SURVEY OF INDIA

GEODETIC REPORT

1935

PUBLISHED BY ORDER OF
BRIGADIER H. J. COUCHMAN, D.S.O., M.C.,
SURVEYOR GENERAL OF INDIA

PRINTED AT THE GEODETIC BRANCH OFFICE,
SURVEY OF INDIA, DEHRA DŪN, 1936.

Price Three Rupees, or Five Shillings and Three Pence

CONTENTS

CHAPTER I

Triangulation

CHAPTER II

Levelling

CHAPTER III

Deviation of the Vertical

Deviation of the Vertical—(*concld.*)

CHAPTER IV

Gravity

CHAPTER V

Geophysical Survey in Bihar

CHAPTER VI

Computing Office and Tidal Section

CONTENTS

TIDAL SECTION

CHAPTER VII

Observatories

CHAPTER VIII

Research and Technical Notes

Charts and Plates

Charts and Plates—(*concld.*)

INTRODUCTION

1. In the year 1934–35 the Geodetic Branch of the Survey of India has undertaken a considerable amount of geodetic work of great variety.

2. *Triangulation.*—(Chapter I). A primary series of triangulation replacing the Assam Valley secondary series was completed, a satisfactory connection being made with the Nāga Hills series; but the connection with the Assam Longitudinal series was unsuccessful, and remains to be done; it is possible that some of the stations of this early series have been displaced by earthquakes.

The extension of this new series through independent Nāga territory to join up with the Upper Irrawaddy series in Burma is on the 1935–36 programme.

3. *Levelling.*—(Chapter II). Progress was made with the high precision level net. Two detachments started work on this, but one was withdrawn early in the season owing to an urgent demand for tertiary levelling by the Eastern Bengal Railway in the neighbourhood of the Hardinge Bridge. This detachment was required for the secondary levelling framework necessary to control the work of two double and eight single detachments of tertiary levellers.

A single detachment revised the precise levelling from Chittagong to Akyab and then forming a double detachment worked in Bihār with a view to connecting the main line of levels affected by the Great Bihār earthquake to Sironj in the stable part of the peninsula. When this line is completed in 1935–36 it will be possible to determine finally what changes in level have occurred. Levels in Bengal have been discussed in previous Geodetic Reports, as there was evidence of a rise in level as compared with Calcutta. Mr. B. L. Gulatee considers this question afresh in the light of levels from Karāchi (Chapter VIII); the result appears to be conclusively against the supposed rise.

4. *Deviation of the vertical.*—(Chapter III). The main east-to-west geoidal section across India and Burma and the north-to-south section in India have now been completed, and a short section north to south across the Bihār plain was also done. Revised geoidal charts using this new data have been prepared.

5. *Gravity.*—(Chapter IV). The gravity survey was extended north of Bombay to Cutch and Rājputāna. Although the pendulum stations are still too sparsely distributed in parts of this area, the results add considerably to our knowledge of the tectonic structure of this part of the peninsula.

An interesting feature is the high positive gravity anomalies at Pokaran east of Jaisalmer and south-west of that place associated with the Malāni series of volcanic rocks.

6. *Geophysical survey.*—(Chapter V). A trial was made of two methods of geophysical exploration in Bihār with a view to detecting the configuration of the bed rocks underlying the alluvium. The result shows that detailed geophysical survey should successfully delineate the buried features, and this is essential for planning measures for protection against earthquakes.

7. *Tide predictions.*—(Chapter VI). The Tide-tables of the Indian Ocean for 1936 have been prepared as usual. An investigation of monthly and annual mean sea-levels is being made by the International Oceanographic Commission, and some work has been done in this connection. The results are likely to be of considerable interest.

8. *Dehra Dūn Observatory.*—(Chapter VII). The regular longitude, magnetic, meteorological and seismographical observations have been carried on as usual. The Shortt and Riefler clocks have been equipped with batteries of Edison Soda cells, which it is hoped will finally put a stop to failures or irregularities due to battery changes.

9. *Non-departmental publications.*—The scientific work of the German Expedition to Nanga Parbat has been set out in several publications(1) (2) (3) by Dr. R. Finsterwalder. The final values are not yet available. It is evident however that at Astor East there is an easterly deflection of about 50″, that is away from Nanga Parbat. A large easterly deflection at Astor East is quite consistent with the high gravity values obtained on the Deosai Plain.

Mr. B. L. Gulatee has employed the isostatic gravity anomalies to determine the distribution of mass-anomalies in India(4). An interesting chart is published which shows India to be largely an area of defect of mass. The first part of Lt.-Colonel Glennie's reply to Dr. W. Bowie's paper (see Geodetic Report 1934, page 4) has now appeared(5). He concludes that an isostatic condition does not prevail in India. A further paper dealing with America on somewhat similar lines will be published shortly.

REFERENCES

(1) *Forschung am Nanga Parbat.* Verlag: Geographischen Gesellschaft in Hannover, 1935.

(2) *Die Wissenschaftlichen Arbeiten der Nanga-Parbat Expedition 1934.* Petermanns Geogr. Mitteilungen 1935, Heft 1.

(3) *Die Haupttriangulation am Nanga Parbat.* Allgemeinen Vermessungs-Nachrichten. Nos. 3 and 6, 1935, Berlin.

(4) *On the Subterranean Mass-anomalies in India.* Proceedings of the Academy of Sciences U.P., India. Vol. 5 part 1, September 1935.

(5) *Isostasy in India.* Gerlands Beiträge zur Geophysik Vol. 43 pp. 340-345, 1935.

PERSONNEL* OF THE GEODETIC BRANCH, 1934–35.

Director, Geodetic Branch

LT.-COLONEL C. M. THOMPSON, I. A., to 20th October 1934
COLONEL C. G. LEWIS, O. B. E., from 21st October 1934

OFFICE OF THE DIRECTOR, GEODETIC BRANCH

Ministerial Service

Head Assistant

Mr. Diwan Chand

Assistants

Mr. Krishna Lal Sharma
22 Clerks.

COMPUTING AND TIDAL PARTY

(RECORDS AND RESEARCH)

Class I Service

Captain G. Bomford, R. E., in charge, to 12th Oct. 1934 and from 14th Dec. 1934 to 3rd April 1935.

Lt.-Colonel E. A. Glennie, D S. O., R. E., in charge, from 13th Oct. to 13th Dec. 1934 and from 4th April 1935.

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

OBSERVATORY SECTION

Magnetic Observer

Mr. Shyam Narain, B. SC., from 1st Jan. 1935.

Lower Subordinate Service

4 Computers.

TIDAL SECTION

Upper Subordinate Service

Mr. H C. Banerjea, B. A. (Tidal Assistant)

Lower Subordinate Service

8 Computers.

COMPUTING SECTION

Upper Subordinate Service

Mr. M. Chatterji (Head Computer).

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

Mr. A. K. Maitra, B. A., to 24th Aug. 1935.

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

Lower Subordinate Service

13 Computers.
1 Librarian.

CHART SECTION

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

Lower Subordinate Service

5 Draftsmen.

No. 14 PARTY (GEOPHYSICAL)

Class I Service

Lt.-Colonel E. A. Glennie, D. S. O., R. E., in charge, to 12th Oct. 1934 and from 23rd Feb. 1935.

Captain G. Bomford, R. E., in charge, from 13th Oct. to 13th Dec. 1934.

Class II Service

Rai Sahib Raj Bahadur Mathur, B. A., to 13th Dec. 1934 and from 23rd Feb. 1935 (in charge from 14th Dec. 1934 to 22nd Feb. 1935).

Class II Service—(contd.)

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

Magnetic Observer

Mr. Shyam Narain, B. SC., to 31st Dec. 1934.

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, to 28th Oct. 1934.

Major G. H. Osmaston, M.C., R.E., from 29th Oct. 1934 to 31st May 1935.

(Charge was held by the Director, Geodetic Branch from 1st June to 30th Sep. 1935).

Class II Service

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

Upper Subordinate Service

Mr. A. A. S. Matlub Ahmad, to 30th April 1935.

Mr. L. R. Howard, to 30th Oct. 1934.

Upper Subordinate Service—(contd.)

Mr. N. M. Bopaiah, from 1st Jan. to 31st July 1935.

Mr. P. C. Sen Gupta, B.SC., from 14th Dec. 1934 to 25th May 1935.

Mr. G. C. Aggarwala, B.A., from 20th Sep. 1935.

Mr. Mohd. Faizul Hasan.

Mr. Mohd. Zafar Ali Qureshi.

Lower Subordinate Service

9 Computers and 3 Clerks. (This excludes 12 Lower Subordinates temporarily employed on Hardinge Bridge 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).

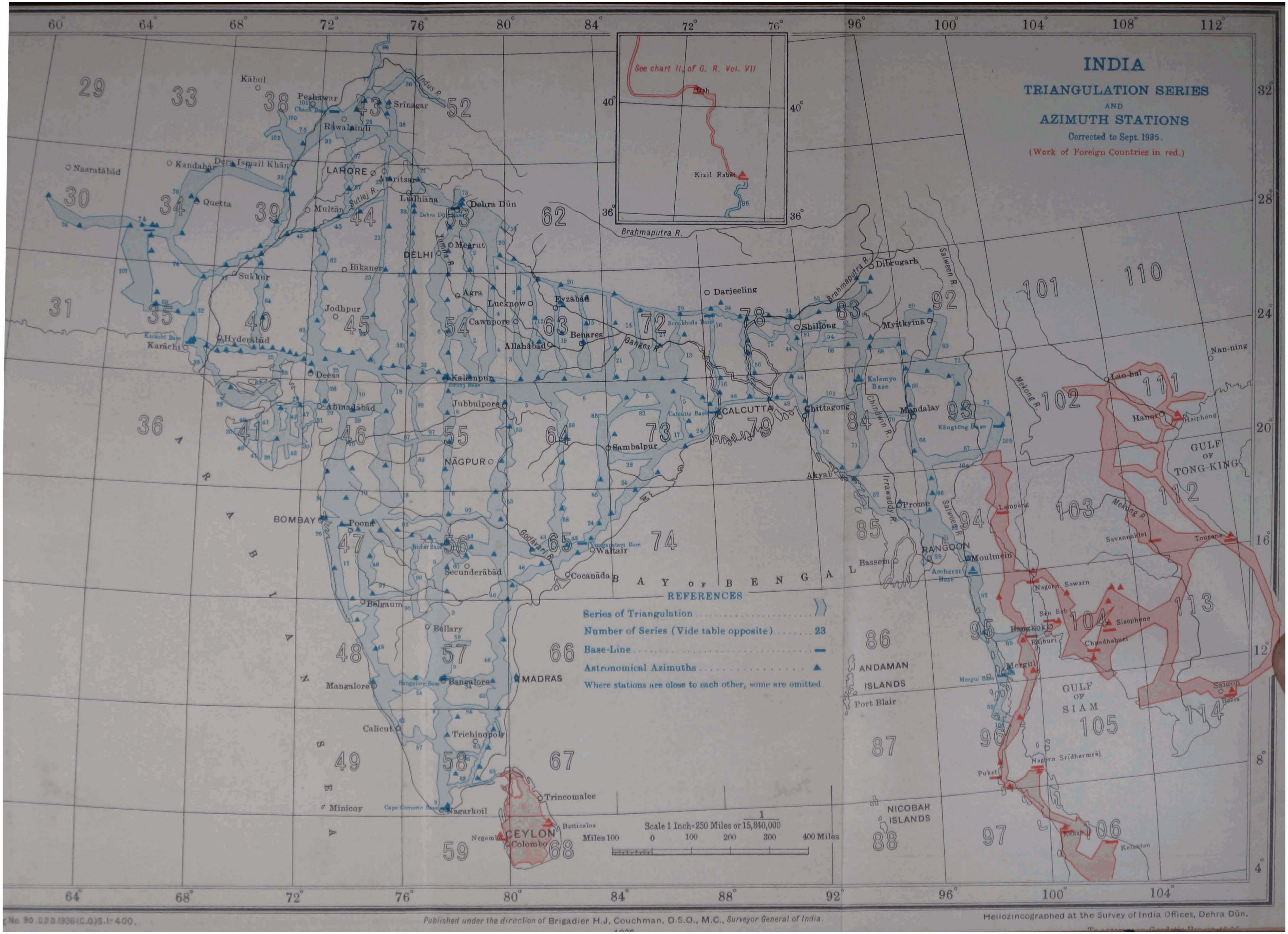
For 42 Series entering the Simultaneous Grinding (shown in italics below) Mean Square M = ± 1·04
For Series up to No. 107 ... ... Mean Square M = ± 1·52

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
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	Bhīr	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	Kohīma	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 Waziristān	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
108	Assam Valley	1934-35	0·341	0·38

Mer. = Meridional Lon. = Longitudinal.

* Replaced by 108

† Replaced by 104.



INDIA
TRIANGULATION SERIES AND AZIMUTH STATIONS

Corrected to Sept. 1935.

(Work of Foreign Countries in red.)

REFERENCES

Series of Triangulation ....))

Number of Series (Vide table opposite) 23

Base-Line .... ▬

Astronomical Azimuths .... ▲

Where stations are close to each other, some are omitted.

Scale 1 Inch=250 Miles or $\frac{1}{15,840,000}$

Miles 100 0 100 200 300 400 Miles

No 90.000.1936(C.0)S.I-400.

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.

CHAPTER I

TRIANGULATION

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

1. Summary.—The season's programme consisted in the measurement of the primary series reconnoitred last year to replace the existing Assam Valley series. In all thirty stations were occupied and astronomical azimuths observed at ten of them. The average triangular error is 0·45 seconds, and the values of m and M are $\pm 0 \cdot 341$ and $\pm 0 \cdot 38$ respectively. Thus the series is up to the average standard of accuracy of modern geodetic triangulation in India.

2. General.—A detachment under Captain G. H. Osmaston, M.C., R.E. took the field at Gauhāti and started observations on 30th October 1934.

Having observed at Hāthimura H.S. and Maiang H.S. it was found that the new readings for angles to Harogaon H.S. did not agree by several seconds with those taken in 1867; further readings to Akchalia H.S. and Tepkilabama H.S. showed similar differences, see Table 1. These discrepancies may well represent actual relative movements of the hills, due perhaps to the earthquakes which are so common in these parts. The great earthquake of 1897 occurred since the original measurements were made.

TABLE 1.—*Difference between old and new values of angles at Hāthimura H.S. and Maiang H.S.*

Angles observed at Hāthimura H.S. between	Old value	New value	Difference (Old-New)
Akchalia H.S. and Harogaon H.S.	30° 16′ 29″·29	30° 16′ 25″·50	+3″·79
Tepkilabama H.S. and Maiang H.S.	43 53 08·83	43 53 12·92	−4·09
Harogaon H.S. and Maiang H.S.	74 42 19·12	74 42 24·29	−5·17

Angles observed at Maiang H.S. between	Old value	New value	Difference (Old-New)
Harogaon H.S. and Hāthimura H.S.	64° 51′ 03″·08	64° 51′ 03″·48	−0″·40
Tepkilabama H.S. and Hāthimura H.S.	92 22 48·81	92 22 46·13	+2·68

It was not considered desirable to pursue this connection further at this time and the main series was therefore taken up without further delay. Observations proceeded eastwards as far as Golāghāt using in all cases the old stations of the Assam Valley series except for two additional stations in the Mīkīr Hills.

A satisfactory connection with three stations of the Nāga Hills series of 1913–14 was made about Golāghāt. The old and new values for the angles are given below:—

Stations		1913			1935		
		°	′	″	°	′	″
Cheniābinshon	H.S	40	39	29·98	40	39	30·41
Golāghāt	T.S.	111	25	02·95	111	25	05·30
Aitepiung	H.S.	27	55	27·62	27	55	27·52

Work was continued through the administered Nāga Hills during February and March, occupying six new stations and completing the connection with the Namtiali Base by 18th March.

3. **Narrative.**—The detachment consisted of the observer Captain Osmaston with Computer S. C. Dhar posting lamp squads in advance, Computer Padam Singh recording and 45 U. P. *khalāsis.* Nine lamp squads of 3 men each were used throughout the season, equipped with 18-inch Argand oil lamps, 9-inch, and 5-inch helios. The observations were made with the large pattern Wild Precision theodolite No. 59 (horizontal circle about 5½-inch).

During November, when the observations were started, the weather was cloudy with several spells of rain, visibility seldom being over 20 miles.

Mosquitoes were troublesome, and some of the party suffered severely from the bites of tiny jungle ticks. As the season progressed these annoyances decreased, and by December the weather was dry and clear, and the snow mountains of North Bhutān, over 100 miles away, were generally visible. From Gauhāti to Nowgong communications were easy as the railway ran close to the series and there were plenty of roads as well as navigable water-ways. Assamese coolies however were not found to be good load carriers, especially when it came to taking camps up the hills.

The long rays in the figure surrounding Nowgong were troublesome to observe owing to misty atmosphere encountered in the main valley of the Brahmaputra. On two or three of these rays the lamps could not be seen at all, and the long diagonal from Khola to Kāmāksha (60 miles) was only seen by helio for a few minutes on one day.

During January the series was carried eastwards across the Mīkīr Hills. This area is a tangle of jungle-covered hills inhabited by the Mīkīr people who are a distinctive tribe of Burmo-Tibetan type. Although surrounded by civilization in the shape of roads and railways and fertile plains, these people have stayed largely in their patch of hills and hence retained to a great extent their distinctive modes and customs. They are cheerful and hardy and proved very loyal and willing porters. A peculiar costume is worn by the men consisting of a kind of waistcoat open at the front with a long fringe of tassels hanging down to knee level. These are made by the women of hand-woven cloth and are often tastefully embroidered (see Plate II). A small sheet is the only extra covering carried even when camping out at the coldest time of year. For warmth at night they build small fires on either side and sleep between them.

Wild elephants are numerous in the Mīkīr Hills, and there were signs of unusually large numbers on both banks of the Kaliāni river. A small fly was met within these hills, whose bite was very poisonous and caused a good deal of swelling, as well as slight fever. Special reference was made to these flies in the report of the original triangulation 50 years ago when they seem to have been even worse, one lamp squad being completely put out of action by them on that occasion.

At Golāghāt the old tower station consisted of a hollow brick pillar about 15 feet high and 2 feet 6 inches square. This was built up to 38 feet in order to see the lines eastwards. As this pillar was only large enough to hold the theodolite, a separate bamboo scaffolding was put up surrounding it to support the observer and his tent. A minor earthquake shook the pillar severely before observations started, but although laterally it was very unstable afterwards, the work was done without any serious decrease in accuracy. Later the pillar was taken down to its old height as it was unsafe to leave it higher.

The last part of the work, involving six new stations in the administered Nāga Hills, was started on the 13th of February. Movement in these hills was easy as there were many excellent paths and much of the jungle had been cleared especially on the ridges and hill tops where the Nāgas like to build their villages. The Nāgas of this administered district are cheerful and well disciplined and have discarded much of the primitive superstition and resulting malpractices which still tend to prevail among the unadministered tribes. The villages are still built on the hill tops, as a precaution against unfriendly neighbours, but there is really no longer any need for this, as head-hunting and inter-village warfare are things of the past. Language is a great difficulty in dealing with the Nāgas. In the past each tribe remained so separate from, and so hostile to those surrounding that they developed distinctive dialects, and often a villager cannot make himself understood at all a few miles away in a different tribal area. Details of their very scanty clothing differ from tribe to tribe but perhaps the most distinguishing feature of the majority of Nāgas met with, was the peculiar way of cutting the hair, shaved up to a horizontal line round the head above the ears, and long on the top, the longer hair being allowed to fall in an even fringe all round. This is in contrast to the Mīkīrs who shave the whole head except for a circular patch round the crown. The Nāgas were very willing, and made excellent porters. When carrying loads they chant a variety of weird cadences as they march along, and this is probably the secret of the great pace that they can maintain, nothing short of a trot suiting the tunes for level and down hill work. Several storms blew up during the last half of February and in March, which although delaying observations temporarily, improved visibility and cleared away the smoke rising from the new *jhums* which were burning at that time. Observations at Lirumen H. S., to complete the connection with the Namtiali Base, were finished on 18th March. The detachment then collected at Golāghāt and dispersed a week later, leaving the equipment at Gauhāti for the recess season.

4. **Health.**—An outbreak of cholera took place in Nowgong and Kāmrūp districts during the hot weather preceding the work. The party took a supply of bacteriophage from Shillong, and no cases of cholera or other serious internal trouble occurred. The few cases of malaria were successfully treated with quinine and esanofele. One *khalāsi* developed pneumonia towards the end of the season but recovered after treatment at the government hospital in Golāghāt.

5. **Method of observation.**—The large Wild was used in an observatory tent. Normally 60 measures of each angle were taken, 3 measures on each of 20 different zeros, the actual procedure being to make 3 consecutive swings in the same direction on one zero, change face and zero and make 3 swings in the opposite direction. Each change of zero amounted to 9° 0′ 6″, the change of seconds tending to eliminate error of run. After completing one-third and two-thirds of the total measures the position of the foot-screws was changed. This precaution is necessary to eliminate as far as possible the effects of axis strain. By changing the position of the foot-screws is meant lifting the whole theodolite and twisting it through 120° so that each foot-screw has a new support. In fair weather work was carried out as follows:—07.00 to 8.30 hours, 3 zeros horizontal angles; 13.00 to 14.00 hours, vertical angles; 15.00 to 17.00 hours, 4 zeros horizontal angles; 18.30 to 22.00 hours, 6 zeros horizontal angles. Thus at least two days and a night and more often two whole periods of 24 hours were necessary at each station.

PLATE II.

Mīkīr youths dressed for ceremony.

Electric illumination was used throughout by day and night. Rough azimuth observations were made at eight stations by measurements of the angle between a station of the triangulation and Polaris, 20 measures being taken on 10 different zeros. The probable error at these stations is 0″·45. Precise azimuth observations for future Laplace stations were made at Tatalia H.S. and Naginimara H.S. The measurements were made as above but 60 measures were taken on 20 different zeros. The average probable error at Tatalia H.S. is 0″·32 and at Naginimara H.S. 0″·50.

6. Observation notes.—An eyeshade over the eye not in use was found invaluable while observing, both to relieve strain and to prevent light and movement from distracting concentration. A special stand similar to the old stands used with 12-inch theodolites was used. This stand weighed about 60 lb. and owing to its rigid shape was a most awkward load in the jungle. It was however very steady and no twist was ever noticed except when the direct rays of the sun fell on the metal cross bracing. Occasionally the stand had to be draped with a blanket to avoid the sun, and this is considered an important point to watch. In previous reports slow drifting of the apparent position of signals has been put down to bad atmospheric conditions, and this drift has generally been noticed during morning work. The only occasions of such drift during the present observations were definitely due to twist of the stand, and it is therefore suggested that observers may have been deceived in the past as to the cause of apparent lateral drift, and that the real cause is twisting due to unequal temperature changes in the stand. This is most likely to occur in the early morning.

7. Refraction notes.—It was noticed that some helio signals remained comparatively steady throughout the day while others 'boiled' as early as 8 o'clock in the morning. Notes on this point were taken at a number of stations and the following points became quite evident. First that boiling is mainly due to hot air rising from the ground near the observer; ground more than a mile or so away has comparatively little effect. Thus rays which pass over ground dropping steeply away from the observer's station will be steady rays, whereas those passing close to the ground or over a gradual slope near the observer will be bad. From this fact it is easy to choose a steady ray for zero line before observations are started. It also follows that a ray which is very bad to observe from one end may be perfectly good from the other, and this was found to be the case.

Lamps as a rule are perfectly steady signals at night, but it was noticed that where a ray passed over water, especially near the observer's station, the signal started to wobble after 10.30 p.m. and in one case became so distorted vertically that it sometimes appeared as several distinct points of light one above the other. This phenomenon is obviously due to a column of warm air rising above water during the later part of the night.

CHAPTER II

LEVELLING

8. Summary.—The original programme consisted of one single detachment to revise the precise levelling from Chittagong to Akyab and then to form into a double detachment to level from Dinājpur to Purnea and from Bagaha to Sironj; one single detachment on high precision levelling from Akola to Nāgpur and Nāgpur to Bhopāl; and another on high precision levelling from Bombay to Surat and Surat to Baroda and from Nakhtrāna Mota in Cutch to Buhāra in Sind. This programme was modified owing to urgent work required by the Eastern Bengal Railway in connection with protective measures for the Hardinge Bridge. On this account the second detachment was withdrawn in December from high precision levelling, after it had worked only from Akola to Thānegaon near Nāgpur, and sent to Bengal with 2 double and 8 single tertiary detachments.

The total out-turn of levelling was :—

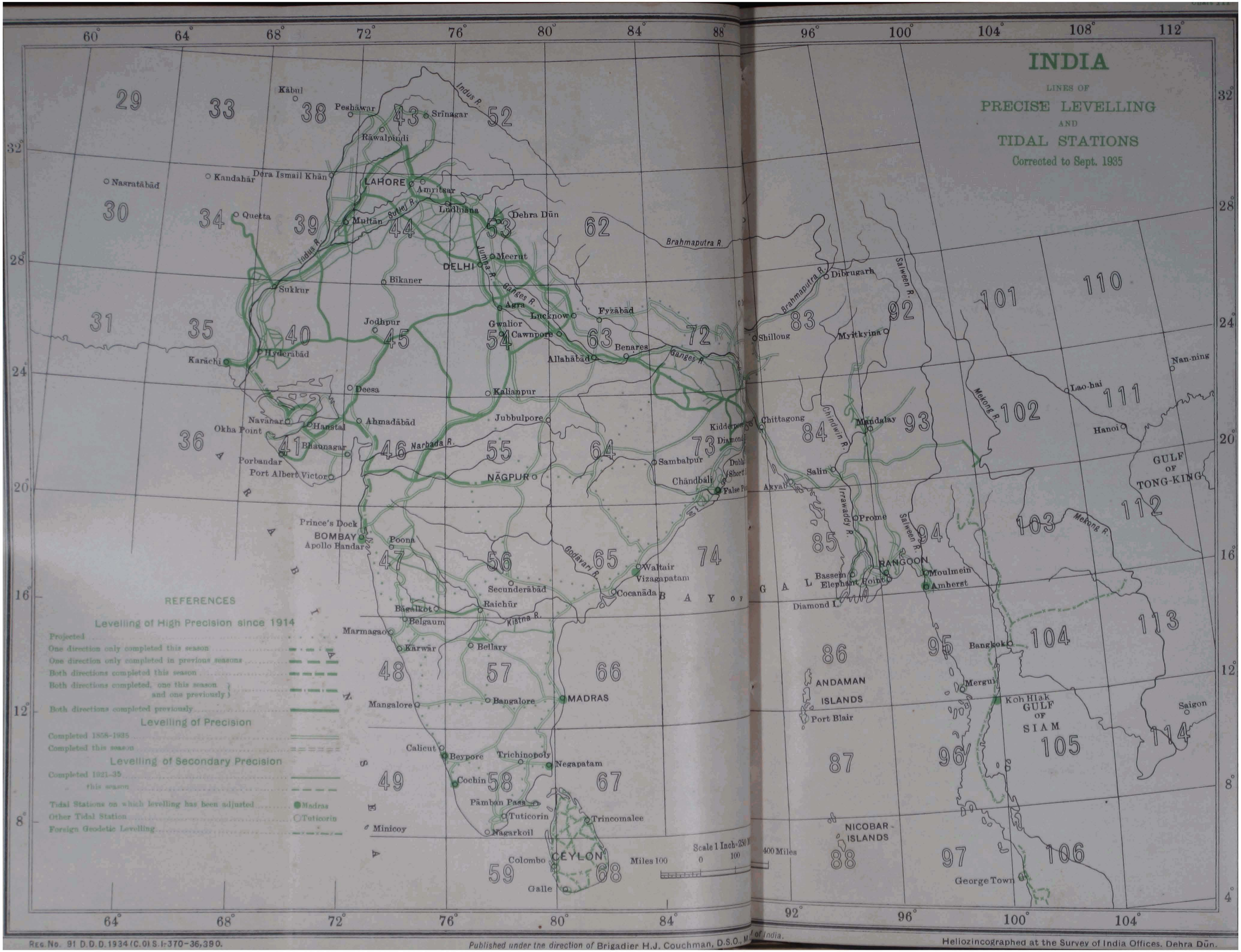
High Precision levelling in fore direction	118 miles	(123 gross)*
,, ,, ,, ,, back ,,	234 ,,	(269 ,,)*
,, ,, ,, ,, both directions	76† ,,	(76 ,,)*
Equivalent total in one direction ...	428 ,,	(468 ,,)*
Precise levelling	255 ,,	(276 ,,)*
,, ,, (revision) ...	259 ,,	(292 ,,)*
Secondary ,, ...	323 ,,	(364 ,,)*
Double tertiary levelling	311 ,,	(311 ,,)*
Single ,, ,, ...	3,056 ,,	(3,056 ,,)*

9. Chittagong–Akyab.—When the computations of precise line 77 W, Chittagong to Magwe, originally executed in 1932–33 for the Indo–Burma connection, were finished, it was found that the mean water level at Akyab was apparently 4·73 feet below mean water level at Chittagong and 0·84 feet above mean water level at Amherst. The discrepancy of 0·84 feet, being reasonable, was adjusted between Minbu and Akyab, but the difference of 4·73 feet was improbable as Chittagong is only about 12 miles from the open sea. In the expectation, therefore, of an error of 3 feet or so in the levelling of 1932–33, between Chittagong and Akyab,

---

* The first of these figures represents the direct distance levelled between terminal bench marks. The second includes additional check-levelling at ends, branch-lines to G. T. Stations etc.

† i.e., 38 miles in fore and 38 miles in back direction.



INDIA

LINES OF

PRECISE LEVELLING

AND

TIDAL STATIONS

Corrected to Sept. 1935

Reg. No. 91 D.D.D.1934(C.O)S.I-370-36,390.

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

Heliozincographed at the Survey of India Offices, Dehra Dūn.

this line was relevelled by single levelling by No. 1 Detachment under Mr. Z. A. Qureshi, and as anticipated an error of 2·4 feet was found about 60 miles north of Akyab which was verified by levelling again in the opposite direction. At Chittagong a branch-line was also run to Juldia gauge near the sea 11 miles south of Chittagong, giving a satisfactory check with the height of Chittagong determined by levelling based on the tide-gauge at False Point.

10. **Dinajpur–Purnea and Bagaha–Sironj.**—These lines were done by No. 1 Detachment under Mr. N. M. Bopaiah with Mr. Z. A. Qureshi as second leveller, in order to determine the disturbance, if any, of the bench marks at Purnea and Bagaha, which were terminals of the levelling done in North Bihār in connection with the earthquake of 1934. The route followed on the line Dinājpur to Purnea was the same as that of old lines 77 B, C and N.

The line Bagaha–Sironj could only be done as far as Ghāzīpur this season. The route followed was the same as that of old lines 71 and 69 up to Dohrīghāt and thence along the metalled road via Mau to Ghāzīpur.

The heights of bench marks at Purnea as now determined from Dinājpur agree to within 3 inches with the pre-earthquake heights. The heights at Bagaha showed a rise of 1¼ to 1½ feet as determined just after the earthquake in 1934 and those as now determined from Gorakhpur and Ghāzīpur show a rise of about ½ foot, but final consideration of this point must await completion of the portion Ghāzīpur to Sironj next season and will be discussed in the Geodetic Report for 1936.

11. **Akola–Nagpur and Nagpur–Bhopal.**—No. 2 Detachment under Mr. Mohammad Faizul Hasan had only worked from Akola to Thānegaon, about 40 miles short of Nāgpur, in the fore direction, when it was transferred to Bengal to do the secondary levelling for the protection of Hardinge Bridge. Akola to Thānegaon forms part of line 114, Dhūlia to Nāgpur, of the new level net. The line follows unmetalled roads through Lākhpuri and Bhātkuli to Amraoti, and thence metalled roads to Thānegaon, via Tivsa and Talegaon.

12. **Bombay–Surat and Surat–Baroda.**—No. 3 Detachment under Mr. A. A. S. Matlub Ahmad carried out levelling in the back direction from Bombay to Surat, which forms part of line 122, Surat to Ratnāgiri, of the new level net. In the middle of January 1935 the detachment left for Cutch to start work there as the Rann can best be crossed in the months of February and March. The line Surat to Baroda which was left to be done after the completion of the work in Cutch, could not be taken up owing to lack of time. The route followed was the same as that of the old precise line 51.

13. **Cutch and Sind.**—The line from Lakhpat in Cutch to Unhia Tār in Sind was done in both directions and from Buhāra in Sind to Unhia Tār and Lakhpat to Nakhtrāna Mota in Cutch in

the back direction only. These lines form part of line 104, Viramgām to Tatta, of the new level net, and were originally started in 1926–27, but both in that year and in the following season the flooded state of the Rann made work impossible.

The line followed the same route as the old precise line 44. Khori Creek was crossed by levelling during low tides over pegs, 3 to 6 feet long, driven in swampy ground and salt beds. The Rann being uninhabited for a length of 38 miles along the route of levelling, special arrangements were made for transport and for dumps of drinking water, fuel and fodder.

14. **Hardinge Bridge levelling.**—In order to prepare a comprehensive scheme to prevent river changes endangering the Hardinge Bridge, the E. B. Railway made an urgent demand for levelling to be done in the area bounded by longitude 88° 30′ on the west and the Jamuna river on the east and between latitudes 23° 30′ and 24° 30′.

Mr. P. C. Sen Gupta, was placed in charge of the work which consisted of secondary levelling by a detachment under Mr. Mohammad Faizul Hasan and double and single tertiary levelling by two double and eight single detachments. The secondary and double tertiary detachments were employed to fix bench marks and *pakka* points for controlling errors in the single tertiary lines running north and south two miles apart over the entire area. Field work was started about the middle of December 1934 and completed at the end of April 1935. Lists, containing heights with descriptions, of 256 bench marks, 1,508 *pakka* points and 15,569 spot heights, and Survey of India Maps on the scale of 1 inch = 1 mile showing the lines of levelling were supplied to the E. B. Railway for the area west of the railway line from Calcutta to Darjeeling at about the end of February 1935, and for the area east of that line at about the middle of June 1935.

15. **Probable errors.**—The probable errors of the high precision and precise lines levelled in 1934–35, 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	151 B Dinājpur-Purnea ...	...	±0·00376
do.	Bagaha-Ghāzīpur ...	...	±0·00336
No. 3 Detachment	122 Bombay-Surat ...	±0·00063	±0·00286
do.	104 Nakhtrāna Mota-Buhāra	±0·00052	±0·00390

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

Line No.	Name of line	Miles completed on main-line	Remarks
104	Viramgām-Tatta ...	102	The whole line is complete.
122	Surat-Ratnāgiri ...	170	Portion Bombay-Ratnāgiri not completed yet.
	Total	272	
	Previously completed ...	8,783	
	Total completed to date	9,055	

In addition to the above, 118 miles have been completed in one direction only. The total mileage of the new level net when complete will be about 15,800 miles.

17. Protected bench marks.—The following bench marks have been added to the list of Primary Protected bench marks published in Geodetic Report Vols. III, VIII and of 1934.

Degree sheet	No. of bench mark	Degree sheet	No. of bench mark
39 H	41 to replace 53 reported destroyed.	53 G	251 (*196*) and not 351 (*196*) as shown in G.R. Vol. VIII.
39 M	11 to replace 8 reported destroyed.	54 H	25 to replace 23 not found.
39 O	87	56 K	32 and not 96 as shown in G.R. Vol. III.
40 D	149 ; 119 ; 146	63 O	100 to replace 59 not traceable.
40 O	77 and not 222 as shown in G.R. Vol. III.	64 O	33 to replace 58 reported destroyed.
41 A	27 (*10*) to replace 14 of G.R. Vol. III, reported destroyed ; 34.	65 K	53 to replace 44 reported destroyed.
41 E	135 ; 142.	72 A	24
41 G	38 and not 32 as shown in G.R. Vol. III.	72 F	14
43 C	6 to replace 5 reported destroyed.	72 G	35 to replace 14 probably destroyed.
44 A	219 (S. B. M., Jhang).	74 B	11 to replace 44 not found.
44 K	35 to replace 44 reported destroyed.	78 D	212 and not 12 as shown in G.R. Vol. III.
45 E	53 to replace 1 destroyed.	79 A	3
46 C	96	94 B	15 to replace 5 not found.
46 D	82 (S. B. M., Navsāri)	94 H	110 and not 10 as shown in G.R. Vol III.
47 A	53 to replace 29 reported destroyed.		

TABLE 1.—*Tabular statement of out-turn of work, season 1934–35.*

Detachments and lines levelled	Months	Distance levelled			Total		Number of stations at which the instruments were set up	Number of bench marks connected		
								Protected Primary		
		Main-line	Extras and branch-lines	Total	Rises	Falls		Rock-cut	Others	Others
		Mls.	*Mls.*	*Mls.*	*feet*	*feet*				
No. 1 Detachment.										
Revision of Part of line 77W (Chittagong-Magwe). Portion Chittagong-Akyab.	Oct. 34 to Jan. 35	259	33	292	5,465	5,594	4,300	...	2	107
Precise Line 151 B (Dinājpur-Purnea).	Jan. to March 35	92	8	100	657	657	1,208	...	3	99
Precise Line (Bagaha-Sironj). Portion Bagaha-Ghāzipur.	March to May 35	163	13	176	939	941	1,704	...	6	146
No. 2 Detachment.										
Part of Line 114 (Dhūlia-Nāgpur). Portion Akola-Thānegaon (Fore).	Oct. to Dec. 34	118	5	123	3,785	2,761	2,064	...	3	159
No. 3 Detachment.										
Part of Line 122 (Surat-Ratnāgiri).* Portion Surat-Bombay (Back).	Oct. 34 to Jan. 35	170	16	186	1,528	1,980	3,160	1	6	211
Part of Line 104 (Viramgām-Tatta).† Portion Nakhtrāna Mota-Buhāra (Back).	Jan. to April 35	140	19	159‡	2,388	2,097	2,340	...	5	48
Hardinge Bridge Levelling.										
Secondary lines.										
(1) Gopālpur-Porādaha	Dec. 34 to Jan. 35	28	10	38	191	184	420	...	...	33
(2) Bheramāra-Meherpur.	Dec. 34 to Jan. 35	74	...	74	554	564	844	...	2	40

(*Continued*)

---

* Relevelled 59 miles.

† Relevelled 15 miles.

‡ Includes 38 miles done in fore direction between Lakhpat and Unhia Tār.

TABLE 1.—*Tabular statement of out-turn of work, season 1934–35—(concld.)*

Detachments and lines levelled	Months	Distance levelled			Total		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*				
Hardinge Bridge Levelling.—(contd).										
(3) Jhenida-Sibrāmpur.	Jan to Feb. 35	46	26	72	491	498	786	...	1	52
(4) Ishurdi-Ishurdi.	Feb. to March 35	144	...	144	989	989	1,610	...	...	107
(5) Nator–Tārās.	March to April 35	31	5	36	316	330	448	...	...	24
Double Tertiary Lines.	Dec. 34 to April 35	311	...	311	...	...	2,538	...	...	132*
Single Tertiary Lines.	Dec. 34 to April 35	3,056	...	3,056	...	...	25,877	...	...	1,376*

* *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 1934-35 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1934-35	
			miles		*feet*	*feet*	*feet*
		At Chittagong on line 77 W.					
58	79 N	S.B.M. ...	0·00	1932-33	0·000	0·000	0·000
57	,,	Culvert ...	0·20	..	+ 1 858	+ 1·862	+0·004
63 (55)	,,	E.B.M. ...	0·76	..	− 0·958	− 0·951	+0·007
61	,,	Masonry pillar ...	2·41	..	−53·999	−53·991	+0·008
64	,,	Graduated pole ...	2·56	..	−53·274	−53·276	−0·002
54	..	Bridge ...	1·78	..	−33·303	−33·275	+0·028
		At Akyab on line 77 W.					
29	84 D	S.B.M. ...	0·00	1932-33	0·000	0·000	0·000
28	..	Prism ...	0·00	,,	− 0·932	− 0·933	−0·001
27	,,	Prism ...	0·00	,,	− 0·904	− 0·905	−0·001
26	..	Iron bolt ...	0·00	..	− 0·614	− 0·614	0·000
25	..	Culvert ...	0·03	,,	+ 4·857	+ 4·851	+0·006
24	..	Step ...	0·04	,,	+ 0·760	+ 0·759	−0·001
23	..	Culvert ...	0·09	,,	+ 2·199	+ 2·196	−0·003
22	..	Magnetic Station ...	0·50	..	− 8·196	− 8·197	−0·001
21	..	Latitude Station ...	0·83	..	− 4·008	− 4·016	−0·008
		At Dinājpur on line 151 B.					
155 (77)	78 C	S.B.M., Dinājpur ...	0·00	1924-25-26	0·000	0·000	0·000
78	..	Step ...	0·25	..	+ 2·895	+ 2·902	+0·007
151	..	Bridge ...	0·69	..	− 0·562	− 0·561	+0·001
		At Purnea on line 151 B.					
177	72 O	S.B.M., Purnea ...	0·00	1934	0·000	0·000	0·000
302	..	Step ...	0·38	..	+ 0·888	+ 0·885	−0·003
13	..	Stone block ...	0 43	..	− 2·562	− 2·557	+0·005
306	..	Bridge ...	2·62	..	− 0·385	− 0·414	−0·029
305	..	Well ...	3·59	..	+ 1·276	+ 1·240	−0·036

(*Continued*)

TABLE 2.— *Check-levelling—(contd.)*

Discrepancies between the old and new heights of bench marks.

Bench marks of the original levelling that were connected for check-levelling			Distance from starting bench mark	Observed height above (+) or below (−) starting bench mark, as determined by			Difference (check − original). The sign + denotes that the height was greater and the sign −, less in 1934-35 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1934-35	
			miles		*feet*	*feet*	*feet*
		At Bagaha on line 71.					
51	72 A	E.B.M., Bagaha ...	0·00	1934	0·000	0·000	0·000
50	,,	Culvert ...	0·46	,,	+11·243	+11·230	−0·013
49	,,	Bridge ...	1·69	,,	+ 8·979	+ 8·976	−0·003
52	,,	Bridge ...	1·36	,,	+12·372	+12·373	+0·001
53	,,	Well ...	0·50	,,	+ 6·190	+ 6·174	−0·016
54	,,	Well ...	2·20	,,	+ 2·354	+ 2·386	+0·032
55	,,	Well ...	2·86	,,	+ 0·351	+ 0·375	+0·024
2	,,	*Shiwāla* ...	3·56	,,	+ 2·165	+ 2·193	+0·028
1	,,	Well ...	3·15	,,	+ 2·135	+ 2·168	+0·033
56	,,	Culvert ...	5·81	,,	− 3·022	− 2·949	+0·073
57	,,	Culvert ...	6·23	,,	− 3·114	− 3·033	+0·081
59	,,	Bridge ...	7·26	,,	− 4·530	− 4·456	+0·074
60	,,	Bridge ...	8·00	,,	− 4·603	− 4·522	+0·081
61	,,	Bridge ...	8·69	,,	− 3·935	− 3·863	+0·072
62	,,	Bridge ...	9·30	,,	− 7·954	− 7·876	+0·078
63	,,	Bridge ..	10·39	,,	− 6·829	− 6·740	+0·089
5	,,	Bakwa T.S. ...	12·38	,,	− 6·269	− 6·220	+0·049
		At Gorakhpur on line 69 A.					
61	63 N	S.B.M., Gorakhpur ...	0·00	1934	0·000	0·000	0·000
60	,,	Flooring ...	0·31	,,	− 3·393	− 3·370	+0·023
11	,,	Flooring ...	0·43	,,	− 1·546	− 1·451	+0·095
59	,,	Step ...	0·53	,,	− 4·510	− 4·540	−0·030
62	,,	Culvert ...	0·58	,,	− 1·582	− 1·575	+0·007
66	,,	Stone ...	1·76	,,	+ 1·425	+ 1·345	−0·080
65	,,	Culvert ...	1·68	,,	− 0·564	− 0·564	0·000
64	,,	Culvert ...	1·41	,,	+ 2·834	+ 2·819	−0·015
67	,,	Flooring ...	1·19	,,	+ 4·275	+ 4·334	+0·059
		At Ghāzīpur on line 69.					
35	63 O	S.B.M., Ghāzīpur ...	0·00	1934	0·000	0·000	0·000
38	,,	Culvert ...	0·50	,,	+ 2·802	+ 2·747	−0·055
41	,,	Step ...	0·79	,,	+ 1·502	+ 1·563	+0·061
43	,,	Step ...	1·91	,,	+ 6·465	+ 6·578	+0·113
44	,,	Step ...	2·08	,,	+ 7·129	+ 7·245	+0·116

(Continued)

TABLE 2.—*Check-levelling*—(*contd.*)

Discrepancies between the old and new heights of bench marks.

Bench marks of the original levelling that were connected for check-levelling			Distance from starting bench mark	Observed height above (+) or below (−) the starting bench mark, as determined by			Difference (check-original). The sign + denotes that the height was greater and the sign −, less in 1934-35 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1934-35	
			miles		*feet*	*feet*	*feet*
		At Nakhtrāna Mota on line 104.					
37	41 E	Interred B.M., Nakhtrāna Mota ...	0·00	1889-90, 1921-24	0·000	0·000	0·000
130	..	Step ...	0·01	,,	+ 2·095	+ 2·088	−0·007
129	..	Rock in situ ...	0·09	,,	+ 3·655	+ 3·651	−0·004
36	..	Platform ...	3·11	1889-90	− 5·506	− 5·520	−0·014
		At Buhāra on line 104.					
4	40 D	E.B.M., Buhāra ...	0·00	1889-90	0·000	0·000	0·000
117	..	Stone pillar ...	6·73	1926-28	+ 5·710	+ 5·741	+0·031
118 (5)	..	Coping bridge ...	7·56	,,	+13·697	+13·741	+0·044
119	..	Moghul Bhin T.S. ...	9·04	,,	+15·851	+15·899	+0·048
120	..	Office veranda ...	10·11	,,	+10·494	+10·532	+0·038
121	..	Veranda of dispensary ...	10·23	,,	+ 9·941	+ 9·985	+0·044
		At Akola on line 114.					
3	55 H	S.B.M., Akola ...	0·00	1909-10	0·000	0·000	0·000
96	..	Culvert ...	0·05	1930-31	+ 1·826	+ 2·036	+0·210
95 (5)	..	Veranda ...	0·09	,,	+ 0·729	+ 0·742	+0·013
93	..	Veranda ..	0·14	,,	+ 0·813	+ 0·822	+0·009
94	..	Step ...	0·23	,,	− 5·922	− 5·918	+0·004
92	..	Step ...	0·34	,,	− 2·284	− 2·282	+0·002
91	..	Step ...	0·36	,,	− 2·414	− 2·413	+0·001

(*Continued*)

TABLE 2.—*Check-levelling*—(*concld.*)

Discrepancies between the old and new heights of bench marks.

Bench marks of the original levelling that were connected for check-levelling			Distance from starting bench mark	Observed height above (+) or below (−) starting bench mark, as determined by			Difference (check − original). The sign + denotes that the height was greater and the sign −, less in 1934-35 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1934-35	
			miles		*feet*	*feet*	*feet*
		At Bombay on line 122.					
2 (1)	47 B	S.B.M. (Type P) ...	0·00	1906-07	0·000	0·000	0·000
5 (88)	,,	Step ...	0·25	,,	− 3·540	− 3·532	+0 008
6 (87)	,,	Step ...	0·26	,,	− 3·458	− 3·449	+0·009
(84)	,,	Step ...	0·68	1914-15	+ 2·584	+ 2·587	+0·003
(129)	,,	Newel ...	0·90	,,	− 2·977	− 2·963	+0·014
9 (130)	,,	Stone ...	0·95	1906-07	− 6·035	− 6·023	+0·012
(85)	,,	Stone ...	1·49	1914-15	− 7·171	− 7·168	+0·003
(90)	,,	Plinth ...	2·65	,,	− 3·352	− 3·349	+0·003
(91)	,,	Step ...	3·06	,,	− 0·008	− 0·014	−0·006
(92)	,,	Step ...	3·49	,,	+ 5·893	+ 5·887	−0·006
23 (93)	,,	Bed-rock ...	3·74	1906-07	+13·816	+13·814	−0·002
(94)	,,	Interred B.M. ...	3·76	1914-15	+12·205	+12·217	+0·012
		At Surat on line 122.					
70	46 C	S.B.M., Surat ...	0·00	1909-10	0·000	0·0 0	0·000
71 (*69*)	,,	Step ...	0·15	1921-22, 1926-27	− 8·831	− 8·840	−0·009
68	,,	Flooring ...	0·23	1875-78	− 3·665	− 3·687	0·022
67	,,	Flooring ...	0·50	,,	− 2·236	− 2·257	−0·021
72 (*66*)	,,	Plinth ...	0·69	1921-22, 1926-27	+ 2·508	+ 2·484	−0·024
73 (*46*)	,,	Step ...	1·14	,,	− 3·098	− 3·116	−0·018
65	,,	Veranda ...	1·16	1875-78	− 1·339	− 1·358	−0·019
74 (*45*)	,,	Step ...	1·84	1921-22, 1926-27	− 1·563	− 1·524	+0·039
75 (*63*)	,,	Coping ...	2·01	,,	+15·471	+15·489	+0·018
76 (*64*)	,,	Interred B.M. ...	2·03	,,	+13·977	+13·926	−0·051

NOTE:—Numbers in brackets are those given in the Addendum to Levelling Pamphlet for sheet 47, Island of Bombay.

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 1934-35 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1934-35	
			miles		*feet*	*feet*	*feet*
				Revision of Line 151B (Dinājpur–Purnea).			
155 (77)	78 C	S.B.M., Dinājpur ..	0·00	1924-26	0·000	0·000	0·000
76	..	Flooring ...	0·14	..	+ 5·226	+ 5·235	+0·009
152	,,	Flooring ...	0·26	..	+ 5·409	+ 5·420	+0·011
153	,,	Step ...	0·41	..	− 1·212	− 1·209	+0·003
156 (*41*)	,,	Bridge ...	0·54	,,	+ 0·478	+ 0·498	+0·020
154	,,	Bridge ...	3·58	,,	− 6·340	− 6·312	+0·028
159 (*46*)	,,	Bridge ...	4·08	,,	− 6·296	− 6·260	+0·036
47	..	Bridge .	4·49	1909-10	− 4·623	− 4·547	+0·076
48	,,	Bridge ...	6·03	,,	− 0·970	− 1·070	−0·100
51	,,	Rāmchandpur T.S. ...	10·05	,,	− 4·560	− 4·627	−0·067
53	,,	E.B.M., Rādhikāpur	12·89	,,	− 2·211	− 2·193	+0·018
54	..	Bridge ...	13·26	..	− 1·884	− 1·739	+0·145
56	..	Bridge ...	15·14	,,	− 3·705	− 3·509	+0·196
57	..	Bridge ...	16·96	,,	+ 4·331	+ 4·544	+0·213
58	..	Bridge ...	18·34	..	+ 4·201	+ 4·469	+0·268
60	,,	E.B.M., Kāliaganj ...	20·04	,,	+ 6·794	+ 7·012	+0·218
61	,,	Bridge ...	21·16	,,	+ 4·171	+ 4·430	+0·259
62	..	Bridge ...	23·10	,,	+ 1·970	+ 2·295	+0·325
63	..	Bridge ...	23·94	,,	+ 2·361	+ 2·693	+0·332
64	..	Bridge ...	25·30	,,	− 2·113	− 1·778	+0·335
66	,,	Bridge ...	29·53	,,	− 2·906	− 2·556	+0·350
67	..	Bridge ...	31·29	,,	− 6·915	− 6·515	+0·400
68	..	Bridge ...	32·43	..	− 8·029	− 7·664	+0·365
69	..	E.B.M.. Raiganj ..	32·94	,,	− 6·128	− 5·811	+0·317
70	..	Bridge ...	33·80	,,	− 3·102	− 3·580	−0·478
72	..	Bridge ...	37·00	..	− 8·791	− 8·386	+0·405
73	..	E.B.M., Kachna ...	39·54	,,	− 6·219	− 6·097	+0·122
75	,,	Bridge ...	41·05	..	− 5·938	− 5·513	+0·425
129	72 O	Bridge ...	41·80	1899-00	− 6·024	− 5·842	+0·18’
128	..	Bridge ...	44·19	,,	− 2·746	− 1·568	+1·178
127	..	E.B.M.. Bārsoi ...	46·24	..	− 4·586	− 4·549	+0·037
132	,,	Bridge ...	48·59	..	− 1·591	− 0·941	+0·650
133	,,	Bridge ...	49 74	,,	− 7·209	− 7·615	−0·406
135	..	Bridge ...	51 99	,,	− 3·688	− 2·987	+0·701
139	..	Bridge ...	56·50	,,	− 5·641	− 5·346	+0 295
140	..	Bridge ...	57·78	..	− 7·713	− 7·480	+0·233
144	,,	Bridge ...	60 76	..	− 7·238	− 5·811	+1·427
146	..	Bridge ...	63·65	..	− 8·190	− 7·913	+0·277
147	..	Bridge ...	65·85	,,	− 9·761	− 8·581	+1·180

(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 1934-35 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1934-35	
			miles		*feet*	*feet*	*feet*
Revision of Line 151B (*Dinājpur–Purnea*)—(*concld.*)							
192 (*150*)	72 O	E.B.M., Katihār	70·58	1920-21	− 8·958	− 8·550	+0·408
193 (*160*)	,,	Bridge	71·64	,,	− 9·543	− 9·126	+0·417
194 (*161*)	,,	Bridge	74·40	,,	− 6·191	− 5·712	+0·479
162	,,	Bridge	76·39	,,	− 4·637	− 5·099	−0·462
195 (*163*)	,,	Bridge	78·58	,,	− 1·299	− 0·898	+0·401
164	,,	E.B.M., Rautāra	79·60	,,	+ 1·860	+ 2·265	+0·405
165	,,	Bridge	80·74	,,	+ 1·461	+ 0·368	−1·093
166	,,	Bridge	83·71	,,	+ 5·254	+ 5·636	+0·382
167	,,	Bridge	85·76	,,	+ 7·459	+ 6·841	−0·618
168	,,	E.B.M., Purnea	88·31	,,	+11·919	+12·192	+0·273
169	,,	Bridge	88·66	,,	+11·370	+11·468	+0·098
177	,,	S.B.M., Purnea	91·66	1930-31	+ 7·617	+ 7·624	+0·007
Revision of old lines 71 and 69, Portion Bagaha–Ghāzīpur.							
51	72 A	E.B.M., Bagaha	0·00	1920-21	0·000	0·000	0·000
52	,,	Bridge	1·36	,,	+12·383	+12·375	−0·008
53	,,	Well	0·50	1934	+ 6·190	+ 6·175	−0·015
54	,,	Well	2·20	,,	+ 2·354	+ 2·386	+0·032
55	,,	Well	2·86	,,	+ 0·351	+ 0·375	+0·024
2	,,	*Shiwāla*	3·56	1870-72	+ 2·367	+ 2·193	−0·174
1	,,	Well	3·15	,,	+ 2·321	+ 2·168	−0·153
56	,,	Culvert	5·81	1934	− 3·022	− 2·950	+0·072
57	,,	Culvert	6·23	,,	− 3·114	− 3·034	+0·080
59	,,	Bridge	7·26	,,	− 4·530	− 4·457	+0·073
60	,,	Bridge	8·00	,,	− 4·603	− 4·523	+0·080
61	,,	Bridge	8·69	,,	− 3·935	− 3·864	+0·071
62	,,	Bridge	9·30	,,	− 7·954	− 7·878	+0·076
63	,,	Bridge	10·39	,,	− 6·829	− 6·742	+0·087
5	,,	Bakwa T.S.	12·38	1870-72	− 6·089	− 6·222	−0·133
67	63 N	Step	68·34	1869-70	−31·081	−31·442	−0·361
64	,,	Culvert	68·51	,,	−32·522	−32·957	−0·435
65	,,	Culvert	68·83	,,	−35·920	−36·341	−0·421
66	,,	Stone prism	68·91	,,	−33·931	−34·432	−0·501
62	,,	Culvert	68·95	,,	−36·938	−37·352	−0·414
61	,,	S.B.M., Gorakhpur	69·53	,,	−35·356	−35·777	−0·421
60	,,	Veranda	69·84	,,	−38·749	−39·148	−0·399
11	,,	Step	69·95	,,	−36·902	−37·229	−0·327

(*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 1934-35 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1934-35	
			miles		*feet*	*feet*	*feet*
Revision of old lines 71 and 69, Portion Bagaha-Ghāzīpur—(*concld.*)							
59	63 N	Step	70·05	1869-70	− 39·866	− 40·319	−0·453
35	63 O	S.B.M., Ghāzīpur	160·71	„	− 72·162	− 72·741	−0·579
38	„	Culvert	161·21	„	− 69·360	− 69·994	−0·634
41	„	Step	161·50	„	− 70·660	− 71·178	−0·518
43	„	Step	162·63	„	− 65·697	− 66·162	−0·465
44	„	Step	162·79	„	− 65·033	− 65·495	−0·462
(*Surat to Bombay*) *old line 51, new 122.*							
70	46 C	S.B.M., Surat	0·00	1909-10	0·000	0·000	0·000
16	46 D	E.B.M., Belimora	31·85	1875-78	− 8·895	− 9·225	−0·330
25	„	Bridge	38·74	„	+ 3·567	+ 4·727	+1·160
32	„	Parnera H.S.	47·75	„	+ 572·881	+ 572·409	−0·472
37	„	E.B.M., Pārdi	52·48	„	+ 5·032	+ 4·586	−0·446
46	„	Coping	62·10	„	+ 46·822	+ 46·423	−0·399
48	„	E.B.M., Damān	62·15	„	+ 45·582	+ 45·159	−0·423
45	„	Interred B.M.	68·73	„	− 16·923	− 17·213	−0·290
55	„	E.B.M., Bhilād	69·08	„	+ 60·895	+ 60·174	−0·721
53	47 A	E.B.M., Borivli	148·08	„	+ 7·863	+ 7·292	−0·571
(12)	47 B	Plinth	167·81	1914-15	− 25·605	− 26·247	−0·642
(11)	„	Plinth	168·01	„	− 24·518	− 25·124	−0·606
(9)	„	Step	168·24	„	− 25·603	− 26·209	−0·606
(10)	„	E.B.M., Bombay	168·29	„	− 26·612	− 27·221	−0·609
(8)	„	Plinth	168·69	„	− 24·276	− 24·977	−0·701
(7)	„	Plinth	169·14	„	− 23·542	− 24·134	−0·592
(6)	„	Step	169·47	„	− 27·027	− 27·625	−0·598
(4)	„	Plinth	169·59	„	− 25·826	− 26·422	−0·596
3 (3)	„	Step	169·78	1906-07	− 23·288	− 23·896	−0·608
4 (2)	„	Step	169·78	„	− 23·254	− 23·856	−0·602
2 (1)	„	S.B.M., Bombay	169·83	„	− 21·115	− 21·723	−0·608

NOTE:—Numbers in brackets are those given in the Addendum to Levelling Pamphlet for sheet 47, Island of Bombay.

(*Continued*)

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

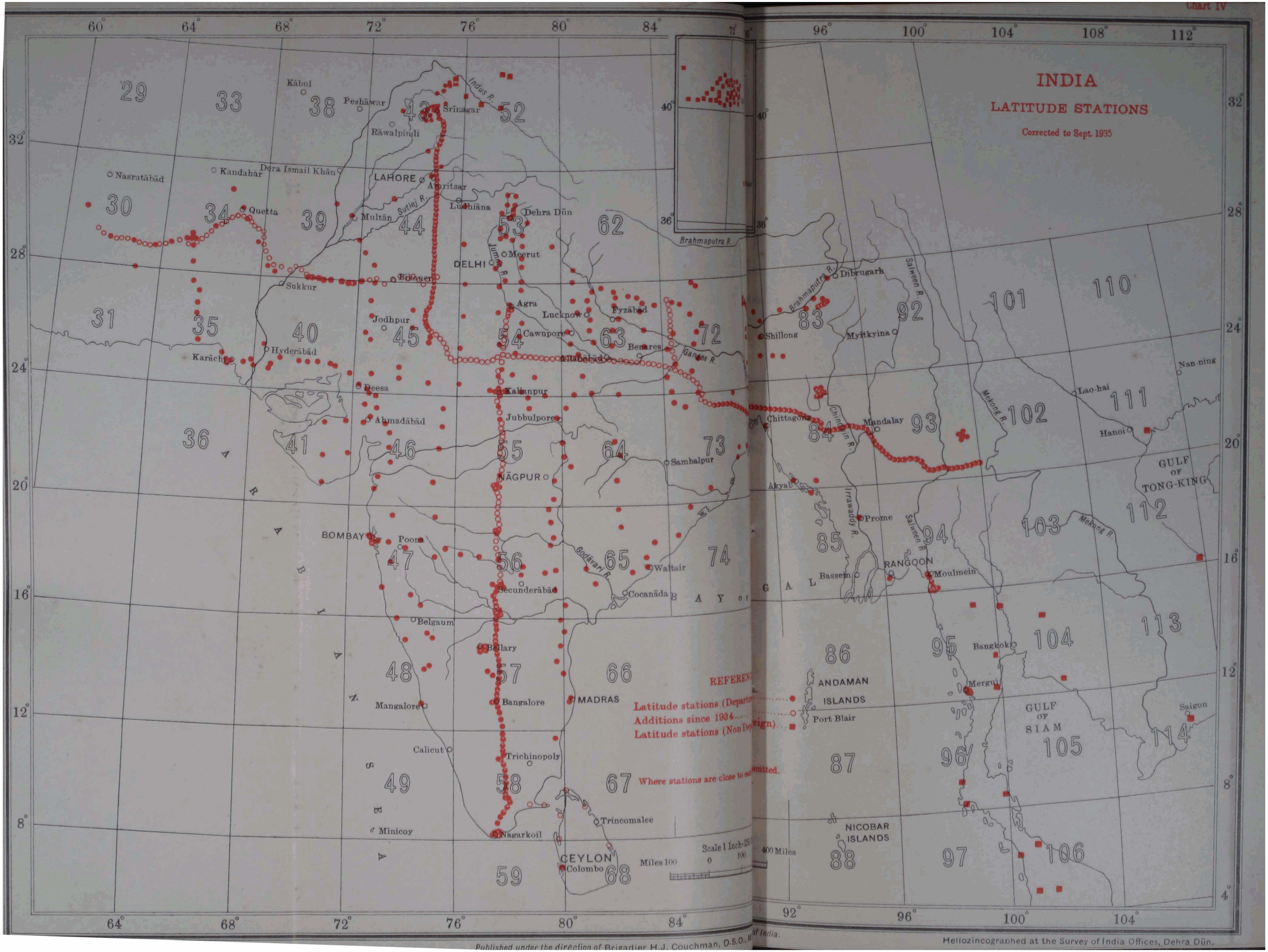
Discrepancies between the old and new heights of bench marks.

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 1934-35 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1934-35	
			miles		*feet*	*feet*	*feet*
(*Nakhtrāna Mota to Buhāra*) *old line 44, new 104.*							
37	41 E	Interred B.M., Nakhtrāna Mota ...	0·00	1889-90	0·000	0·000	0·000
131	,,	Rock ...	1·75	1921-22, 1923-24	+ 53·475	+ 53·472	−0·003
39	,,	Platform ...	3·49	1889-90	+ 72·384	+ 72·420	+0·036
40	,,	I.B.M., Mathal ...	7·48	,,	−103·546	−103·516	+0·030
43	,,	I.B M., Vigori ...	17·04	,,	−140·130	−140·182	−0·052
1	41 A	I.B.M., Mātānomadh	29·24	,,	−108·797	−108·837	−0·040
2	,,	Plinth ...	29·25	,,	−106·528	−106·559	−0·031
4	,,	Stone pillar ...	29·65	,,	− 67·535	− 67·566	−0·031
6	,,	Platform ...	37·78	,,	−102·172	−102·176	−0·004
8	,,	Step ...	51·46	,,	−266·441	−266·350	+0·091
9	,,	Step ...	53·14	,,	−358·352	−358·360	−0·008
10	,,	I.B.M., Lakhpat ...	53·48	,,	−360·699	−360·670	+0·029
11	,,	Lakhpat T.S. ...	54·03	,,	−276·751	−276·599	+0·152
4	40 D	E.B.M., Buhāra ...	102·33	,,	−400·368	−400·230	+0 138

TABLE 4.—*List of triangulation stations connected by spirit-levelling, season 1934–35.*

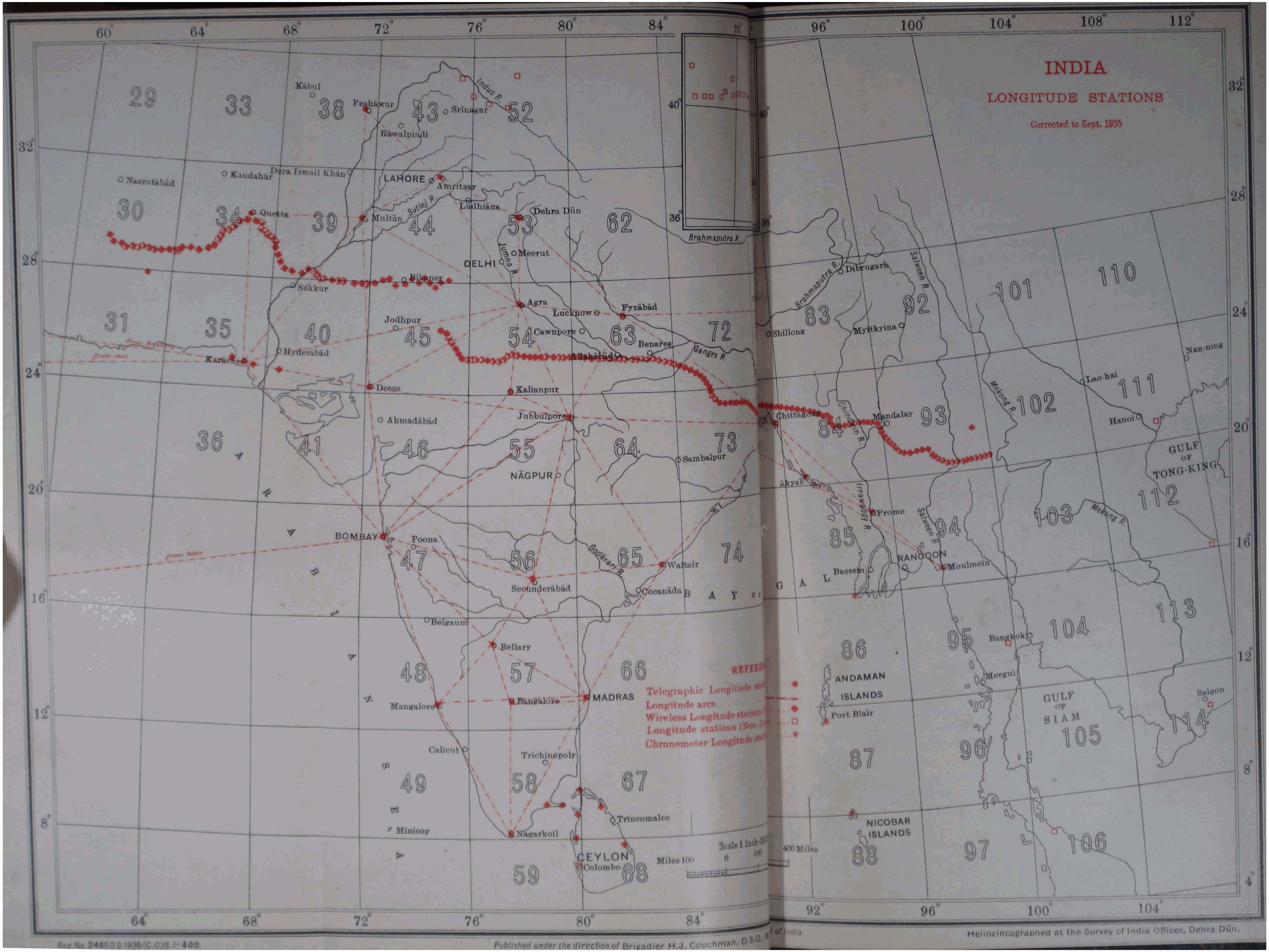
Name of station	Height above mean sea-level		Difference (Trian.—Lev.)	Remarks
	Spirit-levelling	Triangulation		
	feet	*feet*	*feet*	
	Singi Meridional Series			
Surat Pendulum Station Lat. 21° 10′ 5″ Long. 72 48 5	29·562	30	0	
	Bombay Island Series			
Bombay, Colāba s. Lat. 18° 53′ 48″·94 Long. 72 48 48·55	33·879	29	−5	
	Cutch Coast Series			
Hāthria H.S. Lat. 23° 27′ 14″·85 Long. 69 2 45·83	691·131	693	+2	Ground level mark.
Saiyid Ali T.S. Lat. 23° 56′ 25″·77 Long. 68 40 15·16	5·695	6	0	Ground level mark.
Guni T.S. Lat. 24° 2′ 9″·30 Long. 68 33 2·82	5·499	6	+1	

Chart IV



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.



Reg No 2480 D.D. 1936 (C.O.)S.I.-400.
Published under the direction of Brigadier H.J. Couchman, D.S.O., M of India.
Heliozincographed at the Survey of India Offices, Dehra Dūn.

CHAPTER III

DEVIATION OF THE VERTICAL

BY CAPTAIN G. BOMFORD, R.E.

18. Summary.—Both components of the deviation of the vertical were measured at 107 stations, in Baluchistān and between Orissa and Rājputāna. The observations complete the main east-to-west geoidal section across India and Burma.

The meridional component of the deviation was measured at 34 stations along a line from near Hyderābād (Deccan) to Agra, completing the north-to-south geoidal section. This component was also measured at 11 stations in Bihār.

All the observations described above, are tabulated in Table 2 (pages 32 to 45) which constitutes the fifth addendum to the list of deflection stations included in the Supplement to Geodetic Report Vol. VI.

The programme for 1935–36 includes east-to-west sections from Bombay to Waltair, and from Mangalore to Madras.

19. Baluchistan.—The instruments and system of work were the same as those used in the two previous years (see Geodetic Report 1933, pages 16 and 17, and 1934, pages 68 and 69), except that no transit telescope was carried. Observations were made with the astrolabe only, and personal equation was determined by observations at Dehra Dūn immediately before and after the field work. Permanent motor transport was employed. This made it possible to double the rate of work of previous years, and to reduce the strength of the detachment to the officer in charge, 6 inferior servants, two drivers and two cleaners, and generally two men for local escort. The transport used was two 30-cwt. four-wheeled lorries.

The detachment under Captain G. Bomford, left Dehra Dūn on 15th Oct., and started work at Sibi. They worked westwards and observed 27 stations up to the Irānian frontier by 13th Nov., when they returned to Sibi, and by 2nd Dec. completed the remaining 12 stations to Reti where the section is continued eastwards by Major Glennie's observations of 1930–31. The detachment then returned to Dehra Dūn, whence Mr. R. B. Mathur took it to Orissa (see para 20).

The weather was fine throughout and only two nights were lost on account of cloud. Wind caused some annoyance, but this was minimized by drawing up motor lorries on the windward side of the observatory. The Rugby 09.55 and 17.55 G.M.T. wireless time signals were heard without difficulty whenever required.

West of Sibi geodetic position was obtained by resection from existing data, but south and east of Sibi resection was seldom possible and the observatory had to be placed in the immediate vicinity of a trigonometrical station.

20. Orissa to Rajputana.—Mr. R. B. Mathur, working on the system described in para 19, left Dehra Dūn in two motor lorries on 14th Dec., and started work near Rānchi, where he had ceased work the previous spring. By 18th Jan. he had observed at 25 stations to near Allahābād, when he visited the old longitude station at Fyzābād to check his personal equation. He then observed at 32 more stations to near Ajmer where he connected with his north-and-south section of 1930–31 on 8th March, and finally observed at 11 more stations along latitude 28° connecting this section with the west end of Major Glennie's 1930–31 work near Bīkaner. The detachment ceased work in the field on 5th April.

The weather was generally good and only seven nights were lost on account of cloud. Geodetic positions were generally obtained by resection. The Rugby 09.55 and 17.55 wireless signals were heard without difficulty.

21. Hyderabad to Agra.—Observations were made with the small Zenith Telescope on the same system, and with a similar detachment, as in the previous year (see Geodetic Report 1934, pages 72 and 73). The detachment, under Computer J. B. Mathur, left Dehra Dūn on 10th Oct., and started work near Hyderābād, where the previous field season had been closed. Seven stations had been completed when J. B. Mathur fell sick with typhoid. He was replaced by Mr. B. L. Gulatee, who observed 27 stations up to near Agra between 9th Dec. and 25th Jan. Computer J. B. Mathur had by then recovered, and he observed at the 11 stations in Bihār. These Bihār latitude stations were spaced along the west side of the Hurīlāong Meridional series starting from Bājra T.S. about 10 miles WNW. of Rāmnagar near the Nepāl frontier, and ending at Durgādi T.S. near Bikrāmganj railway station.

This detachment was not provided with permanent motor transport. It was sometimes possible to use motor lorries for a few days at a time, but country carts, generally four in number, had to be employed. Geodetic position was obtained by placing the observatory in the immediate vicinity of a trigonometrical station or intersected point. The weather was generally good, and only two nights were lost on account of cloud.

22. Personal equation.—Captain Bomford's personal equation was obtained by series of observations at Dehra Dūn before and after taking the field, when the following corrections were found necessary :—

Oct.	3	$+0^{s}\cdot 08$	Dec.	5	$+0^{s}\cdot 09$
	5	$\cdot 03$		6	$\cdot 12$
	7	$\cdot 11$		7	$\cdot 21$
	8	$\cdot 09$		8	$\cdot 16$
Mean		$+0^{s}\cdot 08$	Mean		$+0^{s}\cdot 14$

For the correction of field stations, the correction for personal equation was assumed to have changed progressively from $0^{s}\cdot 08$ to $0^{s}\cdot 14$.

Mr. R. B. Mathur's personal equation was obtained by two series of observations at Dehra Dūn and also by one at Fyzābād in the middle of his work. Fyzābād is a longitude station of the old telegraphic longitude net. During the observations of the arcs of this net the observers changed ends, and their work is considered to have been reliable. The corrections found necessary were :—

Dec.	5	$+0^{s}\cdot 02$	Jan.	22	$+0^{s}\cdot 03$	April	15	$-0^{s}\cdot 05$
	6	$\cdot 06$		23	$\cdot 06$		16	$\cdot 06$
	7	$\cdot 15$		24	$-0\cdot 02$		17	$\cdot 03$
	8	$\cdot 06$					18	$\cdot 03$
Mean		$+0^{s}\cdot 07$	Mean		$+0^{s}\cdot 02$	Mean		$-0^{s}\cdot 04$

For the correction of field stations, the correction was assumed to have changed progressively between the three values given above.

Both Captain Bomford and Mr. R. B. Mathur observed at Dehra Dūn on Dec. 5, 6, 7 and 8, the one shortly after the other, using the same clocks and wireless signals. Their differences on the four days were $0^{s}\cdot 07$, $0^{s}\cdot 06$, $0^{s}\cdot 06$, $0^{s}\cdot 08$, which indicate that although the observers have considerable personal equations, most of the random error (e.g., the very high correction on 7th Dec.) is due to instrumental or atmospheric causes.

23. **Probable errors.**—In the east-to-west section the mean probable error of the determination of latitude by the astrolabe at each station was $\pm 0''\cdot 35$; of local time $\pm 0^{s}\cdot 019$; and of the time-keeping of the "mean clock" between wireless time and star time $\pm 0^{s}\cdot 019$.

As in previous years, the probable error of a value of personal equation determined by two series of observations at Dehra Dūn (or Fyzābād) cannot be considered to be less than $0^{s}\cdot 02$. The probable error resulting from personal equation in the Baluchistān part of the section (500 miles of easting) will then be 3·4 feet: in the part between Orissa and Allahābād (250 miles) 1·7 feet: and between Allahābād and Bīkaner (600 miles) 4·0 feet. These figures require slight increase to allow for the other sources of error to (say) 4, 2 and 5 feet respectively. The probable errors in the different parts of the section are independent, and if these three probable errors are combined with those of the Bengal and Burma sections of 1933 and 1934, the total probable error of the relative geoidal height of the two ends of the section 2,500 miles long is ± 9 feet.

The average probable error of the Zenith Telescope latitudes in the meridional section was ± 0″·30. In this work there is no personal equation, and the relative geoidal height is determined with much higher accuracy than in the east-to-west line. The largest source of error is the scale error of the primary triangulation.

24. **Laplace stations.**—In Baluchistān two-night programmes were observed at Tozghi (Lat. 28° 50′, Long. 62° 17′), and at Vijnot (Lat. 28° 02′, Long. 69° 50′), trigonometrical stations at which azimuth had previously been observed, in order to form Laplace stations.

At Tozghi the deflection deduced from the azimuth observation is + 16″·3*. The deflection deduced from the longitude observation is:—1st day + 13″·0, 2nd day + 12″·0, mean 12″·5. The discrepancy of 3″·8 suggests an accumulated error in the triangulation of 2″·1. These figures are, of course, with reference to Everest's spheroid.

At Vijnot the deflection deduced from azimuth is + 7″·3. From longitude it is:—1st day + 9″·1, 2nd day + 10″·2, mean 9″·6. The discrepency of 2″·3 suggests an azimuth error of 1″·2 in the triangulation.

Tozghi is 350 miles from Quetta, the nearest existing Laplace station, and Vijnot is 300 miles from Karāchi, so the suggested azimuth errors indicate a satisfactory degree of accuracy in the triangulation.

Between Orissa and Rājputāna longitude stations were observed within 20 or 30 miles of several old azimuth stations. The resulting Laplace equations are liable to error on account of the real difference of deflection at the azimuth and longitude stations, but Table 1 shows the azimuth errors which are deduced if this possible difference is ignored. Where several longitude stations are equally close to the azimuth station, they have been meaned together. The deduced azimuth errors are all satisfactorily small. The non-identity of the stations makes them inapplicable as corrections to the triangulation, but their small magnitude serves to show that the triangulation is of good quality.

---

* This figure, 12″·9 + 1″·9 $\cot \phi$, is that obtained from Professional Paper No. 16 after applying to the geodetic azimuths corrections deduced from old Laplace stations. Similarly at Vijnot.

TABLE 1.—*Laplace equations.*

Longitude station	Azimuth station			Distance between 1 & 2	P.V. deflection (Everest) by longitude at 1	Mean	P.V. deflection* by azimuth at 2	Deduced error in triangulation
1	2			3	4	5	6	7
		Lat.	Long.	*miles*	"	"	"	"
Khaira Bind Dehri-on-Sone ...	Mednipur	25° 05′	84° 22′	20	−7·3 −1·7	−4·5	−7·5	+1·4
Rastogi Tālāb Chakia ... Saukhara	Hirdepur	25 24	83 14	25	−1·3 −2·0 −0·4	−1·2	−1·5	+0·1
Bagrehi Bargarh ...	Pabhosa	25 21	81 19	15	−2·1 −0·7	−1·4	−1·3	0·0
Pāli Lakni ... Amola	Kesri Pahārgarh	25 47 24 56	77 41 77 42	30	+2·4 +4·4 +5·4	+4·1	−2·7 +4·9	+1·4
Mendi ...	Kānkra	25 38	76 07	25	+2·3	...	+3·8	−0·7
Shokli ...	Rājgarh	26 18	74 36	15	+8·1	...	+2·2	+2·9
Gugla Bhar ...	Garinda	27 56	75 01	14	+2·1	...	+5·8	−2·0

* Corrected for the known azimuth errors at old Laplace stations, see Professional Paper No. 16, Table XCIV.

25. **The geoid.**—Between Orissa and Bīkaner the form of the geoid now obtained agrees fairly well with that previously published, except that the rise under the line of the Arāvalli Hills is now more strongly marked than before. In Baluchistān † on the other hand, the rise from east to west is much less than was shown in Geodetic Report Vol. VIII, and in the meridional section along the Great Arc there is also a considerable change between latitudes 15° and 24°, where the rise from south to north is now found to be 25 feet less than before.

Charts VI and VII show the stations observed in the east-to-west section this season, and the detailed geoidal contours which result from them.

The completion of the two new geoidal sections across India makes it desirable to redraw the geoidal charts. The existing charts are based on that drawn relative to Everest's spheroid by Dr. de Graaff Hunter in Geodetic Report Vol. I. This was afterwards converted to the International spheroid by subtraction of the separation

---

† Preliminary results of the 1934-35 work in Baluchistān were available before Geodetic Report 1934 was printed off, and were included in it.

between the two spheroids, and later information was provisionally included in Geodetic Report 1934. In order to incorporate the new information more satisfactorily, the geoid has now been drawn afresh, relative to the International spheroid direct. Chart VIII shows the lines along which deflection stations lie, and along which integration has been carried out to show the form of the geoid. The thick red lines are those along which integration error is negligible, the broken red lines are those in which data are very scanty (intervals of 100 miles or more), or which depend on azimuth stations: and the unbroken thin red lines show meridional sections of fair reliability with station intervals of about 40 or 80 miles. Chart VIII also shows the closing errors, in feet, obtained by clockwise integration round the circuits. Apart from the circuit with an error of + 36 feet in sheet 72, whose error can confidently be attributed to some self-evidently inaccurate azimuth deductions along its northern side, the closures north of latitude 24° are satisfactory, while those south of latitude 24° are generally bad. It is thought that the bad closing errors of these circuits result from the weak azimuth deductions which give the sections between Bombay and Waltair, and between Mangalore and Madras. Accurate sections are being observed along these lines in 1935–36, but in the mean time geoidal contours south of (say) latitude 21° are very uncertain, except for the meridional section along longitude 78°.

Chart IX shows the geoidal contours which result. When distributing circuit closing errors, no correction has been apportioned to the two main section lines, and the errors have been distributed among the weaker lines as has seemed most reasonable in each case.

Chart X shows the compensated geoid, derived from the geoid by subtracting the geoidal rise caused by the actual topography (assumed to be of normal density) and its Hayford compensation (see Geodetic Report Vol. V, Chapter IV).

The ideal way of drawing the compensated geoid is to obtain it direct by integrating the Hayford deflection anomalies, but it has not been found possible to compute the Hayford deflections at all the very numerous stations observed, and the method which has been used instead gives good results if the points at which the separation is calculated are reasonably chosen. As a check on the method, the height of the compensated geoid at Quetta and Nushki above that at Sibi was calculated by both methods, with the results shown below :—

	Height of geoid above Sibi (feet)	Height of compensated geoid above Sibi (feet)	
		(a) By integration of Hayford anomalies	(b) Deduced from the geoid
At Quetta ...	28·5	9·8	10·5
At Nushki ...	23·9	11·6	11·4

THE GEOID IN BALUCHISTĀN

Referred to the International Spheroid

Chart VI

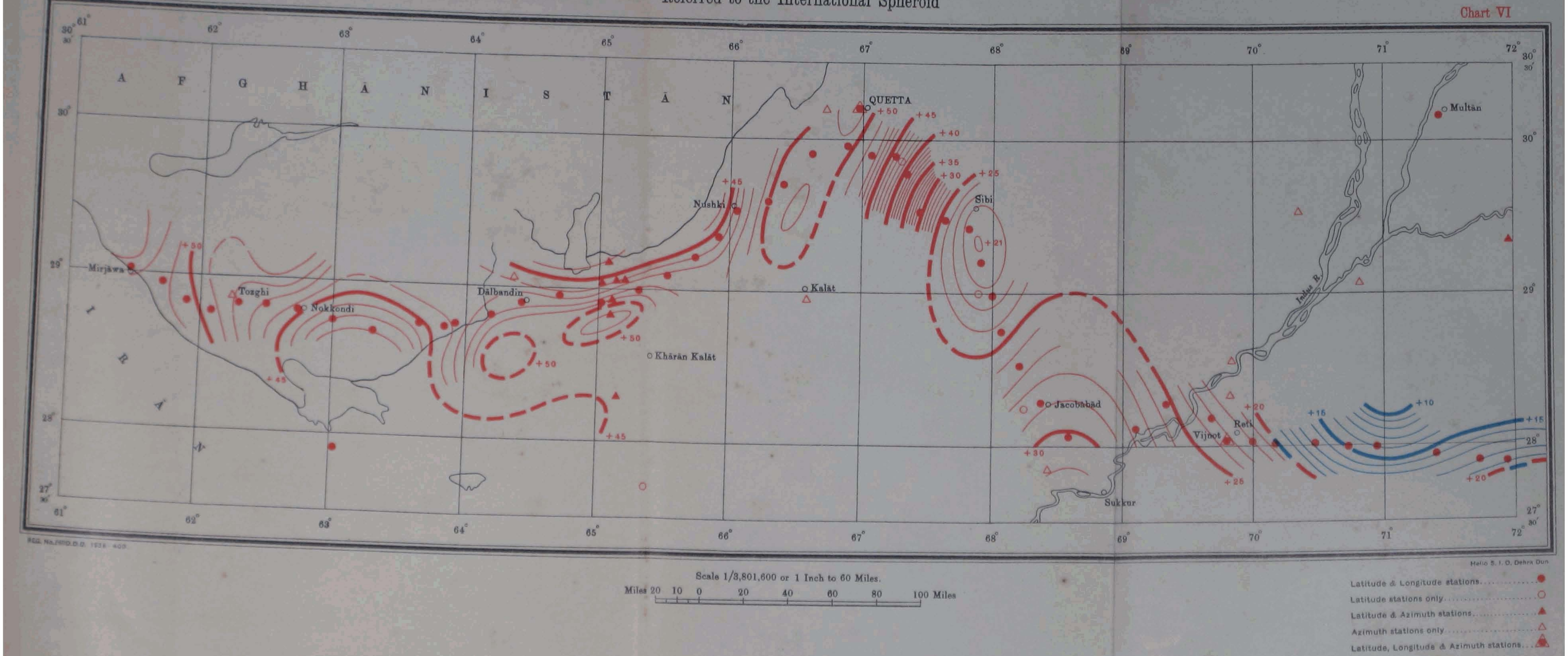
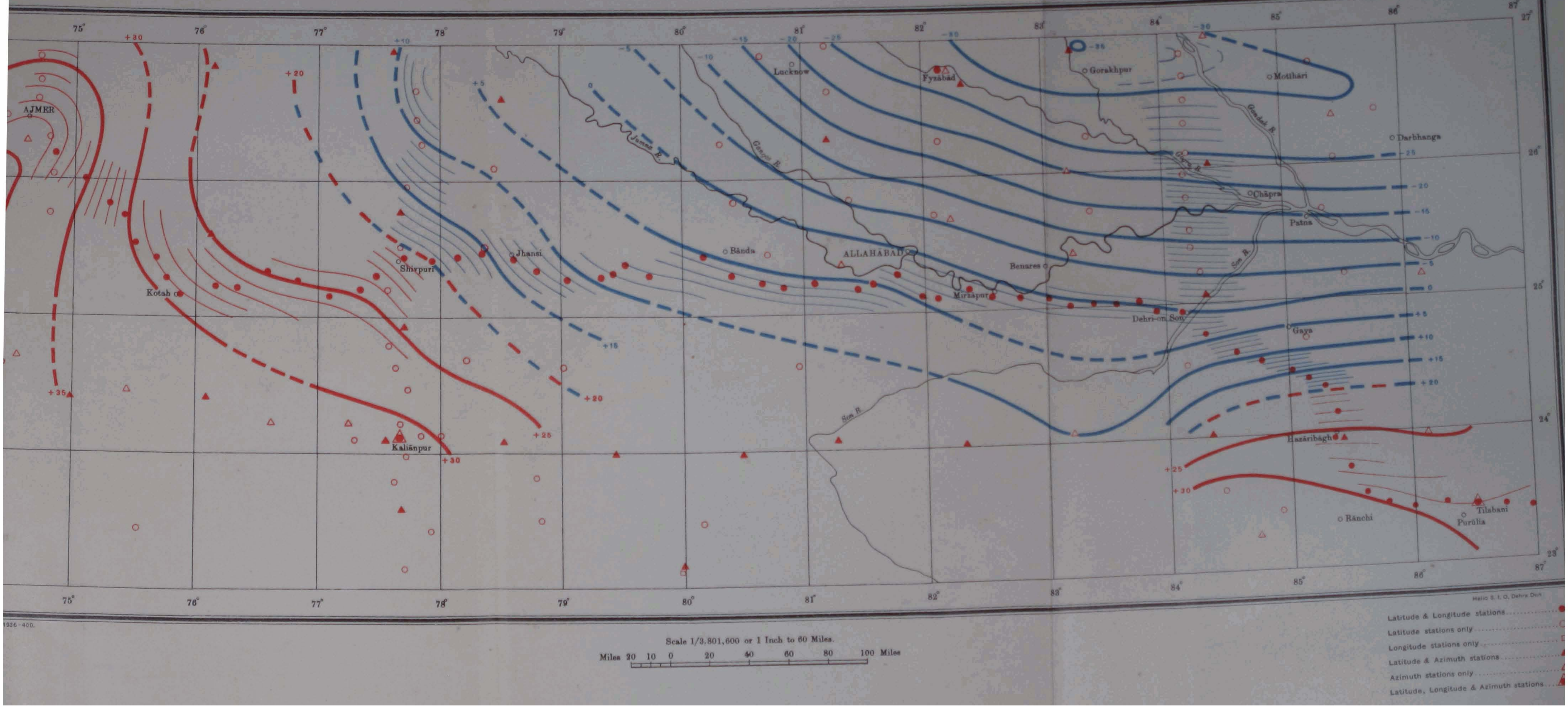
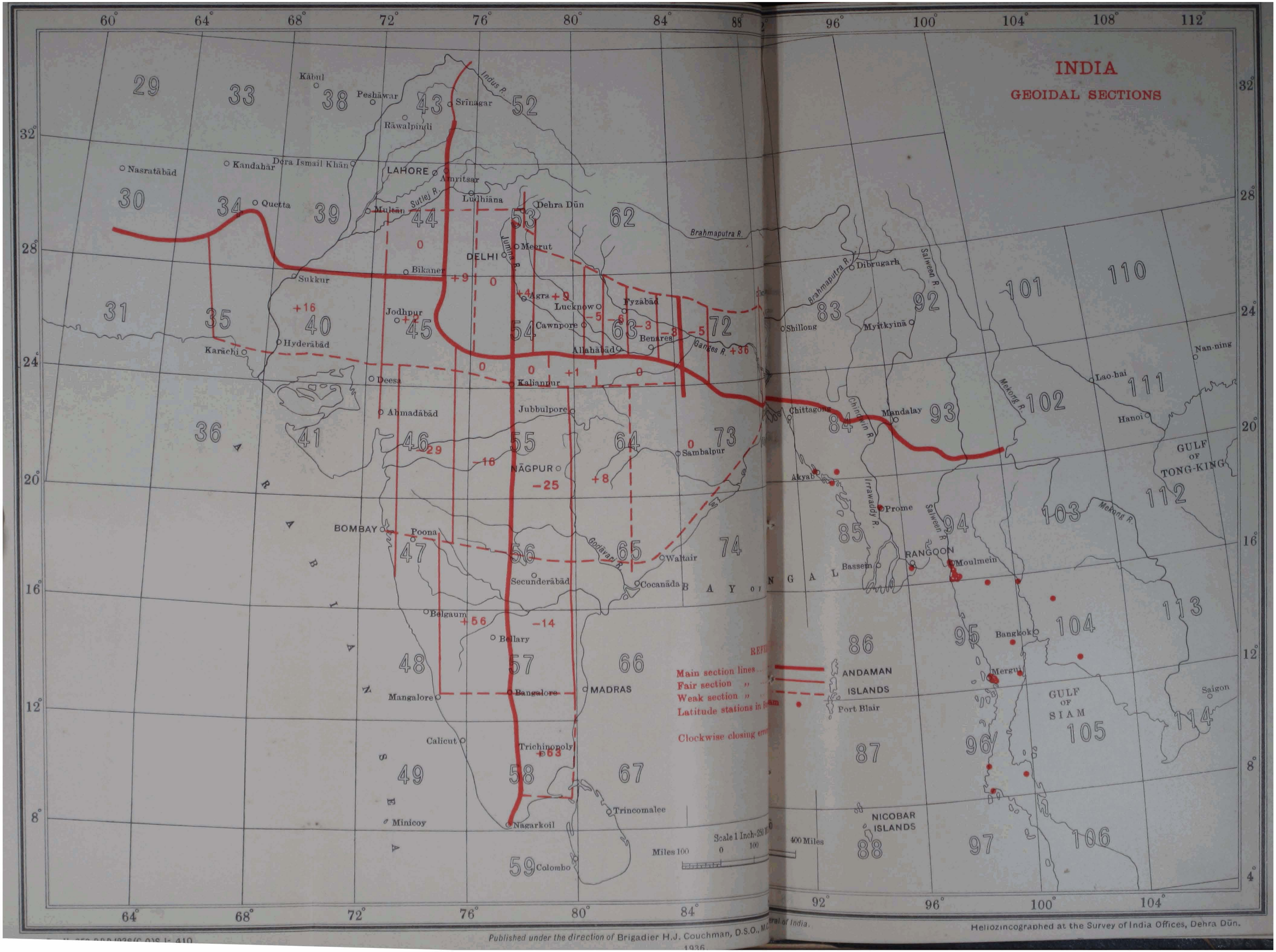


Chart VII

THE GEOID IN CENTRAL INDIA AND BIHĀR

Referred to the International Spheroid





Published under the direction of Brigadier H.J. Couchman, D.S.O., M.C.
eral of India.
1936

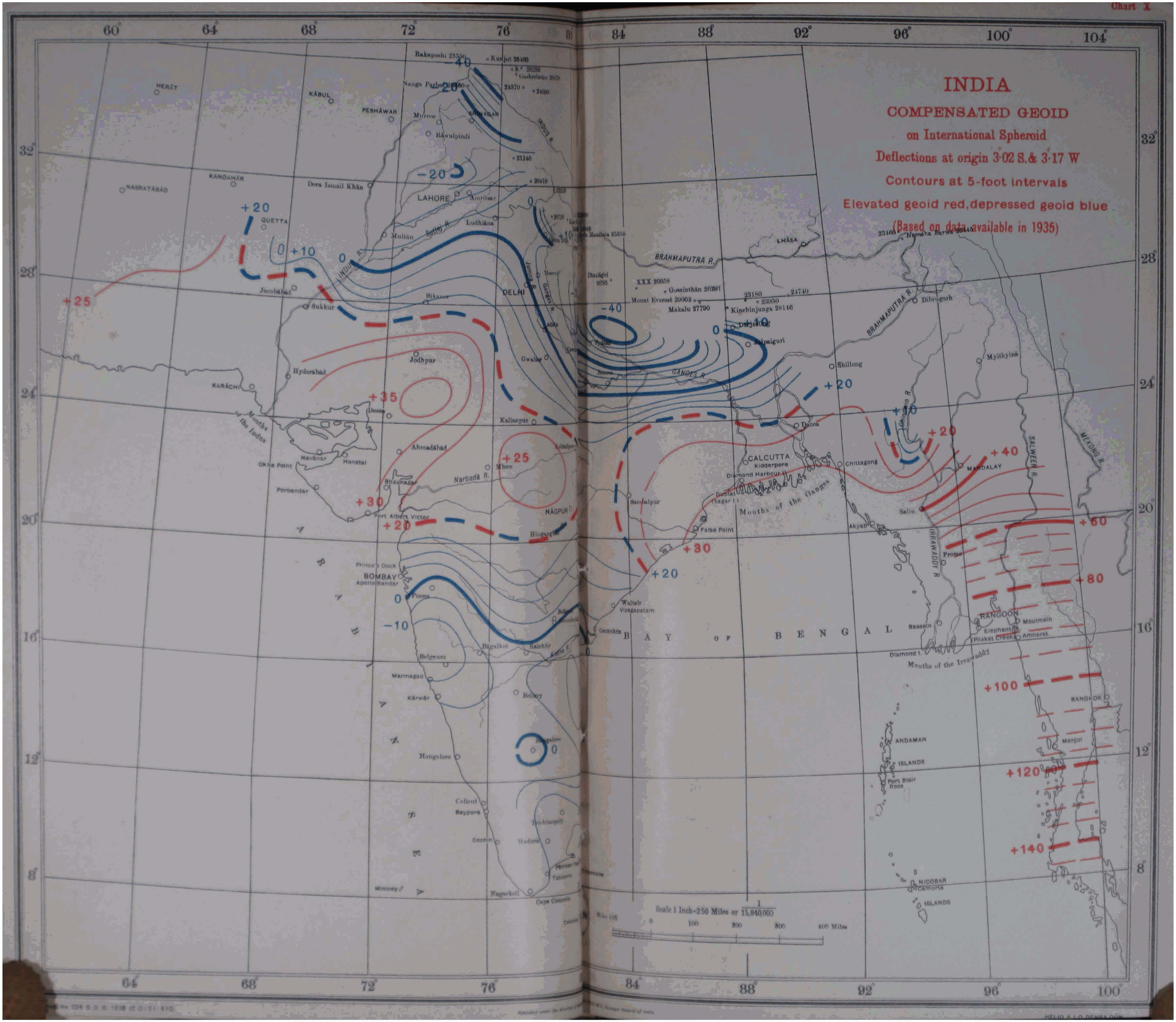
Heliozincographed at the Survey of India Offices, Dehra Dūn.

THE GEOID IN INDIA

Referred to the International Spheroid
with deflections at origin of 3″·02 S. and 3″·17 W.
(Based on data available in 1935)
Contours at 5-foot intervals.
Elevated geoid red, depressed geoid blue.

Published under the direction of M.C., Surveyor General of India.
HELIO & L.O. DEHRA DŪN

Chart X



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 1935)

Quetta is about 70 miles from Sibi, and Nushki is 120 miles. The topography varies from sea-level to 11,000 feet, and deflections are in places as much as 28″, so the geoidal undulations are exceptionally large, and the test of the method is a severe one. The discrepancies (+ 0·7 feet and — 0·4 feet) are thought to be satisfactorily small.

TABLE 2

Serial No.	Sheet No.	Observed at	Height in feet	International Spheroid Deflections		Calculated Deflections. Hayford System		Calculated Deflections. Uncompensated Topography to 2564 miles	
				Meridian	P.V.	Meridian	P.V.	Meridian	P.V.
				″	″	″	″	″	″
785	73 E	Dimra ...	900*	+ 5·8	+ 1·6				
786	E	Chhotki ...	1150*	+ 9·0	+ 3·2				
787	E	Jāra Karmatoli	1300*	+ 4·1	+ 2·0				
788	E	Kunur N. ...	1950*	+ 7·2	− 0·4				
789	72 H	Surujpura ...	1450*	+ 9·3	− 0·3				
790	H	Kamalbār h.s.	1338	+ 13·2	− 1·2				
791	H	Danua ...	600*	+ 17·5	− 4·4				
792	H	Kāhudāg ...	500*	+ 18·0	− 2·0				
793	D	Sherghāti ...	450*	+ 14·3	− 1·4				
794	D	Sirāmpur ...	400*	+ 15·4	− 0·1				
795	D	Khaira Bind s.	362	+ 13·4	− 2·8				
796	D	Dehri-on-Sone	350*	+ 11·2	+ 2·6				
797	63 P	Aūwān ...	300*	+ 13·8	+ 1·0				
798	O	Jahānābād ...	300*	+ 14·2	− 2·4				
799	O	Shiu ...	250*	+ 12·3	+ 2·1				
800	O	Saukhara ...	300*	+ 13·5	+ 3·5				
801	O	Chakia ...	300*	+ 14·3	+ 1·8				
802	O	Rastogi Tālāb	300*	+ 10·6	+ 2·4				
803	K	Dagmagpur ...	300*	+ 12·2	+ 2·1				
804	K	Jaswar ...	300*	+ 11·3	+ 2·5				
805	K	Kathwaya ...	300*	+ 10·0	+ 2·6				
806	K	Meja H.S.	498	+ 8·8	+ 2·8				
807	G	Khorār ...	350*	+ 7·7	+ 3·6				
808	G	Deoria ...	300*	+ 8·9	+ 2·9				
809	G	Sheorajpur ...	400*	+ 11·2	+ 2·0				

* **Approximate.**

DEFLECTIONS 1934-35

EVEREST'S SPHEROID						Serial No.
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections		
				Meridian	P.V.	
° ′ ″	° ′ ″	° ′ ″		″	″	
A 23 27 59·1 G 23 27 55·6	*A* 85 47 36·3 *G* 85 47 43·4			+ 3·5	−3·6	785
A 23 34 41·7 G 23 34 35·0	*A* 85 37 50·1 *G* 85 37 55·3			+ 6·7	−1·9	786
A 23 45 53·1 G 23 45 51·4	*A* 85 29 22·8 *G* 85 29 29·4			+ 1·7	−3·1	787
A 23 57 57·4 G 23 57 52·7	*A* 85 22 22·8 *G* 85 22 31·9			+ 4·7	−5·4	788
A 24 10 45·5 G 24 10 38·8	*A* 85 23 14·0 *G* 85 23 22·9			+ 6·7	−5·3	789
A 24 21 52·38 G 24 21 41·86	*A* 85 19 16·50 *G* 85 19 26·47			+10·5	−6·2	790
A 24 26 24·4 G 24 26 09·6	*A* 85 10 33·2 *G* 85 10 46·6			+14·8	−9·4	791
A 24 29 54·0 G 24 29 38·8	*A* 85 01 56·7 *G* 85 02 07·4			+15·2	−6·9	792
A 24 34 15·3 G 24 34 03·8	*A* 84 47 40·7 *G* 84 47 50·5			+11·5	−6·1	793
A 24 39 00·0 G 24 38 47·4	*A* 84 35 58·2 *G* 84 36 06·6			+12·6	−4·8	794
A 24 47 57·65 G 24 47 47·13	*A* 84 20 24·82 *G* 84 20 36·01			+10·5	−7·3	795
A 24 55 11·8 G 24 55 03·5	*A* 84 09 13·8 *G* 84 09 18·8			+ 8·3	−1·7	796
A 24 57 50·9 G 24 57 40·0	*A* 83 56 18·9 *G* 83 56 25·6			+10·9	−3·2	797
A 25 03 08·0 G 25 02 56·8*	*A* 83 47 15·0 *G* 83 47 25·3*			+11·2	−6·5	798
A 25 01 36·5 G 25 01 27·2	*A* 83 36 23·4 *G* 83 36 28·7			+ 9·3	−1·9	799
A 25 03 14·0 G 25 03 03·5	*A* 83 23 48·8 *G* 83 23 52·3			+10·5	−0·4	800
A 25 02 42·3 G 25 02 31·0	*A* 83 13 02·0 *G* 83 13 07·3			+11·3	−2·0	801
A 25 06 02·8 G 25 05 55·2	*A* 83 02 06·0 *G* 83 02 10·6			+ 7·6	−1·3	802
A 25 05 52·3 G 25 05 43·1	*A* 82 47 05·9 *G* 82 47 10·6			+ 9·2	−1·4	803
A 25 06 37·9 G 25 06 29·7	*A* 82 35 48·3 *G* 82 35 52·5			+ 8·2	−0·9	804
A 25 09 20·5 G 25 09 13·6	*A* 82 23 36·3 *G* 82 23 40·2			+ 6·9	−0·6	805
A 25 07 15·83 G 25 07 10·16	*A* 82 06 49·89 *G* 82 06 53·38			+ 5·7	−0·3	806
A 25 08 34·6 G 25 08 30·0	*A* 81 58 42·5 *G* 81 58 45·0			+ 4·6	+0·6	807
A 25 19 01·6 G 25 18 55·9	*A* 81 47 54·3 *G* 81 47 57·5			+ 5·7	−0·0	808
A 25 12 29·9 G 25 12 21·9	*A* 81 36 42·2 *G* 81 36 46·1			+ 8·0	−0·7	809

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

* Co-ordinates from maps.

TABLE 2

Serial No.	Sheet No.	Observed at	Height in feet	International Spheroid Deflections		Calculated Deflections. Hayford System		Calculated Deflections. Uncompensated Topography to 2564 miles	
				Meridian	P.V.	Meridian	P.V.	Meridian	P.V.
				″	″	″	″	″	″
810	63 G	Bargarh ...	500*	+10·9	+ 2·0				
811	G	Bagrehi ...	400*	+ 9·0	+ 0·4				
812	C	Shiurampur ...	450*	+ 6·6	+ 1·9				
813	C	Badausa ...	450*	+ 9·4	+ 3·4				
814	C	Girwān ...	450*	+ 6·1	+ 0·5				
815	C	Jakhaura ...	450*	+ 7·6	+ 1·8				
816	54 O	Kāri Pahōri ...	600*	+ 7·2	+ 1·4				
817	O	Lādpur ...	600*	+ 5·6	+ 2·2				
818	O	Mahua Itaura	550*	+ 7·0	+ 1·6				
819	O	Gura ...	750*	+ 4·7	+ 2·8				
820	O	Nimoni ...	700*	+ 5·0	+ 5·3				
821	K	Murāra ...	800*	+ 5·2	+ 4·1				
822	K	Jhānsi ...	800*	+ 5·6	+ 7·1				
823	K	Ganj Dināra ...	950*	+ 5·7	+ 5·1				
824	K	Karera ...	950*	+ 5·3	+ 5·2				
825	G	Amola ...	1150*	+ 6·6	+ 5·9				
826	G	Lakni h.s.	1600*	+ 6·2	+ 4·8				
827	G	Pāli ...	1500*	+ 4·3	+ 2·6				
828	G	Thāna Qasba ...	1300*	+ 4·0	+ 0·8				
829	G	Māmoni ...	1600*	+ 4·6	+ 1·9				
830	C	Toria ...	1000*	+ 3·8	− 0·8				
831	C	Bislāi ...	750*	+ 3·9	+ 2·4				
832	C	Badgaon ...	800*	+ 6·4	+ 1·9				
833	C	Mendi ...	850*	+ 5·7	+ 1·7				
834	45 O	Kotah ...	900*	+ 6·5	+ 3·5				

* Approximate.

DEFLECTIONS 1934–35—(*Contd.*)

EVEREST'S SPHEROID						Serial No.
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections		
				Meridian	P.V.	
° ′ ″	° ′ ″	° ′ ″		″	″	
A 25 11 08·0 G 25 11 00·2	*A* 81 26 18·8 *G* 81 26 22·7			+ 7·8	− 0·7	810
A 25 14 04·4 G 25 13 58·6	*A* 81 05 57·2 *G* 81 06 02·6			+ 5·8	− 2·1	811
A 25 12 58·6 G 25 12 55·2	*A* 80 49 57·2 *G* 80 50 00·8			+ 3·4	− 0·4	812
A 25 14 49·4 G 25 14 43·3	*A* 80 38 59·3 *G* 80 39 01·0			+ 6·1	+ 1·3	813
A 25 18 59·5 G 25 18 56·6	*A* 80 23 41·4 *G* 80 23 46·2			+ 2·9	− 1·5	814
A 25 25 30·3 G 25 25 25·9	*A* 80 08 57·9 *G* 80 09 01 1			+ 4·4	− 0·0	815
A 25 19 56·3 G 25 19 52·3	*A* 79 55 28·1 *G* 79 55 31·5			+ 4·0	− 0·3	816
A 25 18 47·5 G 25 18 45·1	*A* 79 43 09·8 *G* 79 43 12·2			+ 2·4	+ 0·6	817
A 25 23 27·3 G 25 23 23·5	*A* 79 31 02·7 *G* 79 31 05·7			+ 3·8	+ 0·1	818
A 25 18 52·7 G 25 18 51·2	*A* 79 19 02·0 *G* 79 19 03·5			+ 1·5	+ 1·5	819
A 25 17 19·4 G 25 17 17·6	*A* 79 03 26·6 *G* 79 03 25·2			+ 1·8	+ 4·1	820
A 25 21 45·5 G 25 21 43·5	*A* 78 49 54·9 *G* 78 49 54·6			+ 2·0	+ 3·1	821
A 25 27 02·1 G 25 26 59·7	*A* 78 36 05·0 *G* 78 36 01·2			+ 2·4	+ 6·2	822
A 25 28 21·5 G 25 28 19·0	*A* 78 20 38·9 *G* 78 20 37·3			+ 2·5	+ 4·3	823
A 25 27 14·8 G 25 27 12·7	*A* 78 08 11·4 *G* 78 08 09·5			+ 2·1	+ 4·6	824
A 25 24 49·8 G 25 24 46·4	*A* 77 56 47·4 *G* 77 56 44·6			+ 3·4	+ 5·4	825
A 25 27 31·50 G 25 27 28·48	*A* 77 43 57·27 *G* 77 43 55·51			+ 3·0	+ 4·4	826
A 25 19 10·5 G 25 19 09·4	*A* 77 29 26·4 *G* 77 29 26·9			+ 1·1	+ 2·4	827
A 25 13 15·6 G 25 13 14·7	*A* 77 20 54·2 *G* 77 20 56·6			+ 0·9	+ 0·6	828
A 25 10 55·9 G 25 10 54·3	*A* 77 06 16·2 *G* 77 06 17·3			+ 1·6	+ 1·9	829
A 25 15 35·5 G 25 15 34·9	*A* 76 50 04·8 *G* 76 50 08·7			+ 0·6	− 0·7	830
A 25 20 18·7 G 25 20 18·0	*A* 76 34 49·8 *G* 76 34 50·0			+ 0·7	+ 2·7	831
A 25 14 56·19 G 25 14 53·00	*A* 76 20 04·50 *G* 76 20 05·11			+ 3·2	+ 2·3	832
A 25 14 37·49 G 25 14 35·01	*A* 76 08 42·30 *G* 76 08 42·94			+ 2·5	+ 2·3	833
A 25 10 00·8 G 25 09 57·4	*A* 75 50 51·5 *G* 75 50 50·0			+ 3·4	+ 4·2	834

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

TABLE 2

Serial No.	Sheet No.	Observed at	Height in feet	International Spheroid Deflections		Calculated Deflections. Hayford System		Calculated Deflections. Uncompensated Topography to 2564 miles	
				Meridian	P.V.	Meridian	P.V.	Meridian	P.V.
				″	″	″	″	″	″
835	45 O	Jamidpura ...	900*	+ 2·5	+ 5·8				
836	O	Būndi ...	1300*	+ 4·0	+ 4·0				
837	O	Aklor ...	1050*	+ 2·5	+ 6·4				
838	O	Deoli ...	1100*	− 0·3	+ 7·4				
839	O	Barla ...	1050*	− 1·1	+ 7·5				
840	N	Dorai ...	1150*	− 1·0	+ 9·0				
841	J	Shokli ...	1300*	− 2·9	+ 6·7				
842	44 P	Gugla Bhar S.	1112	+ 4·5	+ 0·9				
843	L	Birāmsar ...	1300*	+ 1·4	− 2·7				
844	45 I	Randisar ...	1300*	+ 4·1	+ 0·7				
845	44 L	Parsneu ...	1000*	+ 3·2	− 0·1				
846	L	Toliārsar h.s.	979	+ 7·9	− 2·9				
847	H	Banisar ...	900*	+ 5·3	− 2·8				
848	H	Bamlu ...	700*	+ 5·9	− 1·9				
849	H	Bikaner ...	800*	+ 2·7	− 2·2				
850	45 A	Chandni h.s.	892	+ 4·2	− 3·2				
851	44 D	Ronesar H.S.	689	+ 4·8	− 2·1				
852	D	Mankasar H.S.	633	+ 7·1	− 0·2				
853	39 H	Vijnot ...	250*	+ 6·4	+ 5·1				
854	H	Kubba T.S.	242	+ 6·3	+ 3·7				
855	H	Khāi T.S.	234	+ 2·7	+ 5·5				
856	H	Wāsand ...	210	+ 4·4	+ 4·4				
857	D	Kalhora T.S.	201	+ 3·5	+ 3·1				
858	D	Sultān-ka-Got T.S.	189	+ 2·7	− 0·2				
859	D	Pirbax ...	180*	+ 2·7	− 1·5				

* Approximate.

DEFLECTIONS 1934-35—(*Contd.*)

EVEREST'S SPHEROID						Serial No.
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections		
				Meridian	P.V.	
° ′ ″	° ′ ″	° ′ ″		″	″	
A 25 18 26·5 G 25 18 27·2	*A* 75 45 08·7 *G* 75 45 04·5			− 0·7	+ 6·7	835
A 25 26 02·4 G 25 26 01·6	*A* 75 39 02·9 *G* 75 39 00·5			+ 0·8	+ 5·0	836
A 25 33 37·3 G 25 33 38·1	*A* 75 30 53·1 *G* 75 30 47·9			− 0·8	+ 7·5	837
A 25 45 07·5 G 25 45 11·2	*A* 75 23 27·8 *G* 75 23 21·4			− 3·7	+ 8·6	838
A 25 52 38·1 G 25 52 42·6	*A* 75 16 59·3 *G* 75 16 52·8			− 4·5	+ 8·7	839
A 26 00 03·3 G 26 00 07·8	*A* 75 06 45·5 *G* 75 06 37·2			− 4·5	+10·3	840
A 26 12 47·6 G 26 12 54·1	*A* 74 50 41·6 *G* 74 50 35·7			− 6·5	+ 8·1	841
A 28 07 17·58 G 28 07 17·51	*A* 75 01 22·69 *G* 75 01 23·42			+ 0·1	+ 2·1	842
A 28 02 04·09 G 28 02 07·02	*A* 74 45 23·10 *G* 74 45 27·58			− 2·9	− 1·2	843
A 27 52 53·6 G 27 52 53·7	*A* 74 30 29·3 *G* 74 30 29·7			− 0·1	+ 2·4	844
A 28 02 16·3 G 28 02 17·4	*A* 74 22 20·6 *G* 74 22 21·9			− 1·1	+ 1·6	845
A 28 07 52·9 G 28 07 49·4	*A* 74 04 06·1 *G* 74 04 10·3			+ 3·5	− 1·0	846
A 28 04 09·3 G 28 04 08·3	*A* 73 53 42·8 *G* 73 53 46·8			+ 1·0	− 0·8	847
A 28 07 37·8 G 28 07 36·2	*A* 73 30 29·0 *G* 73 30 31·8			+ 1·6	+ 0·3	848
A 28 00 47·6 G 28 00 49·2	*A* 73 18 55·8 *G* 73 18 58·9			− 1·6	+ 0·1	849
A 27 53 17·63 G 27 53 17·60	*A* 72 58 05·10 *G* 72 58 08·96			+ 0·0	− 0·6	850
A 28 02 49·68 G 28 02 49·20	*A* 72 41 05·23 *G* 72 41 07·55			+ 0·5	+ 0·7	851
A 28 00 18·17 G 28 00 15·40	*A* 72 28 33·97 *G* 72 28 34·12			+ 2·8	+ 2·7	852
A 28 02 09·0 G 28 02 06·9	*A* 69 50 23·0 *G* 69 50 15·2			+ 2·1	+ 9·6	853
A 28 11 55·91 G 28 11 53·93	*A* 69 41 35·40 *G* 69 41 29·05			+ 2·0	+ 8·4	854
A 28 16 56·38 G 28 16 57·93	*A* 69 20 15·51 *G* 69 20 06·91			− 1·6	+10·3	855
A 28 06 05·8 G 28 06 05·7	*A* 69 05 56·6 *G* 69 05 49·1			+ 0·1	+ 9·4	856
A 28 08 29·08 G 28 08 29·74	*A* 68 47 22·93 *G* 68 47 16·73			− 0·7	+ 8·3	857
A 28 04 08·05 G 28 04 09·41	*A* 68 36 34·88 *G* 68 36 32·23			− 1·4	+ 5·1	858
A 28 17 35·3 G 28 17 36·9	*A* 68 23 05·3 *G* 68 23 04·0			− 1·6	+ 3·9	859

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

TABLE 2.

Serial No.	Sheet No.	Observed at	Height in feet	International Spheroid Deflections		Calculated Deflections. Hayford System		Calculated Deflections. Uncompensated Topography to 2564 miles	
				Meridian	P.V.	Meridian	P.V.	Meridian	P.V.
				"	"	"	"	"	"
860	39 D	Temple Dera s.	221	+ 3·1	− 5·0				
861	D	Nuttall ...	260*	+ 3·6	− 4·1				
862	D	Bellpat ...	320*	+ 2·7	− 4·8				
863	34 O	Lindsay s.	363	+ 1·5	− 2·7				
864	O	Pirak ...	400*	− 3·1	+ 2·4				
865	O	Dādhar ...	500*	− 3·7	+ 16·1	− 5·8	+ 8·5		
866	O	Kirta ...	1070*	− 0·9	+ 28·5	− 2·6	+ 15·5		
867	O	Tobao ...	2330*	− 11·4	+ 27·9	− 9·5	+ 16·2		
868	O	Sar-i-Bolān ...	4200*	− 11·3	+ 25·1	− 9·7	+ 15·2		
869	O	Dasht Thāna ...	5830*	− 4·8	+ 7·6	− 5·6	+ 3·8		
870	K	Doctor Chah ...	5680*	− 4·5	+ 1·3	− 3·4	− 2·2		
871	K	Shaikh Wāsil ...	5130*	+ 2·2	− 1·3	+ 0·6	− 2·9		
872	K	Pāden ...	5040*	+ 1·6	− 2·3	+ 1·0	− 4·6		
873	K	Galangur ...	4850*	+ 1·3	− 5·0	+ 1·2	− 7·7		
874	K	Nushki ...	3339	+ 1·0	− 13·4	+ 0·4	− 11·9		
875	G	Ahmad Wāl ...	3000*	+ 7·4	− 9·5				
876	G	Mal ...	2900*	+ 10·2	− 4·2				
877	G	Kuchakki ...	2900*	+ 5·7	− 1·8				
878	G	Padag ...	2800*	+ 11·0	− 2·5				
879	H	Zaragho ...	2800*	+ 16·5	− 6·3				
880	D	Karodak ...	2800*	+ 9·8	+ 0·6				
881	D	Taloo ...	2600*	+ 5·0	− 3·3				
882	30 P	Sohtag ...	2500*	+ 1·6	− 6·0				
883	P	Nuhli Koh ...	2350*	− 8·7	− 1·6				
884	P	Gat ..	2150*	− 6·0	− 2·8				

* Approximate.

DEFLECTIONS 1934–35—(*Contd.*)

EVEREST'S SPHEROID						Serial No.
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections		
				Meridian	P.V.	
° ′ ″	° ′ ″	° ′ ″		″	″	
A 28 32 53·20 G 28 32 54·36	*A* 68 13 10·06 *G* 68 13 12·61			− 1·2	+ 0·5	860
A 28 45 20·3 G 28 45 21·1	*A* 68 04 31·8 *G* 68 04 33·2			− 0·8	+ 1·6	861
A 28 59 40·6 G 28 59 42·4	*A* 68 00 26·9 *G* 68 00 29·0			− 1·8	+ 0·9	862
A 29 13 00·51 G 29 13 03·62	*A* 67 55 25·21 *G* 67 55 24·81			− 3·1	+ 3·1	863
A 29 26 47·7 G 29 26 55·5	*A* 67 50 15·0 *G* 67 50 08·6			− 7·8	+ 8·3	864
A 29 29 05·9 G 29 29 14·3	*A* 67 38 59·7 *G* 67 38 37·6			− 8·4	+22·0	865
A 29 34 10·7 G 29 34 16·3	*A* 67 28 37·5 *G* 67 28 01·0			− 5·6	+34·5	866
A 29 46 57·4 G 29 47 13·5	*A* 67 22 02·0 *G* 67 21 25·9			−16·1	+34·0	867
A 29 54 29·2 G 29 54 45·3	*A* 67 15 53·4 *G* 67 15 20·6			−16·1	+31·2	868
A 29 54 57·8 G 29 55 07·4	*A* 67 06 00·3 *G* 67 05 47·5			− 9·6	+13·8	869
A 29 57 19·3 G 29 57 28·6	*A* 66 53 15·8 *G* 66 53 10·0			− 9·3	+ 7·7	870
A 29 53 53·4 G 29 53 56·0	*A* 66 37 56·7 *G* 66 37 53·9			− 2·6	+ 5·2	871
A 29 43 18·4 G 29 43 21·5	*A* 66 24 26·3 *G* 66 24 24·5			− 3·1	+ 4·3	872
A 29 36 04·6 G 29 36 07·9	*A* 66 17 18·8 *G* 66 17 20·0			− 3·3	+ 1·7	873
A 29 32 45·5* G 29 32 49·2†	*A* 66 02 51·6* *G* 66 03 02·3†			− 3·7	− 6·6	874
A 29 22 41·0 G 29 22 38·1	*A* 65 54 58·2 *G* 65 55 04·4			+ 2·9	− 2·7	875
A 29 13 33·3 G 29 13 27·5	*A* 65 45 06·2 *G* 65 45 06·1			+ 5·8	+ 2·8	876
A 29 05 12·6 G 29 05 11·2	*A* 65 31 16·2 *G* 65 31 13·3			+ 1·4	+ 5·3	877
A 29 00 37·7 G 29 00 31·0	*A* 65 18 16·4 *G* 65 18 14·0			+ 6·7	+ 4·8	878
A 28 54 48·2 G 28 54 36·0	*A* 65 01 08·1 *G* 65 01 10·0			+12·2	+ 1·1	879
A 28 57 26·4 G 28 57 20·8	*A* 64 43 36·5 *G* 64 43 30·3			+ 5·6	+ 8·2	880
A 28 49 25·8 G 28 49 25·0	*A* 64 11 11·1 *G* 64 11 09·0			+ 0·8	+ 4·6	881
A 28 45 23·3 G 28 45 25·9	*A* 63 55 21·0 *G* 63 55 21·7			− 2·6	+ 2·2	882
A 28 44 37·8 G 28 44 50·6	*A* 63 38 26 6 *G* 63 38 22·1			−12·8	+ 6·7	883
A 28 42 35·6 G 28 42 45·7	*A* 63 19 00·9 *G* 63 18 57·5			−10·1	+ 5·8	884

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

* Observations of 1927–28.

† Revised co-ordinates of 1934–35.

TABLE 2

Serial No.	Sheet No.	Observed at	Height in feet	International Spheroid Deflections		Calculated Deflections. Hayford System		Calculated Deflections. Uncompensated Topography to 2564 miles	
				Meridian	P.V.	Meridian	P.V	Meridian	P. V.
				″	″	″	″	″	″
885	30 P	Isa Tahir ...	2000*	− 6·2	+ 1·0				
886	L	Alam Reg ...	2300*	− 6·6	+ 2·5				
887	L	Tozghi ...	2300*	− 1·5	+ 3·3				
888	L	Dalil ...	2300*	+ 2·4	+ 4·9				
889	H	Ware Chah ...	2468	+ 2·0	+ 4·3				
890	H	Reg-i-Malik ...	2600*	+ 0·5	+ 3·6				
891	G	Kila Safaid ...	2750*	− 5·8	+ 0·2				
892	54 F	Dholpur H.S.	938	+ 0·1					
893	F	Tohr h.s.	608	+ 5·9					
894	F	Pagaro H.S.	1122	+ 7·1					
895	G	Sikrauli h.s.	1454	+ 7·2					
896	G	Mamoni H.S.	1596	+ 5·7					
897	G	Lakni h.s.	1578	+ 6·4					
898	G	Gugubara H.S.	1614	+ 3·9					
899	H	Nai Sarai s.	1603	+ 3·4					
900	H	Semra h.s.	1751	+ 7·1					
901	55 E	Ladpur h.s.	1774	− 0·0					
902	E	Kamkera h.s.	1830	+ 0·1					
903	F	Aralakhar East Pole ...	1345	+ 0·1					
904	F	Hoshangābād Rock h.s.	1122	− 0·5					
905	F	Kaveli h.s.	1585	− 0·5					
906	F	Harda h.s.	1826	+ 8·8					
907	F	Bijadehi h.s.	2009	+ 10·1					
908	G	Atari h.s.	2291	+ 0·2					
909	G	Jillar h.s.	2446	+ 1·0					

* Approximate.

DEFLECTIONS 1934–35—(*Contd.*)

EVEREST'S SPHEROID						Serial No.
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections		
				Meridian	P.V.	
° ′ ″	° ′ ″	° ′ ″		″	″	
A 28 45 40·8 G 28 45 51·1	*A* 63 00 22·2 *G* 63 00 14·2			−10·3	+ 9·8	885
A 28 49 55·3 G 28 50 06·0	*A* 62 30 34·8 *G* 62 30 24·9			−10·7	+11·5	886
A 28 50 21·8 G 28 50 27·4	*A* 62 17 31·8 *G* 62 17 20·7			− 5·6	+12·5	887
A 28 47 09·8 G 28 47 11·3	*A* 62 05 28·1 *G* 62 05 15·0			− 1·6	+14·2	888
A 28 51 51·2* G 28 51 53·3†	*A* 61 54 37·5* *G* 61 54 25·0†			− 2·1	+13·7	889
A 28 57 06·4 G 28 57 10·0	*A* 61 43 56·4 *G* 61 43 44·5			− 3·6	+13·2	890
A 29 01 12·8 G 29 01 22·7	*A* 61 28 55·8 *G* 61 28 47·7			− 9·9	+ 9·9	891
A 26 39 08·03 G 26 39 11·75	*G* 77 49 32·50			− 3·7		892
A 26 27 26·48 G 26 27 24·25	*G* 77 49 00·49			+ 2·2		893
A 26 16 16·95 G 26 16 13·46	*G* 77 51 11·89			+ 3·5		894
A 25 58 19·69 G 25 58 15·99	*G* 77 43 53·25			+ 3·7		895
A 25 31 30·67 G 25 31 28·34	*G* 77 41 38·24			+ 2·3		896
A 25 27 31·51 G 25 27 28·40	*G* 77 43 55·55			+ 3·1		897
A 25 12 00·80 G 25 12 00·13	*G* 77 34 36·40			+ 0·7		898
A 24 48 10·34 G 24 48 09·91	*G* 77 35 40·26			+ 0·4		899
A 24 28 41·48 G 24 28 37·33	*G* 77 44 47·00			+ 4·2		900
A 23 48 07·83 G 23 48 10·47	*G* 77 37 28·11			− 2·6		901
A 23 25 00·18 G 23 25 02·62	*G* 77 41 56·22			− 2·4		902
A 22 52 36·79 G 22 52 39	*G* 77 46 26			− 2·2		903
A 22 43 50·61 G 22 43 53·45	*G* 77 43 56·90			− 2·8		904
A 22 30 41·55 G 22 30 44·21	*G* 77 50 06·52			− 2·7		905
A 22 18 11·65 G 22 18 04·89	*G* 77 40 21·34			+ 6·8		906
A 22 09 47·75 G 22 09 39·64	*G* 77 40 18·27			+ 8·1		907
A 21 56 50·50 G 21 56 52·22	*G* 77 40 21·32			− 1·7		908
A 21 44 23·07 G 21 44 24·02	*G* 77 44 36·82			− 1·0		909

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

* Observations of 1927–28.

† Revised co-ordinates of 1934–35.

TABLE 2

Serial No.	Sheet No.	Observed at	Height in feet	International Spheroid Deflections		Calculated Deflections. Hayford System		Calculated Deflections. Uncompensated Topography to 2564 miles	
				Meridian	P.V.	Meridian	P.V.	Meridian	P.V.
				″	″	″	″	″	″
910	55 G	Bothi h.s.	2875	− 3·9					
911	G	Dabho a h.s.	1643	− 6·0					
912	H	Dhamori Fort s.	1067	− 3·6					
913	H	Donad s.	1280	+ 0·3					
914	H	Kopdi H.S.	1408	− 3·9					
915	H	Soyjan s.	1527	+ 1·4					
916	56 E	Aregaon h.s.	1500	− 4·5					
917	E	Jannuna h.s.	1699	− 0·3					
918	E	Hadgaon h.s.	1529	− 0·8					
919	E	Terban H.S.	1728	− 2·5					
920	F	Shivalingapa H.S.	1566	− 2·9					
921	F	Baktapur H.S.	1558	− 1·0					
922	F	Burgapali H.S.	1729	− 1·2					
923	G	Shilapalle H.S.	2180	− 2·2					
924	G	Kandenmarai T.S.	2234	− 3·7					
925	G	Marepalli s.	1758	− 5·3					
926	72 A	Bajra T.S.	330	−11·4		−7·7		−55*	
927	A	Bakwa T.S.	284	− 5·2					
928	B	Binharwa T.S.	258	− 1·7					
929	B	Daunaha T.S.	271	+ 3·9					
930	B	Gidaha T.S.	249	+ 6·5					
931	B	Nautan T.S.	223	+ 7·8		−1·8		−30*	
932	B	Katwarpur T.S.	224	+10·1					
933	C	Khadipur T.S.	207	+11·9					
934	C	Bin Chapra T.S.	204	+12·9					

* Topography to 400 miles.

DEFLECTIONS 1934-35—(*Contd.*)

EVEREST'S SPHEROID						Serial No.
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections		
				Meridian	P.V.	
° ′ ″	° ′ ″	° ′ ″		″	″	
A 21 32 27·88 G 21 32 33·58	G 77 44 45·32			− 5·7		910
A 21 21 35·27 G 21 21 42·96	G 77 42 54·21			− 7·7		911
A 20 59 13·93 G 20 59 19·12	G 77 35 16·57			− 5·2		912
A 20 32 55·25 G 20 32 56·36	G 77 37 13·85			− 1·1		913
A 20 20 32·04 G 20 20 37·19	G 77 40 23·20			− 5·2		914
A 20 08 24·70 G 20 08 24·55	G 77 36 50·76			+ 0·2		915
A 19 55 37·39 G 19 55 42·95	G 77 37 29·06			− 5·6		916
A 19 42 28·24 G 19 42 29·58	G 77 36 46·58			− 1·3		917
A 19 28 45·52 G 19 28 47·19	G 77 39 06·37			− 1·7		918
A 19 17 27·19 G 19 17 30·44	G 77 40 51·36			− 3·3		919
A 18 44 52·67 G 18 44 56·23	G 77 35 56·28			− 3·6		920
A 18 29 36·40 G 18 29 38·00	G 77 34 57·63			− 1·6		921
A 18 16 31·78 G 18 16 33·50	G 77 42 04·51			− 1·7		922
A 17 46 11·01 G 17 46 13·61	G 77 40 03·76			− 2·6		923
A 17 31 30·46 G 17 31 34·45	G 77 42 06·29			− 4·0		924
A 17 20 00·48 G 17 20 06·02	G 77 41 46·62			− 5·5		925
A 27 12 11·01 G 27 12 26·23	G 84 08 56·21			−15·2		926
A 27 02 37·03 G 27 02 46·00	G 84 11 17·83			− 9·0		927
A 26 52 44·71 G 26 52 50·12	G 84 11 59·68			− 5·4		928
A 26 42 17·10 G 26 42 16·85	G 84 13 21·91			+ 0·3		929
A 26 30 17·00 G 26 30 14·10	G 84 12 43·76			+ 2·9		930
A 26 19 12·32 G 26 19 07·98	G 84 12 46·29			+ 4·3		931
A 26 07 25·33 G 26 07 18·61	G 84 13 03·79			+ 6·7		932
A 25 57 19·26 G 25 57 10·73	G 84 12 54·09			+ 8·5		933
A 25 46 59·00 G 25 46 49·39	G 84 13 57·34			+ 9·6		934

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

TABLE 2

Serial No.	Sheet No.	Observed at	Height in feet	International Spheroid Deflections		Calculated Deflections. Hayford System		Calculated Deflections. Uncompensated Topography to 2564 miles	
				Meridian	P.V.	Meridian	P.V.	Meridian	P.V.
935	72 C	Kesath T.S.	292	+12″·1	″	″	″	″	″
936	C	Durgādi T.S.	293	+14·7					

Corrigenda to Table 1

For details of stations serial Nos.

18	35 G	Chandragup ...	20	−5·0	+6·9	−6·7	+0·1	−34*	− 8*
29	P	Sāhiji ...	211	−1·0	+1·4	−2·8	+0·1	−19*	− 7*

* Topography to 400 miles.

DEFLECTIONS 1934–35—(*Concld.*)

EVEREST'S SPHEROID						Serial No.
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections		
				Meridian	P.V.	
° ′ ″	° ′ ″	° ′ ″		″	″	
A 25 25 19·86 G 25 25 10·92	*G* 84 14 31·63			+ 8·9		935
A 25 14 46·00 G 25 14 34·43	*G* 84 17 35·56			+ 11·6		936

of Supplement to G. R. Vol. VI.

18 and 29 *substitute* the following :—

A 25 25 55·23 G 25 26 3·25	*A* 65 49 58·80 *G* 65 49 46·56			− 8·0	+ 13·9	18
A 24 51 3·52 G 24 51 7·31	*A* 67 36 22·16 *G* 67 36 17·31			− 3·8	+ 7·3	29

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

Corrigendum to G.R. Vol. VII, page 71.
(*First Addendum to Table 1 of Supplement to G.R. Vol. VI*).

For the longitude of station No. 614 Gūdha H.S. *read* 74° 46′ 06″·1 instead of 74° 26′ 06″·1.

CHAPTER IV

GRAVITY

BY LT.-COLONEL E. A. GLENNIE, D.S.O., R.E.

26. Summary.—At the beginning of field season 1934–35 Mr. M. N. A. Hashmie, B.A. took over charge of the Gravity Detachment. In preparation for this Mr. Hashmie had made during the summer a prolonged series of practice observations at Mussoorie. The detachment consisting of Mr. Hashmie, one computer and 10 *khalāsīs* left Dehra Dūn on 6th October and returned at the end of December, after observing at thirty-three stations of which six were in Bombay Presidency, ten in Kāthiāwār, three in Cutch, two in Baroda State and twelve in Rājputāna. This season's programme was not suited to the employment of permanent lorries and the detachment travelled mainly by railway.

There was some malaria at the beginning, otherwise health was excellent except in the case of the computer who had to return to Dehra Dūn in November owing to appendicitis.

27. Method of observation.—When preliminary base observations at Dehra Dūn were commenced in August, Pendulum A was found to give erratic results ; Pendulums B and C were satisfactory. It was accordingly decided to swing only Pendulums B and C, keeping A fixed in the middle position, so as to use its mirrors. This method had already been used with success for the original standardization of the pendulums and in the field season of 1927–28.

The pendulums were hung throughout in the same position ; that is, C on the front pair of agates, A fixed on the middle pair and B on the back pair.

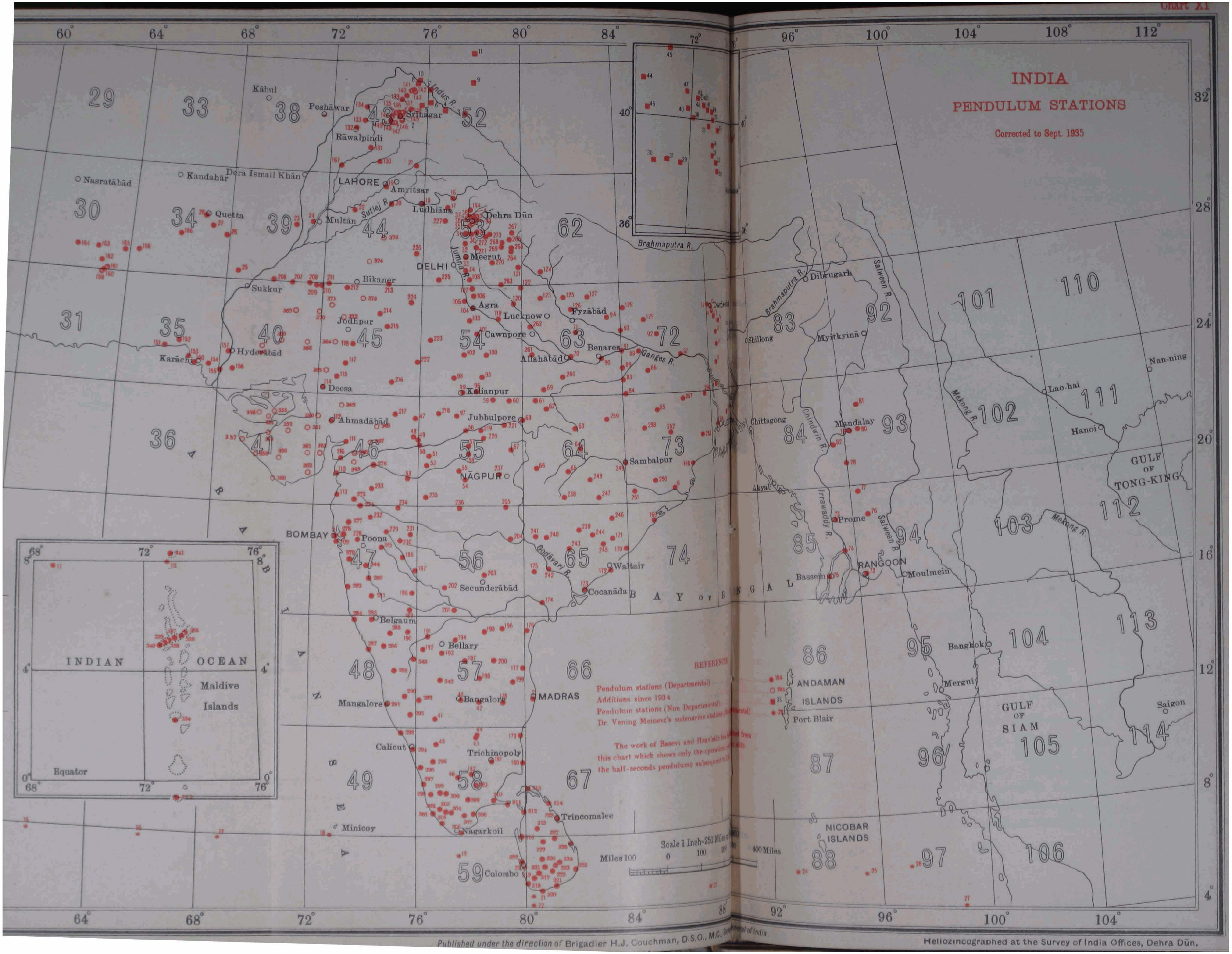
The Marconi wireless receiving set R.P. 11, used in all previous seasons, was employed, and gave no trouble.

The normal programme of observations consisted of 3 sets of duration from 6 to 10 hours each between time signals.

28. 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 Pendulums C and B ; and the times of vibration, the deduced values of g and the probable errors at each field station respectively.

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 fourth addendum to Table 2 of the Supplement to Geodetic Report

Chart XI



Published under the direction of Brigadier H.J. Couchman, D.S.O., M.C., Su[illegible]eneral of India.

Heliozincographed at the Survey of India Offices, Dehra Dūn.

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 the second addendum to Table 6 in Geodetic Report Vol. VIII.

Probable errors computed by the method given in Geodetic Report 1934 are given in Table 3. These probable errors show the results to be fully up to the standard of previous field seasons.

29. **Observations at old stations.**—Observations were repeated at two old stations, that is Station No. 112 Ahmadābād and Station No. 214 Degāna. The results as follows:—

	g (old value) *gals*	g (new value) *gals*
Ahmadābād ...	978·836	978·835
Degāna ...	978·965	978·982

At Ahmadābād the agreement is good and the old value is therefore retained.

At Degāna the original observations made in 1931 were not good owing to bad clock contacts. The large negative gravity anomaly at this station always appeared inconsistent both with neighbouring anomalies and with local geology. It is therefore satisfactory to find that the repeated observations at this station result in a notably higher value of gravity. The new value for Degāna is adopted.

30. **Recomputation of Hayford corrections.**—When gravity observations were made in Bihār in 1924 the modern survey of Nepāl had not been made. These have now been recomputed with the new data, and as anticipated there are some changes. The only large corrections are for Pīlībhīt 9 mgals and for Motīhāri 8 mgals. The Hayford anomalies (Helmert's formula) for these stations are affected as follows:—

Station	$g-\gamma_{CH}$ (old value)	$g-\gamma_{CH}$ (new value)
	mgals	*mgals*
Pīlibhīt ...	−55	−64
Motīhāri ...	−99	−91

Among the Survey of India gravity stations Jaffna now has the greatest Hayford anomaly, $g-\gamma_{CH} = -99$ mgals and Deosai I the greatest positive anomaly, +90 mgals. Considerably higher anomalies have been found elsewhere, especially in the Java Seas.

31. **Consideration of results.**—The publication of the second volume of Dr. Vening Meinesz's important book *Gravity Expeditions*

at Sea[*] has brought a most welcome and valuable confirmation of the *crustal warping hypothesis*, which was developed independently in India from a consideration of gravity data there. His *buckling hypothesis* appears to be in many respects the same as the crustal warping hypothesis and is mainly supported by similar arguments, based on a great wealth of data outside India.

The warp anomalies ($g-\gamma_F$), first shown in an approximate form ($g-\gamma_{EA}$) in Geodetic Report Vol. VI (1929–30) and in their final form in the subsequent yearly issues of the Geodetic Report are believed to show plainly the main warpings in India excluding the widespread " Hidden Range " warp. These anomalies indicate an extension of the Arāvalli upwarp to the Himālayas. This has recently been supported by geological evidence[†]. Geological evidence also confirms an extension of the Arāvalli system to beyond Lahore which again is plainly indicated by an upwarp in this direction[‡]. It is possible that differential compaction of alluvium over this upwarp has contributed towards water logging in the Punjab. There is evidence that the water table was rising in this area even before extensive irrigation began[§].

The above facts are favourable to the use of warp anomalies, hence it is proposed to consider last season's results in the light of these anomalies. They are shown in Chart XII, and Chart XIII (crustal structure lines). Hayford anomalies on Helmert's spheroid ($g-\gamma_{CH}$) and on the International spheroid ($g-\gamma_{CI}$) are shown in Charts XIV and XV.

The first few stations of last season's work were intended to define more closely the western boundary of the downwarp concealed under the Deccan Trap east of Bombay, and to discover whether the Vindhyan downwarp crossed the line of the Sātpuras, though this seemed unlikely. The result has been to shift the boundary of the downwarp westward, thus accentuating the rapid rise to positive anomalies along the coast. The Gulf of Cambay is plainly centered over this upwarp, and is probably a rift due to tension. The Sātpura upwarp evidently continues to the coast, though there is a notable narrowing on the west. An additional gravity station here would be useful, but the area is difficult of access.

Further north large positive anomalies are obtained (Pokaran + 64 mgals) no doubt associated with the volcanic disturbances indicated by the Malāni series. The negative anomaly at Degāna

---

[*] Gravity Expeditions at Sea 1923–32 Vol. II by F. A. Vening Meinesz, J. H. F. Umbrove. Ph. H. Kuenen.

[†] Records. Geological Survey of India Vol. LXVI Part 4, 1933 page 467 and Records. Geological Survey of India Vol. LXVII Part 4. 1934 page 449.

[‡] Records. Geological Survey of India Vol. LXVI Part 4, 1933 page 469.

[§] An investigation of the rise of water table in the Upper Chenāb Canal area. Punjab. Research Publication. Vol. I No. 4. April 1933. Punjab Irrigation Research Institute.

is seen to be associated with an irregular area of relatively small positive anomalies, but it is likely that there are rapid changes in the anomalies in this area which requires a denser distribution of gravity stations. Between this old volcanic area fringing the ancient Arāvalli upwarp and the volcanic area in Irān and Afghānistān the ancient bed of a great bay of the Tethys has buckled.

A narrow downwarp appears to run west of Jaisalmer to the Rann of Cutch, the Gulf of Cutch being associated with this; then there is an upwarp running up from Karāchi to Jacobābād; while to the west and north of this the main downwarp occurs. The boundary fault and igneous formations further west indicate an upwarp. The epicentre of the recent Quetta earthquake appears to have been over the deepest part of the downwarp which is evidently being still further narrowed and deepened. The warp anomalies therefore show very clearly the nature of this event. The negative anomaly at Quetta (-39 mgals) indicates a depth of downwarp of about 11,000 feet.

The structure lines in Baluchistān are shown tentatively in Chart XIII in the area for which gravity data are absent. This area is included in the programme for 1935–36.

TABLE 1.—*Times of vibration at Dehra Dūn, season 1934-35.*

Date	C	Weight	B	Weight
1934	s		s	
September 26 ...	0·507 9525	8	0·507 9552	8
,, 26 ...	9513	14	9544	14
October 1 ...	9522	10	9548	10
,, 1 ...	9512	14	9544	14
,, 2 ...	9519	8	9549	8
,, 2 ...	9512	14	9542	14
Weighted mean ...	0·507 9516$_0$	...	0·507 9545$_7$	...

Date	C	Weight	B	Weight
1934	s		s	
December 28 ...	0·507 9516	8	0·507 9545	8
,, 28 ...	9510	6	9540	6
,, 28 ...	9516	8	9543	8
,, 29 ...	0·507 9517	8	0·507 9542	8
,, 29 ...	9516	6	9544	6
,, 29 ...	9514	8	9540	8
Weighted mean ...	0·507 9515$_1$	...	0·507 9542$_4$	...

Adopted mean times of vibration.

	C	B
	s	s
General mean	0·507 9516	0·507 9544

TABLE 2.—*Mean differences of pairs of pendulums, season 1934–35.*

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

Station No.	C–B	v	Station No.	C–B	v
345	− 5·5	+13·6	361	−28·0	− 8·9
346	−23·7	− 4·6	362	−31·0	−11·9
347	− 8·7	+10·4	363	−15·5	+ 3·6
348	−15·3	+ 3·8	214*	−10·3	+ 8·8
112*	−20·7	− 1·6	364	−23·7	− 4·6
349	−26·3	− 7·2	365	−23·7	− 4·6
350	−18·3	+ 0·8	366	−23·7	− 4·6
351	−28·0	− 8·9	367	−19·6	− 0·5
352	−15·7	+ 3·4	368	− 9·7	+ 9·4
353	− 7·0	+12·1	369	−10·0	+ 9·1
354	−20·7	− 1·6	370	− 8·3	+10·8
355	−22·3	− 3·2	371	−24·7	− 5·6
356	− 5·3	+13·8	372	−11·0	+ 8·1
357	−27·5	− 8·4	373	−10·0	+ 9·1
358	− 7·3	+11·8	374	−28·7	− 9·6
359	−27·0	− 7·9	375	−26·0	− 6·9
360	−27·7	− 8·6			

* Repeat station.

TABLE 3.—*Mean times of vibration, deduced values of g and probable errors, season 1934–35*

Station No.		PENDULUMS		Mean	Probable error of Mean
		C	B		
345	*s*	0·508 0524	0·508 0531	0·508 0528	± 2·98
	g	978·674	978·683	978·679	1·31
346	*s*	0·508 0374	0·508 0399	0·508 0387	1·39
	g	978·732	978·733	978·733	0·84
347	*s*	0·508 0383	0·508 0392	0·508 0388	2·73
	g	978·729	978·736	978·733	1·23
348	*s*	0·508 0390	0·508 0405	0·508 0398	1·47
	g	978·726	978·731	978·729	0·87
112*	*s*	0·508 0111	0·508 0133	0·508 0122	1·57
	g	978·834	978·836	978·835	0·89
349	*s*	0·508 0143	0·508 0170	0·508 0157	1·92
	g	978·821	978·822	978·822	0·99
350	*s*	0·508 0126	0·508 0145	0·508 0136	1·03
	g	978·828	978·831	978·830	0·77
351	*s*	0·080 0223	0·508 0251	0·508 0237	2·34
	g	978·790	978·790	978·790	1·11

* Repeat station.

(Continued)

TABLE 3.—*Mean times of vibration, deduced values of g and probable errors, season 1934–35*—(*concld.*)

Station No.		Pendulums		Mean	Probable error of Mean
		C	B		
352	*s*	0·508 0280	0·508 0296	0·508 0288	± 1·53
	g	978·768	978·773	978·771	0·88
353	*s*	0·508 0249	0·508 0256	0·508 0253	3·11
	g	978·780	978·789	978·785	1·36
354	*s*	0·508 0116	0·508 0136	0·508 0126	1·82
	g	978·832	978·835	978·834	0·96
355	*s*	0·508 0094	0·508 0114	0·508 0104	2·29
	g	978·840	978·843	978·842	1·09
356	*s*	0·508 0120	0·508 0125	0·508 0123	3·10
	g	978·830	978·839	978·835	1·35
357	*s*	0·508 0214	0·508 0241	0·508 0228	2·62
	g	978·794	978·794	978·794	1·20
358	*s*	0·508 0387	0·508 0393	0·508 0390	3·22
	g	978·727	978·736	978·732	1·39
359	*s*	0·508 0316	0·508 0342	0·508 0329	2·32
	g	978·755	978·755	978·755	1·10
360	*s*	0·508 0424	0·508 0452	0·508 0438	2·45
	g	978·713	978·713	978·713	1·14
361	*s*	0·508 0397	0·508 0425	0·508 0411	2·51
	g	978·723	978·723	978·723	1·16
362	*s*	0·508 0422	0·508 0453	0·508 0438	3·16
	g	978·714	978·713	978·714	1·37
363	*s*	0·508 0263	0·508 0279	0·508 0271	1·39
	g	978·775	978·780	978·778	0·85
214*	*s*	0·507 9737	0·507 9746	0·507 9742	2·15
	g	978·978	978·985	978·982	1·05
364	*s*	0·507 9730	0·507 9754	0·507 9742	1·72
	g	978·981	978·982	978·982	0·93
365	*s*	0·507 9887	0·507 9911	0·507 9899	1·72
	g	978·920	978·922	978·921	0·93
366	*s*	0·507 9711	0·507 9735	0·507 9723	1·72
	g	978·988	978·989	978·989	0·93
367	*s*	0·507 9729	0·507 9749	0·507 9739	1·57
	g	978·981	978·984	978·983	0·89
368	*s*	0·507 9667	0·507 9676	0·507 9672	2·82
	g	979·005	979·012	979·009	1·26
369	*s*	0·507 9601	0·507 9611	0·507 9606	2·64
	g	979·030	979·037	979·034	1·20
370	*s*	0·507 9482	0·507 9490	0·507 9486	3·00
	g	979·076	979·084	979·080	1·32
371	*s*	0·507 9527	0·507 9551	0·507 9539	1·88
	g	979·059	979·060	979·060	0·98
372	*s*	0·507 9661	0·507 9671	0·507 9666	2·43
	g	979·007	979·014	979·011	1·14
373	*s*	0·507 9535	0·507 9544	0·507 9540	3·17
	g	979·056	979·063	979·060	1·38
374	*s*	0·507 9255	0·507 9284	0·507 9270	2·66
	g	979·164	979·163	979·164	1·21
375	*s*	0·507 8999	0·507 9025	0·507 9012	2·13
	g	979·262	979·264	979·263	1·05

* Repeat station.

TABLE 4.—*Modern gravity observations in India.*

(Additions in field season 1934–35)

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}
345	46 G	Umbarpāda ...	9 10 34	730	21 27 39	73 28 41	978·679	+ ·026	+ ·002	+ ·018
346	46 G	Rājpīpla ...	13 10 34	145	21 51 56	73 30 03	978·733	+ ·001	− ·004	+ ·010
347	46 J	Chota Udaipur	16 10 34	383	22 18 22	74 01 12	978·733	− ·005	− ·018	+ ·005
348	46 J	Dohad ...	19 10 34	1031	22 50 17	74 15 17	978·729	+ ·018	− ·017	+ ·011
112*	46 A	Ahmadābād ...	21 10 34	156	23 01 20	72 33 55	978·835	+ ·030	+ ·025	+ ·035
349	46 A	Himmatnagar	24 10 34	476	23 36 02	72 57 42	978·822	+ ·009	− ·007	+ ·012
350	46 A	Viramgām ...	27 10 34	92	23 07 31	72 03 18	978·830	+ ·013	+ ·010	+ ·017
351	41 N	Wadhwān ...	29 10 34	225	22 42 20	71 40 08	978·790	+ ·012	+ ·004	+ ·009
352	41 J	Wānkāner ...	31 10 34	385	22 36 06	70 56 29	978·771	+ ·014	+ ·001	+ ·005
353	41 J	Jāmnagar ...	2 11 34	53	22 28 11	70 04 06	978·785	+ ·006	+ ·004	+ ·002
354	41 I	Kandla ...	5 11 34	14	23 02 10	70 13 08	978·834	+ ·015	+ ·015	+ ·002
355	41 I	Bachau ...	8 11 34	106	23 17 30	70 20 19	978·842	+ ·015	+ ·011	+ ·012
356	41 E	Bhūj ...	10 11 34	313	23 15 11	69 41 05	978·835	+ ·029	+ ·019	+ ·017
357	41 B	Dwārka ...	13 11 34	33	22 14 10	68 57 44	978·794	+ ·028	+ ·027	+ ·010
358	41 K	Jetalsar ...	16 11 34	340	21 43 35	70 33 10	978·732	+ ·027	+ ·016	+ ·013
359	41 G	Porbandar ...	18 11 34	16	21 38 20	69 36 25	978·755	+ ·025	+ ·025	+ ·008
360	41 L	Verāval ...	20 11 34	9	20 54 20	70 22 18	978·713	+ ·027	+ ·027	+ ·012
361	41 O	Dhasa ...	22 11 34	297	21 48 25	71 40 58	978·723	+ ·009	− ·001	+ ·002
362	41 O	Mahuva ...	24 11 34	41	21 05 40	71 45 08	978·714	+ ·019	+ ·018	+ ·015
363	46 C	Bhaunagar ...	26 11 34	66	21 46 10	72 08 28	978·778	+ ·044	+ ·042	+ ·044
214*	45 J	Degāna ...	30 11 34	1112	26 53 59	74 19 25	978·982†	− ·001†	− ·038†	+ ·001†
364	45 C	Samdari ...	2 12 34	458	25 50 15	72 34 30	978·982	+ ·014	− ·001	+ ·024
365	45 D	Raniwāra ...	3 12 34	697	24 45 10	72 12 10	978·921	+ ·049	+ ·026	+ ·049
366	40 O	Barmer ...	5 12 34	635	25 44 40	71 23 45	978·989	+ ·044	− ·023	+ ·043
367	40 G	Dhoro Nāro ...	7 12 34	45	25 31 25	69 32 05	978·983	− ·001	− ·003	+ ·006
368	40 K	Jaisingder ...	9 12 34	286	25 45 30	70 21 43	979·009	+ ·031	+ ·021	+ ·038
369	40 J	Jaisalmer ...	12 12 34	743	26 54 10	70 55 00	979·034	+ ·017	− ·008	+ ·018
370	40 N	Pokaran ...	14 12 34	758	26 55 44	71 54 50	979·080	+ ·062	+ ·036	+ ·071
371	45 A	Phalodi ...	16 12 34	771	27 07 50	72 21 20	979·060	+ ·028	+ ·002	+ ·033
372	45 B	Osiān ...	18 12 34	1073	26 43 50	72 54 03	979·011	+ ·037	+ ·001	+ 035
373	45 E	Chilo ...	21 12 34	990	27 28 02	73 30 35	979·060	+ ·024	− ·009	+ ·026
374	44 H	Mahājan ..	23 12 34	657	28 47 20	73 51 20	979·164	− ·002	− ·024	+ ·010
375	44 K	Hanumāngarh	24 12 34	597	29 36 40	74 17 33	979·263	+ ·028	+ ·008	+ ·044

* Repeat station.

† New value. The value given in Geodetic Report Vol. VII, page 84 is rejected.

NOTE :—This table is the fourth 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 1 mgal)

Station No.	Corrections to $g-\gamma_{CH}$			$g-\gamma_F$	Station No.	Corrections to $g-\gamma_{CH}$			$g-\gamma_F$
	Compen-sation	Hidden Range	Spheroid S. of I. II			Compen-sation	Hidden Range	Spheroid S. of I. II	
345	− 7	−14	+25	+22	361	− 3	−14	+26	+11
346	− 4	−18	+26	+14	362	− 1	− 7	+25	+32
347	− 7	−23	+26	+ 1	363	− 1	−14	+26	+55
348	−10	−26	+27	+ 2	214†	−11	−27	+30	− 7‡
112†				+26*	364	− 5	−32	+29	+16
349	− 5	−29	+27	+ 5	365	− 7	−32	+28	+38
350	− 1	−24	+27	+19	366	− 6	−32	+29	+34
351	− 2	−21	+26	+12	367	− 1	−32	+28	+ 1
352	− 3	−19	+26	+ 9	368	− 4	−32	+29	+31
353	− 1	−17	+26	+ 6	369	− 7	−31	+30	+10
354	0	−20	+27	+ 9	370	− 8	−29	+30	+64
355	− 1	−23	+27	+15	371	− 8	−30	+31	+26
356	− 3	−22	+27	+19	372	−10	−28	+30	+27
357	0	−11	+26	+25	373	−10	−22	+31	+25
358	− 4	−10	+26	+25	374	− 7	−11	+32	+24
359	0	− 7	+26	+27	375	− 6	− 1	+32	+69
360	− 1	0	+25	+36					

* Old value, see Professional Paper No. 27, page 31.

† Repeat station.

‡ New value. The value given on page 33, Professional Paper No. 27 is rejected.

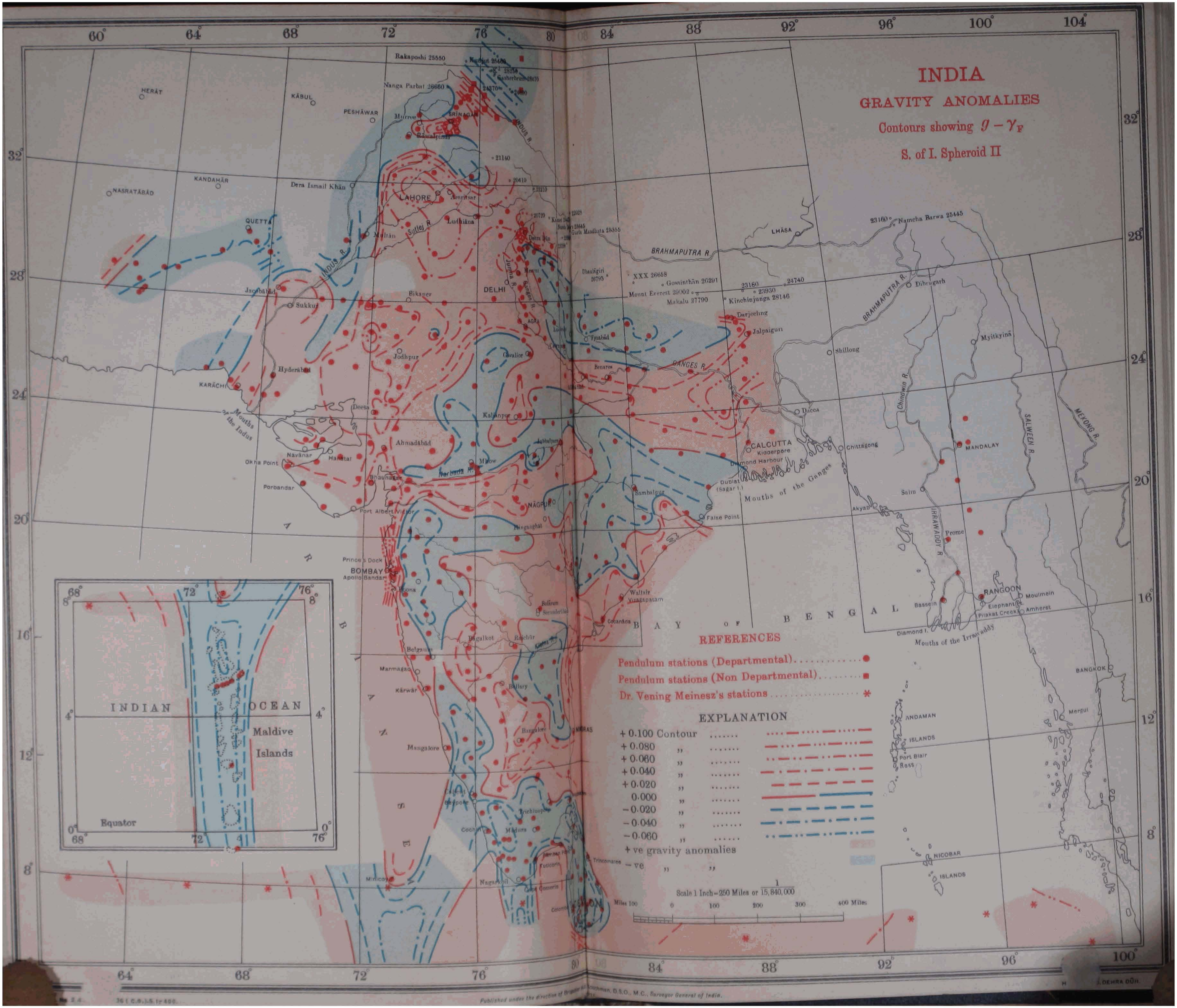
TABLE 6.—*Values of* $g-\gamma_{CI}$.

(The unit is 1 mgal.)

Station No.	$g-\gamma_{CI}$	Station No.	$g-\gamma_{CI}$	Station No.	$g-\gamma_{CI}$
345	− 0	355	− 6	365	+32
346	− 8	356	− 0	366	+26
347	−13	357	− 8	367	−12
348	− 6	358	− 5	368	+21
112*	+18	359	−10	369	+ 1
349	− 5	360	− 6	370	+54
350	− 1	361	−16	371	+16
351	− 9	362	− 3	372	+18
352	−12	363	+26	373	+ 9
353	−20	214*	−16	374	− 7
354	−14	364	+ 7	375	+28

* Repeat station.

Note:—This table is the second addendum to Table 6 of Chapter IV, Geodetic Report Vol. VIII.



INDIA

GRAVITY ANOMALIES

Contours showing $g - \gamma_F$

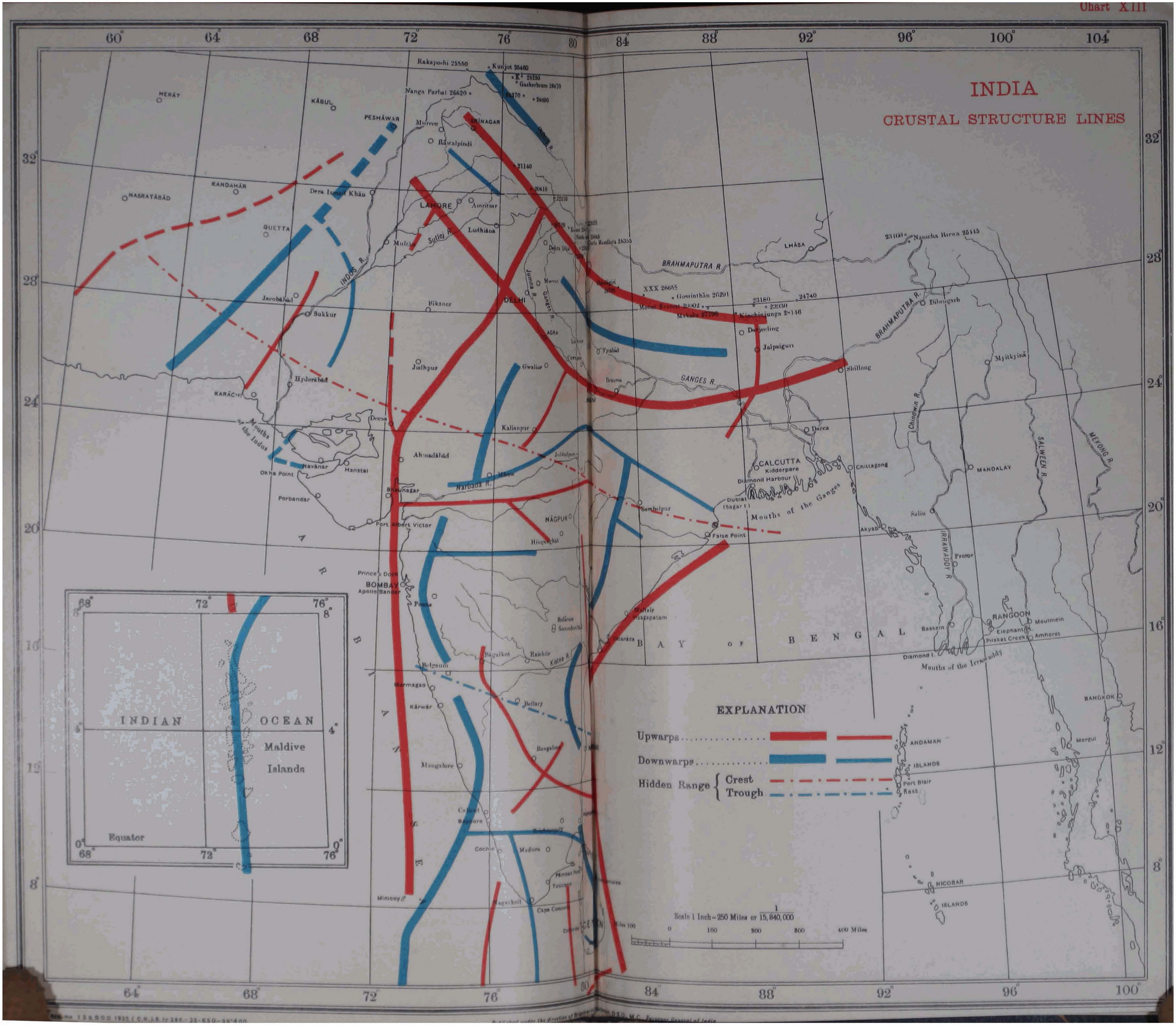
S. of I. Spheroid II

No. Z.4 36 (C.O.) S. Ir 400.

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

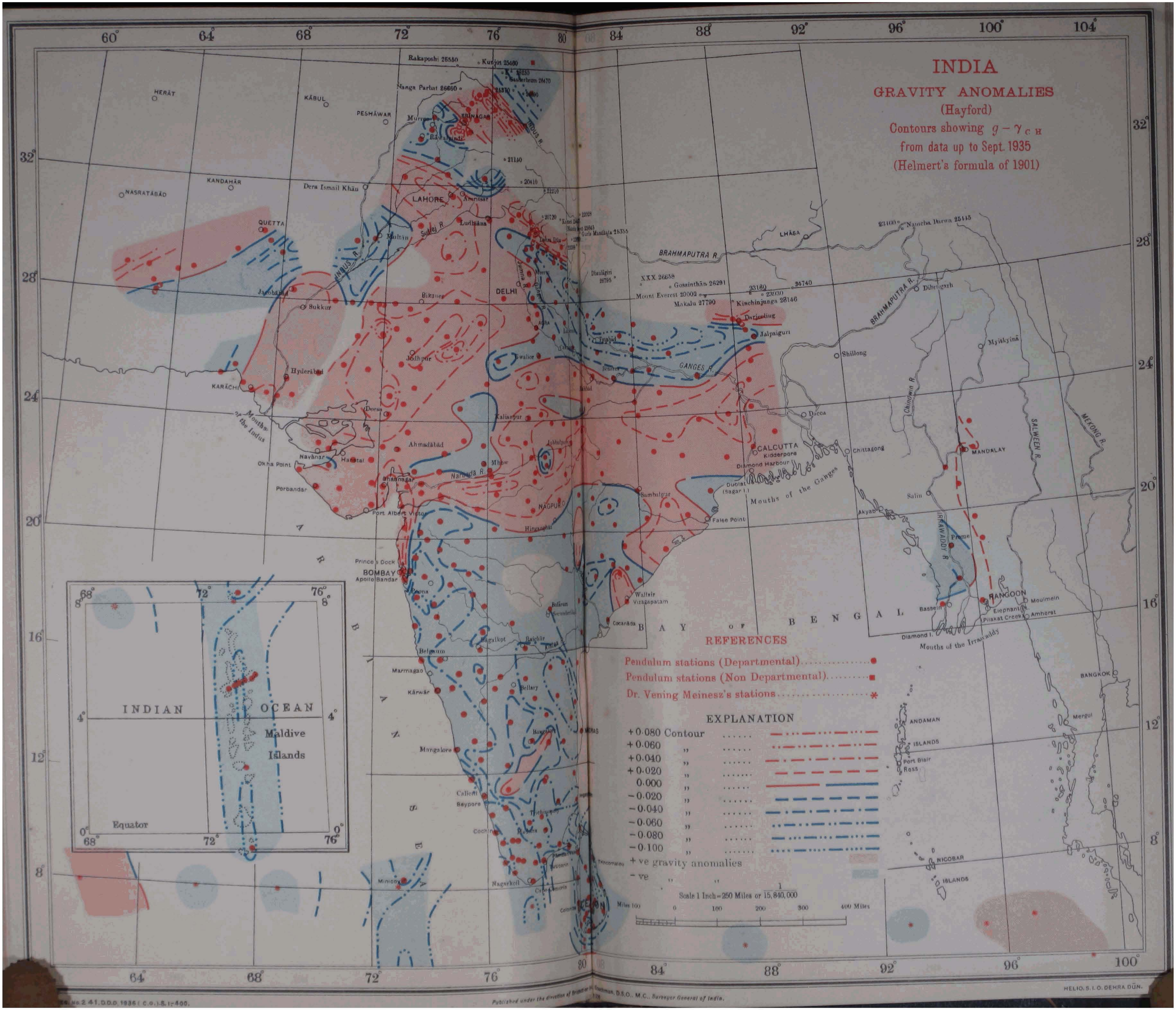
H J. DEHRA DŪN

Chart XIII



INDIA

CRUSTAL STRUCTURE LINES



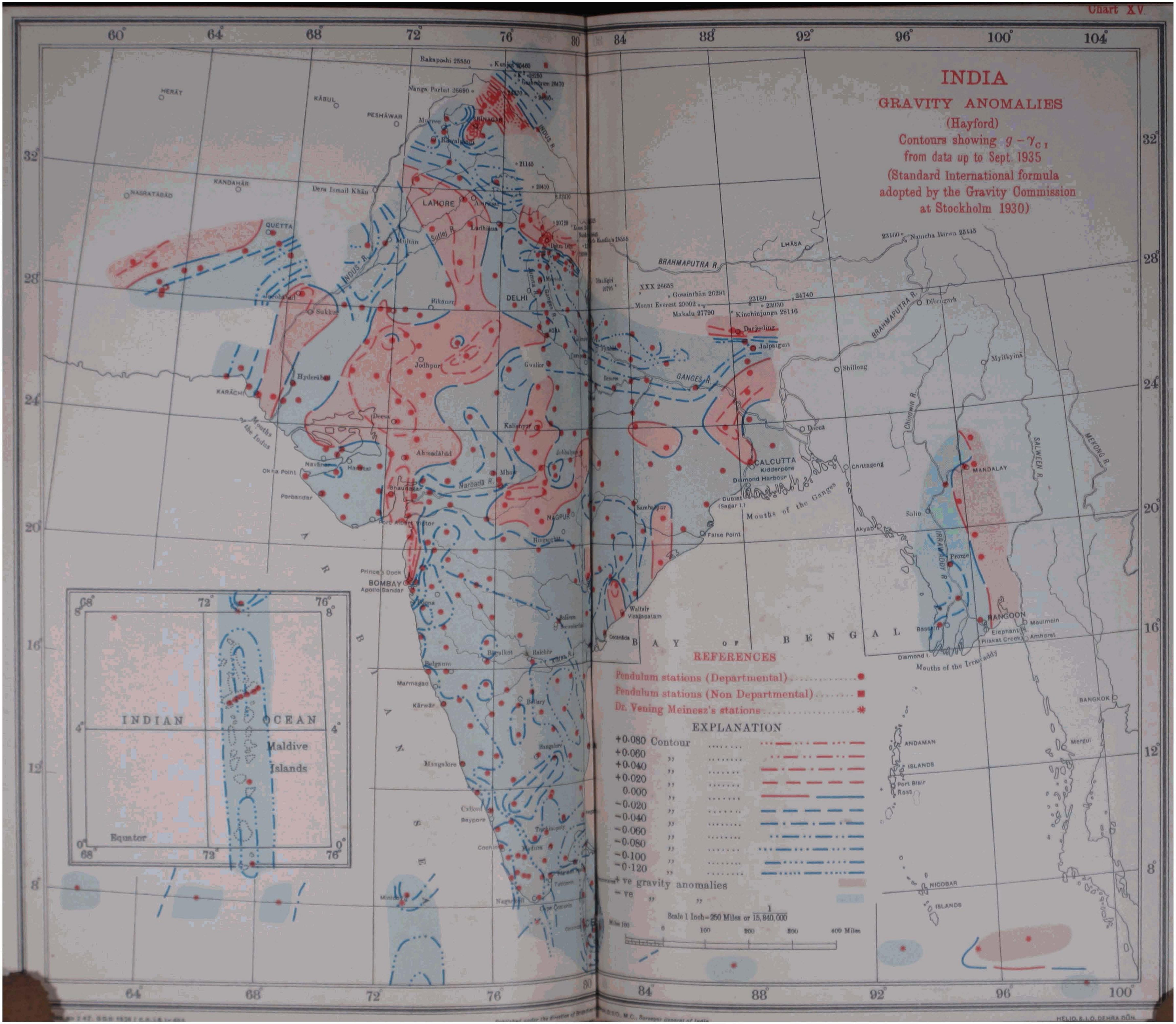
INDIA
GRAVITY ANOMALIES
(Hayford)
Contours showing $g - \gamma_{CH}$
from data up to Sept. 1935
(Helmert's formula of 1901)

No. 2 41. D.D.D. 1936 (C.O.) S. 1,-400.

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

HELIO. S.I.O. DEHRA DŪN.

Chart XV



INDIA
GRAVITY ANOMALIES
(Hayford)
Contours showing $g - \gamma_{C\,I}$
from data up to Sept. 1935
(Standard International formula
adopted by the Gravity Commission
at Stockholm 1930)

CHAPTER V

GEOPHYSICAL SURVEY IN BIHAR

BY LT.-COLONEL E. A. GLENNIE, D.S.O., R.E.

32. **Object of the Survey.**—The tectonic earthquakes of North India are probably due to a continuation of the process which has created the Himālayan Mountains. This process is the narrowing and buckling up and down of an ancient broad downwarp marked for long ages by the Tethys Sea.

Whether this narrowing is due to movement from the north or from the south, or both, is a matter of controversy and is not important from the point of view of the location of earthquakes in North India.

The narrowing of a crustal downwarp filled with uncompacted sediments would probably not result in a catastrophic earthquake but when there are in addition layers of relatively strong and compact rocks these may be thrust forward, and it is these violent relative movements which create the shattering vibrations.

It is, therefore, the local geological conditions of bedding, strike, dip and fracturing of the rock formations and their relative strength and compactness which mainly determine the location of the epicentral tract of an earthquake. In the preliminary account of the Bihār Earthquake of 1934 by the Geological Survey of India it is stated with reference to the thrust plane exposed near Udaipur Garhi that "whatever movement may have occurred along this thrust plane below the surface, nothing remarkable happened at its outcrop with the surface. It is more probable that the movements responsible for the earthquake originated further south, along thrust planes that are now concealed by the Gangetic alluvium ".* It is likely therefore that movement along the line of a fault *concealed under the alluvium* was the local cause of violence in the epicentral tract. It is of prime importance that the course of such a feature and of other geological features concealed under the plain should be mapped.

33. **Geophysical investigation.**—As the features are hidden, ordinary geological investigation cannot be employed. Gravity observations with the pendulum can show the main tectonic downwarps and upwarps, but the pendulum is not suitable for the more detailed investigation required in Bihār. Recourse must be had to more sensitive methods of geophysical research. These are :—

(*a*) Gravimetric (torsion balance).

(*b*) Magnetic.

---

* *Rec. Geol. Sur. Ind.* Vol. LXVIII, Part 2, p. 218.

(*c*) Seismological (artificial earthquakes made by explosions).

(*d*) Electric.

The flat alluvial plains of North Bihār, devoid of marked topographical and geological features, form an ideal field for geophysical exploration. Pendulum results indicate, at the deepest part, a depth of over six thousand feet of light sediments, and since the underlying rocks have probably a notably greater density, the torsion balance should be very suitable for charting the lower surface of the alluvium. Again it is known that the rocks of the Peninsula bordering the south edge of the Gangetic plain contain minerals capable of causing magnetic effects, so magnetic investigation also is promising if these rocks underlie the alluvium.

34. **Preliminary geophysical survey.**—As a result of the above considerations it was decided to undertake a short preliminary investigation using both gravimetric and magnetic methods independently over the same line of country. The line chosen for the traverse was from the Nepāl boundary due south passing just west of Motīhāri, that is, approximately down the 84° 55′ meridian. Since gravity data show the depth of alluvium to be rather over a mile the spacing of the stations should be about the same, so they were spaced 1 to 2 miles apart along the greater part of the line, but closer near Motīhāri where the prolongation of the axis of the epicentral tract came; they were placed closer also where the observations appeared to indicate hidden features.

35. **The magnetic detachment.**—The magnetic detachment consisted of Mr. Shyam Narain, one computer and eight *khalāsis* equipped with a Survey of India magnetometer and an earth inductor with a mirror galvanometer. The earth inductor took the place of the dip circle usually employed in field work in India. Its mirror galvanometer is not designed for field work, and gave trouble at the first station of observation, but thereafter worked well, and the use of the earth inductor instead of a dip circle resulted in increased accuracy and speed.

Observations were made, with the magnetometer for declination and horizontal force, and with the earth inductor for dip. This programme and equipment were suitable for preliminary work, intended to test the utility of magnetic survey in this area, but it would not serve for extensive surveys. Only one station could be occupied daily: the value for vertical intensity (V.I.) was deduced from a combination of the observations for horizontal intensity (H.) and dip, and so has less weight than a direct observation for V.I. and is not independent of the H. observation, and since the disturbing rocks were at a great depth, their effects were small and were masked by the daily variations of the earth's magnetic field until corrected for these. These corrections were only possible some months later when the data from the standard magnetic station at Dehra Dūn became available. For further work of this nature duplicate sets of vertical force and horizontal force variometers are required. With this modern equipment six or more closely spaced stations can be observed in an hour and diurnal variations applied without delay.

Starting in the north near Raxaul in the beginning of October, the detachment had trouble at first owing to floods. Wide detours of many miles had frequently to be made, and some stations had to be omitted. After crossing the Sikrāna river, about eight miles north of Motīhāri, conditions improved very much. Observations were made at 29 stations in all.

36. **The gravimetric detachment.**—On the completion of the pendulum programme in January (see Chapter IV) Mr. Hashmie set out again with the gravimetric detachment consisting of himself as observer, one computer and eleven *khalāsis.* By then the floods had subsided and general conditions were much improved. The final results of the magnetic detachment were not yet ready, so the gravimetric work was entirely independent of the magnetic work. The same line was traversed but the observation stations were not identical with those of the magnetic detachment, and a longer line was traversed. Observations were made at 61 stations in all, one or two stations being completed daily. The instrument used was a gradiometer by Messrs. Oertling & Co. This instrument was obtained in 1930 but owing to damage on the journey out to India was repaired and improved by Messrs. Cooke, Troughton and Simms in 1932 (see Geodetic Report Vol. VII, page 79 and Geodetic Report 1933, page ix). Four new calibrated torsion wires were obtained for the Bihār work, and preliminary test observations were made at Dehra Dūn. No breakage of wire occurred during the field work, and the instrument remained well balanced throughout.

37. **Results.**—Details of the magnetic observations are given in Table 1 and of the gradiometer observations in Table 2.

The magnetic data are corrected for diurnal variation, using for this purpose the continuous magnetic observations of the Dehra Dūn magnetic observatory. The normal horizontal and vertical force intensities employed to obtain the anomalies are derived from the magnetic surveys of 1901 to 1920 and of 1930–31. The extreme range in H.F. anomaly is from $+9\gamma$ to $+137\gamma$; on two occasions there is an abrupt change in anomaly between successive stations of over 50γ, the probable error of observation being about $\pm 5\gamma$.

The observed gravity gradients are small; the northerly gradients range from $+15$E to -8E and the easterly gradients from $+15$E to -15E with a probable error of ± 2E.

Here $1\text{E} = $ one Eotvos unit $= 10^{-9}$ C.G.S. units
$= 10^{-6}$ mgal per cm.

The corrections to be applied are:—

(*a*) Latitude correction* (to northerly gradients only). This correction varied from − 7 E to − 6 E in the south and introduces no appreciable error.

(*b*) Terrain and topographical corrections. These were evaluated following the system given in *Geophysical Prospecting* by Broughton Edge and Laby but, owing to the extreme flatness of the country the corrections proved to be negligible at every station.

(*c*) Cartographical correction. Owing to the great mass of mountains to the north this is a most important correction. It was obtained by computing the Hayford correction in the same way as for a gravity station at five places along the line of the traverse and similarly along lines to the east and west. After interpolating the correction at intermediate stations the gradient correction in both directions was computed.

The cartographical corrections to the northerly gradients computed in this way amount to + 9 E in the north reducing to + 2 E in the south.

Since the correction is positive, it is evidently the isostatic compensation assumed in the computation which has the greatest effect. If, therefore, the assumption of isostatic compensation is incorrect, and a crustal upwarp underlies the outer ranges of the Himālayas, as indeed is indicated by gravity work up to date, the introduction of the cartographical correction will have the effect of giving the gravity gradients a northerly bias especially in the northern part of the traverse. The correction to the easterly gradient is small, amounting to + 2 E in the north and zero in the south.

38. Consideration of the results.—It has been shown above that the range of magnetic effect in this traverse is much greater than that of the gradients, and further that the corrections to the gradients are considerable, and, in the case of the cartographical correction, have probably introduced error.

Interpretation of results based on the magnetic effect is, therefore, most likely to be satisfactory. This does not mean, however, that the gradiometer results are without value. If the results indicate that wherever the magnetic data show sudden changes there is also a sudden change in the gravity gradient either in direction or in amount, this may be taken as a very strong confirmation of the magnetic results.

It has already been pointed out that the vertical force anomalies obtained through a combination of observations have less weight

---

* The latitude correction in Eotvos units is :

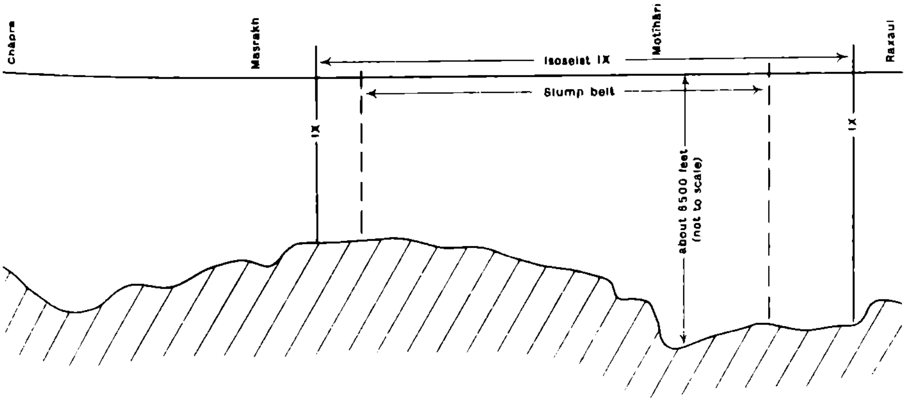
$$\Delta\gamma = (AG' \sin 2\phi - 2 BG' \sin 4\phi)/R \times 10^{-9}$$

where G′, A and B have the values in the formula employed for theoretic gravity, $\gamma_0 = G' (1 + A \sin^2 \phi - B \sin^2 2\phi)$, and R is the radius of the earth in centimetres.

than the horizontal force anomalies. Further when the dip is less than 45°, as is the case in Bihār, the horizontal force anomalies are more useful from the point of view of interpretation. In Plate XVI therefore V.F. anomalies have not been shown; the upper portion shows the magnetic results of dip, declination and H.F. anomaly while the corrected gradients are shown below in plan. Where the gradiometer stations were too close together to be shown conveniently on the small scale of this plan the arrows represent the average gradients. The individual gradient observations were, however, mutually consistent, and are given in detail in Table 2.

Starting in the north marked changes are seen at once in the H.F. anomalies, and this is reflected by a reversal of the gravity gradient. Continuing south conditions are steady as far as Motīhāri, where large changes in the H.F. anomaly occur in two stages followed by a steady increase in H.F. anomaly. The change at Motīhāri is also indicated by a change in the curve of magnetic declinations. At the same places large changes occur in the directions of the gravity gradients. Further south magnetic work comes to an end, but the gradiometer traverse continues south by west to Chāpra and shows further changes in the directions of the gradient arrows. Since gradiometer results in the northern part of the line confirm the magnetic results, they can be used with confidence in the southern part where magnetic data are absent.

39. **Interpretation.**—A final interpretation is not possible from a single traverse line of this nature. The figure below is consistent with the results. It may be supposed that there has been a southerly movement at a concealed thrust fault just south of the Nepāl boundary, and that the feature just south of Motīhāri has opposed southerly movement in the lower layers of the alluvium, so that there is an enhancement of surface effects in this region.



If this is correct then the same feature should screen the areas further south. Reading the preliminary report on the North Bihār earthquake from this point of view the following reports refer to the line of the traverse.

Motihāri. "Motīhāri has suffered severely, faulting, fissuring and emission of sand are very extensive.........".

Masrakh. "Collapse of buildings at Masrakh is rare, but cracking is severe".

Chāpra. "The town of Chāpra has escaped more fortunately than other district headquarters in North Bihār. The town is free from any fissures or sand vents, and the relative intensity of the shock, so far as the collapse of buildings is concerned, was distinctly less......... The collapse of buildings in Chāpra is negligible......... .... In general Chāpra is free from ground cracks and the damage done to buildings is entirely due to ground tremor".

This evidence then is strongly in favour of screening by the feature south of Motīhāri.* Additional geophysical surveys to chart this and other features under the Bihār alluvium are essential for the correct planning of measures for earthquake protection in this area.

---

* Since writing above Mr. J. B. Auden has pointed out that the narrow extension west from Monghyr of the IX isoseist is an argument against screening by this feature. The IX isoseist however stops short of Chāpra and the VIII isoseist curves up close to Chāpra so that it can be argued that screening is marked near Chāpra and diminishes towards east corresponding to a decrease in the height of main feature east of Motīhāri.

Further speculation is idle; additional geophysical surveys should soon make the situation clear.

Bihār Geophysical Survey.

Plate XVI

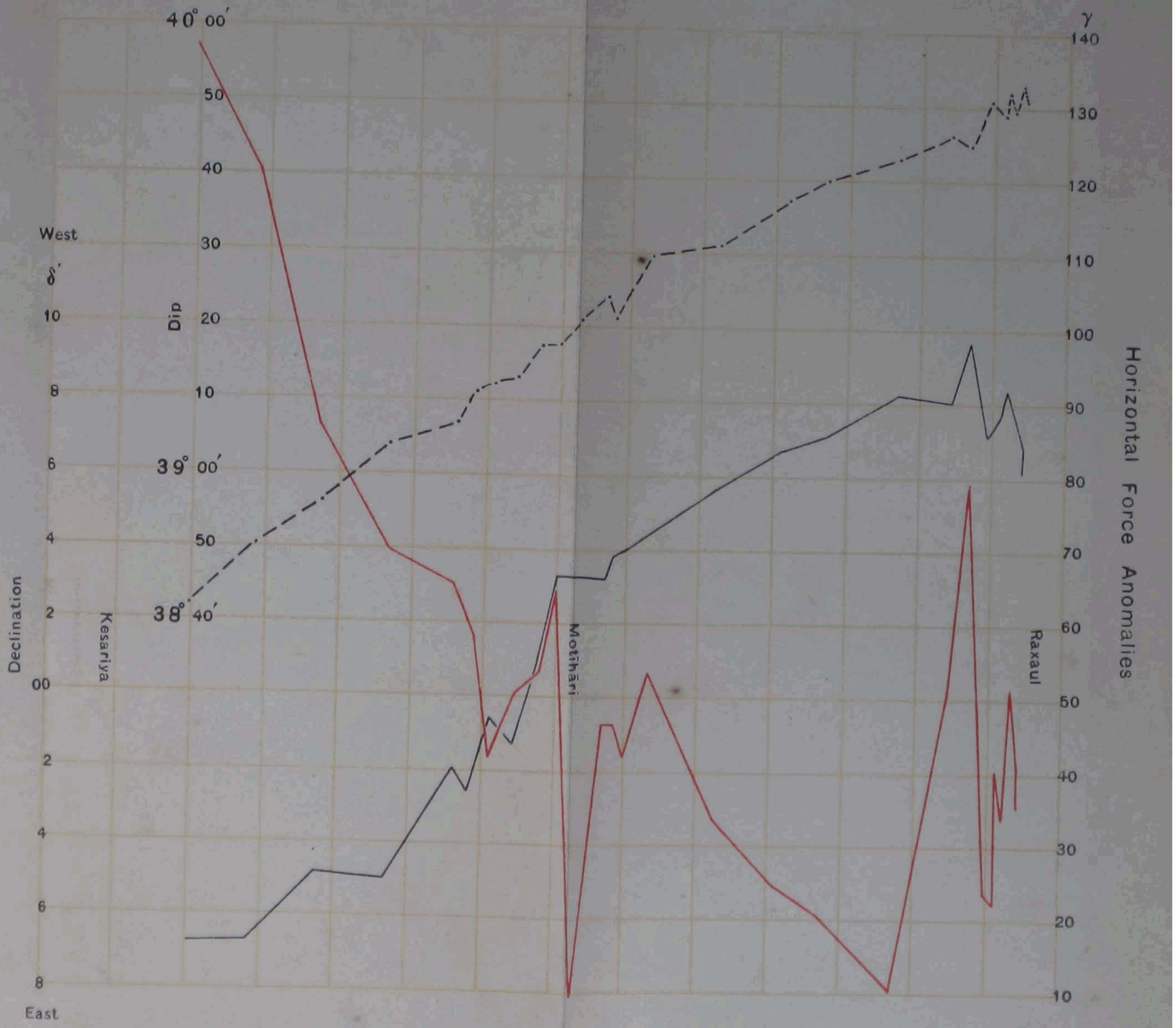
EXPLANATION

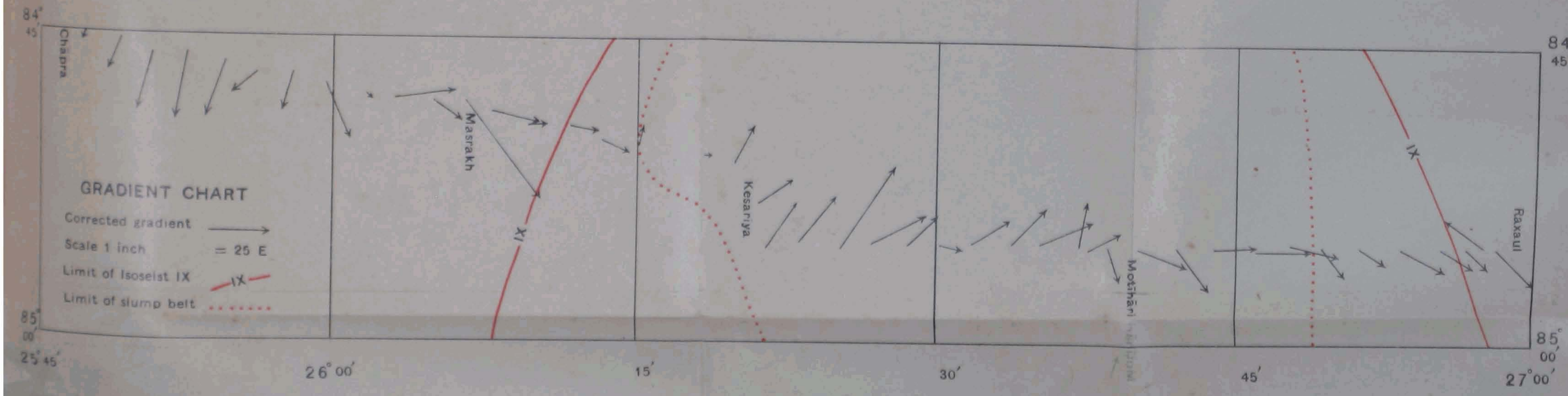
Horizontal magnetic force anomalies...... ━━

Dip.. – – – –

Declination...................................... ──

Magnetic sections are drawn to same horizontal scale as gradient chart. Magnetic stations are not identical with gradiometer stations. They are in longitude 84°55′





REG. No.227D.D.D. 1936–400.

Helio S. I. O. Dehra Dun

TABLE 1.—*Magnetic Stations.*

Station No.	Date	Latitude	Longitude	Declination *	Dip *	H.F.*	Normal H F.	H.F. Anomaly
		° ′ ″	° ′ ″	° ′ ″	° ′	C.G.S.	C.G.S.	γ
1	7-10-34	26 57 45	84 54 53	W. 0 06 48	38 22·4†	0·35476	0·35425	+ 51
2	9-10-34	26 56 52	84 55 00	0 07 06	39 50·6	0·35458	0·35435	+ 23
3	12-10-34	26 56 06	84 55 04	0 09 42	39 45·3	0·35523	0·35444	+ 79
4	13-10-34	26 55 20	84 54 55	0 08 00	39 46·6	0·35501	0·35453	+ 48
5	17-10-34	26 53 05	84 55 11	0 08 06	39 43·1	0·35488	0·35478	+ 10
6	20-10-34	26 50 02	84 54 48	0 07 06	39 38·0	0·35533	0·35513	+ 20
7	22-10-34	26 48 19	84 55 05	0 06 42	39 37·7	0·35556	0·35532	+ 24
8	26-10-34	26 45 50	84 56 07	0 05 24	39 31·3	0·35593	0·35560	+ 33
9	28-10-34	26 43 04	84 54 53	0 04 06	39 29·9	0·35645	0·35592	+ 53
10	30-10-34	26 42 00	84 55 07	0 04 00	39 25·9	0·35645	0·35604	+ 41
11	1-11-34	26 41 28	84 54 57	0 03 48	39 21·0	0·35656	0·35610	+ 46
12	3-11-34	26 40 38	84 55 00	0 03 12	39 24·1	0·35666	0·35619	+ 47
13	8-11-34	26 39 53	84 55 03	0 03 18	39 21·3	0·35637	0·35628	+ 9
14	9-11-34	26 38 58	84 54 54	0 03 18	39 17·6	0·35702	0·35638	+ 64
15	10-11-34	26 38 18	84 55 00	W. 0 00 54	39 17·4	0·35699	0·35646	+ 53
16	13-11-34	26 37 21	84 55 00	E. 0 01 18	39 12·9	0·35707	0·35657	+ 50
17	15-11-34	26 36 20	84 55 05	0 00 36	39 11·5	0·35709	0·35668	+ 41
18	17-11-34	26 35 30	84 54 50	0 02 36	39 11·0	0·35736	0·35678	+ 58
19	19-11-34	26 34 49	84 54 53	0 02 00	39 07·3	0·35751	0·35686	+ 65
20	21-11-34	26 32 11	84 55 03	0 05 00	39 03·7	0·35784	0 35715	+ 69
21	23-11-34	26 29 20	84 55 00	0 04 54	38 55·5	0·35834	0·35748	+ 86
22	25-11-34	26 26 27	84 55 02	0 06 36	38 49·7	0·35898	0·35778	+120
23	27-11-34	26 24 01	84 54 58	E. 0 06 48	38 41·9	0·35945	0·35808	+137
2(*a*)	3-12-34	26 57 05	84 54 59	W. 0 07 42	39 49·5	0·35456	0·35434	+ 22
2(*b*)	4-12-34	26 57 17	84 55 00	0 08 00	39 49·0	0·35471	0·35432	+ 39
2(*c*)	5-12-34	26 57 30	84 55 00	0 08 36	39 52·2	0·35463	0·35430	+ 33
1(*a*)	6-12-34	26 57 45	84 54 39	0 06 48	39 49·1	0·35464	0·35425	+ 39
1(*b*)	7-12-34	26 57 57	84 54 53	0 05 24	39 52·8	0·35458	0·35423	+ 35
1(*c*)	8-12-34	26 58 09	84 54 53	W. 0 05 54	39 51·5	0·35460	0·35420	+ 40

* With observatory correction.

† Rejected: Galvanometer in bad order.

TABLE 2.—*Gravimetric Stations.*

Station No.	Latitude	Longitude	Observed gradients		Latitude correction	Cartographical correction		Corrected gradients	
			North	East		North	East	North	East
	° ′ ″	° ′ ″	E	E	E	E	E	E	E
1	26 58 06	84 55 00	+ 6	+ 1	− 7	+ 9	+ 2	+ 8	+ 3
2	26 57 40	84 55 00	+ 8	+ 7	− 7	+ 9	+ 2	+ 10	+ 9
3	26 57 15	84 55 00	− 8	− 7	− 7	+ 8	+ 2	− 7	− 5
4	26 56 50	84 55 00	+ 3	+ 1	− 7	+ 8	+ 2	+ 4	+ 3
5	26 56 25	84 55 00	+ 3	+ 2	− 7	+ 8	+ 2	+ 4	+ 4
6	26 55 30	84 55 04	+ 6	+ 5	− 7	+ 8	+ 2	+ 7	+ 7
7	26 54 30	84 55 04	+ 5	0	− 7	+ 8	+ 2	+ 6	+ 2
8	26 53 38	84 55 04	+ 8	− 1	− 7	+ 8	+ 2	+ 9	+ 1
9	26 52 50	84 55 11	+ 8	+ 5	− 7	+ 8	+ 2	+ 9	+ 7
10	26 51 07	84 55 00	+ 5	+ 1	− 7	+ 7	+ 2	+ 5	+ 3
11	26 49 15	84 55 00	+ 5	+ 2	− 7	+ 7	+ 2	+ 5	+ 4
12	26 47 28	84 54 50	+ 9	0	− 7	+ 6	+ 2	+ 8	+ 2
13	26 45 40	84 55 10	+ 11	− 2	− 7	+ 6	+ 2	+ 10	0
14	26 44 02	84 55 04	+ 6	− 2	− 7	+ 6	+ 2	+ 5	0
15	26 42 20	84 55 10	+ 3	+ 2	− 7	+ 6	+ 2	+ 2	+ 4
15(*a*)	26 42 08	84 55 06	+ 9	− 1	− 7	+ 6	+ 2	+ 8	+ 1
15(*b*)	26 41 56	84 55 04	+ 5	+ 4	− 7	+ 5	+ 2	+ 3	+ 6
15(*c*)	26 41 45	84 55 02	+ 8	+ 8	− 7	+ 5	+ 2	+ 4	+ 10
15(*d*)	26 41 33	84 55 00	+ 12	+ 5	− 7	+ 5	+ 2	+ 10	+ 7
16	26 40 40	84 55 00	+ 13	− 1	− 7	+ 5	+ 2	+ 11	+ 1
16(*a*)	26 40 21	84 55 00	+ 8	− 1	− 7	+ 5	+ 2	+ 6	+ 1
16(*b*)	26 39 56	84 55 02	+ 6	+ 5	− 7	+ 5	+ 2	+ 4	+ 7
16(*c*)	26 39 35	84 54 59	+ 6	− 4	− 7	+ 5	+ 2	+ 4	− 2
16(*d*)	26 39 13	84 55 00	+ 14	+ 9	− 7	+ 5	+ 2	+ 12	+ 11
16(*e*)	26 38 59	84 54 50	0	− 4	− 7	+ 5	+ 2	− 2	− 2
17	26 38 45	84 54 52	− 1	+ 15	− 7	+ 5	+ 2	− 3	+ 17
17(*a*)	26 38 20	84 55 00	+ 5	− 1	− 7	+ 5	+ 1	+ 3	0
17(*b*)	26 37 56	84 55 02	+ 5	− 6	− 7	+ 5	+ 1	+ 3	− 5
17(*c*)	26 37 42	84 55 00	+ 8	− 5	− 7	+ 5	+ 1	+ 6	− 4
17(*d*)	26 37 28	84 54 58	+ 8	− 1	− 7	+ 5	+ 1	+ 6	0
17(*e*)	26 37 02	84 55 00	+ 2	− 5	− 7	+ 5	+ 1	0	− 4
18	26 36 50	84 54 56	+ 6	− 12	− 7	+ 5	+ 1	+ 4	− 11
19	26 35 07	84 54 46	+ 11	− 5	− 7	+ 5	+ 1	+ 9	− 4
20	26 33 42	84 54 55	+ 8	− 7	− 7	+ 4	+ 1	+ 5	− 6
21	26 31 52	84 55 00	+ 9	− 5	− 7	+ 4	+ 1	+ 6	− 4
22	26 30 10	84 55 00	+ 7	0	− 7	+ 4	+ 1	+ 4	+ 1
23	26 28 25	84 55 00	+ 8	− 6	− 7	+ 4	+ 1	+ 5	− 5
24	26 26 40	84 55 00	+ 12	− 6	− 7	+ 4	+ 1	+ 9	− 5
25	26 25 05	84 55 15	+ 11	− 15	− 6	+ 4	+ 1	+ 9	− 14
26	26 23 12	84 55 00	+ 8	− 9	− 6	+ 4	+ 1	+ 6	− 8
27	26 21 10	84 52 50	+ 9	− 5	− 6	+ 3	+ 1	+ 6	− 4
28	26 21 33	84 55 05	+ 8	− 9	− 6	+ 3	+ 1	+ 5	− 8

(*Continued*)

TABLE 2.— *Gravimetric Stations*—(*concld.*).

Station No.	Latitude	Longitude	Observed gradients		Latitude correction	Cartographical correction		Corrected gradients	
			North	East		North	East	North	East
	° ′ ″	° ′ ″	E	E	E	E	E	E	E
29	26 20 12	84 51 04	+ 6	− 7	− 6	+ 3	+ 1	+ 3	− 6
30	26 18 30	84 50 40	+ 4	+ 1	− 6	+ 3	+ 1	+ 1	0
31	26 15 05	84 50 04	+ 4	− 4	− 6	+ 3	+ 1	+ 1	− 3
32	26 13 20	84 49 50	+ 7	+ 1	− 6	+ 3	+ 1	+ 4	+ 2
33	26 11 42	84 49 25	+ 7	0	− 6	+ 3	+ 1	+ 4	+ 1
34	26 09 50	84 49 20	+ 6	− 1	− 6	+ 3	+ 1	+ 3	0
35	26 08 15	84 48 35	+ 11	+ 1	− 6	+ 3	+ 1	+ 8	+ 2
36	26 06 22	84 48 10	+ 15	+ 15	− 6	+ 3	+ 1	+ 12	+ 16
37	26 04 50	84 48 14	+ 7	+ 2	− 6	+ 3	+ 1	+ 4	+ 3
38	26 03 00	84 47 45	+ 14	− 2	− 6	+ 2	+ 1	+ 10	− 1
39	26 01 30	84 47 46	+ 5	0	− 6	+ 2	+ 1	+ 1	+ 1
40	25 59 45	84 47 23	+ 8	+ 9	− 6	+ 2	0	+ 4	+ 9
41	25 58 05	84 46 57	+ 2	+ 6	− 6	+ 2	0	− 2	+ 6
42	25 56 15	84 46 38	0	+ 11	− 6	+ 2	0	− 4	+ 11
43	25 54 33	84 46 18	+ 1	+ 9	− 6	+ 2	0	− 3	+ 9
44	25 52 47	84 45 47	+ 2	+ 12	− 6	+ 2	0	− 2	+ 12
45	25 51 07	84 45 50	+ 2	+ 10	− 6	+ 2	0	− 2	+ 10
46	25 49 24	84 45 26	+ 2	+ 5	− 6	+ 2	0	− 2	+ 5
47	25 47 36	84 45 00	+ 3	+ 1	− 6	+ 2	0	− 1	+ 1

CHAPTER VI

COMPUTING OFFICE AND TIDAL SECTION

BY LT.-COLONEL E. A. GLENNIE, D.S.O., R.E.

40. **Summary.**—During the year under review the activities of the Computing Office apart from a considerable amount of miscellaneous work have been about equally divided between computations for the Lambert grid, computation and adjustment of geodetic and minor triangulation and computations connected with the field observations for latitude and longitude described in Chapter III. The Tidal Section has followed its usual routine and in addition has computed monthly and yearly mean sea-levels required by the International Association of Physical Oceanography.

COMPUTING OFFICE

41. **Geodetic triangulation.**—The side Hāthimura H.S.-Maiang H. S. of the Assam Longitudinal series is the starting side of the new Assam Valley series, but the observations at these stations have not confirmed the old data and it is intended to reobserve at these stations next field season. The computations of the new Assam Valley series have consequently been based on the side Golaghāt H. S.-Cheniābinshon H. S. of the Nāga Hills series.

The Nāga Hills series was adjusted on the old Assam Valley triangulation, a weak series, which has now been reobserved. Its co-ordinates were computed and published to two decimals of a second. It has, therefore, been necessary to ignore the adjustment of the Nāga Hills series and recompute its co-ordinates to three decimals of a second in terms of the Manipur Longitudinal series. The re-computations have been carried out and the new Assam Valley series has been based on these values. When the connection with the Assam Longitudinal series is finally established, both the new Assam Valley series and the Nāga Hills series will be adjusted on to the Assam Longitudinal series.

Computations of Poona and Padag base extension triangulations have been completed.

42. **Minor triangulation.**—The adjustment of topographical triangulation in 1/M sheets 29, 30, 31 and 33 has been completed and that of the Irānian sheets 1/M 9, 10, 16, 17, 18, 23, 24 and 25 is well in hand. Some framework data for No. 1 Topographical Party in sheets 53 and 54 have also been adjusted.

43. **Lambert grid.**—Satisfactory progress has been made with the conversion of triangulation data on the North-West Frontier

into terms of the Lambert grid. During the year 4,600 points have been converted, and 3,100 classified to indicate the quality of their fixing. The total number of points was estimated to be about 25,000. It has now been found to be about 27,500. Out of the total of 27,500 points, 21,400 have now been converted, 23,000 classified and 18,500 compiled in 23 grid triangulation pamphlets. Nine of these pamphlets have been printed, eight are at press and charts are being drawn for six. It is hoped to complete the work by the middle of 1936, when conversion to grid of data in the training areas will be taken up.

44. **Publications.**—Three Indian triangulation pamphlets and addenda to one have been printed.

The data of about 350 miles of precise levelling have been printed and issued as addenda.

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

(*a*) Geodetic Report 1934.

(*b*) Handbook of Topography, Chapter II, *Constitution and Duties of a Survey Party.*

45. **Miscellaneous.**—Heights from hypsometric readings by Mr. G. Sheriff in the Himālayan regions of Assam and Bhutān and by Colonel Schomberg in Karakoram have been computed. Sir Aurel Stein's barometric and hypsometric readings in Fars have been reduced. A large number of smaller pieces of work have also been attended to as usual.

46. **Chart Section.**—The following are the main items of work completed by the Chart Section :—

(*a*) Charts for 14 grid triangulation pamphlets.

(*b*) 18 charts and plates for Geodetic Report 1934.

(*c*) About 60 miscellaneous charts and diagrams.

TIDAL SECTION

47. **Tidal observations.**—The automatic gauges installed at Aden, Karāchi, Bombay, Colombo, Calcutta and Rangoon worked satisfactorily under the control of the port authorities. The only break exceeding one day occurred at Bombay where the clock stopped for two days. The Kent's pneumatic gauge at Dublat worked with a few breaks. The port officials inspected the tidal observatories at Bombay and Rangoon in May 1935.

Daylight observations on tide-poles have been made at Bhāvnagar, Vizagapatam, Chāndbāli, Chittagong and Akyab.

48. **Corrections to predictions.**—Empirical corrections have been included in the tide predictions for 1936 for Chāndbāli, Kidderpore, Chittagong and Rangoon. These are based on the comparison of the predicted and actual tides of recent years.

49. Tide-tables.—The Tide-tables of the Indian Ocean, and the separate pamphlets for Bombay, the Hooghly River and the Rangoon River, have been prepared and issued for the year 1935 as usual. Predictions for certain ports for 1936 have been sent in advance, on the usual exchange basis, to the Admiralty, the U.S. Coast and Geodetic Survey and the Japanese Hydrographic Department for inclusion in their respective tide-tables.

The amount realized from the sale of tide-tables for 1935 during the year ending 30th September 1935 was Rs. 3,608/8/6 exclusive of agents' commission.

50. Accuracy of predictions.—The greatest errors in the height of low water during 1934 at the ports mentioned in para 47 are given in Table 1.

Tables 2 to 13 give detailed results of the comparison of predicted and actual tides. Except for a slight deterioration at Bhāvnagar the quality of prediction is practically the same as in previous years. The revised correction table for Kidderpore mentioned in last year's report has been used for the first time in the prediction for 1936.

51. Miscellaneous.—At the request of the International Association of Physical Oceanography, the Tidal Section has computed the monthly and yearly values of mean sea-level at Bombay from 1878 (the first year of available data) to 1930. The data do not show any progressive change of sea-level relative to the land at Bombay during this period. Plate XVII, Fig. 1 shows yearly means of sea-level at Bombay. This question of the constancy of sea-level is one of considerable interest. The sea-level surface, imagined extended under the land, is the geoid to which all land heights are referred and to which the figure of the earth adopted for map projections should be closely fitted. Such a datum should not be subject to change, yet geological records show plainly that there have been world-wide changes of sea-level amounting to some hundreds of feet. Eustatic changes of sea-level cannot be detected by observations at a single port, since it may be masked by movements of the land, thus an apparent lowering of sea-level may in reality be due to a local rise of the land. World-wide observations at many tidal stations are therefore required, and the investigation can best be undertaken by an International Association.

When recent eustatic changes of sea-level, if any, have been determined, mean sea-level can be employed to detect changes of level of the land. In 1867 this method was being considered by the Government of Bombay in connection with land levels in the Rann of Cutch, and it was the subject of a lengthy communication by Colonel Walker, Superintendent Great Trigonometrical Survey.

Colonel Walker referred to a correlation between mean sea-level and barometric pressure. Examination of monthly means at

Mean Sea-Level at Bombay

Fig. 1 Yearly means

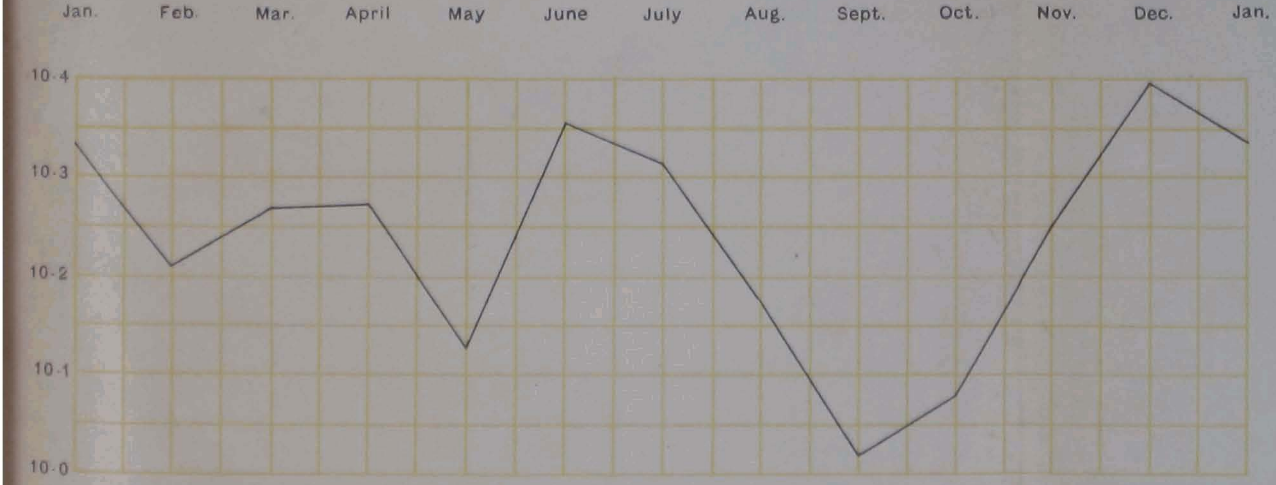


Fig. 2 Average monthly means

REG. No.246 D.D.D. 1936-380.

Helio S. I. O, Dehra Dun

Bombay shows persistent maxima in June and December and minima in May and September. These are shown in Plate XVII, Fig. 2. The sudden change from May to June is remarkable.

These fluctuations in mean sea-level presumably indicate the general changes of barometric pressure over the Arabian Sea, and may be of value to meteorologists in connection with monsoon predictions, though any correlation between them and the average strength of the monsoon is not obvious.

Attention has been drawn in the Comptes Rendus de l'Académie des Sciences to the connection between mean sea-levels and meteorological conditions by M. Jean Legrand who has shown that there is a relation between mean sea-levels in the Mediterranean Sea and rainfall in Abyssinia. He is being supplied with mean sea-level data relating to Aden and other ports so that he can extend his important researches.

TABLE 1.—*Greatest differences between predicted and actual heights of low water during 1934.*

Port	Predicted *minus* Actual	Date	REMARKS
	feet		
Aden ...	−0·6	Feb. 6 and Aug. 25.	
Karāchi ...	−1·1	July 17.	
Bhāvnagar ...	−5·1*	March 16.	Spring-tide.
Bombay (Apollo Bandar)	−1·3	Feb. 13, July 3 and Aug. 10.	
Colombo ...	+0·7	Oct. 13.	
Vizagapatam ...	+1·2	Sept. 15 and 16.	
Chāndbāli ...	−6·2	Aug. 26.	Riverain port. Flood.
Dublat ...	−1·7	Feb. 18.	Riverain port.
Kidderpore (Calcutta)...	−1·5	Sept. 20.	Do.
Chittagong ...	−1·7	July 13.	Do.
Akyab ...	−2·2	Nov. 9.	
Rangoon ...	−2·9	April 20.	Riverain port.

* The mean range of the greatest ordinary spring-tides at this port is 31½ feet.

TABLE 2.—*Mean errors E_1* and E_2* for 1934.*

ADEN

PERIOD 1934	MEAN ERRORS (Predicted – Actual)												Number of errors exceeding			
	E_1*								E_2*				30 minutes in time		0·7† feet in height	
	H. W.				L. W.				H. W.		L. W.					
	Time		Height		Time		Height		Time	Ht.	Time	Ht.				
	minutes		feet		minutes		feet		minutes	feet	minutes	feet	H. W.	L. W.	H. W.	L. W.
	+	−	+	−	+	−	+	−								
Jan. 1-15		10·1		0·1	1·4			0·1	11·9	0·2	5·6	0·2	1	0	0	0
16-31		2·8	0·1			6·8		0·0	7·1	0·1	9·9	0·2	0	2	0	0
Feb. 1-15		7·1		0·0	1·7			0·1	7·5	0·1	9·4	0·2	0	1	0	0
16-28		4·2	0·1			2·8		0·1	5·4	0·1	4·8	0·1	1	0	0	0
Mar. 1-15		2·9		0·0	0·7			0·1	4·9	0·1	6·3	0·2	0	0	0	0
16-31		0·8		0·1		1·2		0·2	6·7	0·2	8·1	0·2	1	0	0	0
April 1-15		3·0		0·2		6·8		0·2	4·3	0·2	7·9	0·2	1	1	0	0
16-30		2·3		0·2		0·6		0·2	7·3	0·2	6·3	0·2	1	1	0	0
May 1-15	0·9			0·1		1·5		0·0	2·4	0·1	5·0	0·1	0	0	0	0
16-31	0·0			0·2	1·1			0·2	5·5	0·2	4·3	0·2	1	1	0	0
June 1-15		4·1		0·3		2·8		0·2	5·4	0·3	4·6	0·2	0	0	0	0
16-30		7·9		0·0		1·2		0·1	11·2	0·2	8·7	0·2	1	0	0	0
July 1-15		19·9		0·0		18·0		0·0	19·9	0·1	18·0	0·1	3	2	0	0
16-31	3·3			0·1	4·4			0·2	4·8	0·2	8·4	0·2	0	1	0	0
Aug. 1-15	0·1			0·3	2·6			0·1	5·2	0·3	6·6	0·2	0	0	0	0
16-31	1·0			0·2	3·6			0·2	4·0	0·2	5·9	0·2	0	0	0	0
Sept. 1-15	5·7			0·1	4·1			0·2	6·0	0·2	5·3	0·2	0	1	0	0
16-30	1·0			0·0		1·5		0·1	6·4	0·1	3·4	0·1	1	0	0	0
Oct. 1-15	1·8			0·1	1·1			0·1	5·0	0·2	5·7	0·1	0	0	0	0
16-31		2·8	0·1			1·9		0·0	5·9	0·1	4·3	0·1	0	0	0	0
Nov. 1-15		3·8	0·2			1·7	0·1		6·2	0·2	7·2	0·2	1	0	0	0
16-30		4·6	0·1			2·3	0·0		8·1	0·1	8·5	0·1	0	1	0	0
Dec. 1-15	4·1			0·0	5·3			0·1	6·8	0·1	9·4	0·1	0	0	0	0
16-31	1·1			0·1	4·6			0·1	7·3	0·1	7·9	0·1	0	0	0	0
TOTALS ..	19·0	76·3	0·6	2·1	30·6	49·1	0·1	2·6	165·2	3·9	171·5	3·9	12	11	0	0
MEANS ..	− 2·4		− 0·1		− 0·8		− 0·1		6·9	0·2	7·1	0·2				

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

† One-tenth of the mean range of the greatest ordinary spring-tides.

TABLE 3.—*Mean errors E_1* and E_2* for 1934.*

KARĀCHI

PERIOD 1934	MEAN ERRORS (Predicted – Actual)												Number of errors exceeding			
	E_1*								E_2*				30 minutes in time		0·9† feet in height	
	H. W.				L. W.				H. W.		L. W.					
	Time		Height		Time		Height		Time	Ht.	Time	Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	–	+	–	+	–	+	–								
Jan. 1-15	0·5			0·2	4·7		0·1		9·3	0·3	15·9	0·2	0	1	0	0
16-31	11·8		0·1		7·8		0·3		14·8	0·2	12·5	0·3	3	2	0	0
Feb. 1-15	0·4			0·2	8·3		0·1		8·3	0·2	15·7	0·3	1	3	0	0
16-28	4·4			0·7	7·2			0·5	8·8	0·7	12·0	0·5	2	1	4	0
Mar. 1-15		5·1		0·5	6·2			0·3	9·8	0·6	12·1	0·3	2	0	0	0
16-31	7·6			0·6	8·4			0·3	9·6	0·6	13·1	0·3	4	4	0	0
April 1-15	0·3			0·6	9·6			0·3	4·3	0·6	9·6	0·3	0	1	0	0
16-30	1·4			0·6	10·6			0·3	5·1	0·6	13·5	0·4	0	1	3	0
May 1-15	2·4			0·4	7·9		0·0		5·2	0·4	10·4	0·1	0	0	0	0
16-31	0·3			0·3	12·5			0·1	5·9	0·4	15·7	0·2	0	2	0	0
June 1-15	0·3			0·3	9·2		0·1		6·3	0·3	11·5	0·2	0	0	0	0
16-30	1·6			0·7	10·2			0·5	6·9	0·7	12·8	0·5	0	0	6	1
July 1-15	0·4			0·7		1·2		0·4	10·8	0·7	10·0	0·4	1	0	4	0
16-31		4·9		0·3		1·9		0·2	8·4	0·4	10·3	0·4	1	3	0	2
Aug. 1-15	2·2			0·4	4·6			0·2	10·8	0·5	10·3	0·3	2	0	0	0
16-31		7·7		0·6		4·3		0·4	9·7	0·6	11·5	0·4	1	2	1	0
Sept. 1-15	1·9			0·5	7·1			0·2	9·9	0·5	12·6	0·2	3	2	0	0
16-30		6·9		0·4		1·2		0·1	9·3	0·4	10·0	0·2	0	0	1	0
Oct. 1-15		19·0		0·2		10·6		0·1	23·4	0·3	15·5	0·2	7	3	0	0
16-31		30·5		0·3		8·2		0·2	30·5	0·3	14·4	0·3	17	4	0	0
Nov. 1-15		7·3		0·4	2·2			0·2	9·9	0·5	9·2	0·4	1	1	1	3
16-30		4·9		0·6	2·6			0·3	7·4	0·6	12·3	0·3	0	2	0	0
Dec. 1-15		8·8		0·7	2·5			0·5	11·6	0·7	8·1	0·5	3	0	5	0
16-31		1·5		0·7	6·9			0·4	8·3	0·7	13·5	0·4	0	1	2	0
TOTALS ...	35·5	96·6	0·1	10·9	128·5	27·4	0·6	5·5	244·3	11·8	292·5	7·6	48	33	27	6
MEANS ...	– 2·5		– 0·5		+ 4·2		– 0·2		10·2	0·5	12·2	0·3				

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

† One-tenth of the mean range of the greatest ordinary spring-tides.

TABLE 4.—*Mean errors E_1* and E_2* for 1934.*

BHĀVNAGAR

PERIOD 1934	MEAN ERRORS (Predicted – Actual†)												Number of errors exceeding			
	E_1*								E_2*				30 minutes in time		1·0‡ feet in height	
	H. W.				L. W.				H. W.		L. W.					
	Time		Height		Time		Height		Time	Ht.	Time	Ht.				
	minutes		feet		minutes		feet		minutes	feet	minutes	feet	H. W.	L. W.	H. W.	L. W.
	+	–	+	–	+	–	+	–								
Jan. 1-15	14·2		1·0			13·5	1·5		14·6	1·0	20·7	1·5	0	4	7	11
16-31	6·9		1·4			35·4		0·1	14·1	1·4	38·5	1·6	1	8	11	10
Feb. 1-15	8·3		1·0			37·1	0·0		10·5	1·0	40·3	1·6	0	9	6	7
16-28		0·2	0·9			28·5	0·1		11·0	0·9	33·6	1·6	0	5	4	9
Mar. 1-15	14·8		1·1			41·3	0·2		16·0	1·1	45·7	1·2	0	9	9	7
16-31	8·8			0·3		36·1		1·6	9·9	0·5	40·3	1·6	0	9	3	8
April 1-15	5·8			0·8		50·9		1·5	9·8	0·9	54·7	1·5	0	11	5	9
16-30	5·3			0·6		27·9		0·7	8·4	0·9	34·7	0·9	0	7	5	4
May 1-15	5·7			0·6		58·0		0·8	9·9	0·8	58·0	0·9	0	12	5	6
16-31	5·1			0·4		36·5		0·3	12·8	0·7	37·5	0·7	0	8	4	3
June 1-15	6·5			0·7		48·1		0·2	12·3	0·9	48·1	0·4	0	12	5	1
16-30	7·6			1·2		32·7		0·6	18·4	1·2	34·2	0·9	2	6	6	4
July 1-15	11·5			1·4		31·9		0·2	11·6	1·4	31·9	0·8	0	8	11	1
16-31	10·6			0·5		48·3		0·3	17·9	0·7	48·3	1·1	0	9	4	7
Aug. 1-15	16·9			0·9		31·7	0·2		16·9	0·9	31·7	0·6	0	7	9	2
16-31	8·1			1·4		38·1		0·4	14·4	1·4	40·2	1·6	0	9	11	10
Sept. 1-15	7·9			0·9		30·3	0·5		8·7	0·9	31·5	0·6	0	8	6	5
16-30	5·8			1·0		32·1		0·2	11·0	1·0	41·4	1·5	0	9	8	10
Oct. 1-15	4·7			0·6		29·8	0·7		11·6	0·6	33·0	0·7	0	6	1	4
16-31	7·9			0·6		27·0		0·1	12·9	0·6	29·3	0·9	0	7	3	6
Nov. 1-15	9·1			0·6		30·7	0·2		16·0	0·7	30·7	0·4	0	8	3	1
16-30	15·7			1·0		20·6		0·3	17·4	1·0	23·5	0·6	2	7	4	4
Dec. 1-15	12·3			0·9		31·1		0·7	18·3	0·9	31·3	0·8	0	8	7	7
16-31	14·8			1·0		9·8		0·4	18·3	1·0	14·9	0·6	1	1	5	2
TOTALS ...	214·3	0·2	5·4	15·4		807·4	3·4	8·4	322·7	22·4	874·0	24·6	6	187	142	13
MEANS ...	+ 8·9		– 0·4		– 33·6		– 0·2		13·4	0·9	36·4	1·0				

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

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

‡ The mean range of the greatest ordinary spring-tides is 31¼ feet.

TABLE 5.—*Mean errors E_1* and E_2* for 1934.*

BOMBAY (APOLLO BANDAR)

PERIOD 1934	MEAN ERRORS (Predicted – Actual)												Number of errors exceeding			
	E_1*								E_2*				*30 minutes* in time		*1·0 feet* in 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		4·1		0·1		6·6		0·1	8·8	0·3	9·1	0·4	1	1	0	0
16-31		9·5	0·2			12·1	0·1		11·7	0·3	14·9	0·3	0	5	0	0
Feb. 1-15		8·3		0·3		10·4		0·2	8·8	0·3	10·4	0·4	0	1	0	2
16-28		6·4		0·2		1·9		0·2	9·7	0·3	11·2	0·3	0	0	0	0
Mar. 1-15		11·0		0·1		8·0		0·1	12·2	0·3	9·3	0·3	0	0	0	0
16-31		10·5		0·5		7·6		0·4	12·3	0·5	10·1	0·5	0	0	0	0
April 1-15		5·5		0·4		6·6		0·3	8·2	0·4	8·6	0·3	0	0	0	0
16-30		5·3		0·5		3·6		0·4	12·0	0·5	10·2	0·4	3	0	2	0
May 1-15		12·4		0·0		7·3		0·1	13·6	0·2	8·7	0·2	3	0	0	0
16-31		4·5	0·1			5·1		0·1	6·5	0·2	6·9	0·2	0	0	0	0
June 1-15		1·7		0·0		4·0		0·1	6·0	0·4	6·6	0·3	0	0	0	0
16-30		9·3		0·2		5·5		0·5	11·4	0·3	8·0	0·5	1	0	1	0
July 1-15	1·4			0·4	7·8			0·7	8·1	0·4	9·8	0·7	0	0	1	3
16-31		5·7	0·4			2·3	0·1		7·4	0·7	7·9	0·3	0	1	6	0
Aug. 1-15	3·8			0·1	4·0			0·5	10·7	0·3	11·9	0·5	1	2	0	2
16-31		3·7		0·2	0·9			0·3	7·4	0·3	7·7	0·3	0	0	0	0
Sept. 1-15	3·5		0·1		5·5			0·1	7·5	0·2	12·4	0·3	0	3	0	0
16-30		2·2	0·2			2·9		0·1	5·6	0·3	7·6	0·2	0	0	0	0
Oct. 1-15	2·7		0·3			1·2	0·0		5·2	0·3	7·2	0·1	0	1	0	0
16-31	1·6		0·1		3·5		0·0		8·0	0·2	7·5	0·3	0	0	0	0
Nov. 1-15		3·9	0·1			0·6		0·1	12·2	0·4	13·9	0·2	1	3	0	0
16-30		0·4		0·2		0·3		0·1	6·8	0·3	7·9	0·3	0	0	0	0
Dec. 1-15		6·2		0·2		9·8		0·4	8·7	0·3	10·1	0·4	0	0	0	0
16-31		8·5		0·2		3·5		0·2	10·7	0·3	9·6	0·2	3	1	0	0
TOTALS...	13·0	119·1	1·5	3·6	21·7	99·3	0·2	5·0	219·5	8·0	227·5	7·9	13	18	10	7
MEANS ...	– 4·4		– 0·1		– 3·2		– 0·2		9·1	0·3	9·5	0·3				

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

TABLE 6.—Mean errors E_1* and E_2* for 1934.

COLOMBO

PERIOD 1934	MEAN ERRORS (Predicted – Actual)												Number of errors exceeding			
	E₁*								E₂*				30 minutes in time		0·3† feet in 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	29·7			0·2	14·9			0·1	29·7	0·2	15·2	0·2	10	1	4	1
16-31	5·0			0·2	9·6			0·1	15·5	0·2	18·5	0·1	3	6	6	1
Feb. 1-15	15·3			0·2	17·3			0·1	15·8	0·2	18·1	0·1	4	3	1	2
16-28	10·5			0·3	19·9			0·2	19·4	0·3	19·9	0·2	4	3	9	1
Mar. 1-15	7·6			0·3	10·6			0·2	13·8	0·3	14·9	0·2	2	0	7	1
16-31	15·0			0·1	10·3			0·1	19·3	0·1	16·5	0·1	5	1	1	0
April 1-15	8·1			0·2	14·6			0·1	11·8	0·2	14·7	0·1	0	1	10	0
16-30	12·8			0·3	2·9			0·2	15·7	0·3	8·8	0·2	1	0	6	1
May 1-15	13·3		0·0		14·0		0·2		15·3	0·1	16·7	0·2	1	4	0	4
16-31	13·3			0·1	9·5		0·1		17·7	0·1	12·4	0·1	5	1	0	0
June 1-15	4·4			0·1	6·0		0·0		9·8	0·1	11·1	0·1	0	0	3	0
16-30	13·5			0·1	1·6			0·1	16·6	0·1	12·7	0·1	3	1	0	0
July 1-15		0·0		0·1	3·8		0·0		13·7	0·2	11·9	0·2	1	1	4	1
16-31	10·3			0·1	4·7			0·0	14·8	0·1	11·8	0·1	0	0	2	0
Aug. 1-15	7·9			0·2	11·9		0·0		12·9	0·2	18·6	0·1	0	3	1	0
16-31	10·4			0·2	11·0			0·0	16·2	0·2	16·1	0·1	4	3	0	0
Sept. 1-15	10·0			0·1	0·3		0·1		18·2	0·1	17·6	0·1	5	3	0	2
16-30	11·6		0·1		15·2		0·2		17·4	0·1	19·4	0·2	2	3	0	2
Oct. 1-15	6·8		0·0		6·5		0·2		12·3	0·2	12·9	0·3	0	0	3	6
16-31	13·6			0·1	7·9			0·0	15·8	0·2	14·7	0·1	3	1	6	2
Nov. 1-15	2·0			0·1	5·0		0·0		10·9	0·2	14·9	0·2	1	3	2	2
16-30	6·6			0·3	5·9			0·2	13·8	0·3	11·1	0·2	1	0	7	5
Dec. 1-15	5·9			0·4	5·0			0·3	12·2	0·4	14·5	0·3	0	2	18	11
16-29	3·9			0·3	11·1			0·2	12·1	0·3	17·7	0·2	0	2	6	5
TOTALS	237·5	0·0	0·1	4·0	219·5		0·8	1·9	370·7	4·7	360·7	3·8	55	42	96	47
MEANS ...	+9·9		–0·2		+9·1		–0·0		15·4	0·2	15·0	0·2				

---

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

† One-tenth of the mean range of the greatest ordinary spring-tides.

TABLE 7.—*Mean errors E_1* and E_2* for 1934.*

VIZAGAPATAM

PERIOD 1934	MEAN ERRORS (Predicted − Actual†)												Number of errors exceeding			
	E_1 *								E_2 *				30 minutes in time		0·5‡ feet in height	
	H. W. Time		H. W. Height		L. W. Time		L. W. Height		H. W. Time	H. W. Ht.	L. W. Time	L. W. Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		feet		minutes		feet		minutes	feet	minutes	feet				
	+	−	+	−	+	−	+	−								
Jan. 1-15		8·7		0·3		5·3		0·1	13·2	0·3	11·7	0·1	1	0	1	0
16-31		10·1		0·3		22·0		0·2	18·4	0·3	22·9	0·2	2	4	1	0
Feb. 1-15		11·6		0·7		12·3		0·4	17·3	0·7	14·4	0·4	2	2	9	3
16-28		27·3		0·6		35·3		0·5	29·2	0·6	35·3	0·5	5	7	4	4
Mar. 1-15		13·2		0·6		18·3		0·4	16·3	0·6	21·6	0·4	0	3	9	3
16-31		11·6		0·2		24·9		0·3	14·7	0·3	29·9	0·3	0	5	1	0
April 1-15		9·0		0·3		11·3		0·0	11·3	0·3	14·0	0·1	0	2	1	0
16-30		24·2		0·3		29·9		0·3	24·2	0·3	29·9	0·3	3	7	0	4
May 1-15		12·7	0·0			5·5	0·2		12·7	0·1	9·9	0·3	0	1	0	0
16-31		18·5	0·2			26·5	0·2		18·5	0·2	27·1	0·3	1	4	1	0
June 1-15		13·1	0·3			14·2	0·4		16·2	0·3	16·7	0·4	2	3	0	2
16-30		7·5	0·1			9·5	0·1		9·5	0·2	19·1	0·1	0	3	0	0
July 1-15		25·7	0·4			20·1	0·3		27·7	0·4	22·3	0·3	4	3	4	5
16-31		19·2		0·2		15·8		0·1	20·1	0·3	20·5	0·2	3	5	0	1
Aug. 1-15		22·2	0·1			5·7	0·1		22·5	0·4	22·8	0·4	4	3	4	2
16-31		20·1	0·2			14·5	0·2		20·2	0·2	16·1	0·3	3	2	0	2
Sept. 1-15		24·4	0·4			26·7	0·4		25·9	0·4	30·4	0·4	4	6	3	3
16-30		17·4	0·4			18·5	0·5		17·4	0·4	18·5	0·5	3	4	7	8
Oct. 1-15		29·7	0·6			22·3	0·7		29·7	0·6	22·6	0·7	3	4	9	12
16-31		30·3	0·3			22·3	0·4		30·6	0·3	23·3	0·4	8	5	0	6
Nov. 1-15		25·5		0·1		12·3		0·1	25·5	0·2	17·0	0·1	4	1	0	0
16-30		29·1	0·0			26·5	0·1		29·1	0·2	26·5	0·2	4	6	0	0
Dec. 1-15		14·3		0·0		23·1	0·1		18·8	0·2	24·4	0·1	1	5	0	0
16-31		23·1	0·4			25·4	0·5		23·9	0·4	25·4	0·5	4	4	1	7
TOTALS ...		448·5	3·4	3·6		448·2	4·2	2·4	492·9	8·2	522·3	7·5	61	89	55	62
MEANS ...	− 18·7		− 0·0		− 18·7		+ 0·1		20·5	0·3	21·8	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.

‡ One-tenth of the mean range of the greatest ordinary spring-tides.

TABLE 8.—*Mean errors E_1* and E_2* for 1934.*

(CHĀNDBĀLI)

PERIOD 1934	MEAN ERRORS (Predicted – Actual†)												Number of errors exceeding			
	E₁*								E₂*				30 minutes in time		0·7‡ feet in height	
	H. W.				L. W.				H. W.		L. W.					
	Time		Height		Time		Height		Time	Ht.	Time	Ht.				
	minutes		feet		minutes		feet		minutes	feet	minutes	feet	H. W.	L. W.	H. W.	L. W.
	+	−	+	−	+	−	+	−								
Jan. 1-15		1·5		0·7	1·9		0·2		16·9	0·7	16·3	0·2	2	2	7	0
16-31		2·2		0·5		8·8		0·1	17·2	0·5	21·6	0·3	2	5	5	0
Feb. 1-15	3·1			0·9		2·1		0·1	15·7	0·9	26·5	0·6	2	6	11	5
16-28	4·1			0·3		14·6		0·1	33·5	0·4	28·8	0·5	8	6	1	4
Mar. 1-15		2·3		0·6		7·1	0·2		12·3	0·6	30·4	0·5	0	9	3	3
16-31		8·6		0·1		18·9	0·2		19·8	0·4	32·3	0·4	5	10	1	3
April 1-15		7·8		0·6		10·2	0·1		10·6	0·6	27·5	0·5	0	6	3	2
16-30		15·4		0·4		17·3	0·1		15·9	0·4	21·7	0·2	2	5	3	0
May 1-15		14·7		0·3		10·7	0·3		14·7	0·3	13·4	0·4	0	1	1	2
16-31		14·8		0·1		13·9	0·6		15·1	0·4	17·9	0·6	1	3	1	3
June 1-15		10·9	0·2		1·3		0·6		11·2	0·3	7·9	0·6	0	0	2	5
16-30		2·4		0·2	6·6		0·3		7·9	0·5	10·5	0·5	0	0	5	4
July 1-15	16·7			0·6	3·3			0·8	24·6	0·6	13·0	1·1	5	1	5	8
16-31		0·8		0·0	1·7		0·4		16·1	0·3	21·2	0·5	2	4	0	4
Aug. 1-15	9·7		0·3			3·1	0·1		17·8	0·4	20·3	0·7	0	3	3	7
16-31	28·5			0·0	14·1			1·8	29·6	0·4	20·6	2·3	8	4	3	12
Sept. 1-15		1·5	0·8			21·5	0·5		13·5	0·8	31·5	0·7	2	7	8	5
16-30	36·7		0·0		12·1			1·9	36·7	0·6	15·5	2·6	8	2	4	13
Oct. 1-15		15·7	1·2			18·3	1·8		19·4	1·3	32·2	1·8	3	9	11	14
16-31	0·9		0·5		2·8		0·7		13·1	0·5	17·6	0·8	1	2	3	9
Nov. 1-15		20·3		0·3		5·4	0·7		20·3	0·4	23·0	0·7	2	4	0	7
16-30		16·1	0·0		1·3		0·5		16·1	0·2	6·7	0·5	2	0	0	4
Dec. 1-15	0·6			0·4	1·1		0·4		9·1	0·4	8·4	0·4	0	0	1	0
16-31		0·3	0·1			4·8	0·4		13·3	0·3	12·4	0·4	1	1	0	2
TOTALS ...	100·3	135·3	3·1	6·0	46·2	156·7	8·1	4·8	420·4	12·2	477·2	17·8	56	90	81	116
MEANS ...	−1·5		−0·1		−4·6		+0·1		17·5	0·5	19·9	0·7				

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

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

‡ One-tenth of the mean range of the greatest ordinary spring-tides.

TABLE 9.—*Mean errors E_1* and E_2* for 1934.*

DUBLAT

PERIOD 1934	MEAN ERRORS (Predicted – Actual)												Number of errors exceeding			
	E_1*								E_2*				30 minutes in time		1·0 feet in height	
	H. W.				L. W.				H. W.		L. W.					
	Time		Height		Time		Height		Time	Ht.	Time	Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	–	+	–	+	–	+	–								
Jan. 1-15	1·0			0·5		4·5		0·1	6·3	0·5	6·5	0·3	0	0	0	0
16-31		2·6		0·2		6·3		0·2	6·4	0·6	9·7	0·4	1	2	6	0
Feb. 1-15	0·9			0·4		3·4		0·5	7·2	0·4	8·1	0·5	0	0	0	2
16-28	15·4			0·6	11·0			0·3	24·0	0·6	19·3	0·7	6	4	5	6
Mar. 1-15	5·2			0·4	0·3			0·1	10·7	0·5	13·7	0·3	0	3	0	0
16-31	4·2			0·2	1·3			0·0	12·3	0·5	11·5	0·5	1	3	0	0
April 1-15		1·5		0·7		7·4		0·5	11·7	0·7	10·2	0·5	2	0	3	1
16-30		0·9		0·7		1·9		0·1	10·0	0·7	9·9	0·2	2	1	5	0
May 1-15		6·3		0·3		14·6		0·0	8·0	0·3	16·2	0·2	0	3	1	0
16-31		1·6		0·5		14·2		0·3	10·0	0·5	14·9	0·4	0	2	2	1
June 1-15		4·1	0·5			16·9	0·5		8·3	0·5	17·8	0·6	0	7	1	3
16-30		8·5		0·1		13·8		0·2	10·6	0·3	14·3	0·4	0	1	0	1
July 1-15	0·8			0·1	1·8		0·1		6·5	0·2	7·7	1·0	0	0	0	12
16-31		1·7	0·2			6·2	0·5		8·2	0·5	9·9	1·0	0	1	1	6
Aug. 1-15	3·7			0·5	5·5			0·4	7·0	0·5	8·2	0·6	0	0	0	5
16-31		5·0	0·0			5·2		0·0	10·0	0·5	12·3	0·3	0	0	1	0
Sept. 1-15		5·3		0·2		2·0	0·0		11·6	0·3	12·0	0·3	2	1	0	0
16-30		5·9		0·1		10·8		0·3	10·1	0·2	12·9	0·5	0	0	0	0
Oct. 1-15		20·5	0·2			16·2	0·4		24·1	0·5	20·4	0·8	3	2	2	5
16-31		16·8	0·0			20·8		0·3	19·8	0·3	23·1	0·4	6	9	1	0
Nov. 1-15		21·8		0·6		27·8		0·9	21·8	0·7	27·8	0·9	3	10	4	7
16-30		16·0		0·5		21·7		0·6	16·7	0·5	21·7	0·6	2	5	4	6
Dec. 1-15		9·3		0·3		17·4		0·6	9·4	0·4	17·6	0·6	0	1	0	0
16-31		3·0		0·1		9·5	0·0		6·3	0·2	11·2	0·2	0	1	0	0
TOTALS...	31·2	130·8	0·9	7·0	19·9	220·6	1·5	5·4	277·0	10·9	336·9	12·2	28	56	36	55
MEANS ...	– 4·2		– 0·3		–8·4		– 0·2		11·5	0·5	14·0	0·5				

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

TABLE 10.—*Mean errors E_1* and E_2* for 1934.*

KIDDERPORE (CALCUTTA)

PERIOD 1934	MEAN ERRORS (Predicted – Actual)												Number of errors exceeding			
	E_1*								E_2*				30 *minutes* in time		1·0 *feet* in height	
	H. W.				L. W.				H. W.		L. W.					
	Time		Height		Time		Height		Time	Ht.	Time	Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	−	+	−	+	−	+	−								
Jan. 1-15		0·2		0·5	6·6			0·0	13·4	0·5	10·3	0·5	0	0	3	1
16-31	0·2			0·4	5·1		0·2		9·8	0·6	17·8	0·5	0	3	5	3
Feb. 1-15		0·3		0·3		2·3	0·1		10·3	0·5	7 ·4	0·3	0	0	2	0
16-28	8·6			1·0	19·1			0·2	13·5	1·0	22·0	0·4	3	4	14	1
Mar. 1-15	9·0			0·8	4·0		0·1		10·4	0·9	8·6	0·3	0	0	6	0
16-31	6·8			0·3	12·6		0·2		9·8	0·5	15·1	0·3	3	4	2	0
April 1-15	6 7			0·7		0·4		0·0	9·5	0·8	7·4	0·3	1	0	7	0
16-30	5·5			0·6	11·4			0·0	10·8	0·6	15·6	0·3	1	3	3	0
May 1-15		1·5		0·2		6·8	0·2		7·3	0·4	10·1	0·3	1	0	3	1
16-31	1·3			0·3	3·1		0·3		8·9	0·3	11·2	0·5	0	2	0	3
June 1-15		7·8	0·5			9·0	0·7		11·4	0·5	16·2	0·7	0	3	3	6
16-30		4·0		0·1		3·3	0·4		9·8	0·4	9·6	0·4	0	0	3	1
July 1-15	14·7			0·9	11·8			0·0	15·6	0·9	15·3	0·3	2	4	10	1
16-31	11·8			0·9	0·6		0·2		13·4	0·9	8·5	0·4	0	0	13	3
Aug. 1-15	16·6			0·7	17·4		0·2		17·4	0·7	17·9	0·4	5	5	7	2
16-31	5·7			0·4	0·7		0·4		8·0	0·5	14·3	0·6	1	1	4	0
Sept. 1-15	10·9			0·8	9·7		0·4		13·3	0·8	11·8	0·4	2	3	7	0
16-30	12·0			1·4	2·1			0·4	12·6	1·4	11·3	0·8	1	0	22	5
Oct. 1-15	5·4			0·8		0·3		0·1	8·5	0·9	11·3	0·3	2	2	5	1
16-31	2·7			0·5	0·1			0·0	9·2	0·5	14·1	0·3	0	3	6	2
Nov. 1-15	0·5			0·7		1·9		0·3	7·9	0·7	7·7	0·4	0	0	6	0
16-30		1·6		0·3	2·9			0·2	16·7	0·5	12·0	0·4	0	2	2	0
Dec. 1-15		0·4		0·2		3·8		0·1	6·2	0·3	9·4	0·3	0	0	0	0
16-31		8·7	0·3			1·9	0·2		12·5	0·3	8·0	0·5	1	0	0	0
TOTALS	118·4	24·5	0·8	12·8	107·2	29·7	3·6	1·3	266·2	15·4	292·9	9·9	23	39	133	30
MEANS	+ 3·9		− 0·5		+ 3·2		+ 0·1		11·1	0·6	12·2	0·4				

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

TABLE 11.—*Mean errors E_1* and E_2* for 1934.*

CHITTAGONG

PERIOD 1934	MEAN ERRORS (Predicted – Actual†)												Number of errors exceeding			
	E_1*								E_2*				30 *minutes* in time		1·0 *feet* in height	
	H. W.				L. W.				H. W.		L. W.					
	Time		Height		Time		Height		Time	Ht.	Time	Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	–	+	–	+	–	+	–								
Jan. 1-15	6·6			0·4	6·8			0·2	7·5	0·4	6·8	0·3	0	0	0	0
16-31	6·8			0·6	2·3			0·3	8·2	0·9	3·5	0·5	0	0	6	2
Feb. 1-15	6·1			0·3	3·3			0·2	7·3	0·4	7·0	0·4	0	0	0	1
16-28	7·5			0·8	4·8			0·2	8·1	1·0	6·5	0·3	0	0	5	1
Mar. 1-15	2·3			0·4	1·3			0·1	8·7	0·6	7·3	0·3	0	0	1	0
16-31	6·4			0·1	2·3		0·1		10·6	0·7	6·8	0·3	0	0	5	0
April 1-15	2·7		0·0		1·1			0·1	5·9	0·4	4·4	0·4	0	0	0	0
16-30	10·6			0·3	3·8		0·1		11·5	0·7	6·5	0·2	0	0	3	0
May 1-15	5·8		0·2		2·2		0·2		7·8	0·7	4·5	0·4	0	0	3	0
16-31	4·7		0·3		3·4		0·3		6·9	0·4	7·9	0·5	0	0	0	1
June 1-15	10·1		0·6		9·6		0·7		10·1	0·6	9·9	0·7	0	0	4	1
16-30	16·5			0·1	13·5			0·0	16·5	0·4	14·5	0·3	0	0	0	0
July 1-15	9·1			0·4	10·0			0·5	11·5	0·6	11·1	0·7	0	0	2	4
16-31	9·7			0·1	15·7		0·2		14·4	0·6	15·7	0·6	0	0	1	2
Aug. 1-15		4·8		0·4	9·5		0·2		14·7	0·6	11·5	0·4	0	0	0	0
16-31		4·4		0·2	0·9		0·5		6·4	0·8	13·4	0·6	0	0	6	1
Sept. 1-15		7·7	0·1			1·1	0·8		8·9	0·3	3·6	0·8	0	0	0	3
16-30	7·4			0·3	4·2		0·6		8·5	0·7	6·3	0·6	0	0	3	2
Oct. 1-15	2·6			0·3	3·7		0·8		5·3	0·4	6·2	0·8	0	0	3	5
16-31		3·1	0·0		2·0		0·7		7·9	0·5	5·8	0·7	0	0	0	2
Nov. 1-15	2·1			0·7		2·4	0·1		8·3	0·7	5·5	0·4	0	0	4	0
16-30		1·1		0·0	3·2			0·1	5·7	0·5	5·3	0·2	0	0	0	0
Dec. 1-15	8·5			0·4	4·4			0·1	9·2	0·5	5·5	0·3	0	0	3	0
16-31		1·4	0·2		2·4		0·2		5·3	0·2	3·6	0·3	0	0	0	0
TOTALS...	125·5	22·5	1·4	5·8	110·4	3·5	5·5	1·8	215·2	13·6	179·1	11·0	0	0	49	25
MEANS...	+ 4·3		– 0·2		+ 4·5		+ 0·2		9·0	0·6	7·5	0·5				

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

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

TABLE 12.—*Mean errors E_1* and E_2* for 1934.*

AKYAB

PERIOD 1934	MEAN ERRORS (Predicted − Actual †)												Number of errors exceeding			
	E_1*								E_2*				30 minutes in time		0·8‡ feet in height	
	H. W. Time		H. W. Height		L. W. Time		L. W. Height		H. W. Time	H. W. Ht.	L. W. Time	L. W. Ht.	H. W.	L. W.	H. W.	L. W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	−	+	−	+	−	+	−								
Jan. 1-15	6·5			0·2	4·5			0·1	6·5	0·2	4·5	0·2	0	0	0	0
16-31	4·3			0·2	4·9			0·3	4·3	0·4	4·9	0·3	0	0	2	0
Feb. 1-15	4·4			0·5	5·1			0·4	4·4	0·5	5·1	0·4	0	0	1	1
16-28	5·5			0·6	4·9			0·5	5·5	0·6	4·9	0·5	0	0	2	1
Mar. 1-15	5·1			0·5	5·1			0·4	5·1	0·5	5·1	0·4	0	0	1	1
16-31	4·6			0·2	5·0			0·3	4·6	0·3	5·0	0·3	0	0	1	1
April 1-15	5·4			0·4	4·9			0·2	5·4	0·4	4·9	0·2	0	0	1	0
16-30	5·1			0·4	4·9			0·4	5·1	0·4	4·9	0·4	0	0	0	0
May 1-15	4·3			0·1	4·6		0·2		4·3	0·2	4·6	0·2	0	0	0	0
16-31	5·1		0·4		4·9		0·4		5·1	0·4	4·9	0·4	0	0	1	0
June 1-15	3·7		0·5		5·0		0·4		5·4	0·5	5·0	0·4	0	0	0	2
16-30	4·4		0·2		5·5		0·2		4·4	0·3	5·5	0·3	0	0	0	0
July 1-15	4·6		0·1		5·3			0·1	4·6	0·3	5·3	0·4	0	0	0	2
16-31	4·7		0·3		4·8			0·2	4·7	0·4	4·8	0·6	0	0	1	4
Aug. 1-15	4·1			0·1	4·2			0·1	4·1	0·2	4·2	0·2	0	0	0	0
16-31	4·6		0·1		5·4		0·3		4·6	0·3	5·4	0·4	0	0	0	0
Sept. 1-15	5·1		0·1		4·5		0·2		5·1	0·3	4·5	0·3	0	0	0	2
16-30	4·7			0·1	5·9		0·2		4·7	0·3	5·9	0·3	0	0	1	1
Oct. 1-15	4·5		0·0		5·1		0·2		4·5	0·3	5·1	0·3	0	0	0	1
16-31	5·7			0·1	5·8		0·0		5·7	0·4	5·8	0·2	0	0	2	0
Nov. 1-15	3·5			0·8	3·4			0·8	3·9	0·8	3·4	1·0	0	0	6	9
16-30	5·3			0·4	5·5			0·1	5·5	0·5	5·7	0·3	0	0	2	0
Dec. 1-15	4·9		0·0		5·1		0·0		4·9	0·1	5·1	0·2	0	0	0	0
16-31	5·8		0·2		6·6		0·2		5·8	0·2	6·6	0·2	0	0	0	0
TOTALS	115·9		1·9	4·6	120·9		2·3	3·9	118·2	8·8	121·1	8·4	0	0	21	25
MEANS	+ 4·8		− 0·1		+ 5·0		− 0·1		4·9	0·4	5·0	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.

‡ One-tenth of the mean range of the greatest ordinary spring-tides.

TABLE 13.—*Mean errors E_1* and E_2* for 1934.*

RANGOON

PERIOD 1934	MEAN ERRORS (Predicted – Actual)												Number of errors exceeding			
	E₁*								E₂*				30 *minutes* in time		1·0 *feet* in height	
	H. W.				L. W.				H. W.		L. W.		H. W.	L. W.	H. W.	L. W.
	Time		Height		Time		Height		Time	Ht.	Time	Ht.				
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	−	+	−	+	−	+	−								
Jan. 1-15	5·8		0·0		5·3		0·4		8·6	0·2	13·3	0·5	0	0	0	4
16-31	3·5			0·1	3·2			0·4	7·5	0·7	13·0	0·6	0	2	9	4
Feb. 1-15	3·1			0·0	3·1			0·0	5·9	0·4	10·5	0·3	0	0	2	1
16-28	0·4		0·2		5·9			0·2	10·4	0·6	10·3	0·5	2	1	3	2
Mar. 1-15	2·6		0·3			0·9	0·2		6·6	0·5	6·4	0·3	0	0	2	0
16-31	6·8		0·1		8·8			0·2	13·3	0·5	11·1	0·5	3	3	3	2
April 1-15	3·6		0·2			0·3	0·0		7·3	0·4	7·4	0·4	0	0	1	0
16-30	7·9			0·2	13·2			0·2	10·7	0·5	14·1	0·6	2	5	3	5
May 1-15		2·6	0·2			3·4	0·4		5·7	0·3	10·2	0·5	0	1	0	4
16-31	0·2		0·6		5·3		0·5		5·7	0·6	11·6	0·6	0	3	4	6
June 1-15		2·5	0·8			3·7	0·6		5·6	0·8	12·4	0·6	0	0	7	6
16-30	2·9		0·5		0·5		0·3		5·4	0·6	8·3	0·6	0	0	1	4
July 1-15	0·2		0·1		0·1		0·1		7·8	0·4	13·7	0·7	0	2	0	6
16-31	2·6		0·4			5·4	0·2		6·9	0·5	11·4	0·5	0	0	4	1
Aug. 1-15		0·6	0·1		8·0		0·2		7·9	0·3	11·4	0·4	0	1	0	1
16-31	3·5		0·3			2·1	0·1		8·9	0·6	7·2	0·3	1	0	5	0
Sept. 1-15	1·2		0·4		3·5		1·0		7·6	0·6	7·9	1·0	1	1	4	16
16-30		3·5	0·5		0·8		0·9		7·9	0·6	8·3	0·9	1	0	2	10
Oct. 1-15		1·4	0·0		5·6		0·6		8·4	0·3	8·4	0·6	1	1	1	3
16-31	1·1		0·3		4·8		0·5		8·2	0·4	13·0	0·6	0	2	0	5
Nov. 1-15		2·9		0·0	3·2		0·3		4·7	0·4	6·7	0·4	0	0	1	0
16-30	3·9		0·1		9·5		0·3		7·2	0·5	15·1	0·5	0	4	1	2
Dec. 1-15	7·3		0·7			1·2	0·7		8·3	0·7	11·8	0·7	0	0	8	7
16-31	1·1		0·6		10·8		0·9		6·1	0·6	17·3	0·9	0	4	3	12
TOTALS ...	57·7	13·5	6·4	0·3	91·6	17·0	8·2	1·0	182·6	12·0	260·8	13·5	11	30	64	101
MEANS ...	+ 1·8		+ 0·3		+ 3·1		+ 0·3		7·6	0·5	10·9	0·6				

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

CHAPTER VII

OBSERVATORIES

BY LT.-COLONEL E. A. GLENNIE, D.S.O., R.E.

52. Longitude.—The usual bi-weekly observations for time were made during the year with the motor and shutter transits. The observers were Messrs. R. B. Mathur, H. C. Banerjea and J. B. Mathur at different times. The resulting values of the variation of longitude are given in Table 1 and the monthly mean values of longitude as determined with the use of the Bordeaux and Rugby signals with the 'demi-definitive' corrections of the Bulletin Horaire and Admiralty Notices are given in the table below. The annual mean values by the two instruments differ by only $0^s{\cdot}02$. Longitude observations at Dehra Dūn are likely to be affected by meteorological conditions just as the latitude variations are, as shown in Geodetic Report 1933, page 45.

	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 1934	4	5 12 11·78	5 12 11·88	2	5 12 11·81	5 12 11·81
November ,,	4	11·69	11·79	4	11·79	11·80
December ,,	4	11·80	11·77	3	11·84	11·82
January 1935	Nil	...	...	6	...	11·78
February ..	2	...	11·81	4	...	11·76
March ,,	4	11·80	11·82	2	...	11·76
April ,,	4	11·77	11·79	4	11·73	11·75
May ..	3	11·74	11·78	4	11·70	11·74
June ..	3	...	11·77	2	...	11·77
July ..	1	...	11·74	2	11·72	11·66
August ..	2	...	11·75	2	11·74	11·68
September ..	3	...	11·81	3	11·73	11·73
Mean ...		5 12 11·76	5 12 11·79		5 12 11·76	5 12 11·76

53. **Clocks.**—The Shortt clock has been used throughout, but on several occasions its behaviour has not been satisfactory and more interruptions occurred than in previous years. These failures and irregularities seem always to have been due to weakness of the battery or associated in some way with the changing of the batteries. Its error and rate are given in Table 2.

The accumulators hitherto in use have now been replaced by a battery of Edison Soda Cells of 500 ampere hour capacity. This should operate unchanged for many years.

The Riefler clock worked satisfactorily throughout.

54. **Invar levelling staves.**—Eight invar staves used by the levelling detachments during field season 1934–35 were standardized before and after the field season between the 2-foot and 8-foot marks against "Bevelled bar No. 1 of 1900" with the following results:—

	No. 1	No. 2	No. 3	No. 4	No. 117	No. 118	No. 121	No. 122
Before ...	7·99977	8·00052	8·00013	8·00051	7·99897	7·99887	7·99935	7·99894
After ...	69	46	11	26	88	86	13	67

One 10-foot steel tape was also compared against standard bar I_s.

55. **Earthquakes.**—The Omori seismograph has been in operation throughout the year. Table 3 gives a list of the earthquakes recorded. As in the case of the Bihār earthquake the Quetta earthquake agitated the pen too violently to give a clear record, but the severe aftershock which occurred four hours later was very well recorded. Many aftershocks from the Quetta region have been recorded; but no trace has been obtained of many others which were reported to be severe in the daily press.

The seismograph at Dehra Dūn, has one arm only placed east-west. Hence no indication of the direction of distant earthquakes can be obtained. The new earthquake tables by Dr. H. Jeffreys and Mr. K. E. Bullen published by the International Seismological Association this year have been brought into use for calculating the distance of epicentres.

56. **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 no interruptions of any consequence have occurred. The year has been free from any flooding of the underground room during the rains.

The mean values of the magnetic elements at Dehra Dūn in 1934 were:—

Declination	...	E. 1° 00′·0
Dip	...	N. 45° 39′·0
Horizontal force	...	0·33087 C.G.S.
Vertical force	...	0·33847 C.G.S.

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

Declination	...	1·03 minutes
Horizontal force	...	4·28 gammas
Vertical force	...	8·68 to 9·69 gammas

The mean temperature of the year in the observatory was 26°·9C with maxima and minima of 27°·5 and 25°·8.

The moment of inertia of magnets Nos. 17 and 5 B was determined in March and April 1935 and log π^2K was found to be 3·41439 and 3·37738 respectively. The values which have been accepted for 1934 are 3·41440 and 3·37738 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 $\bar{1}$·99407 and $\bar{1}$·99308 in 1934 and the accepted values for this factor are $\bar{1}$·99415 and $\bar{1}$·99300. The difference in *H* as determined by magnetometers No. 17 and No. 5 for the year 1934 is about 23γ as against the previous value of about 30γ.

Table 4 shows the monthly values of the magnetic collimation, distribution factors and magnetic moment of No. 17 and Table 5 gives similar information for No. 5. Table 6 gives the mean monthly values of the declination and H. F. base-lines. The values given by No. 17 only have been accepted.

Table 7 gives the mean monthly values of the elements for 1933 and 1934 and the annual changes for the period. Tables 8 to 11 give the mean hourly deviations from the monthly means and Table 12 the classification of the magnetic character of all days of 1934.

During the year H. F. and declination reading scales printed on glass have been constructed whereby the labour of converting the scale readings to corresponding values of the horizontal force in gammas and declination in minutes is saved on the forms used in the computations. The scales are designed to read the values direct off the magnetograms for given values of the base-lines.

TABLE 1.—*Variation of Longitude of Dehra Dūn from accepted value, as determined by reception of wireless signals from Bordeaux and Rugby, 1934–35.*

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
Oct. 5	Motor	R.B.M.	4	4	−0·01	0·00	+0·01	+0·02
9	Shutter	R.B.M.	4	4	+0·05	−0·01	+0·07	+0·01
12	Motor	R.B.M.	4	4	...	+0·11	...	+0·12
19	Motor	R.B.M.	3	4	...	+0·21	...	+0·20
24	Shutter	R.B.M.	3	4	+0·03	+0·08	+0·07	+0·07
29	Motor	R.B.M.	2	4	+0·03	...	+0·06	...
Nov. 2	Shutter	R.B.M.	4	4	+0·01	+0·01	+0·03	+0·03
7	Motor	R.B.M.	3	1	−0·08	−0·08	−0·07	−0·08
10	Motor	R.B.M.	4	4	...	−0·02	...	−0·04
13	Shutter	R.B.M.	4	4	...	+0·03	...	+0·01
16	Motor	R.B.M.	4	4	...	+0·12	...	+0·10
21	Shutter	R.B.M.	2	2	+0·02	+0·04	+0·01	+0·03
24	Motor	R.B.M.	4	4	...	+0·04	...	+0·04
29	Shutter	R.B.M.	3	5	+0·04	+0·06	+0·04	+0·05
Dec. 3	Motor	R.B.M.	3	5	−0·02	0·00	−0·02	0·00
7	Shutter	H.C.B.	4	4	...	+0·06	...	+0·05
12	Motor	H.C.B.	4	5	...	−0·04	...	−0·03
14	Shutter	H.C.B.	4	5	+0·07	+0·05	+0·07	+0·05
19	Motor	H.C.B.	3	3	+0·08	+0·07	+0·09	+0·08
24	Shutter	H.C.B.	4	4	...	+0·03	...	+0·06
31	Motor	H.C.B.	2	3	...	−0·04	...	0·00
1935								
Jan. 3	Shutter	H.C.B.	4	4	...	+0·02	...	+0·04
7	Shutter	H.C.B.	4	4	...	+0·02	...	+0·03
15	Shutter	H.C.B.	4	4	...	0·00	...	0·00
18	Shutter	H.C.B.	3	5	...	−0·02	...	+0·01
26	Shutter	H.C.B.	3	4	...	+0·02	...	+0·02
31	Shutter	H.C.B.	2	3	...	0·00	...	+0·01
Feb. 4	Motor	H.C.B.	2	4	...	+0·04	...	+0·03
9	Motor	H.C.B.	3	4	...	+0·04	...	+0·06
13	Shutter	H.C.B.	4	4	...	−0·03	...	−0·01
19	Shutter	H.C.B.	4	4	...	−0·02	...	−0·02
22	Shutter	H.C.B.	4	4	...	+0·02	...	+0·01
26	Shutter	H.C.B.	3	5	...	...	...	...
Mar. 1	Motor	H.C.B.	4	4	...	+0·12	...	+0·12
5	Shutter	H.C.B.	4	4	...	+0·02	...	+0·02
8	Motor	J.B.M.	3	6	+0·03	+0·03	+0·05	+0·03

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

(*Continued*)

TABLE 1.—*Variation of Longitude of Dehra Dūn from accepted value, as determined by reception of wireless signals from Bordeaux and Rugby, 1934–35—(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
1935						s	s	s	s
Mar.	16	Motor	J.B.M.	3	4	...	−0·03	...	−0·01
	21	Shutter	J.B.M.	4	3	...	−0·04	...	−0·02
	28	Motor	J.B.M.	3	3	...	+0·09	...	+0·08
April	1	Shutter	J.B.M.	2	4	−0·02	−0·02	+0·02	−0·04
	10	Motor	J.B.M.	3	3	+0·02	+0·03	+0·03	+0·02
	12	Shutter	J.B.M.	3	3	...	−0·03	...	−0·04
	18	Motor	J.B.M.	4	4	+0·01	+0·01	+0·05	+0·03
	20	Shutter	J.B.M.	3	3	−0·05	−0·02	−0·02	0·00
	24	Motor	J.B.M.	3	3	...	+0·05	...	+0·07
	27	Shutter	J.B.M.	3	3	−0·06	...	−0·05	...
	30	Motor	J.B.M.	3	3	−0·04	−0·03	−0·03	−0·02
May	2	Shutter	J.B.M.	3	3	−0·11	−0·08	−0·10	−0·09
	8	Motor	J.B.M.	3	3	...	−0·09	...	−0·11
	13	Shutter	J.B.M.	3	3	−0·03	...	+0·02	...
	17	Motor	J.B.M.	3	3	−0·03	+0·05	+0·02	+0·02
	20	Shutter	J.B.M.	3	3	...	+0·03	...	+0·01
	23	Motor	J.B.M.	3	4	...	+0·07	...	+0·04
	28	Shutter	J.B.M.	3	3	...	−0·03	...	−0·06
June	7	Motor	R.B.M.	4	4	...	−0·01	...	−0·02
	12	Shutter	R.B.M.	4	4	...	+0·07	...	+0·05
	17	Motor	J.B.M.	3	4	...	−0·02	...	−0·01
	20	Shutter	J.B.M.	3	3	...	−0·06	...	−0·05
	28	Motor	J.B.M.	3	4	...	+0·02	...	+0·01
July	4	Shutter	J.B.M.	4	3	−0·05	...	−0·02	...
	9	Motor	J.B.M.	4	4	...	−0·03	...	+0·02
	19	Shutter	J.B.M.	3	4	...	−0·11	...	−0·10
Aug.	3	Motor	J.B.M.	3	3	...	+0·02	...	+0·03
	5	Shutter	J.B.M.	3	3	...	−0·10	...	−0·08
	24	Motor	J.B.M.	4	4	...	−0·05	...	−0·02
	27	Shutter	J.B.M.	4	3	−0·03	−0·07	−0·02	−0·05
Sept.	2	Motor	J.B M.	4	2	...	+0·05	...	+0·03
	9	Shutter	J.B.M.	3	3	...	−0·05	...	−0·05
	16	Motor	J.B.M.	3	4	...	+0·02	...	+0·02
	24	Shutter	J.B.M.	3	4	−0·04	−0·02	−0·02	−0·04
	27	Motor	J.B M.	3	5	...	+0·06	...	+0·02
	30	Shutter	J.B.M.	3	4	...	−0·06	...	−0·08

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

TABLE 2.—*Error, rate, pressure and temperature of Shortt clock No. 34, by Rugby time signals during 1934–35.*

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*	
Oct.	5	−0	0·55	0·00	30·0	47·0	26·8	
	10		0·49	+0·01	30·0	46·5	26·3	
	12		0·39	+0·05	30·0	45·9	26·0	
	19		0·19	+0·03	30·0	45·5	25·5	
	24		0·23	−0·01	30·0	46·4	26·6	
Nov.	2		0·20	0·00	30·0	46·5	26·8	
	7		3·20	...	30·0	46·5	26·5	Clock out of order on 6th November 1934.
	10		3·16	+0·01	30·0	46·5	26·6	
	13		3·12	+0·01	30·0	46·2	26·5	
	16		3·14	−0·01	30·0	46·5	26·5	
	21		4·92	...	30·0	46·5	26·8	Clock out of order.
	24		4·87	+0·02	30·0	46·5	26·6	
	30		4·72	+0·03	30·0	46·0	26·7	
Dec.	3		4·64	+0·03	30·0	46·0	26·8	
	7		4·60	+0·01	30·0	46·0	26·7	
	12		4·52	+0·02	30·0	46·0	26·5	
	14		4·45	+0·04	30·0	46·0	26·6	
	19		4·33	+0·02	30·0	46·0	26·7	
	24		4·24	+0·02	30·0	46·0	26·5	
	31		4·04	+0·03	30·0	46·0	26·6	
1935								
Jan.	3		3·94	+0·03	30·0	46·0	26·6	
	7		3·81	+0·03	30·0	46·0	26·6	
	15		3·56	+0·03	30·0	46·0	26·6	
	18		3·50	+0·02	30·0	46·0	26·4	
	26		3·25	+0·03	30·0	45·3	26·5	
	31	−0	3·13	+0·02	30·0	45·0	26·5	
Feb.	9	+0	55·39	...	33·0	40·5	26·5	Clock out of order on 4th Feb. 1934.
	13		55·29	−0·02	33·0	41·3	26·6	
	19		55·17	−0·02	33·0	41·9	26·7	
	22	+0	55·14	−0·01	33·0	42·0	26·6	
	26		...	...	33·0	42·5	26·7	Clock out of order.
Mar.	1	+0	12·15	...	33·0	43·0	26·7	
	5		12·11	−0·01	33·0	43·4	26·7	
	8	+0	11·85	−0·09	33·0	44·0	26·7	
	16	−0	50·34	...	29·0	26·5	25·9	Clock out of order.
	21		50·29	+0·01	29·0	26·9	26·9	
	28		50·19	+0·01	29·0	27·5	26·8	
Apr.	1	−0	50·21	0·00	29·0	28·1	27·0	

* $+^{ve}$ rate = gaining, $-^{ve}$ rate = losing.

(Continued)

TABLE 2.—*Error, rate, pressure and temperature of Shortt clock No. 34, by Rugby time signals during 1934–35—(concld.)*

Date		Error at 15.30 hrs. I.S.T.		During preceding period				REMARKS
				Rate * per day	Pressure	Oil gauge	Temperature	
1935		*m*	*s*	*s*	*mm of mercury*	*mm*	*C* °	
Apr.	10	−0	50·08	+0·01	29·0	29·4	26·7	
	12		50·06	+0·01	29·0	30·0	26·8	
	18		50·02	+0·01	29·0	30·0	26·7	
	20		49·99	+0·02	29·0	30·0	26·3	
	24		50·02	−0·01	29·0	30·0	26·4	
	30		50·06	−0·01	29·0	30·7	26·8	
May	2		50·07	0·00	29·0	31·0	27·2	
	8		50·29	−0·04	29·0	31·0	26·9	
	17		50·20	+0·01	29·0	32·0	27·4	
	20		50·22	−0·01	29·0	32·0	27·6	
	23		50·36	−0·05	29·0	32·5	27·8	
	28		50·56	−0·04	29·0	33·6	28·4	
June	7		51·00	−0·04	29·0	35·0	29·4	
	12		51·11	−0·02	29·0	35·7	29·6	
	17		51·33	−0·04	29·0	35·4	30·1	
	20		51·46	−0·04	29·0	35·2	30·2	
	28	−0	51·70	−0·03	29·0	35·9	30·7	
July	19	+1	48·65	...	31·0	38·1	29·0	Clock out of order.
Aug.	3		48·20	−0·03	31·0	38·2	28·6	
	5	+1	48·17	−0·02	31·1	38·1	28·0	
	24	+0	51·86	...	31·3	38·3	26·8	Clock out of order
	27		51·82	−0·02	31·3	38·3	26·8	
Sept.	2		51·70	−0·02	31·3	38·3	27·0	
	9		51·33	−0·05	31·4	38·8	27·4	
	16	+0	51·12	−0·03	31·6	39·1	27·5	
	24	+0	32·91	...	31·3	38·8	26·5	Clock out of order
	27		32·88	−0·01	31·3	38·8	26·4	
	30	+0	32·82	−0·02	31·2	38·7	26·3	

* $+^{ve}$ rate = gaining, $-^{ve}$ rate = losing.

TABLE 3.—*Earthquakes recorded at Dehra Dūn during 1934–35.*

No.	Date	Direction of 1st motion	Indian standard time					Intensity of record	Distance	REMARKS
			1st P. T.	2nd P. T.	Long wave	Maximum	Finish			
	1934		*h m s*	*h m s*	*h m s*	*h m*	*h m*		*miles*	
1	Oct. 26	N.	22 59 10	23 04 10	23 08 20	23 11	23 30†	slight	2100	
2	„ 29	...	21 50 50†	21 56 20	22 01 30	22 04	22 15	slight	2400	
3	Nov. 6	...	5 14 10†	5 16 50†	5 21 40	5 23	6 00†	slight	1300	
4	„ 12	...	13 02 50	13 05 30	13 10 30	13 13	13 25	slight	1400	
5	„ 18	...	...	...	...	...	...	moderate	...	Clock stopped. Felt at Peshāwar.
6	„ 27	...	12 01 10†	...	...	...	12 30	slight	...	
7	„ 30	...	8 28 00†	8 41 00	8 53 00	8 59	9 43	moderate	7200	
8	Dec. 15	...	2 18 00†	2 18 40†	...	2 19	2 23†	slight	300	
9	„ 15	S.	7 32 00	7 33 50	...	7 34	9 09	moderate	700	
10	„ 18	...	16 56 50	16 57 40	...	16 58	17 09	slight	300	
11	„ 21	...	12 10 10†	12 11 10	...	...	12 12	slight	300	
12	„ 21	...	18 14 00	18 14 50†	18 15 20	18 16	18 21	slight	300	
13	„ 22	...	21 13 10	21 16 40	21 21 40	21 23	21 40	slight	1600	
14	„ 30	...	20 22 20†	...	20 35 40	20 39	20 44	slight	3200	
	1935									
15	Jan. 1	...	0 42 30†	0 56 20	1 22 10	1 30	3 21†	moderate	10000	
16	„ 3	S.	7 23 10	7 23 40	7 24 40	7 25	8 14	slight	200	Felt in South Tibet.
17	„ 4	...	20 23 00†	20 29 20	20 35 00	20 37	21 19†	slight	2900	
18	„ 4	...	21 58 40†	22 04 50	22 13 50	22 16	22 41	slight	3200	
19	„ 23	...	13 12 40†	13 24 00†	13 37 40†	13 46	14 31	great	6300	
20	Feb. 3	...	7 43 50	7 44 10	...	7 46	7 52	slight	...	Local.
21	„ 22	...	22 47 00†	22 57 10	23 14 00	23 15	0 57	great	6200	
22	Mar. 5	...	16 00 50†	16 04 20†	16 09 00	16 11	16 26	slight	1600	
23	„ 6	S.	3 45 40	...	3 45 50	3 46	4 15	slight	...	Felt at Bareilly (U.P.)
24	„ 15	N.	16 04 20	...	...	16 05	16 06	slight	...	Local.
25	„ 21	...	5 36 10†	5 38 20	5 39 30	5 40	5 55	slight	700	Felt in Rājmahāl hills near Murshidābād (Bengal).
26	Apr. 12	...	4 50 50†	4 53 20	4 56 10	4 59	...	moderate	1100	
27	„ 12	S.	18 23 40	18 27 30†	...	18 31	18 46	slight	1500	
28	„ 13	S.	4 11 00	4 14 20	...	4 22	4 34	slight	1200	
29	„ 19	S.	21 02 40	21 10 10	21 20 40†	21 27	23 21	great	4000	
30	„ 21	N.	3 45 30	3 49 20	3 53 20	3 56	4 52	great	1600	Caused considerable damage in Formosa.
31	„ 21	...	13 12 00†	13 20 00	13 27 30	13 31	13 47	slight	3900	
32	„ 23	...	22 19 20†	...	22 22 10	22 22	22 46†	slight	600	Felt at Calcutta.
33	„ 24	S.	21 29 50	21 35 20	21 39 30	21 41	22 14	slight	2300	
34	May 1	S.	16 05 10	16 08 10	16 14 10	16 17	16 38	slight	2100	
35	„ 12	S.	10 53 30	10 54 10	...	10 56	11 04	slight	300	
36	„ 14	S.	1 29 00	1 33 30	1 37 30	1 39	2 16	slight	1800	

† Recognized with difficulty. N. = North, S. = South. (*Continued*)

TABLE 3.—*Earthquakes recorded at Dehra Dūn during 1934–35—(concld.)*

No.	Date	Direction of 1st motion	Indian standard time					Intensity of record	Distance	REMARKS
			1st P. T.	2nd P. T.	Long wave	Maximum	Finish			
	1935		*h m s*	*h m s*	*h m s*	*h m*	*h m*		*miles*	
37	May 15	...	5 14 10†	...	5 32 50†	5 38†	6 27	slight	4600	
38	,, 15	...	7 35 30†	7 36 30	7 37 30	7 38	8 18	moderate	400	Felt at Shikārpur (Sind).
39	,, 16	...	22 58 20†	22 59 40	...	23 01	23 21	slight	500	
40	,, 24	N.	11 14 40	11 21 50	11 29 40	11 42	...	moderate	3500	
41	,, 31	N.	3 05 50	3 07 20	...	3 16	...	great	600	Destructive in Quetta and country round.
42	,, 31	S.	7 38 00	7 39 30	...	7 40	8 03	slight	600	Felt at Quetta.
43	,, 31	N.	22 45 10	22 46 30	...	22 50	23 00	slight	500	Felt at Quetta.
44	June 1	N.	10 03 10	10 04 50	...	10 08	...	slight	600	Felt at Quetta.
45	,, 2	N.	14 48 30	14 50 00	14 51 20	14 52	15 34	slight	600	Felt at Quetta.
46	,, 19	N.	4 12 50	4 15 50	4 19 50	...	5 06	slight	1200	
47	,, 22	...	...	21 35 10	21 37 40	21 58	22 18	slight	1000	
48	,, 25	S.	5 07 00	5 17 00†	5 22 20	5 32	7 41	moderate	3600	
49	,, 25	N.†	18 20 40	18 27 10†	18 34 20	18 36	19 25	moderate	3200	
50	,, 29	...	13 20 30	...	13 36 40	13 40	14 04	moderate	3800	
51	July 5	...	23 25 30	...	23 28 20	23 31	0 03	slight	600	Felt in Khost.
52	,, 7	S.	19 07 20	19 13 10	19 15 40†	19 20	19 42	moderate	2600	Extensive damage caused in Japan.
53	,, 16	S.	22 03 00	...	22 10 40	22 11	23 02	moderate	1700	
54	,, 19	...	6 38 00	6 45 10†	6 50 40	6 52	7 36	moderate	2900	
55	,, 26	...	14 50 50	...	14 51 50	14 52	15 08	slight	200	
56	,, 26	N.	16 10 20	...	16 13 30	16 14	16 57	slight	700	
57	,, 28	S.	10 55 50	10 57 20	...	11 00	11 14	slight	600	
58	,, 29	N.†	13 27 50	...	13 35 00	13 46	14 42	slight	1600	
59	,, 30	N.†	4 51 10	...	4 52 20	4 53	5 11	slight	200	
60	Aug. 3	N.†	6 46 40	6 51 40	6 55 40	7 03	9 27	great	2100	Felt in Sumatra.
61	,, 17	...	7 28 50	7 35 00†	7 42 00	7 42	8 55	moderate	3000	
62	,, 23	S.	19 35 50	19 42 10	...	19 46	20 31	moderate	2800	
63	Sept. 4	S.†	7 16 00	7 21 30	7 29 40	7 31	9 57	moderate	2800	
64	,, 9	...	11 58 00	12 06 40	12 13 50†	12 21	13 35	moderate	4500	
65	,, 11	S.	19 43 30	19 51 20	...	20 11	22 02	moderate	3900	
66	,, 20	S.	7 27 40	7 36 40	7 45 10	7 38	13 07†	great	4500	
67	,, 23	...	14 51 40	14 59 40	15 08 20	15 09	16 39	moderate	4000	
68	,, 29	S.†	12 11 20	...	12 13 40	12 14	12 29	slight	500	

† Recognized with difficulty. N. = North, S. = South.

TABLE 4.—*Mean values of the constants of Magnetometer No. 17 in 1934.*

Month	Declination constants	H. F. constants			
	Mean magnetic collimation	Distribution factors			Mean values of m
		$P_{1\cdot2}$	$P_{2\cdot3}$	$\log(1+P/r^2+Q/r^4)^{-1}$	
	′ ″	cm²	cm²		C.G.S.
January ...	− 6 06	6·02	6·76	Observed $\bar{1}\cdot99407$ Accepted $\bar{1}\cdot99415$	801·32
February...	− 5 48	5·84	6·49		·47
March ...	− 6 01	6·42	6·15		·68
April ...	− 6 02	5·98	6·88		·76
May ...	− 5 58	5·88	6·80		·74
June ...	− 6 13	5·99	7·79		·62
July ...	− 6 00	5·93	6·68		·50
August ...	− 6 00	6·31	7·12		·47
September	− 6 01	5·84	7·58		801·59 798·68
October ...	− 5 58	6·23	7·27		·51
November	− 6 05	6·27	7·54		·62
December	− 6 02	6·29	7·36		798·65

TABLE 5.—*Mean values of the constants of Magnetometer No. 5 in 1934.*

Month	H. F. constants			
	Distribution factors			Mean values of m
	$P_{1\cdot2}$	$P_{2\cdot3}$	$\log(1+P/r^2+Q/r^4)^{-1}$	
	cm²	cm²		C.G.S.
January ...	7·19	8·14	Observed $\bar{1}\cdot99308$ Accepted $\bar{1}\cdot99300$	936·68
February...	7·13	7·58		·62
March ...	7·50	7·98		·54
April ...	7·16	8·32		·34
May ...	7·14	8·28		·36
June ...	7·05	8·23		·18
July ...	7·13	7·97		936·20
August ...	7·20	8·63		935·91
September	6·86	6·89		·65
October ...	7·26	7·75		·83
November	7·21	8·52		935·88
December	7·16	7·51		936·09

TABLE 6.—*Base-line values of Magnetographs at Dehra Dūn from Magnets No. 17 and No. 5.*

Month	1933		1934		
	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	0·32 769	0·32 801	0 31·6	0·327 48	0·327 80
February	774	799	31·7	61	87
March	774	801	32·1	52	82
April	772	798	32·4	58	94
May	770	797	32·5	69	88
June	770	799	32·5	63	85
July	763	784	33·6	64	94
August	769	804	32·5	56	75
September	770	814	32·5	64	84
October	769	804	32·3	61	84
November	765	779	32·5	59	72
December	0·32 758	0·32 761	0 32·3	0·327 52	0·327 62

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

TABLE 7.—*Monthly mean values of the Magnetic elements and their annual changes, Magnetometer No. 17, Dehra Dūn, 1933 and 1934.*

MONTH	Horizontal force			Declination			Dip			Vertical force		
	1933	1934	Annual change	1933	1934	Annual change	1933	1934	Annual change	1933	1934	Annual change
	C. G. S.	C. G. S.	γ							C. G. S.	C. G. S.	γ
January	0·33039	0·33061	+22	E. 1° 4′·2	E. 1° 1′·1	−3′·1	N. 45° 37′·8	N. 45° 39′·3	+1′·5	0·33774	0·33826	+52
February ...	51	75	+24	3·9	0·8	−3·1	37·7	39·4	+1·7	785	41	+56
March	58	66	+ 8	3·7	1·1	−2·6	37·2	40·3	+3·1	781	50	+69
April	52	82	+30	3·6	1·0	−2·6	37·1	38·3	+1·2	772	27	+55
May	56	95	+39	3·1	0·6	−2·5	38·1	37·9	−0·2	795	32	+37
June	56	93	+37	3·0	0·0	−3·0	36·9	38·2	+1·3	774	37	+63
July	58	99	+41	2·6	1 0·5	−2·1	38·9	38·9	0·0	814	57	+43
August	53	86	+33	2·5	0 59·6	−2·9	38·0	39·1	+1·1	792	47	+55
September ...	58	93	+35	2·2	59·2	−3·0	39·5	39·2	−0·3	826	55	+29
October	61	101	+40	2·1	58·9	−3·2	39·6	39·7	+0·1	833	74	+41
November ...	66	103	+37	1·9	58·6	−3·3	38·7	39·6	+0·9	819	74	+55
December ...	0·33064	0·33096	+32	E. 1 1·0	E. 0 58·4	−2·6	N. 45 38·5	N. 45 38·6	+0·1	0·33813	0·33848	+35
Mean ...	0·33056	0·33087	+32	E. 1° 2′·8	E. 1° 0′·0	−2′·8	N. 45° 38′·2	N. 45° 39′·0	+0′·9	0·33798	0·33847	+49

γ = 0·00001 C. G. S.

TABLE 8.—*Declination at Dehra Dūn in 1934* (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 ...	0·0	+0·4	+0·3	+0·3	+0·3	0·0	−0·3	−0·6	−0·7	−0·1	**+0·8**	+0·8	−0·5	**−1·3**	−1·2	−0·6	0·0	+0·3	+0·5	+0·4	+0·4	+0·3	+0·2	+0·3	+0·4	+0·2
February ...	0·0	+0·4	+0·2	+0·2	+0·1	−0·3	−0·3	+0·6	−0·3	+0·2	**+0·9**	+0·8	+0·2	−0·2	**−0·4**	−0·1	−0·3	−0·2	−0·2	−0·2	−0·2	−0·2	+0·1	+0·2	+0·1	+0·2
March ...	0·0	+0·4	+0·4	+0·5	+0·3	0·0	−0·1	−0·4	+0·1	+1·2	**+1·8**	+1·8	+0·6	−0·7	**−1·6**	−1·5	−1·0	−0·3	+0·1	−0·2	−0·1	−0·3	−0·3	−0·2	−0·2	−1·0
October ...	0·0	+0·2	+0·3	+0·3	+0·3	+0·2	+0·1	0·0	+0·7	**+1·7**	+1·6	+1·0	−0·6	−1·7	**−2·0**	−1·6	−0·4	−0·1	0·0	0·0	−0·1	−0·1	−0·1	+0·1	+0·5	+0·1
November ...	0·0	−0·1	+0·1	+0·1	+0·1	−0·4	−0·4	−0·3	+0·1	+0·6	**+1·0**	+0·7	−0·7	**−1·4**	−1·0	−0·7	−0·2	+0·1	+0·1	+0·2	0·0	+0·2	+0·1	+0·2	+0·2	+0·2
December ...	0·0	+0·4	+0·1	−0·1	−0·1	−0·4	−0·3	−0·3	−0·2	+0·4	**+0·8**	+0·8	−0·4	**−1·1**	−1·0	−0·3	0·0	+0·4	+0·3	+0·5	+0·4	+0·3	+0·2	+0·3	+0·3	+0·1
Winter Means ...	0·0	+0·3	+0·2	+0·2	+0·2	−0·2	−0·2	−0·2	−0·1	+0·7	**+1·2**	+1·0	−0·2	**−1·1**	−1·2	−0·8	−0·3	0·0	+0·1	+0·1	−0·1	0·0	0·0	+0·2	+0·2	0·0
April ...	−0·1	+0·2	+0·2	+0·3	+0·2	+0·2	+0·1	+0·3	+1·3	+1·2	**+2·3**	+1·5	−0·6	−1·9	**−2·3**	−2·2	−1·5	−0·6	−0·2	−0·1	−0·3	−0·2	+0·1	+0·3	+0·4	+0·5
May ...	0·0	+0·3	+1·4	+0·6	+0·8	+0·8	+0·7	+1·4	**+2·5**	+2·3	+1·7	+0·1	−1·5	−2·4	**−2·9**	−2·6	−1·6	−0·6	−0·1	+0·2	−0·3	−0·3	−0·3	−0·1	+0·1	+0·2
June ...	0·0	+0·7	+0·7	+0·7	+0·7	+0·5	+1·8	+2·0	**+3·1**	+2·2	+2·1	+0·5	−1·2	−2·6	**−3·0**	−2·9	−2·2	−1·2	−0·5	0·0	−0·3	−0·3	−0·1	0·0	+0·2	+0·5
July ...	0·0	+0·3	+0·3	+0·5	+0·7	+0·7	+0·9	+2·3	**+3·3**	+3·2	+2·4	+0·8	−1·2	−2·5	**−3·1**	−2·7	−2·3	−1·6	−0·7	0·0	−0·4	−0·5	−0·5	−0·1	0·0	+0·3
August ...	+0·1	+0·1	+0·2	+0·3	+0·6	+0·4	+0·7	+2·4	**+3·5**	+3·3	+2·1	+0·2	−1·9	−3·1	**−3·2**	−2·3	−1·6	−0·7	+0·1	+0·5	−0·1	−0·4	+0·1	0·0	0·0	+0·2
September ...	0·0	0·0	+0·2	+0·3	+0·6	+0·5	+0·8	+1·3	+2·4	**+2·6**	+1·4	+0·6	−2·2	**−3·3**	−3·2	−1·9	−0·7	+0·1	+0·2	+0·3	0·0	0·0	−0·1	+0·1	0·0	+0·2
Summer Means ...	0·0	+0·3	+0·6	+0·5	+0·6	+0·5	+0·8	+1·6	**+2·7**	+2·5	+2·0	+0·6	−1·4	−2·6	**−3·0**	−2·4	−1·7	−0·8	−0·2	+0·2	−0·2	−0·3	−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 9.—*Horizontal force at Dehra Dūn in 1934* (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 ...	33061	− 6	− 6	− 6	**− 7**	− 7	− 5	− 1	+ 1	+ 4	+ 5	+ 3	− 1	+ 2	+ 6	**+11**	+ 9	+ 5	+ 5	+ 3	+ 2	+ 1	0	− 2	− 7	− 2
February ...	075	− 6	− 5	**− 7**	− 7	− 3	− 4	− 3	0	+ 3	**+ 7**	+ 5	+ 6	+ 7	+ 7	+ 5	+ 4	+ 1	+ 2	0	+ 1	0	− 1	− 2	0	+ 1
March ...	066	− 6	− 7	− 5	− 5	− 6	− 3	− 1	0	0	+ 3	+ 6	+11	**+17**	+16	+10	+ 3	− 5	**− 8**	− 7	− 8	− 4	− 3	− 2	− 1	− 1
October ...	101	− 6	− 5	− 4	− 3	− 4	− 4	− 2	− 2	− 7	**−10**	− 5	+ 5	+10	**+14**	+14	+ 8	+ 1	− 2	− 1	0	− 1	− 1	− 2	− 1	− 2
November ...	103	**− 8**	− 6	− 3	− 2	+ 1	− 1	− 0	+ 2	0	+ 1	0	+ 7	**+13**	+11	+ 8	+ 2	0	− 1	+ 2	− 3	− 3	− 3	− 4	− 5	− 4
December ...	096	**− 6**	− 4	− 2	0	− 2	0	+ 2	+ 1	− 1	− 2	− 4	0	+ 4	+ 6	**+ 7**	+ 5	+ 4	+ 2	+ 4	− 0	− 1	− 2	0	+ 1	− 1
Winter Means ...	33084	**− 6**	− 6	− 5	− 4	− 4	− 3	− 1	0	0	+ 1	+ 1	+ 5	+ 9	**+10**	+ 9	+ 5	+ 1	0	0	− 1	− 1	− 2	− 2	− 2	− 2
April ...	33082	− 3	− 4	− 5	− 4	− 5	5	− 3	− 5	− 6	− 3	+ 4	+11	+17	**+20**	+18	+11	+ 4	− 2	− 4	− 7	− 6	**− 8**	− 7	− 7	− 7
May ...	95	− 2	− 2	− 1	− 2	− 2	− 2	− 1	− 4	− 6	− 5	+ 3	+ 8	+13	+13	**+14**	+ 8	+ 2	− 3	− 7	**− 8**	− 6	− 4	− 2	− 3	− 3
June ...	93	− 1	− 2	− 1	− 3	− 3	− 2	− 3	− 6	**− 9**	− 8	0	+ 4	+10	+14	**+15**	+ 6	0	− 1	− 3	− 5	− 3	− 4	− 1	+ 1	0
July ...	99	− 2	− 2	− 4	− 2	− 1	+ 1	+ 1	0	− 4	− 6	− 1	+ 6	+11	**+13**	+12	+ 6	− 1	− 6	**− 8**	− 8	− 5	− 2	− 1	− 2	0
August ...	86	+ 2	0	− 1	0	0	0	+ 1	− 1	− 2	− 3	**− 7**	− 6	+ 3	+14	**+18**	+12	+ 3	− 3	− 5	− 5	− 2	− 2	− 3	− 3	+ 2
September ...	93	0	− 1	0	0	− 2	− 1	− 3	− 6	**−11**	− 9	− 4	− 1	+ 7	**+13**	+13	+ 7	+ 1	0	− 1	− 3	− 4	− 1	0	0	+ 2
Summer Means ...	33091	− 1	− 2	− 2	− 2	− 2	− 2	− 1	− 4	**− 6**	− 6	− 1	+ 4	+10	**+15**	+15	+ 9	+ 2	− 3	− 5	− 6	− 4	− 4	− 2	− 2	− 1

γ = 0·00001 C. G. S.

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

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

TABLE 10.—*Vertical force at Dehra Dūn in 1934* (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 ...	33826	− 4	− 4	− 4	− 4	− 3	− 3	− 2	− 2	− 1	0	**− 6**	− 3	+ 1	+ 4	**+ 5**	+ 5	+ 5	+ 3	+ 2	+ 2	+ 1	+ 1	+ 1	− 1	0
February ...	41	+ 2	0	+ 1	0	+ 1	0	+ 1	+ 1	+ 2	+ 1	− 3	**− 4**	− 2	− 2	− 2	− 2	− 1	0	0	+ 1	+ 2	+ 3	**+ 4**	+ 4	+ 4
March ...	50	− 3	− 4	− 2	− 3	− 4	− 3	− 3	− 1	+ 2	+ 1	− 3	− 3	− 4	**− 5**	− 3	+ 3	**+ 5**	+ 4	+ 3	+ 4	+ 5	+ 4	+ 4	+ 4	+ 4
October ...	74	− 3	− 3	− 3	− 3	− 3	− 4	− 3	− 2	− 1	− 6	**−11**	−10	−10	− 5	+ 1	+ 5	+ 7	+ 7	+ 7	+ 7	+ 8	**+ 9**	+ 9	+ 9	+ 9
November ...	74	+ 1	+ 2	+ 2	+ 2	+ 2	**+ 3**	+ 3	+ 3	+ 3	0	− 3	− 4	**− 5**	− 4	− 4	− 3	− 1	0	0	0	0	0	0	+ 1	+ 1
December ...	48	− 3	− 3	− 2	− 3	− 3	− 3	− 3	− 3	− 3	− 5	**− 9**	− 6	− 2	− 1	+ 2	+ 3	+ 4	+ 3	+ 4	**+ 7**	+ 6	+ 3	+ 3	+ 4	+ 3
Winter Means ...	33852	− 2	− 2	− 1	− 2	− 2	− 2	− 1	− 1	0	− 2	**− 6**	− 5	− 4	− 2	0	+ 2	+ 3	+ 3	+ 3	**+ 4**	+ 4	+ 3	+ 4	+ 4	+ 4
April ...	33827	+ 4	+ 2	+ 2	+ 2	+ 2	+ 2	+ 4	**+ 6**	+ 5	− 1	− 7	**−16**	−12	− 9	− 4	+ 1	+ 3	+ 2	+ 1	+ 1	+ 2	+ 3	+ 3	+ 4	+ 4
May ...	32	+ 3	+ 3	+ 4	+ 4	+ 4	+ 5	**+ 8**	+ 7	+ 3	− 3	−10	**−15**	−13	−11	− 5	− 1	+ 2	+ 2	+ 2	+ 1	+ 2	+ 3	+ 4	+ 3	+ 2
June ...	37	+ 3	+ 4	+ 5	+ 4	+ 5	+ 8	**+10**	+ 8	+ 4	− 1	− 8	**−24**	−20	−17	−11	− 5	0	+ 4	+ 4	+ 4	+ 5	+ 5	+ 6	+ 7	+ 7
July ...	57	0	+ 1	+ 1	+ 1	+ 1	+ 2	+ 5	+ 3	− 2	− 9	**−16**	−14	−12	− 8	− 2	+ 1	+ 4	+ 6	+ 6	+ 5	+ 6	+ 7	+ 7	+ 6	**+ 8**
August ...	47	− 2	− 2	− 1	− 1	− 1	0	+ 3	+ 2	− 2	−11	**−18**	−12	− 9	− 4	+ 2	+ 3	+ 5	+ 7	+ 5	+ 5	+ 7	+ 7	+ 7	**+ 8**	+ 8
September ...	55	+10	+10	+11	+11	+11	+11	**+13**	+13	+10	+ 6	− 1	**−22**	−18	−11	− 8	− 6	− 4	− 5	− 7	− 5	− 5	− 4	− 4	− 4	− 4
Summer Means ...	33843	+ 3	+ 3	+ 4	+ 4	+ 4	+ 5	**+ 7**	**+ 7**	+ 3	− 3	−10	**−17**	−14	−10	− 5	− 1	+ 2	+ 3	+ 2	+ 2	+ 3	+ 4	+ 4	+ 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 11.—*Dip at Dehra Dūn in 1934* (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 ...	39·3	+ 0·1	+0·1	+0·1	+0·2	+0·2	+0·1	0·0	−0·1	−0·2	−0·2	**−0·5**	0·0	0·0	0·0	−0·3	−0·2	0·0	0·0	0·0	+0·1	0·0	+0·1	+0·2	**+0·4**	+0·1
February ...	39·4	+ **0·4**	+0·2	+0·4	+0·3	+0·2	+0·1	+0·2	0·0	−0·1	−0·3	−0·5	**−0·6**	−0·5	−0·5	−0·4	−0·3	−0·1	−0·1	0·0	0·0	+0·1	+0·1	+0·3	+0·1	+0·1
March ...	40·3	+ 0·1	+0·1	+0·1	+0·1	+0·1	0·0	−0·1	0·0	+0·1	−0·1	−0·5	−0·8	−1·0	**−1·1**	−0·7	0·0	+0·5	**+0·6**	+0·5	+0·6	+0·4	+0·3	+0·2	+0·2	+0·2
October ...	39·7	+ 0·2	+0·1	+0·1	0·0	+0·1	0·0	0·0	0·0	+0·3	+0·2	−0·3	−0·8	**−1·0**	−1·0	−0·7	−0·2	+0·3	+0·5	+0·4	+0·3	+0·4	+0·5	**+0·6**	+0·5	+0·6
November ...	39·6	+ **0·4**	+0·4	+0·2	+0·2	0·0	+0·2	+0·1	0·0	+0·1	−0·1	−0·2	−0·6	**−1·0**	−0·8	−0·6	−0·2	−0·1	+0·1	−0·1	+0·2	+0·2	+0·2	+0·2	+0·3	+0·3
December ...	38·6	+ 0·2	+0·1	0·0	−0·2	−0·1	−0·2	−0·2	−0·2	−0·1	−0·1	−0·2	**−0·3**	−0·3	−0·3	−0·2	−0·1	0·0	+0·1	0·0	**+0·4**	+0·4	+0·3	+0·2	+0·2	+0·2
Winter Means ...	39·5	+ 0·2	+0·2	+0·1	+0·1	+0·1	0·0	0·0	−0·1	0·0	−0·1	−0·4	−0·5	**−0·6**	−0·6	−0·5	−0·2	+0·1	+0·2	+0·1	**+0·3**	+0·2	+0·2	+0·3	+0·3	+0·2
April ...	38·3	+ 0·3	+0·3	+0·3	+0·3	+0·3	+0·3	+0·3	+0·5	**+0·6**	+0·1	−0·6	−1·4	**−1·5**	−1·5	−1·2	−0·5	0·0	+0·2	+0·2	+0·4	+0·4	+0·5	+0·5	+0·5	+0·5
May ...	37·9	+ 0·2	+0·2	+0·2	+0·3	+0·3	+0·3	+0·4	**+0·5**	+0·5	+0·1	−0·7	−1·2	**−1·4**	−1·3	−1·1	−0·5	−0·1	+0·2	+0·4	+0·4	+0·4	+0·4	+0·3	+0·3	+0·2
June ...	38·2	+ 0·2	+0·3	+0·3	+0·3	+0·4	+0·5	**+0·7**	+0·7	+0·7	+0·4	−0·4	−1·4	−1·5	**−1·6**	−1·3	−0·7	0·0	+0·3	+0·3	+0·5	+0·4	+0·5	+0·4	+0·3	+0·3
July ...	38·9	+ 0·1	+0·2	+0·3	+0·2	+0·1	+0·1	+0·2	+0·2	+0·1	−0·1	−0·7	−1·0	**−1·2**	−1·1	−0·7	−0·2	+0·3	+0·6	**+0·8**	+0·7	+0·6	+0·5	+0·5	+0·5	+0·5
August ...	39·1	− 0·2	−0·1	0·0	0·0	0·0	0·0	+0·1	+0·2	0·0	−0·4	−0·6	−0·3	−0·6	**−0·9**	−0·8	−0·5	+0·1	+0·5	+0·5	+0·5	+0·4	+0·4	+0·5	**+0·6**	+0·3
September ...	39·2	+ 0·4	+0·5	+0·5	+0·5	+0·6	+0·6	+0·8	+0·9	**+1·0**	+0·7	+0·1	−1·1	**−1·4**	−1·3	−1·2	−0·7	−0·3	−0·3	−0·4	−0·2	−0·1	−0·2	−0·3	−0·3	−0·4
Summer Means ...	38·6	+ 0·2	+0·2	+0·3	+0·3	+0·3	+0·3	+0·4	**+0·5**	+0·5	+0·1	−0·5	−1·1	**−1·3**	−1·3	−1·0	−0·5	0·0	+0·3	+0·3	+0·4	+0·4	+0·4	+0·3	+0·3	+0·2

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

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

Dehra Dūn {Lat. 30° 19′ 19″ N. / Long. 78 3 19 E.

TABLE 12.—*Classification and dates of Magnetic disturbances at Dehra Dūn in 1934.*

Dates	January	February	March	April	May	June	July	August	September	October	November	December
1934												
1	G	C	C	M	C	C	C	C	C	C	C	S
2	S	C	S	C	M	C	C	C	S	C	C	C
3	C	C	C	C	S	C	M	M	C	C	C	M
4	C	C	M	M	C	S	C	S	C	C	C	M
5	C	C	M	M	C	S	C	C	C	C	C	C
6	C	C	C	C	C	S	C	C	C	C	C	C
7	C	C	M	C	C	C	C	C	C	C	G	C
8	C	S	C	C	C	C	C	C	S	C	M	C
9	C	M	C	C	C	C	C	C	C	C	C	C
10	C	S	C	C	C	C	C	C	C	C	C	C
11	C	C	C	C	M	C	C	C	C	C	C	S
12	C	C	C	C	C	M	C	M	C	C	C	C
13	C	C	C	C	C	C	C	C	C	C	C	C
14	S	C	C	C	C	C	S	C	C	C	C	C
15	C	S	C	C	C	C	C	C	C	S	C	S
16	C	G	C	S	C	S	C	S	S	C	C	C
17	C	S	C	C	C	C	C	C	S	C	C	C
18	C	S	C	C	V.G.	C	C	C	C	C	C	C
19	C	C	C	C	C	C	C	C	C	C	C	C
20	C	C	C	C	C	C	C	C	C	C	C	C
21	C	C	C	C	C	C	C	C	C	C	C	M
22	S	C	S	C	C	C	C	C	C	C	C	C
23	C	C	S	C	C	C	C	C	C	C	C	C
24	C	C	C	C	C	C	S	C	M	M	S	—
25	C	C	S	C	S	C	C	C	M	M	C	—
26	C	C	C	C	C	C	C	S	C	M	C	C
27	C	C	C	C	C	S	C	S	C	C	C	C
28	C	C	C	C	C	C	C	M	C	C	C	C
29	S	...	C	C	C	C	C	S	C	C	C	G
30	C	...	C	C	C	C	G	S	S	C	C	M
31	C	...	G	...	C	...	M	C	...	C	...	C
C	26	21	23	26	26	24	26	22	23	27	27	21
S	4	5	4	1	2	5	2	6	5	1	1	3
M	...	1	3	3	2	1	2	3	2	3	1	4
G	1	1	1	...	...	...	1	...	...	...	1	1
V.G.	...	...	...	...	1	...	...	...	...	...	...	...
T.L.	...	...	...	...	...	...	...	...	...	...	...	2

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

CHAPTER VIII

RESEARCH AND TECHNICAL NOTES

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

CHANGES OF LEVEL IN BENGAL

In Geodetic Report Vol. VI of the Survey of India, from a discussion of some circuits comprising old and new lines of levelling, the conclusion was reached, that the plains of Bengal and Bihār have been rising at an average rate of 0·05 feet a year for the last 70 years. Colonel Sir Sidney Burrard* while criticizing the theory gave the alternative explanation that the large circuit errors might be due to the inferiority of older work. He also pointed out that Calcutta was devoid of a reliable datum of levels, there being no rock-cut bench mark in its vicinity. Howrah bench mark being on alluvial ground may have sunk since the time of the old levelling on account of the slow shrinkage of the silt after its deposition.

The matter was further discussed by Dr. J. de Graaff Hunter in the R. E. Journal† and in Geodetic Report 1933, Chapter VII. In the latter note, it was emphasized that on account of the inexplicably large systematic errors, which occur in levelling, one could not be dogmatic about changes of level being real.

It is interesting to record further evidence as exhibited from a comparison of new and old level nets.

In the first place, it can be said definitely that Howrah bench mark cannot have sunk by 2 or 3 feet. This was shown in Geodetic Report 1933 by citing check-levelling in 1913–14 along 10 miles of a branch-line 75 B, and comparing it with 1882–83 levelling. The differential heights of the various bench marks agree very satisfactorily. Check-levelling would no doubt agree, if all the bench marks had sunk by equal amounts by 2 feet or so, but this would be very improbable.

Yet another evidence in favour of the stability of the Howrah bench mark is afforded by the fact that the height difference between False Point and Howrah has remained constant. Chart XVIII shows the new and old levelling from Howrah to Kendrāpāra. The accidental probable errors of the two secondary lines from Balasore to Chāribātia and Chāribātia to Kendrāpāra are

---

* "Movements of the ground level in Bengal" by Colonel Sir Sidney Burrard. (*The Royal Engineers Journal*, June 1933).

† "Changing ground levels in Bengal" by Dr. J. de Graaff Hunter. (*The Royal Engineers Journal*, June 1934).

±0·00372 feet/miles$^{\frac{1}{2}}$ and ±0·00377 feet/miles$^{\frac{1}{2}}$ respectively. These are within the permissible limits.

New difference of levels (1924–32) between Howrah B.M. 264/79 B and Kendrāpāra B.M. 43/73 L ...	= +4·569 feet
Old difference of levels (1881–83) between Howrah B.M. 264/79 B and Kendrāpāra B.M. 43/73 L ...	= +5·323 feet

The positive sign means that Kendrāpāra is above Howrah. The discrepancy old *minus* new is +0·754 feet. The length of the circuit is 528 miles. The maximum probable error of levelling in this distance, according to the criterion laid down by the International Geodetic Association for levelling of high precision should not exceed half a foot. Bearing in mind the fact that two of the lines involved in the circuit are of secondary precision, the discrepancy of 0·754 feet can safely be attributed to the levelling errors. This is confirmed by the fact that the line Howrah to Balasore (148 miles) has been done by precise levelling both by our predecessors and ourselves, and the discrepancy there is only −0·049 feet.

The following table gives the check-levelling at Kendrāpāra.

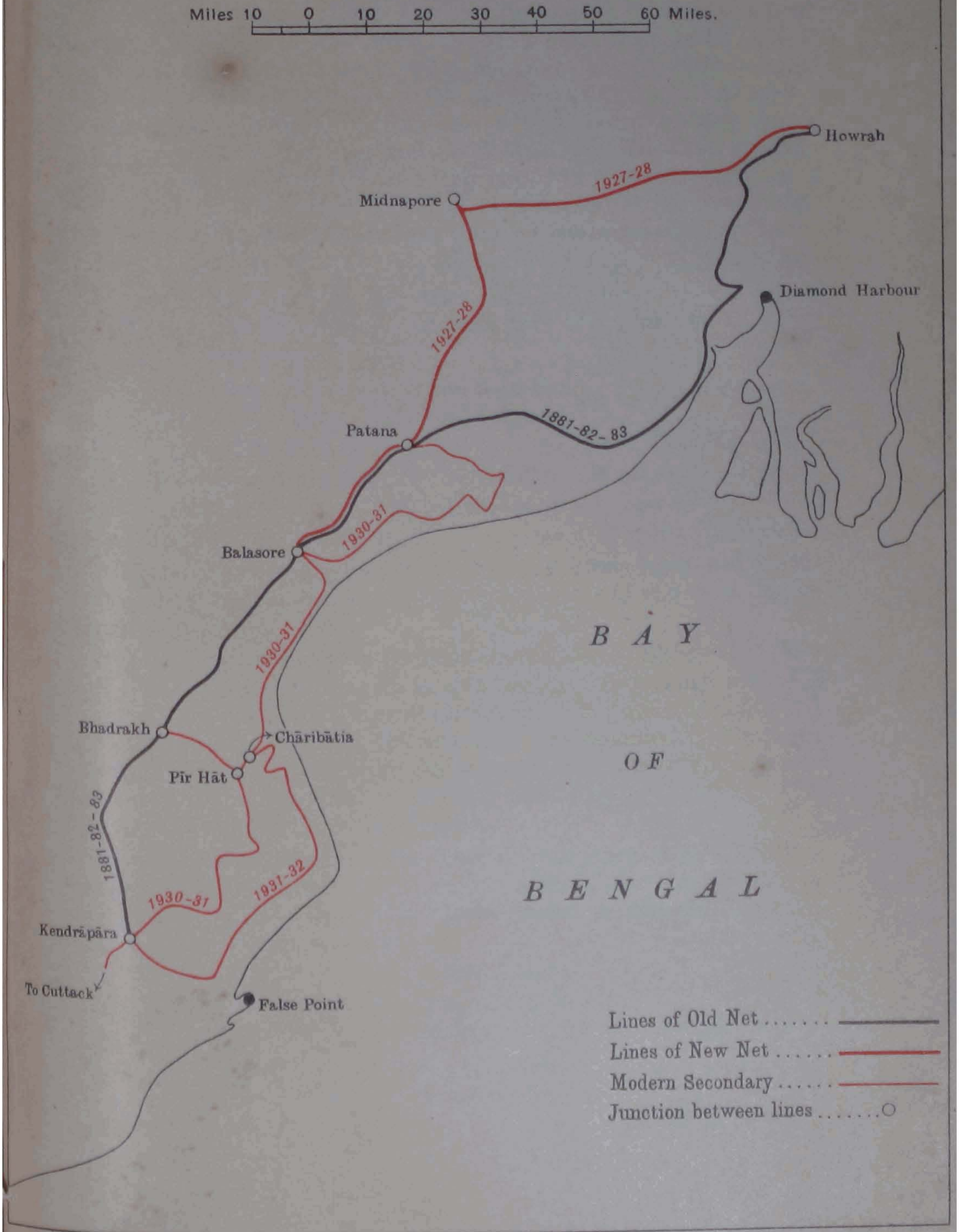
Discrepancies between the old and new heights of bench marks

Bench marks of the original levelling that were connected for check-levelling				Distance from starting bench mark	Unadjusted dynamic height above (+) or below (−) starting bench mark			Difference (check—original). The sign + denotes that the height was greater and the sign −, less in 1930-32 than when originally levelled.
Old line No.	No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1930-32	
				miles		*feet*	*feet*	*feet*
Line 75 E (Cuttack to Pir Hāt)								
41	43	73 L	E.B.M. at Kendrāpāra	0·0	1893–94	0·000	0·000	0·000
41	35	,,	Stone embedded pillar ...	4·9	,,	+ 2·479	+ 2·466	−0·013
41	30	,,	E.B.M. at Dānur Lock	10·0	,,	+15·986	+15·957	−0·029
41	29	,,	Parapet of ,, ,,	10·0	,,	+12·946	+12·911	−0·035
Line 75 F (Kendrāpāra to Chāribātia)								
75	43	73 L	E.B.M. at Kendrāpāra	0·0	1881–82	0·000	0·000	0·000
75	42	..	Subdivisional officer's *kachahri* ...	0·0	,,	− 1·329	− 1·301	+0·028
42	67	,,	Canal Lock, Kalapada	5·4	,,	− 1·022	− 1·126	−0·104
42	62	..	Parapet of sluice, Mārsāghāi ...	9·0	,,	+ 0·766	+ 0·675	−0·091

Chart XVIII

LEVELLING FROM HOWRAH TO KENDRĀPĀRA

Scale $\frac{1}{2,000,000}$ or 1·014 Inches to 32 Miles.



REG. No243 D.D.D. 1936-390.

Helio S. I. O. Dehra Dūn.

The Kendrāpāra bench marks have thus preserved their differential heights, and we can infer that the area round Howrah has remained stable. Kendrāpāra B.M. 43/73 L is about 30 miles distant from False Point and is the nearest bench mark to it, which is common to both new and old levelling.

In Geodetic Report 1933, it was pointed out that the hypothesis of the rise of Bengal plains has been weakened by evidence from the west. If Benares has gone up by 2 feet since 1864, and if Agra has remained stationery, then the new height difference of Agra–Benares should differ from the old by that amount. Actually, the discrepancy is only 0·162 feet in a distance of 380 miles. Similarly comparing Benares and Allahābād, we see that discrepancy between new and old levelling is 0·035 feet in a distance of 75 miles. If then a rise of 2 feet is postulated for Benares, both Allahābād and Agra will also have risen at the same rate.

It is advisable to take the evidence of some other circuits. With the completion of the line Bombay–Surat in the back direction, it is possible now to compare the new and old levelling from Agra to Bombay.

Old height difference (1861–1907) between Agra B.M. 33/54 I and Bombay B.M. 2/47 B ...	= + 531·022 feet
New height difference (1915–1935) between Agra B.M. 33/54 I and Bombay B.M. 2/47 B ...	= + 531·469 feet

The discrepancy of half a foot is in the sense that Agra has risen. The old levelling is via Sironj–Nāndgaon–Kalyān and is of length 836 miles.

The new levelling is via Gwalior–Jhānsi–Bīna–Bhopāl–Sehore–Dhūlia–Surat, and its length is 921 miles. A closing error of half a foot in 1,760 miles signifies nothing. It might be remarked that the major portion of the old line was executed in the years 1861 to 1878. Only the last 34 miles from Kalyān to Bombay were levelled in 1906–07. Similarly the major portion of new levelling was done from 1929 to 1935.

We can also compare another circuit from Agra B.M. 33/54 I to Tāpas-ka-dhoi (Navanar B.M. 1/41 F), although in the new levelling a small portion (97 miles) from Surat to Baroda has been observed in one direction only:—

Old height difference (1861–1907) via Agra–Sironj–Bombay–Viramgām–Rājkot–Jorya–Shikārpur ...	= – 539·420 feet
New height difference (1915–35) via Agra–Surat–Viramgām–Rājkot–Jorya–Shikārpur ...	= – 538·888 feet

The length of the old line is 1,490, and of the new 1,242 miles. The discrepancy is only 0·532 feet in this distance. Agra to Bombay is also connected by another route.

Old height difference (1861–1909) via Meerut–Ferozepur–Ahmedābād–Viramgām–Rājkot–Jorya–Shikārpur ... ... = −540·343 feet

New height difference (1922–30) via Agra–Muttra–Mārwār Pāli–Viramgām–Rājkot–Jorya–Shikārpur ... ... = −538·900 feet

The closing error of the circuit comprised of old and new levelling is 1·443 feet, the length of the circuit being 2,360 miles.

These figures if anything show Agra to have sunk. They are however not significant enough for definite conclusions to be drawn from them, and are due probably to errors of levelling. The circuit Agra to Karāchi via Muttra–Mārwār Pāli–Barmer–Kotri–Karāchi–Tatta–Shikārpur–Murghai–Ferozepur–Meerut–Agra comprised of new and old levelling shows a closing error of 1·003 feet, the length of the circuit being 2,040 miles. The sense of the discrepancy agrees with the above figures, that Agra has sunk with respect to Karāchi. The agreement however can only be regarded as fortuitous.

Height difference between Benares B.M. 96/63 K and Bombay B.M. 2/47 B was next compared.

Old height difference (1863–1909) = −237·197 feet

New height difference (1917–1935) = −236·889 feet

Length of the new and old lines are 1,127 miles and 980 miles respectively.

We thus see that the rise of Benares is only indicated by the lines from Howrah. All other lines of evidence available so far, tend to show that both Benares and Agra have remained stable.

The circuit Howrah–Pirpainti–Benares–Rānīganj–Howrah is 1,287 miles long. If the old line Benares–Pirpainti–Howrah is included in it, the closing error is 2·170 feet. The closing error of the nearly identical new circuit Kulgaria–Pirpainti–Benares–Rānīganj–Kulgaria is 1·324 feet. The maximum permissible probable error according to International standards is 1·1 feet for high precision levelling. The probable error by the Survey of India formula deduced from a consideration of all circuits of levelling of precision in India is ±0·8 feet. No doubt the chances against a closing error of 2 feet are rather large, but the possibility of error in levelling cannot well be excluded.

Definite conclusions about secular changes of level of an area can only be drawn when a large number of rock-cut bench marks

(i.e. bench marks on firm ground) are available in the area. If these bench marks are about two miles apart, and if it can be ensured, that they are rigidly connected with the crust, and do not rise or fall irregularly with respect to it, then the movements of the crust if any can be delineated with certainty. The levelling error plays an unimportant role, as the distances between the bench marks are small.

The above procedure however was not feasible for the line from Howrah to Benares, as the new and old levellings are along different routes.

PUBLICATIONS
OF THE
SURVEY OF INDIA
(Corrected up to 31st December 1935)

PUBLICATIONS
OF THE
SURVEY OF INDIA

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

SYNOPSIS

---

* 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

Triangulation Pamphlets.—(*Concluded*).

of triangulated points and other data with chart. The chart shows the plan of triangulation with the position of stations and points. Triangulation data falling in 1/M sheet are printed in a series of sixteen pamphlets A to P. In the last pamphlet of every series published up till 1932, a coloured map is given in addition to the chart, to illustrate the topographical features of the area covered by the 1/M sheet. Pamphlets having this map are charged Rs. 1-8 extra.

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

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

Levelling Pamphlets.

(i) **Levelling of Precision.** Giving heights and descriptions of all Bench marks fixed by Levelling of Precision and of certain selected secondary lines. Each pamphlet embraces an area of 4° × 4° and the numbering is the same as that of the corresponding sheets of the 1/M map of India. Each is illustrated by a map of the area. Published at Dehra Dūn.

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

Pamphlet		Latitude N.	Longitude E.	Published in	Price
Sheet	Distinctive name of Sheet				
		° °	° °		
34	(Quetta) ...	28–32	64–68	1916	Rs. 2-0-0
35	(Karāchi) ...	24–28	64–68	1911	Rs. 2-0-0
38	(Kābul) ...	32–36	68–72	1912	Rs. 2-0-0
39	(Multān) ...	28–32	68–72	1913	Rs. 2-0-0
	Addendum to 39 ...	...	..	1916	Rs. 2-0-0
40	(Hyderābād, Sind)	24–28	68–72	1934	Rs. 2-0-0
41	(Rājkot) ...	20–24	68–72	1913	Rs. 2-0-0
43	(Srīnagar) ..	32–36	72–76	1913	Rs. 2-0-0
	Addendum to 43 ...	...	...	1915	Rs. 2-0-0
44	(Lahore) ...	28–32	72–76	1926	Rs. 3-0-0
45	(Ajmer) ...	24–28	72–76	1911	Rs. 2-0-0
46	(Baroda) ...	20–24	72–76	1912	Rs. 2-0-0
47	(Bombay) ...	16–20	72–76	1912	Rs. 2-0-0
	Addendum to 47, Island of Bombay	...	...	1915	Re. 1-0-0

Levelling Pamphlets.—(*Continued*).

Pamphlet		Latitude N.	Longitude E.	Published in	Price
Sheet	Distinctive name of Sheet				
		° °	° °		
48	(Goa) ...	12–16	72–76	1912	Rs. 2-0-0
49	(Calicut) ...	8–12	72–76	1911	Re. 1-0-0
52	(Leh) ...	32–36	76–80	1912	Re. 1-0-0
53	(Delhi) ...	28–32	76–80	1929	Rs. 3-0-0
	Addendum to 53 ...	...	...	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
57	(Mysore) ...	12–16	76–80	1919	Rs. 2-0-0
58	(Ootacamund) ...	8–12	76–80	1914	Rs. 2-0-0
62	(Mānasarowar) ...	28–32	80–84	1922	Re. 1-0-0
63	(Allahābād) ...	24–28	80–84	1923	Rs. 2-0-0
64	(Raipur) ...	20–24	80–84	1912	Rs. 2-0-0
65	(Vizagapatam) ...	16–20	80–84	1913	Rs. 2-0-0
66	(Madras) ...	12–16	80–84	1912	Rs. 2-0-0
72	(Kātmāndu) ...	24–28	84–88	1930	Rs. 2-0-0
73	(Cuttack) ...	20–24	84–88	1913	Rs. 2-0-0
	Addendum to 73 ...	...	...	1927	Rs. 2-0-0
74	(Puri) ...	16–20	84–88	1913	Rs. 2-0-0
78	(Darjeeling) ...	24–28	88–92	1923	Rs. 2-0-0
79	(Calcutta) ...	20–24	88–92	1924	Rs. 2-0-0
83	(Dibrugarh) ...	24–28	92–96	1912	Rs. 2-0-0
84	(Akyab) ...	20–24	92–96	1918	Rs. 2-0-0
85	(Prome) ...	16–20	92–96	1917	Rs. 2-0-0
92	(Bhamo) ...	24–28	96–100	1918	Rs. 2-0-0
93	(Mandalay) ...	20–24	96–100	1917	Rs. 2-0-0
94	(Rangoon) } ...	16–20	96–100	1916	Rs. 2-0-0
95	(Mergui) }	12–16	96–100		

(b) Levelling of Precision in Mesopotamia.

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

Levelling Pamphlets.—(*Continued*).

(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	,,	,,
5	52E (Rohri to Jām Sahib)	40 A, B & E	,,	,,
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	52I (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 Seorāphuli) 74E (Bāndel Church to Bāndel Ry. Stn.) 74F [B.M. 251 (*118*)/79A to Pandua Ry. Stn.]	79 A & B	,,	As. 8

Levelling Pamphlets.—(*Continued*).

Serial No.	Line number	Situated in degree sheets	Published in	Price
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.) 70I (B.M. 15/73M to Asansol, Kālīpāhari and Churulia) 70M (Khāna Ry. Stn. to Galsi Ry. Stn.)	73 I & M	1928	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
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	,,	Rs. 2

Levelling Pamphlets.—(*Continued*).

Serial No.	Line number	Situated in degree sheets	Published in	Price
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	1928	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 (Ahar Bela 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) 55 J (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 63 B, 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	88G (Thanatpin to Tongyi) 88H (Ohne to Thongwa and Ohne)	94 C & D	1933	As. 10
45	57 I (Khudiān to Lodhrān) 57K (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	55Q (Rohilānwāli to Leiah)	39 J, K & O	1933	As. 14

Levelling Pamphlets.—(*Continued*).

Serial No.	Line number	Situated in degree sheets	Published in	Price
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) 70T (Patna to Gaya)	72 C, D, G, H & K	”	As. 6
50	121B (Toposi to Ondal) 121C (Toposi to Gaurāngdih) 151A (Pāndaveswar to Palāsthāli) 70R (Ikrah to Sītārāmpur) 70U (Pradhānkhunta to Pāthardīh) 70V (Dhānbād to Jamuniātānr) 70Q Toposi to Bārābani	73 I & M	”	As. 10
51	56I (Ferozepore to Jagraon) 61I (Mahna to Head of Bhadaur distributary) 61J (Badhni Kalān to Alamwāla)	44 I, J, M & N	”	As. 14
52	57O (Bhatinda to Dorāha) 57P (Islāmwāla to Lambi)	44 J, K & N and 53 B	”	As. 10
53	57Q (Hanumāngarh to Hissār) 57R (Hissār to Bālsamand)	44 K, O & P and 53 D	”	As. 10
54	75C (Muhammadnagar Patna to Bhadrakh) 75D (Bhadrakh to Cuttack) 75E (Cuttack to Pīr Hāt)	73H, K, L & O	”	As. 14

Levelling Pamphlets.—(*Continued*).

Serial No.	Line number	Situated in degree sheets	Published in	Price
55	74J (Saktigarh to Bally) 74K (Seorāphuli to Tārakeswar) 74L (Bāndel to Barharwa)	72 P, 73 M, 78 D and 79 A & B	1933	As. 10
56	74M (Khāna to Kiul: portion Tinpahār to Pirpainti) 74N (Nalhāti to Azimganj) 74O (Tinpahār to Rājmahāl)	72 K, O & P, 73 M and 78 D	,,	As. 14
57	70O (Jasidih to Baidyanāth Dhām) 70P (Madhupur to Girīdih) 72A (Bhāgalpur to Mandār hill)	72 K, L & P	,,	As. 6
58	74I (Uttarpāra to Kālna)	79 A & B	,,	As. 6
59	52M (S.B.M. Sukkur to Barrage Road Bridge, Sukkur) ...	40 A	,,	As. 6
60	57S (Bhiwāni to Bahādurgarh) 57T (Hānsi to Bhatinda) 57U (Mānsa to Sohūwāla)	44 J, K, N & O and 53 C, D & H	,,	As. 14
61	57V (Badopāl to Narwāna) 57W (Narwāna to Rājpura)	44 O and 53 B & C	,,	As. 10
62	61K (Chandigarh to Dorāha) 57X (Dorāha to Patiāla)	53 B	,,	As. 10

Levelling Pamphlets.—(*Concluded*).

Serial No.	Line number	Situated in degree sheets	Published in	Price
63	75 F (Chāribātia to Kendrāpāra) 75 G (Kiarbank to Puri) 39 B (Puri to Puri)	73 H, K & L and 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 (Karnāl 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*	,,

PART II. GEODETIC WORKS OF REFERENCE

Everest's Great Arc Book.

1. An account of the measurement of an Arc of the Meridian between the parallels of 18° 3′ and 24° 7′, by Captain George Everest, F.R.S. &c., East India Company, London, 1830 (Out of print).

2. An account of the Measurement of two Sections of the Meridional Arc of India, bounded by the parallels of 18° 3′ 15″, 24° 7′ 11″ and 29° 30′ 48″, by Lt.-Colonel G. Everest, F.R.S. and his assistants. East India Company, London, 1847. (Out of print).

3. Engravings to illustrate the above. London, 1847. (Out of print).

G. T. S. Volumes. Describing the operations of the Great Trigonometrical Survey.

Vol. I **The Standards of Measure and the Base-Lines,** also an Introductory Account of the early operations of the Survey, during the period of 1800–1830. Dehra Dūn, 1870. (Out of print).

G.T.S. Volumes.—(*Continued*).

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, NW. Himālaya, and the Great Indus Series. Dehra Dūn, 1873. (Out of print).

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

Vol. IV A **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 Captain 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°-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 year 1875–77 and 1880–81. Dehra Dūn, 1883. *Price Rs. 10-8.*

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

Vol. XI **Astronomical Latitudes.** During the period 1805–1885. Dehra Dūn, 1890. *Price Rs. 10-8.*

Vol. XII **Southern Trigon.** General Description and Simultaneous Reduction. Also details of the following two series:—Great Arc-Section 8°-18°, and Bombay Longitudinal. Dehra Dūn, 1890. *Price Rs. 10-8.*

G. T. S. Volumes.—(*Concluded*).

Vol. XIII **Southern Trigon.** Details of the following five series:— South Konkan Coast, and Mangalore Meridional, Madras Meridional and Coast, South-East Coast, and Madras Longitudinal. Dehra Dūn, 1890. *Price Rs. 10-8.*

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

Vol. XV **Telegraphic Longitudes.** From 1885 to 1892 and the Revised Results of Volumes IX and X: also the Simultaneous Reduction and final Results of the whole Operations. Dehra Dūn, 1893. *Price Rs. 10-8.*

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

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

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

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

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

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

PART III. HISTORICAL AND GENERAL REPORTS

Memoirs.

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

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

Annual and Special Reports.

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

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

Ditto **Trigonometrical Branch.** 1861 to 1878. (1861 to 1863, out of print). *Price Rs. 2.*

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

General Reports from 1877 to 1900. *Price Rs. 3 per volume.*
from 1900 to 1922. *Price Rs. 2 per volume.*
from 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 1924 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.*

Annual Reports &c.—(*Continued*).

1903-04. Utilization of old Traverse Data for Modern Surveys in the United Provinces. Identification of Snow Peaks in Nepāl. Topographical Surveys in Sind. Notes on town and Municipal Surveys. Notes on Riverain Surveys in the Punjab. Calcutta, 1906. *Price Rs. 1-8.*

1904-05. Triangulation in Baluchistān. Survey Operations with the Somāliland Field Force. Calcutta, 1907. *Price Rs. 1-8.*

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

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

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

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

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

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

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

Vol. III **1911-12.** Calcutta, 1913. *Price Rs. 4.*

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

Vol. V **1912-13.** Note on the relationship of the Himālayas to the Indo-Gangetic Plain. Calcutta, 1914. *Price Rs. 4.*

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

Vol. VII **1913-14.** Note on Scales and cost rates of Town plans. Calcutta, 1915. *Price Rs. 4.*

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

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

Vol. IX **1914-15.** Criterion of strength of Indian Geodetic Triangulation. A traverse signal for City Surveys. "The plains of Northern India and their relationship to the Himālaya Mountains" an address by Colonel S. G. Burrard, F.R.S. Report on Turco-Persian Frontier Commission. Calcutta, 1916. *Price Rs. 4.*

Vol. X **1915-16.** Mechanical Integrator for calculating Attractions (illustrated). Traverse Survey of the boundary of Imperial Delhi. Dehra Dūn, 1917. *Price Rs. 4.*

Annual Reports &c.—(*Continued*).

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	**1918-19.** Levelling in Mesopotamia. Dehra Dūn, 1920. *Price Rs. 4.*
Vol. XV	**1919-20.** Levelling; proposed new level net. The Earth's Axes and Figure, by J. de Graaff Hunter (a paper read at the R. A. S. Geophysical Meeting). Report on the expedition to Kamet. Note on the Topography of the Nun Kun Massif in Ladākh. Dehra Dūn, 1921. *Price Rs. 4.*
Vol. XVI	**1920-21.** High Climbs in the Himālaya prior to the Everest Expedition. Mt. Everest Survey Detachment, 1921. Traverse Survey of Allahābād city. Settlement of Boundary between Mysore and South Kanara. Dehra Dūn, 1922. *Price Rs. 4.*
Vol. XVII	**1923.** Memoir on Maps of Chinese Turkistān and Kansu from the Surveys made during Sir A. Stein's Explorations, 1900–01, 1906–08, 1913–15. Dehra Dūn, 1923. *Price Rs. 12.*
Vol. XVIII	**1921-22.** Traverse Survey of Allahābād city. Settlement of Boundary between Mysore and South Kanara. Notes on Revision Survey in the neighbourhood of Poona. Dehra Dūn, 1923. *Price Rs. 4.*
Vol. XIX	**1901-20.** The Magnetic Survey, by Lt.-Colonel R. H. Thomas, D.S.O., R.E., and E. C. J. Bond, V.D. Dehra Dūn, 1925. *Price Rs. 4.*
Vol. XX	**1914-20.** The War Record. Dehra Dūn, 1925. *Price Rs. 3.*
Vol. XXI	**1922-23-24.** I. Air Survey in the Irrawaddy Delta 1923–24, by Major C. G. Lewis, R.E., and II. Reconnaissance Survey in Bhutān and South Tibet 1922, by Captain H. R. C. Meade, I.A. Dehra Dūn, 1925. *Price Rs. 1-8.*
Vol. XXII	**1926.** Exploration of the Shaksgam Valley and Aghil Ranges, 1926, by Major K. Mason, M.C., R.E. Dehra Dūn, 1928. *Price Rs. 3.*

Annual Reports &c.—(*Continued*).

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

Vol. XXIV **1901-29.** Riverain Surveys in the Punjab, 1901 to 1929. Dehra Dūn, 1934. *Price Rs. 1-8.*

Vol. XXV **1925-31.** Surveys in Swāt, Chitrāl & Gilgit and neighbouring territories, carried out by 'A' Survey Company from 1925 to 1931, by Lt.-Colonel C. G. Lewis, O.B.E., R.E. Dehra Dūn, 1934. *Price Rs. 1-8.*

(*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.*

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.*

Annual Reports &c.—(*Concluded*).

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.*

1935. Triangulation. Levelling. Deviation of the Vertical. Gravity. Geophysical Survey in Bihār. Computing Office and Tidal Section. Observatories. Research and Technical Notes. Dehra Dūn, 1936. *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.**	869
2.	**Circular Orders (Administrative).**	432
3.	**Circular Orders (Professional).**	196
4.	**Departmental Orders** (appointments, promotions, transfers etc.)	

These are numbered serially and had reached the above numbers by September 1935. *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

Departmental Orders.—(*Concluded*).

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.
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.*

List 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, or 3 s.*

---

* For Departmental use only.

Catalogues and Lists.—(*Concluded*).

6. **Green Lists.** —(*Contd.*) 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, or 2 s.*

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 have been published on 1st April in a single volume. *Price Rs. 9-2, or 15 s.*

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.*

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, 1936. (at Press).

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.*

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

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

Old Manuals.

1. A Manual of Surveying for India, detailing the mode of operations on the Revenue Surveys in Bengal, and the North-Western Provinces. Compiled by Captains R. Smyth, and H. L. Thuillier. Calcutta, 1851.

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.*

---

* For Departmental use only.

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 Duties of a Survey Party, Third Edition, 1936. (at Press).

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

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

,, V Plane-tabling. Fourth Edition, 1935. *Price Re. 1.*

,, VI Fair Mapping. Seventh Edition, 1935. *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.

---

* 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 of 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.

---

* For Departmental use only.

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 Survey operations in connections, with the Mission to Yārkand and Kashgar in 1873-74, by Captain Henry Trotter, R.E. Calcutta, 1875. (Out of print).

---

* **For Departmental use only.**

Unclassified Papers.—(*Continued*).

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.

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
,, 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.
Price As. 12.

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

Special Reports.

1. *Report on the Mussoorie and Landour, Kumaun and Garhwāl, Rānīkhet and Kosi Valley Surveys, extended to Peshāwar and Kāghān Triangulation during 1869-70, by Major T. G. Montgomerie, R. E. (Out of print).

2. Report on the Recent Determination of the Longitude of Madras, by Captain S. G. Burrard, R.E. Calcutta, 1897. (Out of print).

---

* **For Departmental use only.**

Unclassified Papers.—(*Continued*).

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'Armēe" by Captain W. M. Coldstream, R.E. Calcutta, 1906.

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

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

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.

---

* For Departmental use only.

Unclassified Papers.—(*Concluded*).

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).

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.*

---

* **For Departmental use only.**

Professional Papers.—(*Continued*).

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.*

---

* For Departmental use only.

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.*

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

No. 22. **Levelling.** Three Sources of error in Precise Levelling, Captain G. Bomford, R.E. Dehra Dūn. 1929. *Price Rs. 1-8.*

No. 23. * **Air Survey.** Air Survey of Wazīristān 1923 to 1928, by Captain G. F. Heaney, R.E. Dehra Dūn, 1928. *Price As. 8.*

No. 24. **Air Survey.** Notes on Air Survey in India, by Major W. J. Norman, M.C., R.E. Dehra Dūn, 1929. *Price Rs. 1-8.*

No. 25. **Glaciers.** The representation of Glaciated Regions on maps of the Survey of India, by Major Kenneth Mason, M.C., R.E. Dehra Dūn, 1929. *Price As. 8.*

No. 26. **Geography.** Mount Everest and its Tibetan Names, by Colonel Sir S. G. Burrard, K.C.S.I., F.R.S. Dehra Dūn, 1931. *Price As. 8.*

No. 27. **Gravity.** Gravity Anomalies and the Structure of the Earth's Crust, by Major E. A. Glennie, D.S.O., R.E. Dehra Dūn 1932. *Price Rs. 1-8.*

Departmental Papers†.

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

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

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

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

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

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

---

* For Official use only.

† For Departmental use only.

Departmental Papers*.—(*Concluded*).

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

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

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

No. 10. **Base Lines.** A Booklet of Instructions with full descriptions and tables for the Hunter Short Base, First Edition compiled by Major C. M. Thompson, I.A. Dehra Dūn, 1928. Second Edition compiled by H. C. Banerji, B.A. Dehra Dūn, 1931.

No. 11. **Gravity and Isostasy.** Investigations regarding Gravity and Isostasy by W. Heiskanen (Translated by V. Pelts, Esq. Revised and completed by Major C. M. Thompson, I.A.) Dehra Dūn, 1928.

No. 12. **Geodesy.** Geodesy, by J. de Graaff Hunter, M.A. SC.D., F. INST. P. Dehra Dūn, 1929.

No. 13. **Spherical Trigonometry and Astronomy.** Notes on Spherical Trigonometry, and Astronomy etc., by Lt.-Colonel C. M. Thompson, I.A. Dehra Dūn, 1929.

No. 14. **Wild Theodolite.** Instructions for the use of the Wild Universal Theodolite by Captain D. R. Crone, R.E., and the Wild Photo-Theodolite, by Lt.-Colonel C. G. Lewis, O.B.E., R.E. Dehra Dūn, 1932.

No. 15. **Air Survey.** Notes on Air Survey and Map Publication in England, 1931, by Major H. R. C. Meade, I.A., with a foreword by Captain D. R. Crone, R.E. Calcutta, 1932.

Professional Forms.

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

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

1. †India's Contribution to Geodesy, by General J. T. Walker, R.E., C.B., F.R.S., LL.D. (Philosophical Transactions, Royal Society, Series A, Volume 186, 1895).

---

* For Departmental use only.

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

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

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).

4. *On the origin of the Indo-Gangetic trough, commonly called the Himālayan Foredeep, by Colonel Sir S. G. Burrard, K.C.S.I., R.E., F.R.S. (Proceedings of the Royal Society, Series A, Volume 91, pages 220–238, 1915).

5. †Three comprehensive articles on "Comparators for the Indian Government" from a report by Major H. McC. Cowie, R.E. (Engineering, Aug. 20, Aug. 27, Sept. 3, 1915).

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).

8. ‡War Surveys in Mesopotamia, by Colonel F. W. Pirrie, C.M.G., I.A. (Geographical Journal, December 1918).

9. ‡Mapping from Air Photographs, by Lt.-Colonel M. N. Mac Leod R.E. (Geographical Journal, June 1919).

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

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

12. §A lecture on the Earth's Axes and figure, by J. de Graaff Hunter, M.A. (The Observatory, May 1920).

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

14. ‡A note on the topography of the Nun Kun Massif in Ladākh, by Major K. Mason, M.C., R.E. (Geographical Journal, August 1920).

---

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

---

* Obtainable from the Institution of Royal Engineers, Chatham.

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

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

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

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

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

31. †The Demarcation of the Turco-Persian Boundary in 1913–14, by Colonel C. H. D. Ryder, R.E. (Geographical Journal, September 1925).

32. Geodesy, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. (Enc. Brit. 13th Edition, New Vol. ii. 1926).

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

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

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

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).

43. Figure of the Earth. Presidential address by J. de Graaff Hunter, M.A., SC.D., F. INST. P. at the Section of Mathematics and Physics of the Fifteenth Indian Science Congress, Calcutta 1928 (Published by the Asiatic Society of Bengal, Calcutta).

---

* Obtainable from the Institute of Physics, 90 Great Russel Street, London W.C. 1.
† Obtainable from the Royal Geographical Society, Kensington Gore, London, S.W. 7.
‡ Obtainable from the office of Nature. St. Martin's Street, London, W.C. 2.

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

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

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

46. *The Cambridge Pendulum Apparatus, by Colonel Sir Gerard Lenox-Conyngham, F.R.S. (Geographical Journal, April 1929).

47. ‡The Attraction of the Himālaya, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. (Himālayan Journal, Vol. I, No. 1, April 1929, pages 59–66.).

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

49. §The Geographical Representation of the Mountains of Tibet by Colonel Sir S. G. Burrard, K.C.S.I., R.E., F.R.S. (Proceedings of the Royal Society, Series A, Volume 127, 1930, pages 704–712).

50. ||The Glaciers of the Kara-koram and Neighbourhood, by Major Kenneth Mason, M.C., R.E. (Records of the Geological Survey of India, Volume LXIII, part 2, 1930, pages 214–278).

51. A Report on the Geodetic work of the Survey of India for the period 1927–30, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. presented at the fourth meeting of the International Union of Geodesy and Geophysics, Stockholm, August 1930. Dehra Dūn, 1930. *Price Rs. 1-12.*

52. The Indian Geoid and Gravity Anomalies by J. de Graaff Hunter, M.A., SC.D., F. INST. P. and Captain G. Bomford, R.E. (Bulletin Géodésique, No. 29 Jan.–Mar. 1931, pages 20, 21, Paris).

53. Construction of the Geoid, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. and Captain G. Bomford, R.E. (Bulletin Géodésique, No. 29 Jan.-Mar. 1931, pages 22–26, Paris).

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).

---

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

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

‡ Obtainable from Messrs. W. Thacker & Co., 2, Creed Lane, Ludgate Hill, London. E. C. 4, or Messrs. Thacker, Spink & Co., Calcutta.

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

|| Government of India Central Publication Branch, Calcutta.

¶ Obtainable from the Crown Agents for the Colonies, 4 Millbank, London, S.W. 1.

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

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

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, January 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, January 1933).

61. * "Crustal Warpings", discussing the gravity work of the Survey of India, by Major E. A. Glennie, D.S.O., R.E. (The Observatory, January and April 1933).

62. § Time Determination, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. (Nature, 8th April 1933).

63. ‡ Figures of reference for the Earth, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. (Empire Survey Review No. 8, Vol. II, April 1933).

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, October 1933, pages 221–225).

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

---

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

† Obtainable from the Royal Astronomical Society, Burlington House, London W. 1.

‡ Obtainable from the Crown Agents for the Colonies, 4 Millbank, London, S.W. 1.

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

|| Obtainable from Akademische Verlagsgesellschaft M.B.H., Leipzig.

¶ Obtainable from the International Hydrographic Bureau, Monte-Carlo, Monaco.

$ Obtainable from Mr. Humphrey Milford, Oxford University Press, Amen House, Warwick Square, London, E.C. 4.

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

69. *Inequalities of Loading of the Earth's Crust, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. (The Observatory, Oct. 1934).

70. † The study of Threatening Glaciers, by Professor Kenneth Mason, (Geographical Journal, January 1935).

71. ‡ Isostasy in India, by Lt.-Colonel E. A. Glennie, D.S.O., R.E. (Gerl. Beit. Zur Geophysik, Vol. 43, No. 4, 1935).

72. § On the map of the Zemu Glacier, by Prof. R. Finsterwalder (Translated from the German by Lt.-Colonel C. M. Thompson, I.A.) (Himālayan Journal Vol. VII, 1935).

73. || The Figure of the Earth from Gravity Observations and the Precision obtainable, by J. de Graaff Hunter, C.I.E., SC.D. (Philosophical Transactions, Royal Society, Series A, Vol. 234, 1935).

74. ¶ On the Subterranean Mass-Anomalies in India by B. L. Gulatee, M.A. (Cantab.) (Proceedings of the Academy of Sciences, U. P., India, Vol. 5, Sept. 1935).

---

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

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

‡ Obtainable from Akademische Verlagsgesellschaft M.B.H., Leipzig.

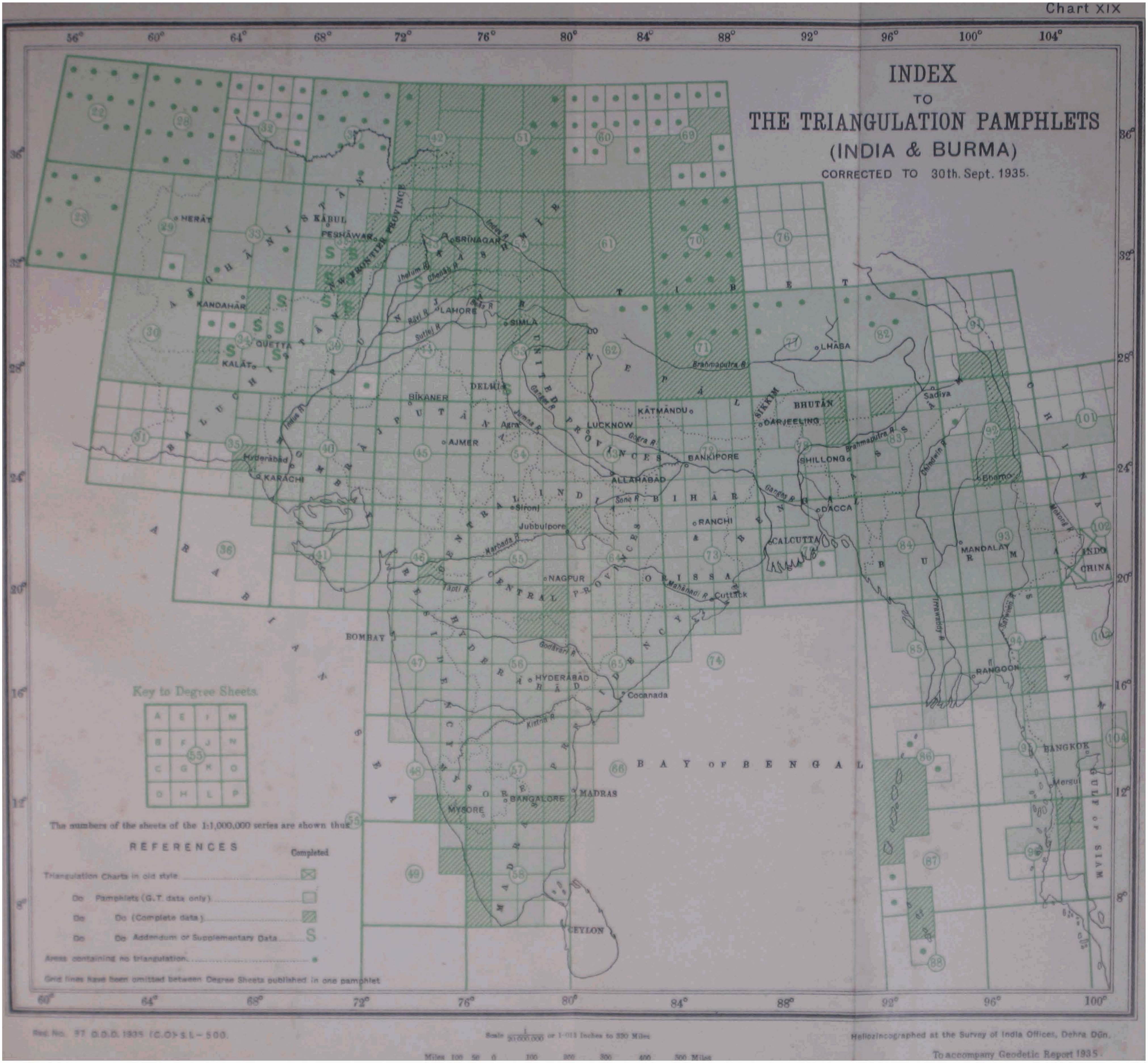
§ Obtainable from Mr. Humphrey Milford, Oxford University Press, Amen House, Warwick Square, London, E.C. 4.

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

¶ Obtainable from the Academy of Sciences, U. P., India, Allahābād.

G.B.—P.O.—J.S. 661—9-12-35—350 bks.

Chart XIX



INDEX
TO
THE TRIANGULATION PAMPHLETS
(INDIA & BURMA)
CORRECTED TO 30th. Sept. 1935.

Key to Degree Sheets

A	E	I	M
B	F	J	N
C	G	K	O
D	H	L	P

The numbers of the sheets of the 1:1,000,000 series are shown thus (55)

REFERENCES

	Completed
Triangulation Charts in old style	☒
Do Pamphlets (G.T. data only)	☐
Do Do (Complete data)	▨
Do Do Addendum or Supplementary Data	S
Areas containing no triangulation	●

Grid lines have been omitted between Degree Sheets published in one pamphlet

Reg. No. 97 D.O.D. 1935 (C.O.)-S.L.-500.

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

Miles 100 50 0 100 200 300 400 500 Miles

Heliozincographed at the Survey of India Offices, Dehra Dūn.

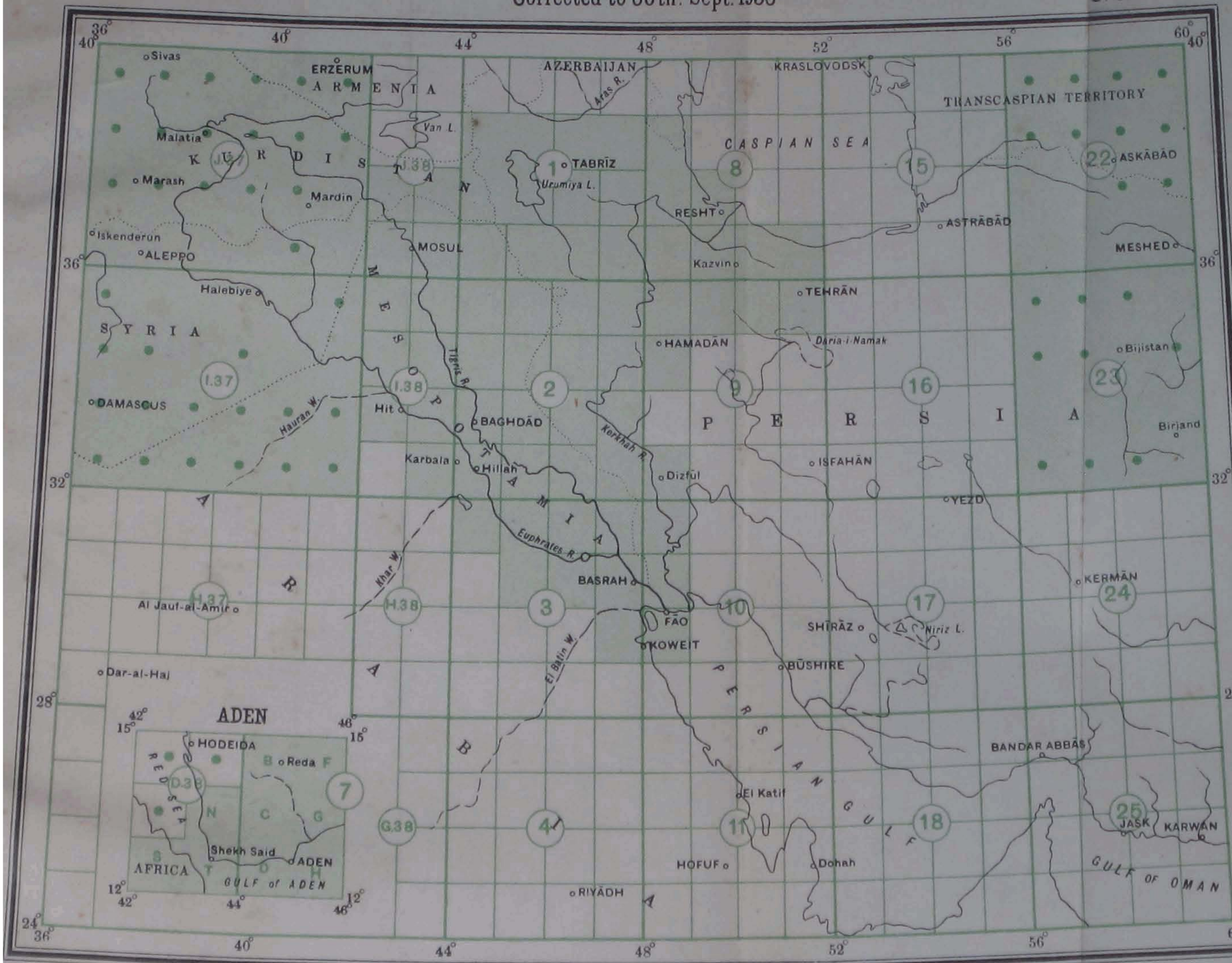
To accompany Geodetic Report 1935.

INDEX TO THE TRIANGULATION PAMPHLETS

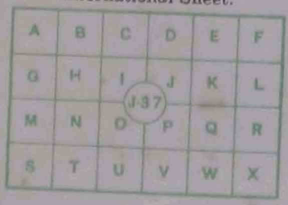
IRĀQ, PERSIA & ADEN

Corrected to 30th. Sept. 1935

Chart XX



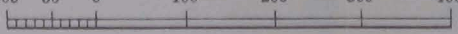
Key to Sheet lettering International Sheet.



In this system each numbered sheet (e.g. J·37) covers an area of 4° in latitude by 6° in longitude. The degree sheets are designated thus $\frac{\text{North J·37}}{\text{S}}$

Scale $\frac{1}{15,000,000}$ or 1·013 inches to 240 Miles.

Miles 100 50 0 100 200 300 400 Miles



REFERENCES.

1. Sheet published . . . . 🟩
2. Area containing no data ●

Note:- Grid lines have been omitted between Degree sheets published in one pamphlet

Key to Sheet lettering Indian Sheet.

In this system each numbered sheet (e.g. 2) covers an area of 4° in latitude by 4° in longitude. The degree sheets are designated thus. 2.A

HELIO.S.I.O. DEHRA DŪN.
Reg. No. 88.D.D.D. 1935-500

To accompany Geodetic-
Report 1935