. error of clock at 23.30 G.M.T.: By Motor	Dehra L.S.T. error of clock at 23.30 G.M.T.: By Shutter	Dehra L.S.T. error of clock at 23.30 G.M.T.: By Bent
	h m s	*h m s*	*h m s*	*h m s*	*h m s*	*m s*	*m s*	*m s*
Nov. 1	15 54 11·85	17 48 30·52	18 53 39·74	01 49 49·40	02 54 59·88	+00 21·74 (*d*)	...	+00 21·88 (*a*)
2	15 58 08·45	52 27·11	18 57 37·82	53 45·96	02 58 56·62	21·77 (*d*)	...	21·91 (*a*)
3	16 02 05·04	17 56 23·71	19 01 32·43	01 57 42·58	03 02 52·85	21·81 (*d*)	...	21·94 (*a*)
4	...	18 00 20·30	05 30·07	02 01 39·16	06 49·60	21·84 (*d*)	...	21·98 (*a*)
6	13 54·86	08 13·52	13 22·85	09 32·36	14 42·80	...	+00 21·94 (*b*)	22·05 (*c*)
7	17 51·43	12 10·11	17 21·07	13 28·97	18 39·58	...	21·97 (*b*)	22·08 (*c*)
8	21 47·99	16 06·71	21 16·40	17 25·53	...	...	22·01 (*b*)	22·11 (*c*)
9	...	20 03·29	25 12·03	21 22·14	26 32·88	...	22·04 (*b*)	22·15 (*c*)
10	...	23 59·88	29 10·10	...	30 29·25	...	22·08 (*b*)	22·19 (*c*)
11	33 37·71	27 56·47	...	29 15·32	34 25·80	...	22·11 (*b*)	22·22 (*c*)
13	41 30·89	35 49·62	40 59·73	37 08·47	...	22·12 (*a*)	22·19 (*d*)	...
14	45 27·47	39 46·18	44 57·03	41 05·00	46 15·63	22·15 (*a*)	22·23 (*d*)	...
15	49 24·04	43 42·77	48 52·70	45 01·58	50 12·34	22·17 (*a*)	22·26 (*d*)	...
16	53 20·60	47 39·34	52 50·03	48 58·19	54 08·67	22·20 (*a*)	22·28 (*d*)	...
17	16 57 17·26	51 35·88	19 56 46·64	52 54·74	03 58 05·60	+00 22·22 (*a*)	22·30 (*d*)	...
18	17 01 13·81	18 55 32·51	20 00 43·33	02 56 51·36	04 02 01·89	...	22·31 (*d*)	...
20	...	19 03 25·67	08 35·92	03 04 44·51	09 55·33	...	22·35 (*c*)	22·45 (*b*)
21	...	07 22·29	12 32·64	08 41·11	13 51·55	...	22·38 (*c*)	22·47 (*b*)
22	...	11 18·85	16 29·48	12 37·67	17 49·67	...	22·41 (*c*)	22·50 (*b*)
23	20 56·71	15 15·44	20 26·10	16 34·30	21 45·12	...	22·43 (*c*)	22·53 (*b*)
24	24 53·33	19 12·04	24 22·58	20 30·86	25 41·85	...	22·46 (*c*)	22·56 (*b*)
25	17 28 49·85	19 23 08·60	20 28 19·44	03 24 27·45	04 29 38·25	...	+00 22·49 (*c*)	+00 22·58 (*b*)

NOTE:—1. (*a*) Signifies observer B.L.G., (*b*) R.B.M., (*c*) H.C.B. and (*d*) J.B.M.
2. Although recorded as time of reception of 1st signal, the times are derived from the recording of several rythmic dots throughout the series. See para 63.
3. These figures are times of reception. No allowance has been made for velocity of propagation.
4. Clock errors have been taken from the smooth curves of Plate XXVI.
5. + error indicates that clock is fast.

Chapter VII

OBSERVATORIES

by Captain G. Bomford, r.e.

66. Standards of length.—The measurement of the three bases described in Chapter I completes the programme of new bases started in 1930. During the year the invar wires were compared with the 4-metre invar bar on four occasions, and the 4-metre bar has been re-compared with the 1-metre nickel and silica standards. The wires have shown a satisfactory degree of stability, having apparently settled down after the large changes of 1931–33. The standardization of the 4-metre bar also agrees well with that of 1930. Details of the observations are given below. The observers were Captain G. Bomford and Mr. B. L. Gulatee. The N. P. L. certificates of the standard bars are given in Geodetic Report Vol. VII, page 11, and the coefficients of expansion of the invar wires, as determined in India, are in Geodetic Report 1933, page 39.

(a) **Silica 1-m** *minus* **Nickel 1-m.**—

Date	Temperature	G.B.	B.L.G.
17-1-34 ..	T_S =23°·09 T_N =23°·09	−0·3272mm ·3284 ·3340 ·3318 ·3293 ·3313 ·3252 ·3275	−0·3291mm ·3306 ·3323 ·3292 ·3316 ·3303 ·3257 ·3283
	Mean	−0·3293	−0·3296

Reputed length of nickel	= 1m + 0·3056mm
Reputed length of silica	= 1m − 0·0240
∴ Reputed silica *minus* nickel	= −0·3296
Observed silica *minus* nickel	= −0·3294
Discrepancy	= 0·0002

The discrepancy of 0·2 in 10^6 is satisfactory, but must be regarded as fortunate. By the "reputed length" is meant the length at the temperature of observation, according to the 1931 N. P. L. certificates.

(b) Invar 4-m (Baros plugs) *minus* Nickel 1-m.—

First metre (0 to 1) of invar bar.

Date	Temperature	G.B.	B.L.G.
10-4-34 ...	T_I = 23°·35 T_N = 23°·32	−0·2460mm ·2495 ·2505 ·2520 ·2516 ·2516 ·2518 ·2509	−0·2483mm ·2489 ·2510 ·2509 ·2500 ·2507 ·2505 ·2501
	Mean	−0·2505	−0·2501

Reputed length of nickel = 1m + 0·3087mm
Observed invar *minus* nickel = −0·2503
∴ length of invar at 23°·35 = 1m + 0·0584
and length of invar at 24°·3 = 1m + 0·0598

24°·3 C is the common temperature to which the four separate sections are reduced.

Second metre (1 to 2) of invar bar.

Date	Temperature	G.B.	B.L.G.
9-4-34 ...	T_I = 23°·17 T_N = 23°·12	−0·2575mm ·2555 ·2585 ·2548 ·2560 ·2569 ·2559 ·2576	−0·2552mm ·2562 ·2593 ·2555 ·2550 ·2545 ·2569 ·2584
	Mean	−0·2566	−0·2564

Reputed length of nickel = 1m + 0·3062mm
Observed invar *minus* nickel = −0·2565
∴ length of invar at 23°·17 = 1m + 0·0497
and length of invar at 24°·3 = 1m + 0·0512

Third metre (2 to 3) of invar bar.

Date	Temperature	G.B.	B.L.G.
6-4-34 ...	T_I =21°·88 T_N =21°·79	−0·2383mm ·2406 ·2395 ·2374 ·2389 ·2407 ·2423 ·2400	−0·2381mm ·2398 ·2397 ·2417 ·2371 ·2406 ·2419 ·2409
	Mean	−0·2398	−0·2399

Reputed length of nickel = 1m + 0·2891mm
Observed invar *minus* nickel = −0·2399
∴ length of invar at 21°·88 = 1m + 0·0492
and length of invar at 24°·3 = 1m + 0·0526

Fourth metre (3 to 4) of invar bar.

Date	Temperature	G.B.	B.L.G.
5-4-34 ...	T_I =21°·43 T_N =21°·41	−0·2263mm ·2297 ·2299 ·2277 ·2298 ·2282 ·2281 ·2275	−0·2270mm ·2300 ·2296 ·2259 ·2292 ·2274 ·2288 ·2281
	Mean	−0·2284	−0·2283

Reputed length of nickel = 1m + 0·2843mm
Observed invar *minus* nickel = −0·2284
∴ length of invar at 21°·43 = 1m + 0·0559
and length of invar at 24°·3 = 1m + 0·0599

Combining the four sections of the invar bar gives the total length of the bar (baros plugs) as 4m + 0·2235mm at 24°·3 C according to comparison with the nickel.

(c) Invar 4-m *minus* Silica 1-m.—

First metre (0 to 1) of invar bar.

Date	Temperature	G.B.	B.L.G.
16-4-34 ...	T_I = 22°·88 T_S = 22°·87	+0·0775mm ·0772 ·0779 ·0770 ·0768 ·0771 ·0804 ·0797	+0·0787mm ·0768 ·0765 ·0758 ·0777 ·0780 ·0780 ·0802
	Mean	+0·0780	+0·0777

Reputed length of silica = 1m −0·0241mm
Observed invar *minus* silica = +0·0779
∴ length of invar at 22°·88 = 1m +0·0538
and length of invar at 24°·3 = 1m +0·0558

Second metre (1 to 2) of invar bar.

Date	Temperature	G.B.	B.L.G.
13-4-34 ...	T_I = 24°·17 T_S = 24°·16	+0·0726mm ·0773 ·0745 ·0765 ·0748 ·0761 ·0746 ·0775	+0·0748mm ·0786 ·0752 ·0749 ·0760 ·0752 ·0761 ·0773
	Mean	+0·0755	+0·0760

Reputed length of silica = 1m −0·0235mm
Observed invar *minus* silica = +0·0758
∴ length of invar at 24°·17 = 1m +0·0523
and length of invar at 24°·3 = 1m +0·0524

Third metre (2 to 3) of invar bar.

Date	Temperature	G.B.	B.L.G.
12-4-34 ...	T_I = 24°·19 T_S = 24°·19	+0·0756mm ·0751 ·0722 ·0734 ·0752 ·0723 ·0753 ·0744	+0·0740mm ·0752 ·0738 ·0733 ·0747 ·0712 ·0718 ·0735
	Mean	+0·0742	+0·0734

Reputed length of silica	=	1m −0·0235mm
Observed invar *minus* silica	=	+0·0738
∴ length of invar at 24°·19	=	1m +0·0503
and length of invar at 24°·3	=	1m +0·0504

Fourth metre (3 to 4) of invar bar.

Date	Temperature	G.B.	B.L.G.
11-4-34 ...	T_1 =23°·67 T_S =23°·63	+0·0870mm ·0832 ·0838 ·0833 ·0834 ·0825 ·0853 ·0854	+0·0874mm ·0821 ·0855 ·0843 ·0835 ·0832 ·0860 ·0868
	Mean	+0·0842	+0·0849

Reputed length of silica	=	1m −0·0238mm
Observed invar *minus* silica	=	+0·0846
∴ length of invar at 23°·67	=	1m +0·0608
and length of invar at 24°·3	=	1m +0·0617

Combining the four sections of the invar bar gives the total length of the bar as 4m + 0·2203mm at 24°·3 C according to comparison with the silica. This may be compared with 4m + 0·2235mm obtained from the nickel (sub-para b). The discrepancy is 0·8 in 10^6 which is satisfactory. The mean is accepted, and gives

4m + 0·2219mm at 24°·3 C in 1934

for the length of the 4-m invar bar (baros plugs). The 1930 value was 4m + 0·2158mm (Geodetic Report Vol. VII, page 17), so the growth has been 0·4 in 10^6 per year, about the same rate as between 1914 and 1930. But see sub-para d.

(d) 4-m Invar. Edge B *minus* Baros plugs.—

Date	G.B.	B.L.G.
19-4-34 ...	−0·0007mm	+0·0016mm
	− ·0058	− ·0066
20-4-34 ...	− ·0053	− ·0024
	− ·0045	− ·0057
23-4-34 ...	− ·0040	− ·0040
	+ ·0012	+ ·0016
	− ·0052	− ·0088
Mean	−0·0035	−0·0035

General mean B *minus* Baros	=	−0·0035mm
∴ length of Edge B at 24°·3	=	4m +0·2184mm
and at 28°·0 C (required below) it is		4m +0·2395mm

This figure of $-0\cdot0035$mm must be compared with $+0\cdot0008$mm found in 1930. The discrepancy is $1\cdot1$ in 10^6, which is not very serious, but is surprisingly large, as the observation is an easy one. Assuming the observations to be correct, Edge B has grown by only $0\cdot0018$mm since 1930, compared with $0\cdot0061$mm which is the growth shown by the baros plugs. The difference between Edges A and B in 1934 is nearly the same as it was in 1930 (see sub-para e) so it appears that the centre of the bar has grown by $0\cdot4$ in 10^6 per year, while the edges have only grown by $0\cdot1$ in 10^6 per year. This may not really be the case, but the observations are accepted, and the length of Edge B is taken as

4m + 0·2395mm at 28°·0 C in 1930.

When deducing the lengths of the 24-metre wires from observations made in 1932 and 1933, allowance was made for the probable growth of the 4-metre invar bar at the rate of $0\cdot5$ in 10^6 per year found between 1914 and 1930. As, in fact, the edges of the bar (which have been used on the 24-metre comparator) have grown less than this, the figures given for the length of the wires in Geodetic Report 1933, pages 48 and 49, require to be reduced by $0\cdot5$ in 10^6, or $0\cdot012$mm. Small changes result in the lengths of the base-lines measured in 1932–33. These are given in Chapter I of this report, para 6.

(e) 4-m Invar. Edge B *minus* Edge A.

Date	G.B.	B.L.G.
19-4-34 ...	+0·0087mm	+0·0092mm
	− ·0021	− ·0005
20-4-34 ...	+ ·0002	+ ·0042
	− ·0022	+ ·0011
23-4-34 ...	+ ·0029	+ ·0029
	+ ·0097	+ ·0098
	+ ·0025	− ·0006
Mean	+0·0028	+0·0037

General mean B *minus* A = $+0\cdot0032$mm

Compare 1930 value of $+0\cdot0038$

(f) 4-m nickel-steel *minus* 4-m invar.—The Survey of India possess a nickel-steel 4-metre bar of reputedly stable composition, and comparison of the 4-metre invar bar with it is much less laborious than a comparison with the 1-metre bars. To enable re-standardization of the invar bar to be easily carried out if required in the near future, comparisons have been made between it and the nickel-steel bar as below:—

Date	Temperature	G.B.	B.I.G.
24-4-34 ...	$T_I = 25°\cdot25$ $T_{NS} = 25°\cdot21$	+0·5314mm ·5299 ·5362 ·5336	+0·5314mm ·5272 ·5362 ·5350
	Mean	+0·5328	+0·5325

Reputed length of invar* = 4m + 0·2273mm
Observed nickel-steel *minus* invar = +0·5326
∴ length of nickel-steel at 25°·21 = 4m + 0·7599mm
Reputed length of nickel-steel (1914) = 4m + 0·770 mm.

It therefore appears that the nickel-steel bar has decreased by 0·01 mm, or 2·5 in 10^6, since 1914.

The N.P.L. certificate of the nickel-steel bar (baros plugs) in 1914 was :—

$$L_{20} = 4m + 0\cdot613mm$$

Coefficient of expansion = +0·000,007,52 per °C between 0° and 30°.

(g) **Lengths of 24-m wires.**— During the winter 1933-34 the six invar wires were hung on the comparator on two different days on four occasions, and the 4-metre invar bar was stepped along the comparator before and after each comparison. Plate XXVII shows the resulting lengths of the comparator. The values given depend on the finally determined length of the 4-metre bar. The invar tape which constitutes the comparator base shows a rather considerable increase of length between November 1933 and January 1934, but has otherwise remained steady.

Table 1 (page 122) gives details of the comparisons of the wires, which are summarized below:—

Millimetres in excess of 24 metres at 28°C.

Date	Wire No.						Temperature of comparison
	243	244	247	248	249	252	
7 & 8-11-33 ...	−0·17	−2·30	+1·64	+1·72	+4·06	+3·07	21°C
9 & 10-1-34 ...	−0·11	−2·35	+1·63	+1·74	+4·06	+3·07	14°C
15 & 16-2-34 ...	−0·16	−2·41	+1·60	+1·72	+3·99	+3·06	19°C
19 & 20-3-34 ...	−0·15	−2·38	+1·58	+1·74	+4·02	+3·08	20°C

A base in Baluchistān was measured between the first and second of the above standardizations, one near Poona between the second and third, and one in Assam between the third and fourth. Wires 243 and 252 were used as field standards. The wires have

* As determined in 1934 from nickel and silica metres.

maintained their lengths fairly well, although significant changes have occurred. At each base at least 3 wires have been free from significant change, and the daily comparisons in the field have satisfactorily located the times of the changes in the others.

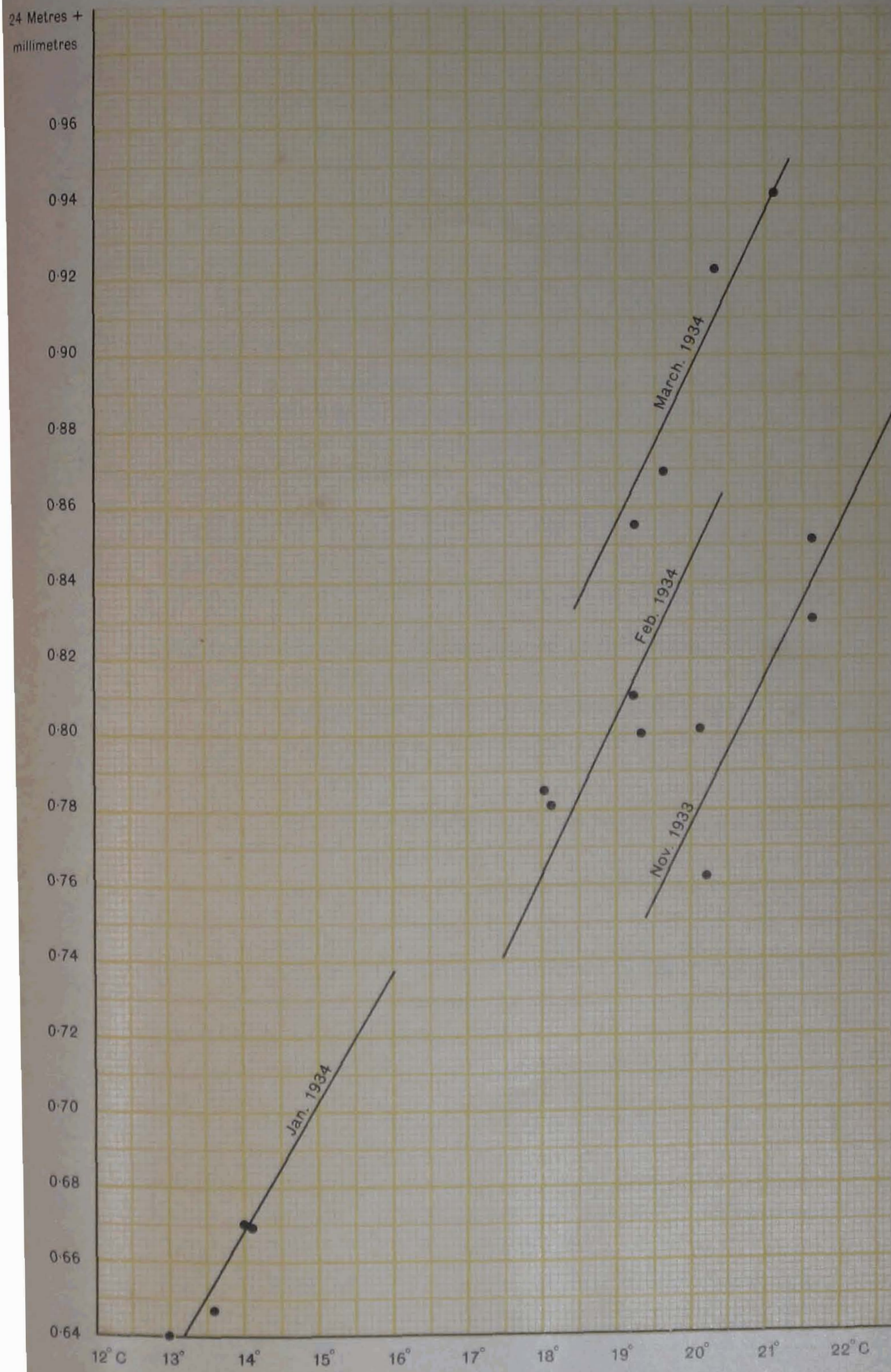
(h) New 24-m wires.—Two new wires were received in March 1934, with certificates from the Bureau International at Sèvres. They were received too late for use in the field, but were included with the other wires in the March standardization. See Table 1. The lengths found for them (reduced to 15°C) were 24m + 0·80mm and 24m + 0·77mm, which compare well with 24m + 0·78mm and 24m + 0·76mm given by their certificates. The mean discrepancy is 0·6 in 10^6, which provides a satisfactory check on the lengths of our standards, and on the stepping-up from one metre to 24 metres.

(i) 8-m wire and 4-m tape.—The 8-metre invar wire was standardized before and after the field season. Its length was found to be 8m + 0·63mm at 28°C in November and 8m + 0·68mm in March. The length of the 4-metre invar tape was found to be 4m + 1·38mm in November and 4m + 1·35mm in March.

67. Longitude.—Observations made during October and November 1933 in connection with the international programme are described in Chapter VI. The usual bi-weekly observations

	Motor Transit			Shutter Transit		
	No. of days	Bordeaux	Rugby	No. of days	Bordeaux	Rugby
		h m s	h m s		h m s	h m s
October 1933	19	5 12 11·80	5 12 11·84	15	5 12 11·78	5 12 11·81
November ..	9	11·81	11·83	18	11·77	11·78
December ..	3	11·88	11·93	1	...	11·91
January 1934	1	...	11·73	2	...	11·81
February ..	3	...	11·83	4	...	11·80
March ..	4	...	11·79	3	...	11·81
April ..	5	...	11·91	4	...	11·87
May ..	3	...	11·81	4	11·81	11·83
June ..	3	11·77	11·86	3	11·77	11·84
July ..	4	...	11·82	1	...	11·77
August ..	4	...	11·82	Nil	...	...
September ..	5	...	11·81	3	11·76	11·73
Mean ...	5	5 12 11·82	5 12 11·83	5	5 12 11·78	5 12 11·81

Length of 24-metre Comparator, 1933-34.



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were made during the remaining months of the year, with the motor and shutter transits. The observers were Messrs. B.L. Gulatee, R.B. Mathur, H.C. Banerjea and J.B. Mathur at different times.

The resulting values of the longitude are given in Table 2, and the monthly mean values are given opposite, as determined from the Bordeaux and Rugby signals with the "demi-definitive" corrections of the Bulletin Horaire and Admiralty Notices. The annual mean values by the two instruments are very nearly equal.

The Shortt clock has been in use throughout the year, but five interruptions occurred. One was on account of the Bihār earthquake, and the others were probably due to battery weakness. Its error and rate are given in Table 3. The Riefler clock has run without interruption.

68. Latitude observations.—Attention has been given to the corrections for deviation and collimation applicable to zenith telescope observations. The corrections to an observed zenith distance are generally given as:—

$$\text{For deviation } -\frac{a^2}{2}\,\frac{\sin\gamma\sin\zeta}{\sin\Delta}\,\sin 1''.$$

$$\text{For collimation } \pm\, 15^2\,(c+k)^2 \cot\Delta \sin 1'' \text{ for } \frac{\text{south}}{\text{north}} \text{ stars,}$$

where a = deviation (of the line of collimation) in seconds of arc

c = collimation error in equatorial seconds of time

k = wire interval in equatorial seconds of time

γ = co-latitude

ζ = zenith distance

Δ = north polar distance.

These formulæ are correct for either deviation or collimation taken separately, but when both are present there is also a term $15a\,(c+k)\sin\gamma\operatorname{cosec}\Delta\sin 1''$. When an outer wire is being used, k is 27^s (of time) so the product $a\,(c+k)$ is likely to be very much greater than a^2, and the usual formula is no guide to the deviation error which can be permitted.

With ordinary care this term is negligible in field-work, but it has been necessary to apply it to the 1930–33 variation of latitude observations at Dehra Dūn, where it has a small effect. The result of this correction, and of an error of sign which was found in the application of the collimation correction, is to increase the latitudes given in Geodetic Report 1933, Chapter V by 0·16 seconds of arc, but to leave the variation practically unchanged.

69. Invar levelling staves.—Examination of the intermediate graduations of six invar levelling staves (carried out in October 1932) has shown a material difference of scale between the bottom foot and the remaining nine. Results are given in Table 4. It has also been found that greater changes of length occur as the result of use in the field if the staff is standardized between its 0 and 10-foot marks, than when standardization is between the 2 and 10-foot marks.

Observations are seldom made on the bottom foot of the staff on account of risk of refraction, so the scale there is of little interest, and it has accordingly been decided to standardize between the 2 and 10-foot marks in future, and to accept 10/8 of this distance as the total length of the 10-foot staff.

The standardizations of intermediate marks have been made by comparison with the "Bevelled bar" No. 1-1900. The latter has been standardized against bar I_s for its overall length, and its intermediate 2-foot intervals have been inter-compared in the comparator.

70. Miscellaneous.—The Omori seismograph was in operation throughout the year, and Table 5 gives a list of the earthquakes recorded. The Bihār earthquake caused too violent movement of the pen to give any information other than the time of arrival of the first phase.

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

71. 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 and there was no interruption of any consequence.

The mean values of the magnetic elements at Dehra Dūn in 1933 were:—

Declination	...	E. 1° 2′·8
Dip ...	...	N. 45° 38′·2
Horizontal force	...	0·33056 C.G.S.
Vertical force	...	0·33798 C.G.S.

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

Declination	...	1·03 minutes
Horizontal force	...	4·27 gammas
Vertical force	...	8·28 to 13·80 gammas.

The mean temperature of the year in the observatory was 26°·7 C with maxima and minima of 27°·3 and 25°·6.

The moment of inertia of magnets Nos. 17 and 5 B was determined in May and June 1934, and log $\pi^2 K$ was found to be 3·41436 and 3·37737 respectively. The values which have been accepted for 1933 are 3·41441 and 3·37741 for the two magnets.

The observed values of the factor log $(1 + P/r^2 + Q/r^4)^{-1}$ for magnets Nos. 17 and 5 B have been $\bar{1}$·99393 and $\bar{1}$·99335 in 1933, and the accepted values for this factor are $\bar{1}$·99415 and $\bar{1}$·99340.

For the last two or three years the observed factor of No. 5 B has been larger than the value $\bar{1}$·99292 which has been accepted since 1924, viz:—$\bar{1}$·99313 in 1931, $\bar{1}$·99346 in 1932 and $\bar{1}$·99335 in 1933. It appears that a real change has occurred, and that $\bar{1}$·99340 should probably have been accepted in 1932. The systematic difference in H as determined by magnetometers No. 17 and No. 5, which was about 15γ between 1924 and 1930*, has also increased to about 30 γ since 1931.

Table 6 shows the monthly values of the magnetic collimation, distribution factors and magnetic moment of No. 17, and Table 7 gives similar information for No. 5. Table 8 gives the mean monthly values of the declination and H.F. base-lines. The values given by No. 17 only have been accepted.

Table 9 gives the mean monthly values of the elements for 1932 and 1933, and the annual changes for the period. Tables 10 to 13 give the mean hourly deviations from the monthly means, and Table 14 gives the classification of the magnetic character of all days of 1933.

* Geodetic Report Vol. VII, page 140, Table 16.

TABLE 1.—*Lengths of 24-metre wires.*

Date	Wire	Temperature	Wire *minus* Base. Observed	Length of wire at 28°C
7-11-33	243	21·0°C	−1·036mm	24m −0·158mm
	244	21·0	−3·166	−2·285
	247	21·0	+0·807	+1·641
	248	20·9	+0·896	+1·712
	249	20·8	+3·266	+4·066
	252	20·5	+2·285	+3·067
8-11-33	243	21·0	−1·058	−0·180
	244	21·0	−3·194	−2·313
	247	21·0	+0·801	+1·635
	248	20·9	+0·909	+1·725
	249	20·8	+3·253	+4·053
	252	20·5	+2·283	+3·065
9-1-34	243	14·0	−0·873	−0·105
	244	14·1	−3·135	−2·358
	247	14·0	+0·956	+1·635
	248	13·8	+1·090	+1·735
	249	13·5	+3·440	+4·051
	252	13·4	+2·474	+3·072
10-1-34	243	14·2	−0·904	−0·130
	244	14·1	−3·131	−2·354
	247	14·1	+0·936	+1·619
	248	14·0	+1·086	+1·739
	249	14·0	+3·426	+4·056
	252	14·0	+2·443	+3·065
15-2-34	243	18·6	−1·023	−0·159
	244	18·9	−3·286	−2·409
	247	18·8	+0·797	+1·610
	248	18·8	+0·929	+1·724
	249	18·8	+3·205	+3·986
	252	18·5	+2·287	+3·048
16-2-34	243	19·0	−1·035	−0·158
	244	19·0	−3·293	−2·413
	247	19·0	+0·775	+1·595
	248	18·8	+0·928	+1·723
	249	18·9	+3·210	+3·994
	252	19·0	+2·294	+3·077
19-3-34	243	19·9	−1·112	−0·152
	244	20·0	−3·367	−2·400
	247	19·9	+0·671	+1·580
	248	20·0	+0·844	+1·743
	249	20·0	+3·140	+4·026
	252	19·7	+2·207	+3·073
	1037	20·0	−0·124	+0·797
	1038	20·0	−0·149	+0·782
20-3-34	243	20·1	−1·119	−0·152
	244	20·6	−3·355	−2·368
	247	20·4	+0·654	+1·583
	248	20·5	+0·817	+1·737
	249	20·6	+3·106	+4·017
	252	20·0	+2·203	+3·084
	1037	20·3	−0·139	+0·793
	1038	20·2	−0·159	+0·777

TABLE 2.—*Variation of Longitude of Dehra Dūn from accepted value, as determined by reception of wireless signals from Bordeaux and Rugby, 1933–34.*

Date (Greenwich)	Instrument used	Observer	No. of time stars		Observed value *minus* accepted* value			
					With demi-definitive corrections		With definitive corrections	
			North	South	Bordeaux	Rugby	Bordeaux	Rugby
1933					s	s	s	s
Dec. 5	Motor	H.C.B.	6	5	+0·13	+0·14	+0·14	+0·12
13	Motor	B.L.G.	3	4	+0·08	+0·16	+0·08	+0·13
18	Shutter	B.L.G.	4	3	...	+0·14	...	+0·09
26	Motor	B.L.G.	3	4	...	+0·18	...	+0·11
1934								
Jan. 16	Shutter	B.L.G.	3	4	...	+0·06	...	+0·05
23	Motor	B.L.G.	3	3	...	−0·04	...	−0·02
27	Shutter	H.C.B.	3	5	...	+0·02	...	+0·03
Feb. 1	Motor	B.L.G.	3	4	...	+0·05	...	+0·05
2	Shutter	H.C.B.	3	5	...	+0·01	...	+0·01
6	Motor	B.L.G.	4	4	...	+0·03	...	+0·03
9	Shutter	H.C.B.	4	4	...	+0·05	...	+0·06
17	Shutter	H.C.B.	4	4	...	+0·03	...	+0·03
19	Motor	B.L.G.	4	4	...	+0·11	...	+0·10
27	Shutter	H.C.B.	4	4	...	+0·04	...	+0·03
Mar. 4	Motor	B.L.G.	3	4	...	−0·14	...	−0·16
9	Shutter	H.C.B.	1	3	...	+0·07	...	+0·07
10	Motor	H.C.B.	3	3	...	+0·06	...	+0·07
13	Motor	B.L.G.	4	4	...	−0·01	...	0·00
15	Shutter	H.C.B.	3	5	...	0·00	...	+0·01
23	Motor	H.C.B.	3	3	...	+0·17	...	+0·15
27	Shutter	H.C.B.	4	5	...	+0·05	...	+0·04
April 5	Motor	H.C.B.	5	4	...	+0·22	...	+0·23
6	Shutter	H.C.B.	4	3	...	+0·12	...	+0·11
11	Motor	B.L.G.	2	2	...	+0·15	...	+0·16
14	Shutter	H.C.B.	3	1	...	+0·12	...	+0·12
15	Motor	H.C.B.	4	4	...	+0·15	...	+0·16
17	Motor	B.L.G.	2	2	...	+0·09	...	+0·09
19	Motor	H.C.B.	4	4	...	+0·09	...	+0·10
27	Motor	B.L.G.	4	3	...	+0·10	...	+0·08
28	Shutter	H.C.B.	4	4	...	+0·07	...	+0·05
May 3	Motor	H.C.B.	4	3	...	+0·12	...	+0·12
7	Shutter	H.C.B.	4	3	+0·04	+0·06	+0·06	+0·08
10	Shutter	H.C.B.	4	3	...	+0·04	...	+0·06
11	Motor	B.L.G.	4	3	...	+0·13	...	+0·17
15	Shutter	H.C.B.	4	4	...	+0·04	...	+0·05
19	Motor	H.C.B.	4	4	...	+0·04	...	+0·05
23	Shutter	H.C.B.	4	4	...	+0·09	...	+0·08

* 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 and Rugby, 1933–34*—(*concld.*)

Date (Greenwich)		Instrument used	Observer	No. of time stars		Observed value *minus* accepted value			
						With demi-definitive corrections		With definitive corrections	
				North	South	Bordeaux	Rugby	Bordeaux	Rugby
1934						s	s	s	s
June	6	Motor	J.B.M.	4	4	...	+0·10	...	+0·08
	8	Shutter	J.B.M.	4	4	−0·03	...	+0·02	...
	11	Motor	J.B.M.	3	5	0·00	...	+0·05	...
	14	Shutter	J.B.M.	2	2	+0·03	...	+0·06	...
	18	Motor	J.B.M.	4	4	...	+0·08	...	+0·06
	28	Shutter	J.B.M.	3	3	...	+0·07	...	+0·07
July	3	Motor	J.B.M.	3	4	...	+0·06	...	...
	4	Shutter	J.B.M.	2	2	...	0·00	...	...
	11	Motor	J.B.M.	5	4	...	0·00	...	...
	19	Motor	J.B.M.	3	3	...	+0·02	...	...
	26	Motor	J.B.M.	4	3	...	+0·11	...	...
Aug.	3	Motor	J.B.M.	2	4	...	−0·01	...	...
	6	Motor	J.B.M.	3	3	...	+0·09	...	...
	13	Motor	J.B.M.	2	2	...	+0·08	...	...
	15	Motor	J.B.M.	3	3	...	+0·03	...	...
Sept.	2	Motor	J.B.M.	2	2	...	−0·01	...	...
	5	Motor	J.B.M.	4	4	...	+0·05	...	...
	9	Motor	J.B.M.	3	3	...	−0·03	...	...
	11	Shutter	R.B.M.	3	3	−0·01	−0·04	...	...
	14	Motor	R.B.M.	4	4	...	+0·11	...	...
	21	Shutter	R.B.M.	4	4	...	−0·06	...	...
	25	Motor	R.B.M.	4	4	...	+0·07	...	...
	28	Shutter	R.B.M.	3	4	...	−0·02	...	...

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 signals, and by the demi-definitive corrections of the Bulletin Horaire in the case of Bordeaux signals. In addition, values up to June 1934 are given with definitive corrections of the Bulletin Horaire.

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 Française à la Révision des Longitudes Mondiales, Lambert, p. 103). This $0^s{\cdot}02$ has not been applied to values derived with definitive corrections.

The speed of propagation has been taken to be 300,000 km. per second.

TABLE 3.—*Error, rate, pressure and temperature of Shortt clock No. 34, by Rugby time signals during 1933–34.*

Date		Error at 15.30 hrs. I.S.T.		During preceding period				REMARKS
				Rate * per day	Pres-sure	Oil gauge	Tem-pera-ture	
1933		*m*	*s*	*s*	*mm of mercury*	*mm*	*C*	
Oct.	2	+0	20·92	+0·02	29·1	35·9	26°·1	
	3		20·99	+0·07	29·1	35·8	26·0	
	4		20·96	−0·03	29·1	35·7	25·9	
	5		21·02	+0·06	29·1	35·7	25·8	
	6		20·98	−0·04	29·1	35·6	25·8	
	7		21·03	+0·05	29·1	35·4	25·7	
	9		21·10	+0·03	29·1	35·4	25·7	
	10		21·14	+0·04	29·1	35·3	25·8	
	11		21·16	+0·02	29·1	35·3	25·8	
	12		21·16	0·00	29·1	35·3	25·7	
	13		21·20	+0·04	29·1	35·3	25·6	
	14		21·23	+0·03	29·1	35·2	25·4	
	16		21·31	+0·04	29·1	34·7	25·2	
	17		21·35	+0·04	29·1	34·2	25·0	
	22		21·50	+0·03	29·0	33·9	24·8	
	23		21·55	+0·05	29·1	33·9	26·1	
	24		21·57	+0·02	29·1	34·2	26·4	
	25		21·60	+0·03	29·1	34·4	26·4	
	26		21·62	+0·02	29·1	34·7	26·4	
	28		21·67	+0·02	29·1	35·9	26·9	
	29		21·69	+0·02	29·1	35·6	26·6	
	30		21·72	+0·03	29·1	35·3	26·8	
	31		21·76	+0·04	29·1	35·2	26·3	
Nov.	1		21·77	+0·01	29·1	35·3	26·7	
	2		21·81	+0·04	29·1	34·3	26·3	
	3		21·85	+0·04	29·2	37·0	27·7	
	4		21·87	+0·02	29·1	34·4	26·4	
	6		21·98	+0·05	29·1	36·7	27·4	
	7		22·00	+0·02	29·1	36·0	26·7	
	8		22·04	+0·04	29·1	36·4	26·9	
	9		22·06	+0·02	29·1	36·4	26·8	
	10		22·09	+0·03	29·1	35·4	26·2	
	11		22·13	+0·04	29·1	33·4	25·4	
	13		22·18	+0·03	29·1	34·2	25·8	
	14		22·20	+0·02	29·1	34·8	25·0	
	15		22·24	+0·04	29·1	34·6	27·0	
	16		22·26	+0·02	29·1	34·6	26·8	
	17		22·25	−0·01	29·1	35·4	26·7	
	18	+0	22·33	+0·08	29·1	35·4	26·7	

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

TABLE 3.—*Error, rate, pressure and temperature of Shortt clock No. 34, by Rugby time signals during 1933–34*—(*contd.*)

Date		Error at 15.30 hrs. I.S.T.		During preceding period				Remarks
				Rate * per day	Pressure	Oil gauge	Temperature	
1933		*m*	*s*	*s*	*mm of mercury*	*mm*	*C*	
Nov.	20	+0	22·38	+0·03	29·1	35·4	26°·7	
	21		22·43	+0·05	29·1	35·4	26·7	
	22		22·44	+0·01	29·1	35·4	26·7	
	23		22·44	0·00	29·1	35·4	26·7	
	24		22·50	+0·06	29·1	35·4	26·7	
	25		22·52	+0·02	29·1	35·4	26·6	
Dec.	5		22·80	+0·03	29·1	35·4	26·7	
	13		23·06	+0·03	29·1	35·3	26·7	
	18		23·18	+0·03	29·1	35·1	26·6	
	26		23·43	+0·03	29·1	34·8	26·6	
1934								
Jan.	16		22·28	...	29·1	34·7	26·7	Disturbed by Bihār earthquake.
	23		22·73	+0·06	29·1	34·5	26·8	
	27		22·98	+0·06	29·1	34·4	26·7	
Feb.	1		23·35	+0·07	29·1	34·4	26·7	
	2		23·33	−0·02	29·1	34·4	26·7	
	6		23·55	+0·06	29·1	34·0	26·4	
	9		23·70	+0·05	29·1	34·0	26·7	
	16		23·96	+0·04	29·1	33·7	26·6	
	19		18·18	...	29·1	33·5	26·5	Out of order on 17th February 1934.
	27		18·36	+0·02	29·1	33·6	26·5	
Mar.	4		18·51	+0·03	29·1	33·5	26·6	
	9		18·61	+0·02	29·1	33·5	26·4	
	10		18·65	+0·04	29·1	33·7	26·8	
	13		18·73	+0·03	29·1	33·6	26·6	
	15		18·82	+0·04	29·1	33·6	26·7	
	23		19·10	+0·03	29·1	33·6	26·8	
	27		19·30	+0·05	29·1	33·6	26·9	
Apr.	5		19·30	0·00	29·1	33·2	26·5	
	6		19·32	+0·02	29·1	33·4	26·8	
	11		19·30	0·00	29·1	33·4	26·8	
	14		19·30	0·00	29·1	33·4	26·7	
	15		19·33	+0·03	29·1	32·5	25·9	
	17		19·34	+0·01	29·1	33·2	26·8	
	19		19·35	0·00	29·1	33·2	26·8	
	27		29·81	...	29·1	33·2	26·7	Out of order on 23rd April 1934.
	28		29·81	+0·01	29·1	33·2	26·5	
May	3		29·83	0·00	29·1	33·2	26·7	
	7		29·84	0·00	29·1	33·1	26·7	
	10		29·90	+ 0·02	29·1	32·9	26·6	
	11		29·88	− 0·01	29·1	32·9	26·7	
	15		29·91	+ 0·01	29·1	32·9	26·8	
	19		29·80	− 0·03	29·1	32·9	26·7	
	23	+0	29·92	+ 0·03	29·2	33·0	27·5	

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

(*Continued*)

TABLE 3.—*Error, rate, pressure and temperature of Shortt clock No. 34, by Rugby wireless time signals during 1933–34.—(concld.)*

Date		Error at 15.30 hrs. I.S.T.	During preceding period				REMARKS
			Rate * per day	Pressure	Oil gauge	Temperature	
1934		m s	s	mm of mercury	mm	°C	
June	6	−0 15·92	...	29·2	34·8	28·3	Out of order on 26th May 1934.
	18	16·21	− 0·02	29·5	37·5	30·4	
	28	16·30	− 0·01	29·5	34·2	27·8	
July	3	16·26	+ 0·01	29·4	33·0	27·0	
	4	16·28	− 0·02	29·4	33·0	27·2	
	11	16·30	0·00	29·4	33·2	27·7	
	19	00·93	...	29·5	43·0	29·2	Out of order on 16th July 1934.
	26	00·90	0·00	29·5	44·5	28·5	
Aug.	3	00·88	0·00	30·0	44·5	27·3	
	6	00·87	0·00	30·0	45·2	27·4	
	13	00·84	+ 0·01	30·0	45·5	27·2	
	15	00·81	+ 0·02	30·0	45·6	27·2	
Sept.	2	00·63	+ 0·01	30·0	46·0	26·8	
	5	00·60	+ 0·01	30·0	46·1	26·8	
	9	00·55	+ 0·01	30·0	46·2	26·8	
	11	00·44	+ 0·06	30·0	46·3	26·8	
	14	00·45	0·00	30·0	46·3	27·0	
	21	00·54	− 0·01	30·0	46·8	27·2	
	25	00·55	0·00	30·0	47·3	27·5	
	28	−0 00·52	+ 0·01	30·0	47·6	27·5	

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

NOTE:—The error is that derived from wireless time signals. The corrections f the Admiralty Notices have been applied to the times of emission of the signals.

TABLE 4.—*Lengths of invar levelling staves.*

Staff / Mark	Actual distance from zero mark in feet					
	No. 1	No. 2	No. 3	No. 4	No. 121	No. 122
0·4	0·40016	0·39948	0·40023	0·40011	0·40063	0·40045
0·8	0·80047	0·79944	0·80041	0·80047	0·80097	0·80083
1·2	1·20079	1·19909	1·20075	1·20083	1·20118	1·20107
1·6	1·60091	1·59934	1·60093	1·60089	1·60115	1·60119
2·0	2·00076	1·99913	2·00072	2·00061	2·00117	2·00108
4·0	4·00060	3·99894	4·00045	4·00038	4·00061	4·00056
6·0	6·00040	5·99925	6·00085	6·00071	6·00062	6·00027
8·0	8·00016	7·99918	8·00072	8·00070	8·00017	8·00013
10·0	10·00034	9·99914	10·00047	10·00079	10·00001	9·99979

TABLE 5.—*Earthquakes recorded at Dehra Dūn during 1933–34.*

No.	Date	Indian standard time: 1st P. T.	2nd P. T.	Long wave	Maximum	Finish	Intensity of record	Distance	Remarks
	1933	*h m s*	*h m s*	*h m s*	*h m*	*h m*		*miles*	
1	Oct. 2	21 19 10	21 33 30†	...	22 41	23 22	slight	11000	Felt at Los Angeles.
2	„ 5	19 04 00	19 07 00	19 11 30	19 12	19 54	slight	1400	
3	Nov. 21	5 03 10	5 12 50	5 26 10	5 38	8 20	moderate	5500	
4	„ 28	16 47 20	16 48 50	16 50 00	16 51	17 44	great	600	
5	Dec. 15	0 26 20	0 30 00	0 33 10	0 35	1 03	slight	1400	
	1934								
6	Jan. 3	2 29 50	2 33 10	2 35 40	2 36	3 01	slight	1200	
7	„ 15	14 15 10	...	...	14 19	18 05	very great	...	North Bihār.
8	„ 20	0 24 20†	...	...	0 26	0 50	slight	...	North Bihār.
9	„ 20	23 38 10	...	23 43 10†	23 44	0 13	slight	1100	
10	„ 21	12 46 00†	...	...	12 49	13 23	slight	...	
11	„ 22	1 22 50†	...	...	1 25	1 30	slight	...	Felt at Muzaffarpur.
12	„ 23	...	...	2 56 20	2 57	3 09	slight	...	
13	„ 25	18 09 30†	...	18 09 50	18 10	18 10	slight	100	Local.
14	„ 29	0 59 10†	...	1 02 40	1 03	1 19	slight	800	
15	„ 29	1 59 30	2 00 50	2 02 10	2 04	2 44	slight	500	
16	Feb. 4	19 02 20	19 06 20	19 10 50	19 13	19 55	slight	1700	
17	„ 12	17 10 20†	...	17 14 10	17 16	17 29	slight	800	Felt at Sitāmarhi and Darbhanga, Bihār.
18	„ 14	...	...	...	...	11 31	great	...	Missed while changing paper
19	„ 19	16 02 30	16 08 40	16 18 50†	16 24	16 57	slight	3300	
20	„ 22	13 48 10	...	13 52 50†	14 01	14 11	slight	1000	
21	„ 24	12 03 10	12 11 40	...	...	...	moderate	4500	Clock stopped.
22	„ 28	20 04 10	20 13 40	20 24 40†	20 49	21 32	slight	5100	
23	Mar. 2	3 35 30	3 39 40	3 45 10†	3 59	4 57	slight	1900	
24	„ 5	17 42 20†	...	18 13 10	18 22	19 58	moderate	7700	Southern part of North Island, New Zealand
25	„ 12	0 47 00	...	...	0 50	1 02	slight	...	
26	„ 24	17 58 10	18 11 20	18 24 20†	18 50	19 41	slight	7500	
27	Apr. 10	16 02 00	16 07 40	16 13 40†	16 26	17 12	slight	2600	
28	„ 12	14 48 30	...	14 51 20	14 52	15 11	slight	700	
29	„ 14	7 02 10/50†	...	...	7 03	7 11	slight	...	Felt at Sāmbhar Lake and Delhi.
30	„ 16	3 54 10	4 01 40	4 09 20	4 18	6 35	moderate	3600	
31	May 1	9 12 40†	9 14 00	9 15 00	9 17	9 38†	slight	500	Felt at Ratoder[illegible] Sind.
32	„ 1	12 43 00†	12 46 50	12 51 50	12 56	13 18†	slight	1700	
33	„ 4	10 18 00	10 28 10	10 49 20	10 56	11 49	moderate	6700	
34	„ 13	14 43 50	...	14 53 40	14 54	15 32	slight	2300	

† Recognized with difficulty.

(Continued)

TABLE 5.—*Earthquakes recorded at Dehra Dūn during 1933–34—(concld.)*

No.	Date	Indian standard time: 1st P. T.	2nd P. T.	Long wave	Maximum	Finish	Intensity of record	Distance	Remarks
	1934	*h m s*	*h m s*	*h m s*	*h m*	*h m*		*miles*	
35	June 2	11 30 40	...	...	11 31	11 53	slight	...	Local.
36	" 2	19 32 00†	...	...	19 51	20 14	slight	...	
37	" 4	11 29 30	...	...	11 30	11 34	slight	...	Local. Felt at Nawabshah, Punjab.
38	" 5	17 00 30	...	...	17 01	17 02	slight	...	Local. Felt at Simla.
39	" 14	3 43 30	3 45 50	3 48 00	3 49	5 09†	great	900	Felt at Dera Ismail Khān. Epicentre in South Afghānistān.
40	" 18	15 29 40†	...	...	15 33	15 40	slight	...	
41	" 22	2 09 20†	...	...	2 15	5 01	slight	...	
42	" 23	7 27 30†	...	...	7 49	...	slight	...	
43	" 24	11 49 40†	...	12 03 10†	12 59	13 57	slight	3200	
44	" 25	21 35 20	...	...	21 36	21 38	slight	...	Local.
45	" 29	14 04 00†	14 11 10†	...	14 04	14 56	slight	3500	
46	July 3	14 24 00	14 24 10†	...	14 24	14 26	slight	...	Local. Felt at Dehra Dūn and Kedārnāth.
47	" 7	4 44 10†	4 55 00	5 10 00	5 26	6 48	slight	6200	
48	" 18	7 23 00	...	8 06 40	8 19	11 43	moderate	11600	Near Panama.
49	" 18	22 13 40	...	...	22 16	22 28	slight	...	
50	" 18	22 52 00	...	...	23 50	1 07	slight	...	
51	" 19	1 23 10	1 34 40	1 45 10	2 06	...	great	6000	Vanikoro (Pacific).
52	" 19	7 07 30	7 16 00	7 22 50	7 23	8 57	slight	4000	
53	" 19	13 31 10	...	...	14 18	15 25	slight	...	
54	" 21	...	12 13 10	12 19 20†	12 27	15 57	slight	...	
55	" 21	16 31 20	...	...	17 33	18 44	slight	...	
56	" 23	1 28 30	1 29 30	1 30 10	1 30	1 40	slight	100	Local. Felt at Rāwalpindi, Simla & Delhi.
57	" 28	7 39 10	7 41 10	7 42 40	7 43	8 00	slight	700	
58	" 29	3 16 00†	3 28 50	3 49 10	3 59	7 23†	moderate	8200	
59	Aug. 7	17 23 50	17 27 00	17 30 00	17 31	17 49	slight	1300	
60	" 11	14 02 40	...	14 10 30	14 11	14 48	slight	1800	
61	" 13	5 28 10	5 35 00	5 39 40	5 51	6 44†	slight	3000	
62	" 22	1 09 20	1 12 20	1 17 20	1 19	2 00	slight	1700	
63	" 31	20 30 00	20 32 10	20 33 10	20 34	21 29	moderate	700	

† Recognized with difficulty.

TABLE 6.—*Mean values of the constants of Magnetometer No. 17 in 1933.*

Month	Declination constants: Mean magnetic collimation	H. F. constants: Distribution factors $P_{1\cdot2}$	$P_{2\cdot3}$	$\log(1+P/r^2+Q/r^4)-1$	Mean values of m
	′ ″	cm^2	cm^2		C.G.S.
January ...	− 6 09	6·34	6·89	Observed $\bar{1}$·99393 Accepted $\bar{1}$·99415	801·43
February ...	− 6 06	5·87	7·34		·55
March ...	− 6 04	5·98	7·48		·51
April ...	− 6 05	6·64	7·32		·50
May ...	− 6 04	6·55	7·30		·52
June ...	− 6 04	6·04	7·34		·48
July ...	− 6 02	6·07	7·82		·47
August ...	− 6 06	6·23	6·93		·52
September	− 6 08	5·75	6·76		·45
October ...	− 6 02	5·87	6·79		·35
November	− 6 07	6·04	7·76		·47
December	− 5 54	5·91	7·11		801·41

TABLE 7.—*Mean values of the constants of Magnetometer No. 5 in 1933.*

Month	H. F. constants: Distribution factors $P_{1\cdot2}$	$P_{2\cdot3}$	$\log(1+P/r^2+Q/r^4)-1$	Mean values of m
	cm^2	cm^2		C G.S.
January ...	7·66	8·21	Observed $\bar{1}$·99335 Accepted $\bar{1}$·99340	938·27
February ...	7·10	7·47		·15
March ...	7·09	7·66		938·05
April ...	7·19	7·47		937·93
May ...	7·15	7·83		·89
June ...	6·97	7·44		·75
July ...	7·03	8·21		·46
August ...	7·17	8·20		·81
September	6·72	6·64		·29
October ...	7·21	7·46		·86
November	7·24	8·34		·46
December	7·24	8·12		937·14

TABLE 8.—*Base-line values of Magnetographs at Dehra Dūn from Magnets No. 17 and No. 5.*

Month	1932		1933		
	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	0·32 774	0·32 824	0 31·3	0·32 769	0·32 801
February	771	818	31·1	774	799
March	773	819	31·3	774	801
April	779	822	31·5	772	798
May	787	822	31·5	770	797
June	787	825	31·7	770	799
July	783	828	31·5	763	784
August	781	825	31·7	769	804
September	779	831	32·0	770	814
October	783	828	31·9	769	804
November	775	828	31·7	765	779
December	0·32 778	0·32 832	0 30·7	0·32 758	0·32 761

NOTE:—The values given by No. 17 have been accepted.

TABLE 9.—*Monthly mean values of the Magnetic elements and their annual changes, Magnetometer No. 17, Dehra Dūn, 1932 and 1933.*

Month	Horizontal force			Declination			Dip			Vertical force		
	1932	1933	Annual change	1932	1933	Annual change	1932	1933	Annual change	1932	1933	Annual change
	C.G.S.	C.G.S.	γ							C.G.S.	C.G.S.	γ
January	0·33019	0·33039	+20	E. 1° 6′·7	E. 1° 4′·2	−2′·5	N. 45° 36′·6	N. 45° 37′·8	+1′·2	0·33729	0·33774	+45
February ...	14	51	+37	6·6	3·9	−2·7	36·4	37·7	+1·3	20	785	+65
March	19	58	+39	6·6	3·7	−2·9	36·6	37·2	+0·6	29	781	+52
April	19	52	+33	6·3	3·6	−2·7	37·1	37·1	0·0	39	772	+33
May	32	56	+24	6·0	3·1	−2·9	37·1	38·1	+1·0	53	795	+42
June	42	56	+14	5·5	3·0	−2·5	37·1	36·9	−0·2	63	774	+11
July	44	58	+14	4·8	2·6	−2·2	37·7	38·9	+1·2	77	814	+37
August	37	53	+16	4·9	2·5	−2·4	37·1	38·0	+0·9	58	792	+34
September ...	27	58	+31	4·2	2·2	−2·0	37·6	39·5	+1·9	58	826	+68
October	43	61	+18	4·5	2·1	−2·4	37·9	39·6	+1·7	80	833	+53
November ...	38	66	+28	4·3	1·9	−2·4	38·0	38·7	+0·7	77	819	+42
December ...	0·33046	0·33064	+18	E. 1 4·3	E. 1 1·0	−3·3	N. 45 37·8	N. 45 38·5	+0·7	0·33781	0·33813	+32
Mean ...	0·33032	0·33056	+24	E. 1° 5′·4	E. 1° 2′·8	−2′·6	N. 45° 37′·3	N. 45° 38′·2	+0′·9	0·33755	0·33798	+43

γ = 0·00001 C.G.S.

TABLE 10.—*Declination at Dehra Dūn in 1933* (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 ...	4·2	+0·3	+0·2	+0·1	0·0	0·0	−0·2	−0·3	**−0·6**	−0·1	+0·6	**+1·0**	+0·1	−0·6	−0·6	−0·4	0·0	+0·2	+0·2	0·0	+0·1	+0·1	+0·3	+0·1	+0·1	+0·1
February ...	3·9	+0·2	+0·2	+0·1	−0·2	−0·2	−0·3	−0·2	+0·1	+0·7	**+1·5**	+1·1	+0·2	−0·9	**−1·2**	−0·7	−0·3	0·0	0·0	−0·4	−0·2	−0·2	0·0	0·0	+0·1	0·0
March ...	3·7	0·0	+0·1	+0·2	+0·1	−0·1	−0·4	−0·1	+0·1	+0·4	**+2·2**	+2·1	+1·1	−0·5	−1·4	**−1·8**	−1·3	−0·6	0·0	−0·1	−0·3	−0·3	−0·2	−0·3	−0·1	−0·1
October ...	2·1	0·0	−0·1	+0·1	+0·1	−0·1	−0·2	0·0	+0·6	+1·2	**+1·5**	+1·1	+0·3	−0·9	**−1·5**	−0·9	0·0	+0·3	+0·1	−0·3	−0·3	−0·3	0·0	+0·1	+0·2	+0·2
November ...	1·9	+0·1	+0·4	+0·2	0·0	0·0	−0·5	−0·3	−0·3	0·0	+0·3	0·0	−0·7	**−0·9**	−0·7	0·0	+0·5	**+0·7**	+0·3	+0·2	+0·2	0·0	0·0	+0·3	+0·3	+0·4
December ...	1·0	+0·2	0·0	+0·2	+0·1	−0·2	−0·3	−0·4	−0·5	−0·1	+0·6	**+1·3**	−0·5	**−1·0**	−0·8	−0·2	0·0	+0·4	+0·4	+0·2	+0·2	+0·3	−0·1	0·0	0·0	0·0
Winter Means ...	2·8	+0·1	+0·1	+0·2	0·0	−0·1	−0·3	−0·2	−0·1	+0·4	**+1·1**	+1·1	+0·1	−0·8	**−1·0**	−0·7	−0·2	+0·2	+0·2	−0·1	−0·1	−0·1	0·0	0·0	+0·1	+0·1
April ...	3·6	+0·4	+0·3	+0·4	+0·3	+0·2	0·0	+0·7	+1·4	+2·5	**+2·7**	+1·7	−0·3	−1·9	**−2·9**	−2·6	−1·8	−0·8	−0·2	0·0	−0·2	−0·2	+0·1	+0·3	+0·3	+0·3
May ...	3·1	+0·4	+0·4	+0·5	+0·4	+0·3	+0·6	+1·8	+2·8	**+3·2**	+2·6	+0·6	−2·0	−3·3	**−3·8**	−2·1	−2·1	−1·0	−0·2	+0·3	−0·2	−0·2	−0·1	0·0	+0·1	+0·4
June ...	3·0	+0·3	+0·4	+0·7	+0·6	+0·5	+0·7	+2·0	**+3·0**	+2·8	+2·1	+0·8	−0·9	−2·1	−2·5	**−2·7**	−2·2	−1·4	−0·5	−0·1	−0·5	−0·3	−0·2	0·0	+0·1	+0·3
July ...	2·6	0·0	+0·3	+0·4	+0·5	+0·5	+0·9	+2·2	+3·3	**+3·4**	+2·8	+1·2	−1·1	−2·2	**−3·1**	−2·9	−2·3	−1·2	−0·4	−0·1	−0·3	−0·5	−0·2	−0·2	0·0	+0·2
August ...	2·5	+0·2	+0·3	+0·5	+0·5	+0·6	+0·7	+1·8	+3·0	**+3·2**	+2·2	+0·5	−1·5	−2·6	**−3·1**	−2·5	−1·9	−1·0	−0·2	+0·1	−0·1	−0·2	−0·2	−0·1	0·0	+0·2
September ...	2·2	+0·3	+0·4	+0·4	+0·4	+0·1	+0·2	+0·8	+1·8	**+2·6**	+1·8	+0·1	−1·4	−2·6	**−2·7**	−2·4	−1·5	−0·2	+0·4	**+0·2**	0·0	0·0	+0·1	+0·1	+0·2	+0·3
Summer Means ...	2·8	+0·3	+0·4	+0·5	+0·5	+0·4	+0·5	+1·6	+2·6	**+3·0**	+2·4	+0·8	−1·2	−2·5	**−3·0**	−2·5	−2·0	−0·9	−0·2	+0·1	−0·2	−0·2	−0·1	0·0	+0·1	+0·3

* 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 11.—*Horizontal force at Dehra Dūn in 1933* (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	γ
January ...	33039	− 7	**− 8**	− 6	− 4	− 4	− 5	− 2	− 1	+ 3	+ 2	+ 1	+ 5	**+ 9**	+ 8	+ 5	+ 4	+ 4	+ 1	− 4	− 6	− 5	− 6	− 3	+ 7	− 3
February ...	51	**− 8**	− 8	− 6	− 5	− 3	− 3	− 1	− 1	− 1	− 1	− 2	0	+ 4	**+ 9**	+ 6	+ 7	+ 7	+ 5	+ 3	+ 1	0	+ 3	+ 1	0	− 1
March ...	58	− 5	− 4	**− 6**	− 6	− 5	− 5	− 2	− 1	− 1	+ 1	+ 7	**+16**	+15	+14	+13	+ 5	− 3	− 3	− 6	− 2	− 4	− 4	− 3	− 3	+ 1
October ...	61	+ 3	+ 2	+ 1	+ 1	− 3	− 3	− 1	− 4	− 7	**− 9**	− 4	+ 3	+10	**+12**	+ 9	+ 6	+ 3	− 1	− 1	0	− 2	− 4	− 3	− 2	− 3
November ...	66	− 4	**− 8**	− 5	− 2	− 5	− 2	− 3	0	+ 5	+12	**+15**	+13	+ 8	+ 8	+ 4	+ 1	0	− 3	− 3	− 3	− 3	− 5	− 8	− 4	− 2
December ...	64	− 7	0	− 5	− 6	− 4	− 3	− 2	− 2	+ 2	**− 9**	− 3	+ 2	+ 4	+ 5	+ 4	+ 4	**+ 7**	+ 1	0	− 2	− 1	+ 1	+ 1	+ 2	0
Winter Means ...	33058	**− 5**	− 4	− 5	− 4	− 4	− 4	− 2	− 2	0	− 1	+ 2	+ 7	+ 8	**+ 9**	+ 7	+ 5	+ 3	0	− 2	− 2	− 3	− 3	− 3	0	− 1
April ...	33052	− 6	− 2	− 3	− 5	− 5	0	− 6	− 8	− 8	**−10**	− 4	+ 3	+12	**+15**	+13	+11	+ 8	+ 2	− 3	− 3	− 6	− 2	0	− 2	− 2
May ...	56	− 8	− 6	− 5	− 3	− 3	− 3	− 4	− 8	**−11**	− 8	− 1	+10	+11	**+13**	+10	+ 7	+ 2	− 2	− 3	− 2	− 2	− 1	+ 1	+ 4	+ 2
June ...	56	+ 2	+ 3	0	**− 9**	0	+ 1	+ 3	0	− 1	− 4	− 4	− 1	+ 6	+10	**+11**	+ 7	+ 3	− 3	− 5	− 2	− 1	0	+ 2	+ 3	+ 2
July ...	58	+ 1	+ 1	+ 1	0	0	+ 1	0	− 3	**− 6**	− 6	− 6	0	+ 5	+ 8	**+11**	+ 7	+ 1	− 3	− 2	− 3	− 2	− 1	0	0	0
August ...	53	− 2	+ 3	− 1	− 1	− 1	− 1	+ 1	− 6	**− 7**	− 6	− 3	+ 3	+ 3	+ 2	+ 3	+ 3	+ 3	0	+ 1	0	0	0	+ 3	+ 3	**+ 4**
September ...	58	+ 2	+ 4	+ 4	+ 3	+ 6	+ 3	+ 4	− 2	−10	−16	**−18**	− 8	0	+ 3	**+10**	+ 9	+ 4	− 2	0	− 2	+ 1	− 3	− 2	+ 2	+ 3
Summer Means ...	33056	− 2	+ 1	− 1	− 3	− 1	0	0	− 5	− 7	**− 8**	− 6	+ 1	+ 6	+ 9	**+10**	+ 7	+ 4	− 1	− 2	− 2	− 2	− 1	+ 1	+ 2	+ 2

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.

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.
		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	...	33774	**+ 3**	+ 2	+ 2	+ 1	+ 2	+ 1	0	0	+ 1	+ 2	− 2	**− 7**	− 4	− 3	− 1	0	+ 2	+ 1	− 1	− 1	− 1	0	0	0	− 1
February	...	785	0	0	0	0	0	0	0	+ 1	**+ 2**	0	− 3	− 5	**− 7**	− 4	− 1	0	+ 2	+ 1	+ 1	0	+ 1	− 1	+ 1	+ 1	+ 1
March	...	781	− 1	− 1	− 1	+ 1	− 1	− 1	− 1	+ 2	+ 3	+ 3	0	− 4	**− 9**	− 7	− 3	0	+ 1	+ 3	0	+ 1	+ 2	+ 2	+ 3	+ 3	**+ 4**
October	...	833	**− 6**	− 6	− 6	− 5	− 6	− 6	− 5	− 3	− 3	− 4	− 6	− 3	− 4	0	+ 4	**+ 7**	+ 6	+ 3	+ 3	+ 4	+ 4	+ 4	+ 6	+ 5	+ 4
November	...	819	+ 2	0	+ 1	0	− 1	− 1	− 1	− 1	0	− 2	− 8	**−13**	−10	− 4	0	+ 4	**+ 5**	+ 3	+ 3	+ 3	+ 4	+ 4	+ 4	+ 4	+ 4
December	...	813	+ 1	0	− 1	− 1	− 1	− 1	− 2	− 2	0	− 1	− 4	**− 9**	− 6	− 1	+ 1	+ 2	**+ 3**	+ 2	+ 2	+ 2	+ 2	+ 3	+ 3	+ 3	+ 3
Winter Means	...	33801	0	− 1	− 1	− 1	− 1	− 1	− 2	− 1	+ 1	0	− 4	**− 7**	− 7	− 3	0	+ 2	**+ 3**	+ 2	+ 1	+ 2	+ 2	+ 2	+ 3	+ 3	+ 3
April	...	33772	+ 3	+ 5	+ 3	+ 3	+ 2	+ 3	+ 4	+ 7	**+ 8**	+ 3	− 5	−12	**−16**	−11	− 7	− 2	+ 1	+ 1	− 2	− 2	0	+ 1	+ 2	+ 1	+ 2
May	...	795	+ 5	+ 6	+ 6	+ 6	+ 6	+ 7	**+11**	+ 8	+ 2	− 7	−18	**−22**	−15	−11	− 3	+ 2	+ 4	+ 5	+ 3	+ 2	+ 3	+ 4	+ 4	+ 4	+ 4
June	...	774	+ 2	+ 3	0	+ 1	+ 1	+ 3	+ 6	+ 5	− 1	− 8	**−15**	−14	−12	−10	− 5	− 2	+ 3	+ 5	+ 5	+ 6	+ 6	**+ 8**	+ 8	+ 8	+ 7
July	...	814	+ 2	+ 2	+ 3	+ 2	+ 2	+ 4	+ 9	+ 7	+ 5	− 1	− 9	−10	**−13**	−12	− 8	− 2	+ 1	+ 4	+ 1	0	+ 3	+ 4	+ 4	**+12**	+11
August	...	792	+ 7	+ 8	+ 6	+ 6	+ 6	+ 7	**+11**	+ 9	+ 6	− 2	− 6	**−12**	−10	− 7	− 2	0	− 1	− 1	− 2	− 5	− 5	− 4	− 3	− 4	− 4
September	...	826	+ 3	+ 3	+ 3	+ 3	+ 4	+ 2	+ 4	**+ 5**	+ 4	− 2	− 9	**−12**	−10	− 8	− 4	− 1	+ 1	+ 1	0	+ 1	+ 3	+ 3	+ 4	+ 4	+ 4
Summer Means	...	33796	+ 4	+ 5	+ 4	+ 4	+ 4	+ 4	**+ 8**	+ 7	+ 4	− 3	−10	**−14**	−13	−10	− 5	− 1	+ 2	+ 3	+ 1	0	+ 2	+ 3	+ 3	+ 4	+ 4

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 13.—*Dip at Dehra Dūn in 1933* (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 ...	37·8	+ **0·6**	+0·6	+0·4	+0·3	+0·4	+0·4	+0·1	+0·1	−0·1	0·0	−0·1	−0·6	**−0·7**	−0·6	−0·3	−0·2	−0·1	0·0	+0·2	+0·3	+0·2	+0·3	+0·2	−0·4	+0·1
February ...	37·7	+ **0·5**	+0·5	+0·3	+0·3	+0·2	+0·2	+0·1	+0·2	+0·2	+0·1	0·0	−0·2	−0·5	**−0·6**	−0·3	−0·3	−0·2	−0·1	0·0	0·0	+0·1	−0·1	+0·1	+0·1	+0·2
March ...	37·2	+ 0·2	+0·2	+0·2	**+0·4**	+0·2	+0·2	0·0	+0·2	+0·2	+0·1	−0·4	−1·1	**−1·2**	−1·1	−0·9	−0·3	+0·2	+0·3	+0·3	+0·2	+0·3	+0·3	+0·3	+0·3	+0·1
October ...	39·6	− 0·4	−0·3	−0·3	−0·2	−0·1	−0·1	−0·1	+0·1	+0·3	+0·3	0·0	−0·3	**−0·6**	−0·5	−0·2	+0·1	+0·2	+0·3	+0·3	+0·3	+0·4	**+0·5**	+0·5	+0·4	+0·4
November ...	38·7	+ 0·3	+0·4	+0·3	+0·1	+0·2	+0·1	+0·1	0·0	−0·3	**−0·7**	−0·2	−0·3	+0·1	−0·6	−0·2	+0·2	+0·3	+0·3	+0·3	+0·3	+0·4	+0·4	**+0·6**	+0·4	+0·3
December ...	38·5	+ **0·4**	0·0	+0·2	+0·3	+0·2	+0·1	0·0	0·0	−0·1	+0·4	−0·1	**−0·5**	−0·5	−0·3	−0·1	−0·1	−0·2	+0·1	+0·1	+0·2	+0·2	+0·1	+0·1	+0·1	+0·1
Winter Means ...	38·3	+ **0·3**	+0·2	+0·2	+0·2	+0·2	+0·2	0·0	+0·1	0·0	0·0	−0·1	−0·5	**−0·6**	−0·6	−0·3	−0·1	0·0	+0·2	+0·2	+0·2	+0·3	+0·3	+0·3	+0·2	+0·2
April ...	37·1	+ 0·4	+0·3	+0·3	+0·4	+0·3	+0·1	+0·5	+0·7	**+0·8**	+0·6	−0·1	−0·8	**−1·5**	−1·4	−1·1	−0·7	−0·4	−0·1	0·0	0·0	+0·3	+0·1	0·0	+0·1	+0·1
May ...	38·1	+ 0·6	+0·5	+0·5	+0·4	+0·4	+0·4	**+0·7**	+0·7	+0·6	−0·1	−1·0	**−1·7**	−1·4	−1·3	−0·8	−0·3	0·0	+0·3	+0·2	+0·1	+0·2	+0·1	+0·1	−0·1	0·0
June ...	36·9	0·0	0·0	0·0	**+0·6**	+0·1	+0·2	+0·2	+0·3	0·0	−0·2	−0·5	−0·6	−0·9	**−1·0**	−0·8	−0·4	0·0	+0·5	+0·6	+0·5	+0·4	+0·5	+0·3	+0·3	+0·3
July ...	38·9	0·0	0·0	+0·1	+0·1	+0·1	+0·1	+0·4	+0·5	+0·5	+0·2	−0·2	−0·5	−0·9	**−1·1**	−1·0	−0·5	0·0	+0·3	+0·1	+0·1	+0·2	+0·2	+0·2	**+0·6**	+0·5
August ...	38·0	+ 0·5	+0·3	+0·4	+0·4	+0·4	+0·4	+0·6	**+0·8**	+0·7	+0·2	−0·1	**−0·8**	−0·6	−0·5	−0·2	−0·2	−0·2	0·0	−0·1	−0·2	−0·2	−0·2	−0·3	−0·4	−0·4
September ...	39·5	0·0	−0·1	−0·1	0·0	−0·2	−0·1	0·0	+0·3	**+0·7**	+0·7	+0·5	−0·2	−0·5	−0·6	**−0·7**	−0·5	−0·2	+0·1	0·0	+0·1	+0·1	+0·3	+0·3	+0·1	0·0
Summer Means ...	38·1	+ 0·3	+0·2	+0·2	+0·3	+0·2	+0·2	+0·4	**+0·6**	+0·6	+0·2	−0·2	−0·8	**−1·0**	−1·0	−0·8	−0·4	−0·1	+0·2	+0·1	+0·1	+0·2	+0·2	+0·1	+0·1	+0·1

* 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 14.—*Classification and dates of Magnetic disturbances at Dehra Dūn in 1933.*

Dates 1933	January	February	March	April	May	June	July	August	September	October	November	December
1	M	(C)	C	C	G	C	C	C	C	(C)	(C)	(C)
2	C	S	C	(C)	C	C	C	C	C	C	C	C
3	(C)	C	C	C	C	C	C	C	(C)	C	C	S
4	(C)	C	C	C	C	(C)	C	C	C	(C)	C	S
5	C	C	C	C	C	C	(C)	G	C	S	C	S
6	S	C	C	C	C	C	(C)	C	(C)	C	S	C
7	S	C	C	S	C	C	C	C	C	S	S	C
8	C	C	(C)	C	(C)	C	S	(C)	S	C	C	(C)
9	C	C	(C)	C	(C)	C	S	C	M	C	C	S
10	(C)	(C)	C	C	C	C	C	(C)	S	C	C	C
11	C	C	C	C	C	C	C	(C)	C	S	C	C
12	C	C	C	(C)	(C)	C	C	C	C	C	(C)	C
13	C	C	C	(C)	C	S	C	S	M	C	C	C
14	S	C	C	C	C	C	(C)	C	S	S	(C)	(C)
15	S	C	(C)	S	C	(C)	C	C	S	(C)	C	—
16	C	C	(C)	S	C	(C)	C	C	S	C	C	—
17	C	(C)	C	S	C	C	C	C	C	C	C	C
18	C	(C)	M	C	C	(C)	C	C	C	S	C	S
19	M	M	S	S	C	C	C	C	C	C	C	C
20	C	S	S	S	C	C	C	S	(C)	C	C	C
21	C	M	S	C	(C)	C	(C)	S	C	C	(C)	C
22	M	M	S	S	C	C	C	(C)	C	C	C	(C)
23	S	M	M	S	C	C	M	S	(C)	C	(C)	C
24	C	M	S	(C)	(C)	(C)	M	C	(C)	S	C	C
25	C	S	C	(C)	C	S	C	C	S	C	C	C
26	S	S	C	C	C	C	C	C	C	C	S	C
27	M	C	S	C	C	C	C	C	C	(C)	C	C
28	M	(C)	C	C	C	C	C	C	C	(C)	C	C
29	C	...	C	C	S	C	C	(C)	C	C	C	C
30	(C)	...	C	M	S	C	(C)	C	C	C	...	(C)
31	(C)	...	(C)	...	C	...	C	C	...	C	...	C
C	20	19	23	21	28	28	27	26	22	25	27	24
S	6	4	6	8	2	2	2	4	6	6	3	5
M	5	5	2	1	...	...	2	...	2	...	...	...
G	...	...	...	...	1	...	...	1	...	...	...	...
T.L.	...	...	...	...	...	...	...	...	...	...	...	2

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

CHAPTER VIII

RESEARCH AND TECHNICAL NOTES

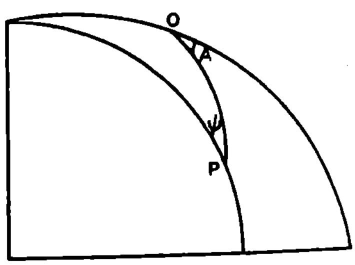
BY B. L. GULATEE, M. A. (CANTAB.)

I. GRAVITY AND DEVIATION OF THE VERTICAL

Summary.—Formulæ and tables based on Stokes' Theorem are given for computing the separation between the geoid and its reference spheroid as well as the deflections, from gravity anomalies. It is shown that provided there are no widespread systematic gravity anomalies over the whole globe, the deflections can be obtained with a fair degree of accuracy from the available gravity data.

The reference spheroid, apart from its linear dimensions, is usually defined by the plumb-line deflections (η_0, ξ_0) at the geodetic datum and the height N_0 of the geoid above the spheroid there. It is also so placed that its minor axis is parallel to the axis of rotation of the earth.

It is of interest to find out the orientation of the reference spheroid with respect to the geoid at the datum from the gravity anomalies. Let O be the datum and P a point on the earth having a gravity anomaly Δg. The separation between the two surfaces at O in terms of the Δg's is given by Stokes' Theorem



$$N_0 = \frac{R}{4\pi G} \iint \Delta g \; F(\psi) \; d\omega \qquad \dots \qquad \dots \qquad (1)$$

If A is the azimuth of P from O reckoned positive from south by west, and if η_0, ξ_0 are the meridional and prime vertical deflections at O, reckoned positive towards south and west respectively, then differentiating (1) and simplifying by spherical trigonometry, we get

$$\eta_0 = -\frac{1}{4\pi G} \iint \Delta g \; \frac{\delta F}{\delta \psi} \cos A \; d\omega \qquad \dots \qquad (2)$$

$$\xi_0 = -\frac{1}{4\pi G} \iint \Delta g \; \frac{\delta F}{\delta \psi} \sin A \; d\omega, \qquad \dots \qquad (3)$$

$d\omega$ being an elementary area on a unit sphere.

For numerical computations, the space round the origin is divided by a series of concentric circles of width $\Delta\psi_0$ and the formulæ are put into the following forms:—

$$N_0 = \frac{R}{2G} \Delta\psi_0 \Sigma \left\{ \sin\psi\, F(\psi) \right\}_M \Delta g_M \quad \ldots \quad \ldots \quad (4)$$

$$\eta_0 = -\frac{\Delta\psi_0}{2G} \operatorname{cosec} 1'' \Sigma \left\{ \sin\psi \frac{\delta F}{\delta\psi} \cdot 10^{-3} \right\}_M \left\{ 10^3\, \Delta g \cos A \right\}_M \ldots \quad (5)$$

$$\xi_0 = -\frac{\Delta\psi_0}{2G} \operatorname{cosec} 1'' \Sigma \left\{ \sin\psi \frac{\delta F}{\delta\psi} \cdot 10^{-3} \right\}_M \left\{ 10^3\, \Delta g \sin A \right\}_M \ldots \quad (6)$$

$$F(\psi) = \left\{ \operatorname{cosec} \frac{\psi}{2} + 1 - 6 \sin \frac{\psi}{2} - 5 \cos\psi - 3 \cos\psi \log_e \sin \frac{\psi}{2} \left(1 + \sin \frac{\psi}{2} \right) \right\} \quad \ldots \quad (7)$$

$$\sin\psi \frac{\delta F}{\delta\psi} = -\frac{\cos^2 \frac{\psi}{2}}{\sin \frac{\psi}{2}} - 3 \sin\psi \cos \frac{\psi}{2} + 5 \sin^2\psi + 3 \sin^2\psi \log_e \left(\sin \frac{\psi}{2} + \sin^2 \frac{\psi}{2} \right) - 3 \cos\psi \cos^2 \frac{\psi}{2} \left(\frac{1 + 2 \sin\psi/2}{1 + \sin\psi/2} \right) \quad \ldots \quad (8)$$

The suffix M denotes the mean value of the expression in a zone of width $\Delta\psi_0$.

Tables 1 and 2 give the effect of an anomaly of one milligal in different zones on N_0, η_0 and ξ_0.

It has been shown elsewhere [1] that the sensitivity of N_0 with respect to Δg detracts considerably from the value of Stokes' Theorem. The effect of the outer zones is very large, as can be seen from Table 1, and a fair knowledge of Δg over the whole globe is required before N_0 can be determined with any degree of accuracy.

Table 2 can be used to find the deflections at any point due to a given set of gravity anomalies in a known area. Thus, supposing the Tibetan plateau to be an area of gravity anomaly $-0{\cdot}020$[2] gals, and to be bounded by latitudes 30° to 36° and longitudes 80° to 100°, it was found that it would produce a meridional deflection of $+\ 0''{\cdot}3$, and a prime vertical deflection of $+\ 0''{\cdot}4$, at Kaliānpur. These are surprisingly small considering the large anomaly assumed and its large extent.

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(1) *Stokes' Formula in Geodesy* by B. L. Gulatee. *Nature*, Vol. 129, page 279.

(2) There is no reason to suppose that this is actually the anomaly in this area. It is simply given as an example of what might reasonably be found.

An attempt has been made to find out the orientation of the International and Helmert spheroids at Kaliānpur from the gravity anomalies in India. Five zones of radii $0^\circ-1^\circ$, $1^\circ-2^\circ$, $2^\circ-5^\circ$, $5^\circ-8^\circ$, and $8^\circ-10^\circ$ were taken and the average values of $\Delta g \cos A$ and $\Delta g \sin A$ were computed. The deflections with respect to Helmert's spheroid come out to be $\eta_H = +1''\cdot6$, $\xi_H = +4''\cdot2$, and with respect to the International spheroid as $\eta_I = +1''\cdot3$, $\xi_I = +4''\cdot0$. These latter differ by about $1''$ from the deflections adopted at Kaliānpur H.S. (Serial No. 240 of Supplement to Geodetic Report Vol. VI). It was not possible to go beyond a radius of 10° from the station, as gravity data are not available beyond this distance. A much more reliable value of the deflections would be obtained if Δg's were known in the Arabian sea (between latitudes 12° and 20°), in the Bay of Bengal, and in Burma, Siam and Tibet.

If we could put faith in isostasy being nearly perfect over the whole globe, so that no systematic gravity anomalies can exist over large areas, then the effect of the outer zones on the deflections will be small, and a consideration of the near zones only should give the deflections with some accuracy.

The effect of systematic gravity anomalies is easily investigated.

As an example, let the geoid be the tri-axial ellipsoid

$$r = k \left\{ 1 + \left(\tfrac{1}{3} - \sin^2\theta \right)\epsilon + C \cos 2\,(\lambda - \lambda_0) \cos^2\theta \right\} \quad \ldots \quad (9)$$

and let its reference spheroid be

$$r = k \left\{ 1 + \left(\tfrac{1}{3} - \sin^2\theta \right)\epsilon \right\} \quad \ldots \quad \ldots \quad (10)$$

The gravity anomaly is now represented by the systematic longitude term $\Delta g = GC \cos 2\,(\lambda - \lambda_0) \cos^2\theta$ ... (11)

From (9) and (10), we get

$$N = kC \cos 2\,(\lambda - \lambda_0) \cos^2\theta \quad \ldots \quad (12)$$

$$\eta = -\frac{\delta N}{k\,\delta\theta} = +C \cos 2\,(\lambda - \lambda_0) \sin 2\theta \quad \ldots \quad (13)$$

$$\xi = -\frac{\delta N}{k \cos\theta\,\delta\lambda} = +2\,C \sin 2\,(\lambda - \lambda_0) \cos\theta \quad \ldots \quad (14)$$

Heiskanen gets $C = 19 \times 10^{-6}$, $\lambda_0 = 0$. Using these values, we get for Kaliānpur (latitude 24°, longitude 78°),

$$\eta = -2''\cdot6, \quad \xi = +2''\cdot9.$$

Using Table 2, we find the effect of these gravity anomalies comprised within a radius of 15° round Kaliānpur to be only $\eta = -0''\cdot43$, $\xi = +0''\cdot45$ so that the outer zones beyond this are responsible for over $2''$ in each component.

This residual error may be much greater in an extreme case. Thus, at latitude 24°, longitude 45°, the deflection would be $\eta=0$, $\xi = +2\ C \cos 24° = +7''$. The assumed gravity anomalies within a radius of 15° only produce a prime vertical deflection of about $+1''$, showing that the outer zones are most important.

However, as in the case of the vertical separation, the relative deflections of two points, not too far from one another can be obtained from a consideration of the near zones alone, the effect of the remote anomalies being nearly the same for both. To verify this, deflections were computed for another station Kesri H.S. (Serial No. 234 of G. R. VI, Supplement). As before, zones up to 10° external radius were taken and the meridional deflection came out to be $+7''\cdot 8$. The relative meridional tilt with respect to Kaliānpur is therefore $+7''\cdot 8 - 1''\cdot 3 = +6''\cdot 5$. The value obtained by the usual method and printed in G. R. VI, Supplement is $+9''\cdot 2 - 2''\cdot 4 = +6''\cdot 8$. The agreement is very satisfactory.

The prime vertical component could not be checked, as the P. V. deflection at Kesri H.S. is based on azimuth observations, and we know that no reliance can be placed upon these deflections.

TABLE 1.—*Elevation of Geoid due to a gravity anomaly of one milligal in each zone.*

Limiting radii of zones	N_0	Limiting radii of zones	N_0	Limiting radii of zones	N_0	Limiting radii of zones	N_0
° °	*feet*	° °	*feet*	° °	*feet*	° °	*feet*
0 – 2	+0·81	20 – 30	+2·67	80 – 90	−3·77	140 – 150	+2·06
2 – 4	+0·87	30 – 40	+0·78	90 – 100	−2·89	150 – 160	+1·94
4 – 6	+0·91	40 – 50	−1·13	100 – 110	−1·56	160 – 170	+1·37
6 – 8	+0·92	50 – 60	−2·71	110 – 120	−0·46	170 – 180	+0·49
8 – 10	+0·91	60 – 70	−3·74	120 – 130	+0·84		
10 – 20	+1·10	70 – 80	−4·09	130 – 140	+1·68		

TABLE 2.—*Meridional deflections due to $\Delta g \cos A = 1$ milligal in each zone, or P. V. deflections due to $\Delta g \sin A = 1$ milligal in each zone.*

Limiting radii of zones	$\Delta g \cos A$ or $\Delta g \sin A$	Limiting radii of zones	$\Delta g \cos A$ or $\Delta g \sin A$	Limiting radii of zones	$\Delta g \cos A$ or $\Delta g \sin A$	Limiting radii of zones	$\Delta g \cos A$ or $\Delta g \sin A$
$\frac{1}{2}° - 1°$	$+0''\cdot16$	$10° - 15°$	$+0''\cdot12$	$40° - 50°$	$+0''\cdot09$	$90° - 100°$	$-0''\cdot06$
1 – 2	+0·16	15 – 20	+0·10	50 – 60	+0·06	100 – 120	−0·14
2 – 5	+0·24	20 – 25	+0·08	60 – 70	+0·02	120 – 140	−0·11
5 – 8	+0·12	25 – 30	+0·07	70 – 80	−0·01	140 – 160	−0·06
8 – 10	+0·06	30 – 40	+0·12	80 – 90	−0·04	160 – 180	−0·01

II. THE SEPARATION BETWEEN DIFFERENT SPHEROIDS

In the Survey of India, there are three spheroids in general use, namely Everest, International and Survey of India II.

The Everest and International spheroids have been defined in the Supplement to Geodetic Report Vol. VI. Survey of India spheroid II is that which best fits the compensated geoid in India, so far as the latter was known in 1927.

It is often necessary to find out the separations between these spheroids at different points. To obviate the necessity of having to compute afresh every time, two Charts XXVIII and XXIX have been prepared showing the distances between these spheroids for the whole of India.

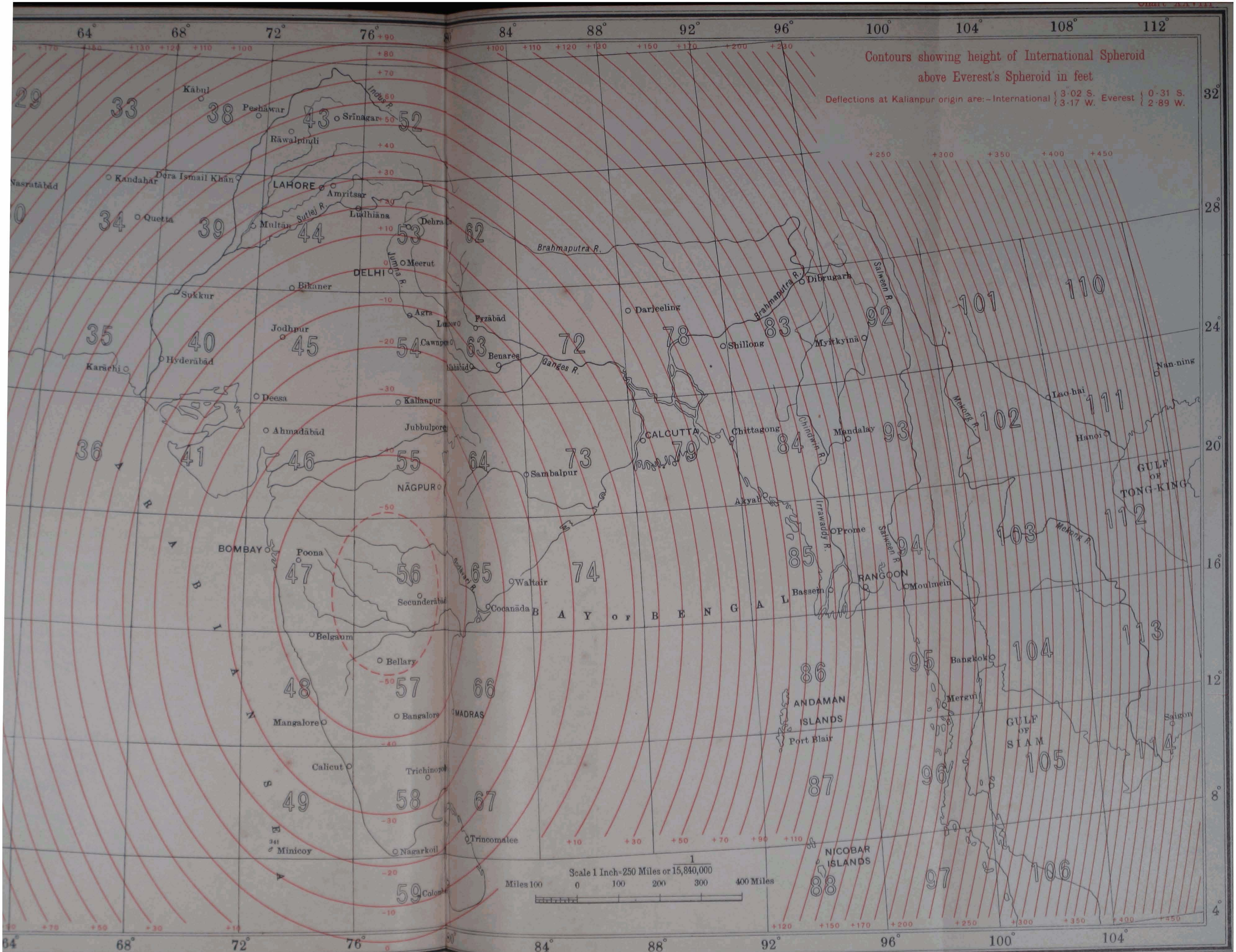
The separation is given by the following formula :—

If A and B are two spheroids, the height of B above A at the point (ϕ, λ) is

$$N = P(U\sin\phi_0' + V\cos\phi_0') - Q\delta\xi_0 + R(V\sin\phi_0' - U\cos\phi_0') + S\delta a - T\delta\epsilon,$$

where

$$P = \cos\phi' \cos\lambda$$
$$Q = a\cos\phi' \sin\lambda$$
$$R = \sin\phi'$$
$$S = 1$$
$$T = a\sin^2\phi'$$
$$U = a\,\delta\eta_0 - a\delta\epsilon \sin 2\phi_0'$$
$$V = (N_0 - \delta a) + a\delta\epsilon \sin^2\phi_0'$$



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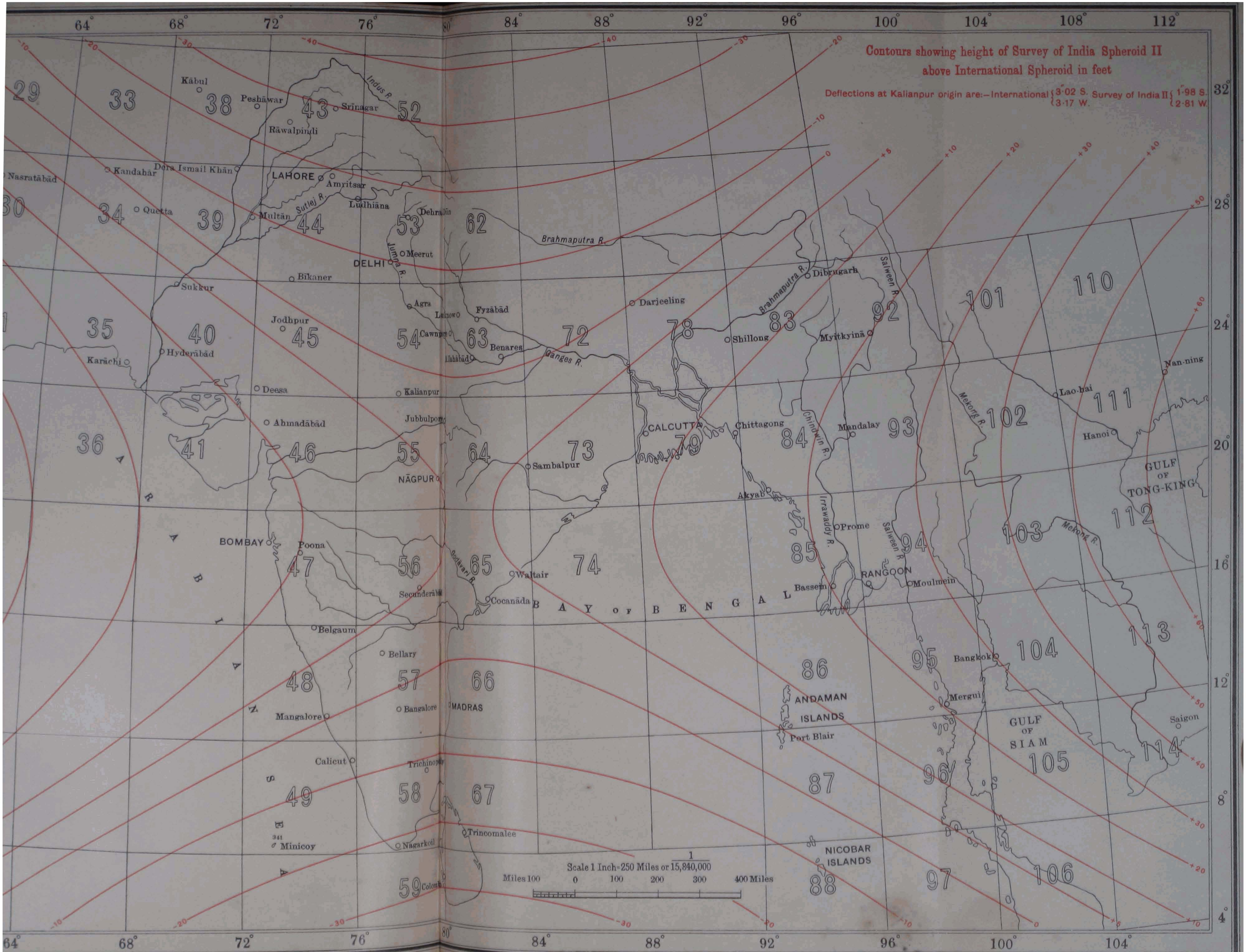

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ϕ' is the reduced latitude [viz., $\tan \phi' = (1 - \epsilon) \tan \phi$] of the point at which the separation is required, and λ is the difference of longitude between the station and Kaliānpur.

λ is reckoned positive when the station is to the east of Kaliānpur and negative when it is to the west.

ϕ_0' is the reduced latitude of Kaliānpur.

This formula has been used by Dr. J. de Graaff Hunter from time to time*, and is now put on record for future reference.

Table 3 shows the differences between the constants of the various spheroids.

TABLE 3.—*Differences between the constants of the spheroid.*

	A = Everest B = International	A = Everest B = Survey of India II	A = International B = Survey of India II
$\delta a = a_B - a_A$	+ 3647 feet + 1112 metres	+ 4149 feet + 1265 metres	+ 502 feet + 153 metres
$\delta b = b_B - b_A$	+ 2735 feet + 834 metres	+ 2136 feet + 652 metres	− 599 feet − 182 metres
$\delta \epsilon = \epsilon_B - \epsilon_A$	$+ 0 \cdot 4255 \times 10^{-4}$	$+ 0 \cdot 9552 \times 10^{-4}$	$+ 0 \cdot 5297 \times 10^{-4}$
$\delta \eta_0 = \eta_{0A} - \eta_{0B}$	− 2″·71	− 1″·67	+ 1″·04
$\delta \xi_0 = \xi_{0A} - \xi_{0B}$	− 0″·28	+ 0″·08	+ 0″·36
N_0	− 31 feet	− 29 feet	+ 2 feet

N_0 is the separation between the two spheroids at the origin. Positive when B is above A.

* See Departmental Paper No. 12. page 139, formula (7).

PUBLICATIONS

OF THE

SURVEY OF INDIA

(Corrected up to 31st December 1934)

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

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* 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. XXX & XXXI 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.

(1) **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	1934	Rs. 2-0-0
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	Addendum to 43 ...	...	...	1915	Rs. 2-0-0
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	Addendum to 47, Island of Bombay ...	...	...	1915	Re. 1-0-0
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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 ...	...	..	1934	Rs. 2-0-0
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		Latitude N.	Longitude E.	Published in	Price
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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 Girīdīh) 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
64	57 Z (Jākhal to Rohti) 57AA (Bhūrthala to Kotli Mauvān)	44 N & O and 53 B	1934	As. 10
65	61 L (Chandigarh to Jagādhri) 61 M (Jagādhri to Karnāl) 61 N (Butāna to Chandāna) 61 O (Karnal to Jīnd) 57 Y (Rohtak to Pānīpat)	53 B, C, D, F & G	1934	Rs. 1-2
66	87 (Pegu to Amherst: portion Pegu to Myitkyo revised in 1933-34) 88 (Elephant Point to Thazi: portion Rangoon to Pyinbongyi revised in 1933-34) 88 G (Thanatpin to Tongyi revised in 1933-34) 88 H (Ohne to Thongwa and Ohne revised in 1933-34)	94 C & D	1934	As. 14

NOTE:—See also pamphlets of "Levelling of Precision in India and Burma" pages iii and iv, 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* „

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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).

G.T.S. Volumes—(*Continued*).

Vol. IV **North-West Quadrilateral.** The Principal Triangulation, the Great Arc-Section 24°-30°, Rahūn, Gurhāgarh and Jogi-Tīla Meridional Series, and the Sutlej Series. Dehra Dūn, 1876. *Price Rs. 10-8.*

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

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

Vol. VI **South-East Quadrilateral.** The Principal Triangulation and Simultaneous Reduction of the following Series:—Great Arc-Section 18° to 24°, the East Coast, the Calcutta and the Bīdar Longitudinal, the Jubbulpore and the Bilāspur Meridionals. Dehra Dūn, 1880. (Out of print).

Vol. VII **North-East Quadrilateral.** General Description and Simultaneous Reduction. Also details of the following five series:—North-East Longitudinal, the Budhon Meridional, the Rangīr 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, Hurīlāong Meridional, Chendwār Meridional, North Parasnāth Meridional, North Malūncha Meridional, Calcutta Meridional, East Calcutta Longitudinal, Brahmaputra Meridional, Eastern Frontier-Section 23°-26°, and Assam Longitudinal. Dehra Dūn, 1882. *Price Rs. 10-8.*

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

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

G.T.S. Volumes—(*Concluded*).

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.*

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

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Memoirs.

1. A Memoir on the Indian Surveys, by C. R. Markham, India Office, London, 1871. *Price Rs. 5.*
2. A Memoir on the Indian Surveys. (Second Edition), by C. R. Markham, C.B., F.R.S., India Office, London, 1878. *Price Rs. 5-8.*
3. Abstract of the Reports of the Surveys and of other Geographical operations in India, 1869-78, by C. R. Markham and C. E. D. Black, India Office, London. Published annually between 1871 and 1879. (Out of print).
4. A Memoir on the Indian Surveys, 1875-1890, by C. E. D. Black, India Office, London, 1891. *Price Rs. 5-8.*

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

Annual and Special Reports.

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.*

Annual Reports &c.—(*Continued*).

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 1923 onwards prices as given below.

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, Publication Office, and topographical parties.

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.*

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.*

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

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Annual Reports &c.—(*Continued*).

(*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.*

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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.*

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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.*

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 **1981-91.** 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.*

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Annual Reports &c.—(*Continued*).

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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.*

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(*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.*

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.*

Annual Reports &c.—(*Concluded*).

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.*

1934. Triangulation and Base Measurement. Levelling. Gravity. Deviation of the Vertical. Computing Office and Tidal Section. The International Longitude Project. Observatories. Research and Technical Notes. Dehra Dūn, 1935. *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.**	868
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 1934. *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.

* For Departmental use only.

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 Books in the headquarters Library, Calcutta, 1901. (Out of print).
3. **Catalogue** of Scientific Books and Subjects in the Library of the Trigonometrical Survey Office. Dehra Dūn, 1908. *Price Re. 1.*
4. **Catalogue** of books in the Library of the Great Trigonometrical Survey. Dehra Dūn, 1911.
5. Classified **Catalogue** of the Trigonometrical Survey Library. Dehra Dūn, 1921. *Gratis.*
6. **Green Lists.** Part I List of Officers in the Survey of India (annually to date 1st January. Special Supplementary Edition dated 1st July 1932). Calcutta. *Price Rs. 1-12.*

   Part II History of Services of Officers in the Survey of India (annually up to 1st July 1931. 1932 Edition not published. Biennially up to 1st July, from 1933 inclusive), Calcutta. *Price Rs. 1-2.*
7. **Blue Lists.** Ministerial and Lower Subordinate Establishments of the Survey of India.

   Part I Headquarters and Dehra Dūn offices (annually to date 1st April. Special 1932 Edition published on 1st July). Calcutta. *Price Rs. 3-10.*

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

From 1935 inclusive onwards Parts I and II will be published in a single volume.

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

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 Handbooks.

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 form

Chapter I Introductory. Fifth Edition 1932. *Price As. 8.*

„ II Constitution and Organisation of a Survey Party, Third Edition 1935. (at Press).

„ 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. Fourth Edition, 1934. *Price Re. 1.*

„ 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). 1933. *Price Re. 1.*

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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* For Departmental use only.

Survey of India Handbooks.—(*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, 1919. *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. *Price Rs. 9-2, or 15s.*

,, IV The Geology of the Himālaya. *Price Rs. 12-8, or 20s. 3d.*

All four Parts bound in one volume. *Price Rs. 28 or £ 2, 3s. 6d.*

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, Bhutān 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, Rānikhet 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. (Out of print).

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 Prēsentēs par Divers. Savants ā l' Acadēmie des Sciences de l' Institute de France). Dehra Dūn, 1899. (Out of print).

No. 3. **Base Lines.** Method of measuring Geodetic Bases by means of Colby's Compensated Bars, compiled by Lieut. H. McC. Cowie, R.E. Dehra Dūn, 1900. (Out of print).

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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. (Out of print).

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

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

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

No. 17. **Isostasy.** Investigations of Isostasy in Himālayan and neighbouring regions by Colonel Sir S. G. Burrard, K.C.S.I., R.E., F.R.S. Dehra Dūn, 1918. *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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List of more important contributions by the Officers of the Survey of India to various extra-departmental publications and related articles.

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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).

3. †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).

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6. §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).

7. §Geological interpretations of Geodetic Results, by Colonel Sir S. G. Burrard, K.C.S.I., R.E., F.R.S. (Geographical Journal, October 1918).

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

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

38. A Report on the Geodetic work of the Survey of India for the period 1924-27, by J. de Graaff Hunter, M.A., SC.D., F. INST. P., presented at the third meeting of the International Union of Geodesy and Geophysics, Prague, September 1927. Dehra Dūn, 1927. *Price Re. 1.*

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

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

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

42. *Reply to Captain G. Bomford's letter on Figure of the Earth (No. 41 of list), by Captain G. T. McCaw and A. R. Hinks, C.B.E., F.R.S. (Geographical Journal, December 1927).

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44. * 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. ¶Two Notes on Short Tertiary Bases, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. (Empire Survey Review No. 1, Vol. I, July 1931, pages 12-15).

55. †Contribution to discussion on paper by Mr. A. R. Hinks, C.B.E., F.R.S. "Some Problems of the Earth's Crust". British Association, 1931, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. (Geographical Journal, November 1931).

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57. ‡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).

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

59. §A New Principle of Time Observation, especially for determination of Longitude, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. (Nature, 29th October 1932).

60. ‡Isostasy in India, by J. de Graaff Hunter, M.A., SC.D., F.INST.P. (Empire Survey Review, Vol. II, Jan. 1933).

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64. ‖Figure of the Earth, by B. L. Gulatee, M.A. (Cantab.), (Gerl. Beiträge, Bd. 38, H. 3/4, S. 426, 1933).

65. A Report on the Geodetic work of the Survey of India for the period 1930-33, presented at the fifth meeting of the International Union of Geodesy and Geophysics, Lisbon, September 1933. Dehra Dūn, 1933. *Price As. 6.*

66. ‡Some factors in determining heights from Air Photographs, by Captain D. R. Crone, R.E. (Empire Survey Review, Vol. II, Oct. 1933, pages 221-225).

67. ¶ Deflection of the Plumb-Line, by B. L. Gulatee, M.A. (Cantab.) (Hydrographic Review, Vol. X, No. 2, Nov. 1933, pages 182-189).

68. $ A note on the Nepāl Himālaya, by Lt.-Colonel Kenneth Mason, M.C., R.E. (Himālayan Journal Vol. VI, 1934).

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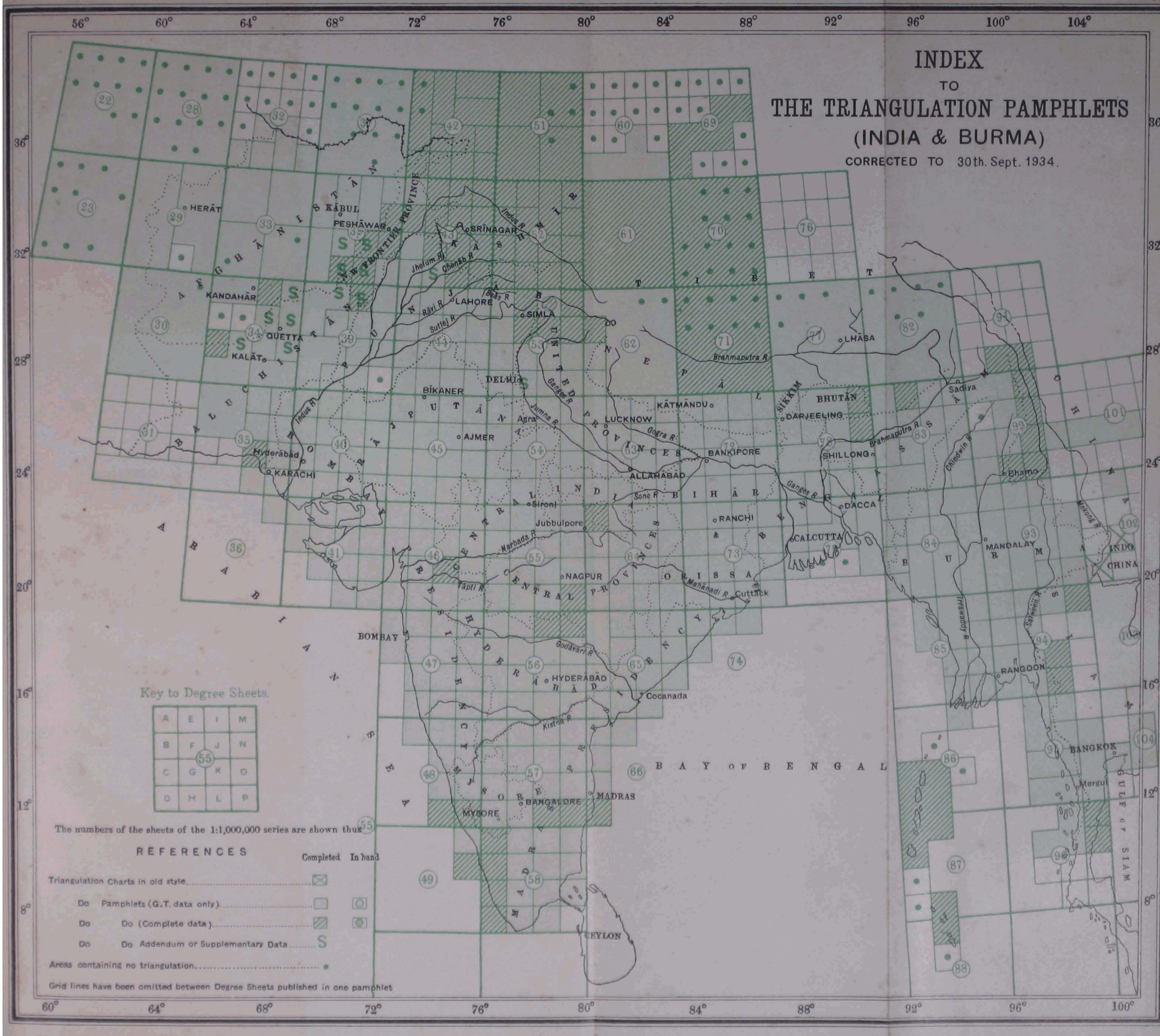
Chart XXX



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To accompany Geodetic Report 1934

INDEX TO THE TRIANGULATION PAMPHLETS

IRĀQ, PERSIA & ADEN

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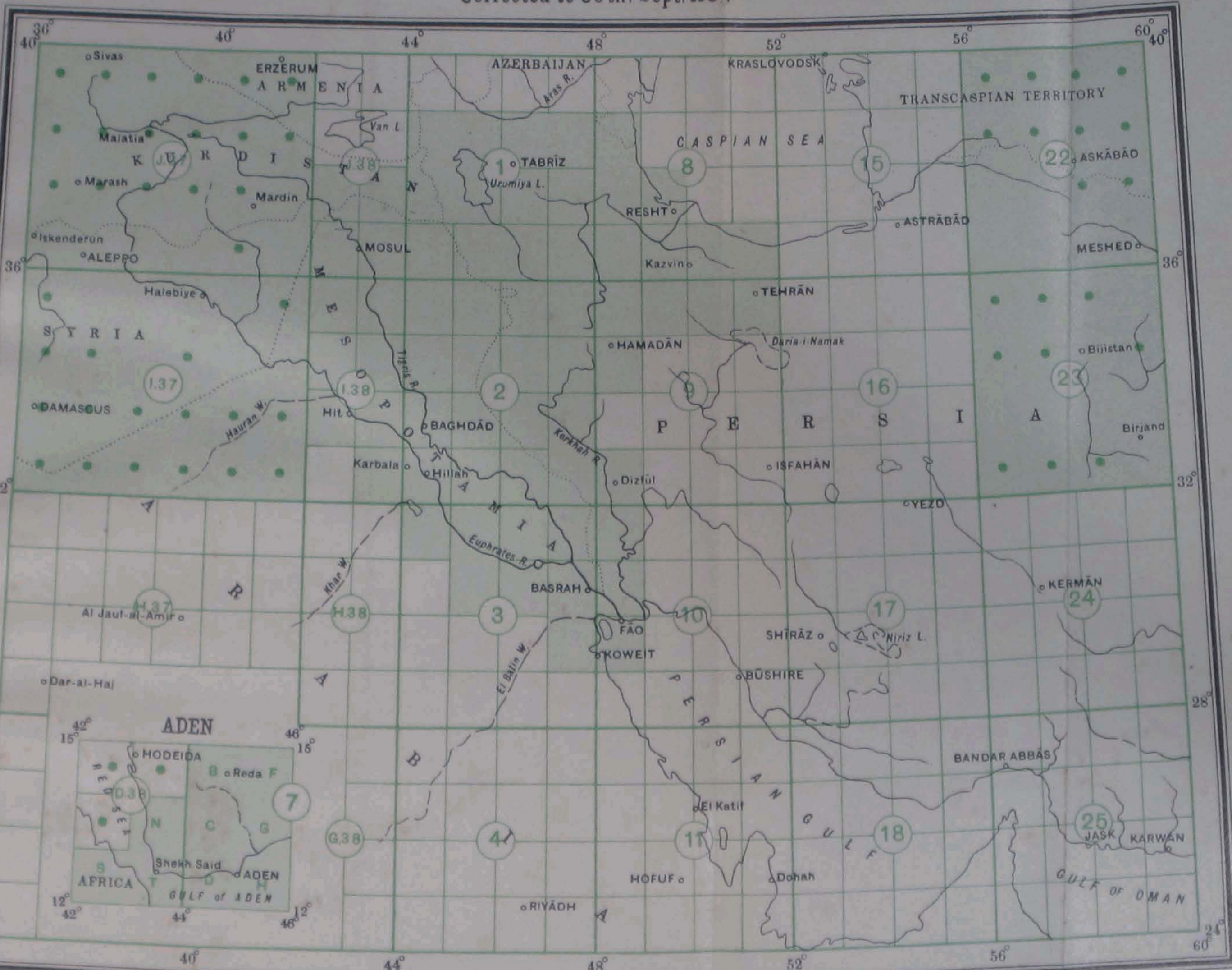
Chart XXXI



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M	N	O	P	Q	R
S	T	U	V	W	X

(J.37)

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Miles 100 50 0 100 200 300 400 Miles

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3. Area containing no data ....

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