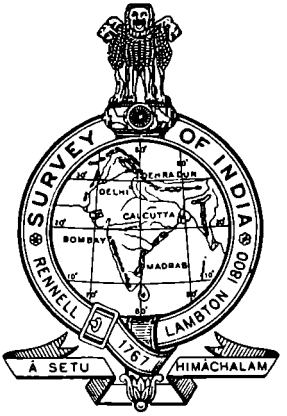
SURVEY OF INDIA

TECHNICAL REPORT
1950



PART III—GEODETIC WORK

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INTRODUCTION

This report gives a detailed account of the activities of the Geodetic and Training Circle (formerly known as the Geodetic and Research Branch) during the period 1st April 1949 to 31st March 1950. The following is a brief review of the contents.

2. *Triangulation and Base Measurement.*—(Chapter I). To provide planimetric control for the large scale surveys for the development of the Port of Kandla, a new geodetic base 5¾ miles long, has been measured, about 60 miles to the north east of Kandla. The old secondary triangulation has been re-observed for about 100 miles and Laplace observations for controlling the error in azimuth have been made.

The hydrographic triangulation in the Kandla creek carried out by the Marine Survey of India has been extended inland and connected to the new geodetic triangulation.

It is hoped to establish a new astronomical datum, measure a geodetic base and execute a series of geodetic triangulation in the Andaman Island next year. Precision traverses and levelling will also be carried out to provide framework data for the air survey of the Car Nicobars.

3. *Levelling.*—(Chapter II). During the period under report good progress has been made with levelling. Out of the nine levelling detachments which were sent to the field, three carried out 654 miles of levelling of high precision in one direction and 27 miles in both directions, one 114 miles of levelling of precision in both directions and five 1,240 miles of secondary levelling.

The high precision levelling has been carried out to test the stability of some bench-marks in Calcutta area and also to make new additions to the High Precision Levelling net of India.

The precision levelling was undertaken for the River Surveyor to the Commissioners for the port of Calcutta to provide height datums for his tide-gauges. A special detachment carried levelling across un-bridged rivers at seven places by the vertical angle and double target methods.

The secondary levelling has been mainly done for various Irrigation projects in Madhya Pradesh and Bihār and for the development project for the port of Kandla.

4. *Gravity.*—(Chapter III). A preliminary discussion of gravity and magnetic observations in Madhya Pradesh is given. The results on the whole seem to conform to the geology. It is hoped to continue the work in this area for another 2 or 3 years.

5. *Deviation of the Vertical.*—(Chapter IV). Observations were made with an astrolabe at four stations in Kutch for providing

Laplace control for the new geodetic triangulation and these ha provided some useful information about the Geoid. Observation a geoidal section from Dohad to Deesa, a longitudinal section Saurashtra and a line in Assam are on the programme for the ne 2 or 3 years.

6. *Magnetic Observations.*—At the Oslo Assembly of t International Association of Terrestrial Magnetism and Electrici in 1948, a resolution was adopted to promote observations of da variation of the Horizontal Magnetic force in defferent parts of t world near the magnetic equator. In accordance with this Reso tion, some stations were selected in South India where spec observations were taken with three Q.H.Ms. The results are great interest and will be discussed at the forthcoming meeting the International Union of Geodesy and Geophysics in Bruss (1951).

7. *Computing Office.*—(Chapter VII). Main occupation of t Computing Office has been the computation of results of fi observations.

The task of systematic examination, compilation and adju ment of the huge mass of topographical triangulation in In (about 3½ lakhs of points) is a very gigantic one. Although start has been made in that direction, the progress is seriou impeded due to lack of adequate staff.

8. *Headquarters Routine.*—(Chapter V and VI). The tid predictions, seismic and meteorological observations at Dehra D have been continued as usual. With a view to over-hauling t present methods of tidal predictions and analysis followed in t department, an officer was deputed to undertake a course advanced studies at the Liverpool Observatory and Tidal Institut It is proposed to introduce modern improved methods in all o future analysis and prediction work to achieve better accuracy f our predictions.

DEHRA DŪN,
July, 1951.

B. L. GULATEE, M.A. (CANTAB. F.R.I.C.S., M.I.S. (INDIA
Director, Geodetic and Training Circ Survey of India, Dehra Du

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Primary and Secondary Triangulation Series

No.	Name of Series	Season	± m	± p	Instrument
	Primary Series		"	ft.	inches
5	Calcutta Longitudinal	1864–80	0.360	2.23	36 & 24
6	Great Arc Meridional, Section 24°–30°	1835–66	0.708	4.26	36
7a	Bombay Longitudinal, East of 75°	1862–63	0.762	2.13	24
8	Great Arc Meridional, Section 18°–24°	1837–41	0.567	1.26	36
9	Great Arc Meridional, Section 8°–18°	1866–74	0.300	1.80	24
11b	South Konkan Coast	1866–67	0.392	0.77	24
20a	North-East Longitudinal, West of 80°	1850–51	0.658	1.05	24
22	North West Himálaya	1848–53	0.641	2.15	24
23b	Gurhágarh Meridional between 26½°–32½°	1850–62	0.362	0.96	24
24	East Coast	1848–63	0.608	1.58	24
25	Karáchi Longitudinal	1849–55	0.558	1.88	36
32	Great Indus	1853–61	0.350	1.74	36 & 24
33	Rahún Meridional	1853–63	0.327	1.24	24
34	Assam Longitudinal	1854–60	0.579	1.52	24
37	Jogi-Tila Meridional	1855–62	0.481	1.67	36 & 24
43	Bhtar Longitudinal	1860–72	0.311	1.21	36 & 24
44	Eastern Frontier or Shillong Meridional	1860–64	0.409	1.24	24
45	Sutlej	1861–63	0.346	1.74	36
46	Madras Meridional and Coast	1860–68	0.426	1.28	36 & 24
48	Mangalore Meridional	1863–73	0.440	1.14	24
52a	Burma Coast (See 106)	1864–82	0.386	1.21	24
53	Jubbulpore Meridional	1864–67	0.340	1.04	36
54	Madras Longitudinal	1865–73	0.384	1.23	24
56	Brahmaputra Meridional	1868–74	0.564	1.02	24
58	Bilaspur Meridional	1869–73	0.302	0.98	36 & 24
62	Jodhpur Meridional	1873–76	0.291	1.11	24
63	South-East Coast	1874–80	0.522	1.33	24
64	Eastern Sind Meridional	1876–81	0.244	1.25	24
66	Mandalay Meridional (See 109)	1889–05	0.418	1.46	12
68	Manipur Longitudinal	1894–99	0.453	1.45	12
69	Makrán Longitudinal	1895–07	0.285	0.92	12
72	Great Salween (See 105)	1900–11	0.404	4.28	12
74	Kalát Longitudinal	1904–08	0.306	3.15	12
76	North Baluchistán	1908–10	0.221	1.82	12
77	Gilgit	1909–11	0.443	2.62	12
80	Upper Irrawaddy	1909–11	0.506	3.14	12
85	Sahibalpur Meridional	1911–14	0.250	1.28	12
103	Chittagong	1925–30	0.453	2.181	5½
104	Mong Hsat	1929–31	0.441	1.67	12 & 5½ Wild
105	Great Salween	1929–31	0.682	3.04	12 & 5½ Wild
106	Burma Coast	1930–31	0.205	1.29	12
107	Dálbandin	1931–32	0.472	4.55	5½ Wild
108	Assam Longitudinal	1934–36	0.426	1.034	5½ Wild
109	Mandalay Meridional	1936–37	0.422	2.900	5½ Wild
110	Kandla ◆	1949–50	0.536	1.94	Geodetic Tavistock
	Secondary Series				
1	South Pársanáth Meridional	1836–39	8.308	9.98	18
2	Budhon Meridional	1831–43	2.242	7.47	18 & 15
3	Amóa Meridional	1834–38	1.647	4.71	18
4	Sangir Meridional	1834–41	1.643	7.52	18 & 15
7b	Bombay Longitudinal West of 75°	1837–39	0.919	2.24	15
10a	Singi Meridional 21°–25°	1860–62	0.723	1.19	18
10b	Singi Meridional 19°–21°	1842–46	1.711	1.39	15
11a	South Konkan Coast 15½°–19°	1842–44	2.425	1.71	15
12	Karára Meridional	1843–45	1.507	3.46	18 & 15
13	North Malúncha Meridional	1844–46	1.246	3.68	18 & 15
14	Chendwár Meridional	1844–46	0.841	1.51	36, 24 & 18
15	Gora Meridional	1845–47	0.973	3.09	15
16	Calcutta Meridional	1845–48	1.173	1.52	18
17	South Malúncha Meridional	1845–53	1.606	1.49	24 & 18
18	Khánpisura Meridional	1845–48	1.227	2.11	24 & 15

No.	Name of Series	Season	± m	± p	Instrument
	Secondary Series—*Contd.*		"	ft.	inches
10	Gurwani Meridional	1846–47	1.165	2.57	24 & 18
20b	North-East Longitudinal East of 80°	1846–51	0.422	1.41	36, 24 & 15
21	Hurliáong Meridional	1848–52	1.502	2.42	24 & 18
23a	Gurhágarh Meridional 24½°–26½°	1848–50	1.461	2.09	18 & 15
26	Abu Meridional	1851–52	0.617	1.53	18
27	North Pársanáth Meridional	1851–52	0.805	2.10	24
28	Káthiáwár Meridional	1852–56	0.090	2.01	18
29	Gujarát Longitudinal	1852–62	0.859	1.37	18
30	Káthiáwár Longitudinal	1853	1.481	1.66	18
31	Sábarmati	1853–54	1.348	0.01	18
35	Cutch Coast	1855–58	0.986	1.80	18
36	Kashmír Principal	1855–60	0.894	2.48	14 Vernier
38	Sambalpur Longitudinal	1856–57	0.806	1.48	14 Vernier
39	(Cutch) Coast Line	1856–60	0.975	1.44	18 & 15
40	Káthiáwár Meridional No. 1	1858–59	0.930	0.87	18
41	Káthiáwár Meridional No. 2	1859–60	1.247	1.39	18
42	Káthiáwár Meridional No. 3	1859–60	0.069	3.36	18
47	Káthiáwár Meridional No. 4	1863–64	1.154	..	18
48	East Calcutta Longitudinal	1863–69	0.379	0.06	24
50	Kumaun and Garhwál	1864–65	1.742	1.81	14 & 18 Vernier
51	Násik	1864–65	2.030	0.78	14 & 6
52b	Burma Coast 14½°–16°	1876–77	0.327	1.69	24
57	Columbatore No. 1	1869–71	1.547	2.50	14
59	Cuddapáh	1871–72	0.826	1.32	10
60	Hyderabad	1871–72	1.405	0.78	24 & 7
61	Malabar Coast	1872–80	1.632	1.17	14 & 12 Vernier
65	Siam Branch	1878–81	3.711	2.55	12
67	Mong Hsat	1901–03	3.054	2.71	14, 12 & 10
70	Mandalay Longitudinal	1899–1900	1.606	1.00	8
71	Manipur Meridional	1899–1902 & 1915–1916	0.760	2.22	12
73	Kidarkanta	1902–03	1.323	2.17	12 & 7
75	"Baluchistán" (Bannu)	1903–09	1.348	2.97	12 & 8
78	Khási Hills	1909–13	2.038	0.70	8
81	Jaintia Hills	1910–11	0.980	0.40	8
82	Bhir	1911–12	0.794	2.49	8
83	Ránchi	1911–12	1.840	0.01	8
84	Vilupuram	1911–12	1.184	0.46	8
86	Indo Russian Connection	1912–13	2.790	2.17	6
87	Khandwa	1912–13	0.990	1.71	8
88	Ashta	1913–14	1.048	1.33	8
89	Buldána	1913–14	0.304	0.98	8
90	Naldrug	1913–14	1.465	1.91	8
91	Nága Hills	1913–14	0.913	2.17	12
92	Middle Godávari	1914–15	0.913	0.72	8
93	Kohima	1913–15	1.094	1.48	12 & 8
94	Cáchár	1914–15	1.077	1.17	12
95	Bombay Island	1911–14	..	..	8
96	Madura	1916–17	1.148	1.49	8
97	Bágalkot	1916–17	0.701	1.15	8
99	Rangoon	1925–27	1.246	..	12
100	Kurram	1927–28	2.098	3.80	3½ Wild
101	Peshawar	1927–28	1.267	5.56	3½ Wild
102	North Waziristán	1927–28	1.895	2.16	3½ Wild

± *m* = root-mean-square error of an unadjusted horizontal angle (in seconds).

± *p* = root-mean-square error of the unadjusted height difference between two stations (in feet).

◆ Replaces portions of series 28 and 35.

CHAPTER I

TRIANGULATION AND BASE MEASUREMENT

BY B. L. GULATEE, M.A. (CANTAB.), F.R.I.C.S., M.I.S. (INDIA)

1. General.—Chart I shows in blue the Primary and in green the Secondary Triangulation of India. The secondary triangulation is of much inferior quality to the primary. An idea of the relative precision of these two categories of triangulation is given by the value of the Ferero number 'm' recorded in the table facing this Chart.

Due to the financial stringency and the shortage of personnel trained in precision base measurements and geodetic observations, it has not been possible to commence immediately a vigorous programme of systematic geodetic triangulation and primary traverse. Good progress is being made in imparting the necessary training to suitable personnel.

During the year under report an urgent requisition for large scale maps of the Kāthiāwār area was received from the Development Commissioner for the Port of Kandla. It then became necessary to take up the consideration of the provision of a suitable basic geodetic control. The existing geodetic triangulation in the area consists of two secondary series, viz., Kutch Coast Series (No. 35) and Kutch Coast-line Series (No. 39). It was decided to strengthen this triangulation by the measurement of a geodetic base, reobservation of some weak triangles and the establishment of Laplace stations.

Information was also received that the Marine Survey of India would also be carrying out some triangulation and levelling near the Port of Kandla and in the Kandla creek. A liaison was established with this department and the Marine Survey of India agreed to base their work on the control provided by the new primary triangulation.

2. Reconnaissance.—The first step towards the execution of the above programme was to have the area rapidly reconnoitred and to select a suitable site for the geodetic base.

A small detachment consisting of Mr. U. D. Mamgain, B.SC., Officer Surveyor and two computers was formed and left Dehra Dūn on 27th May 1949, arriving at Kandla on 1st June 1949.

The programme of reconnaissance was to visit all old G.T. stations and permanent levelling bench-marks between Vandhia S. and Chitrod H.S. in sheet 41 I and Sāmatra H.S. and Vārār H.S. in sheet 41 E. (See Chart II).

There was barely a month at the disposal of the detachment in which to complete the reconnaissance as the monsoon starts in these

parts towards the end of June. There had been insufficient rain during the two previous years and drought and famine conditions were prevailing in the area. The heat was abnormal and movement by carts would have been slow. A jeep hired from the Government Stores Department Bhuj was found to be of very great help.

As a result of the reconnaissance a site for the proposed new base-line was selected near Mānāba, about 60 miles north-east of Kandla. A stretch of flat ground extending for about six miles in a north-westerly direction was located. Mānāba H.S. is an old G.T. station fixed in the year 1856. The upper mark-stone of this station was missing, but the lower mark-stone was in tact. In order to simplify the base-extension figure it was decided to make this station into one end of the base-line and to build a new station at the other end.

All the other G.T. stations except Khari Rohar S. and Rahiāda S. were found to be usable after minor repairs. Khari Rohar S. had completely disappeared and a new station was built about 3½ miles north of it, and was named Naransar Tarai S. A new station was also built at Rahiāda. It is called Rahiāda (New) S.

Kānmer H.S. and Chitrod H.S. were selected as Laplace stations on the eastern end of the series and Sāmatra H.S. and Vārār H.S. on the western end.

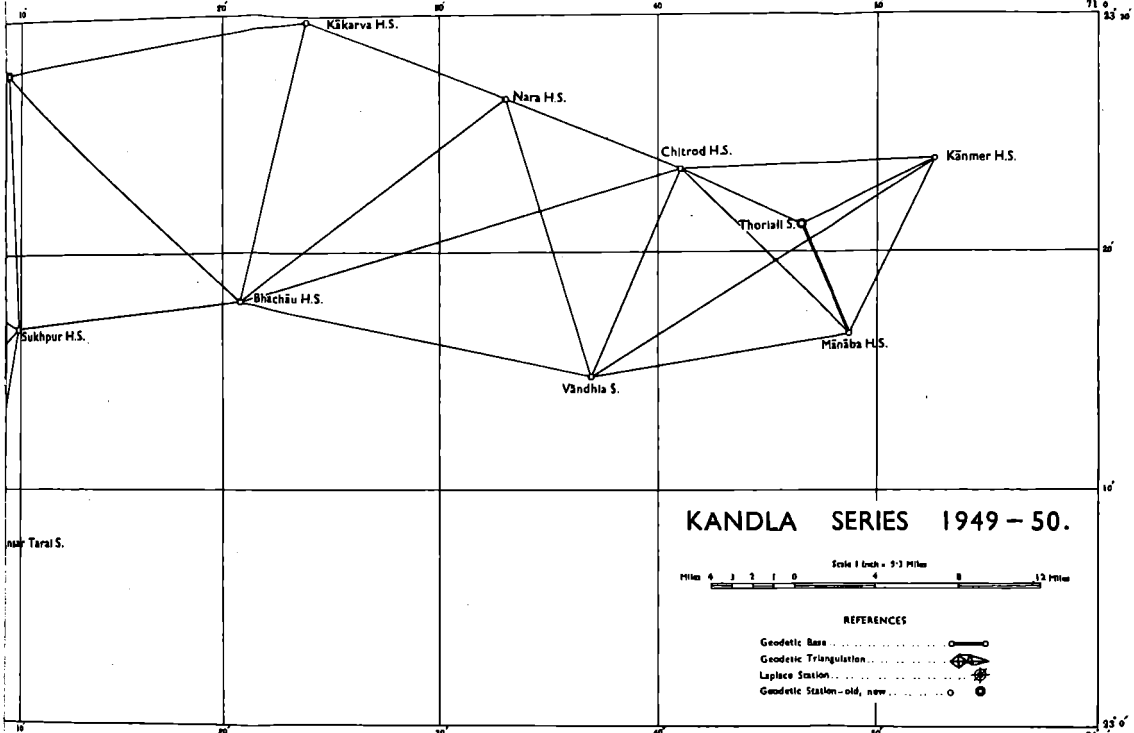
All the permanent levelling bench-marks in the area appeared to have remained undisturbed.

The detachment closed its work at Morvi on 28th June 1949 and arrived in Dehra Dūn on 1st July 1949 to prepare for the final programme during the coming winter.

3. **Narrative of the Observation Party.**—The programme of observations having been finally decided upon, Mr. U. D. Mamgain, B.SC., who was in charge of the detachment left Dehra Dūn on 10th October and arrived in Bhuj on the 13th October in advance of the rest of the detachment in order to make arrangements for transport and rations. The rest of the detachment consisting of Mr. J. B. Mathur, Surveyor, one Observatory Assistant, two computers and 28 *khalāsīs* reached Kandla on 15th October. The whole detachment moved to Bhachāu on 17th October 1949. From this place Mr. J. B. Mathur, with his recorder proceeded to Kānmer H.S. for Laplace observation, and Mr. U. D. Mamgain, with one Observatory Assistant and one computer started for Mānāba for reconnoitring and clearing the site for the base.

On 2nd November 1949 Mr. J. B. Mathur rejoined the base-measurement party after completing Laplace observations at Kānmer H.S. and Chitrod H.S. By this time sufficient ground had been cleared, slopes evened up by digging where necessary and the alignment of the base-line secured. Measurement was commenced on 2nd November and completed on 21st November.

Chart II



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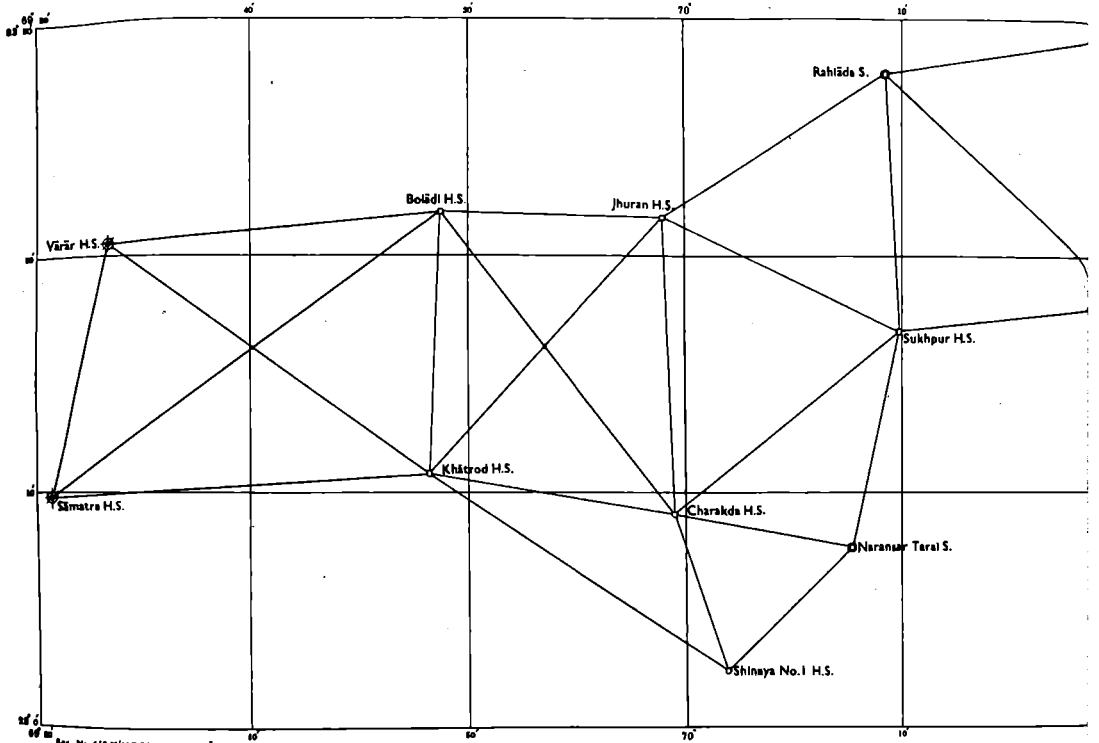


Reg. No. 668 M/NC D' 51 (G & T C) '-5.3 mds.) 373.

Mr. J. B. Mathur then left to make Laplace observations at Vārār H.S. and Sāmatra H.S. and Mr. U. D. Mamgain commenced the observation of triangulation at Mānāba H.S.

After completing Laplace observations Mr. J. B. Mathur returned to Dehra Dūn on 15th December 1949. Mr. U. D. Mamgain completed the observation of triangulation on 25th January 1950 and returned to headquarters at Dehra Dūn.

The detachment was inspected at Sukhpur on 24th December by the Director, Geodetic and Training Circle.

Except for minor cases of malaria and dysentry the health of the detachment remained satisfactory.

4. **Mānāba Base-line.**—The base-line is $5\frac{3}{4}$ miles long with Mānāba H.S. as southern end of the base and Thoriali H.S. (a new station) as the northern end.

Mānāba H.S. is situated on a low hill 54 feet high. For the first 300 yards from Mānāba H.S., the hill face sloped unevenly in height falling by about 23 feet to the edge of low ground. The next mile was along fairly level ground ending on an outcrop of small hillocks covered with bushes. The third mile was also over level ground except that a small *nāla* with uneven banks had to be crossed. The fourth mile of the base-line passed over a depression with *nāla* banks about 8 feet high. The rest of the base-line was fairly even except for a small stretch of undulating ground near the north end.

Exact sites for the north-end-base station and the central-base station were first reconnoitred. In finalizing this alignment of the base-line, care was taken that the slopes of the individual 24-metre legs did not exceed 1 in 40 anywhere, and that the route involved the least possible clearing and building. The central-base station thus reconnoitred lay exactly midway between and in line with the two end stations.

The description of the terminal stations of the base-line is given in the next para. A *pakka* station mark was laid at the central-base station, also intermediate points lying on these two halves of the base at about one mile or shorter intervisible distances were next surveyed and demarcated by flags. Alignment of the flags was carried out with the help of a geodetic Tavistock theodolite—the flags being shifted to fall on the exact base-line by computing the small satellite corrections between the flags and the straight base-line. The base was thus marked from north end to south end and all obstructions such as bushes, trees, mounds, etc., were cleared away. A certain amount of raising, cutting and filling had to be done to overcome inconvenient slopes. The uneven north slope of Mānāba hill was cut down to an average slope of 3·5 feet in 24 metres.

5. **Description of Terminal Stations.**—***Mānāba SE. End Base S.***—The station consists of a platform of loose stones 12 feet × 12 feet enclosing a solid circular isolated pillar about 4 feet in height.

A brass plug with a cross mark on it is laid at the centre of the existing pillar vertically above the lower mark (a circle and dot).

Thoriali NW. End Base S.—The station consists of a platform of loose stones and earth 12 feet × 12 feet enclosing a circular pillar of masonry 3½ feet in height having two brass plugs, one at the bottom with ⊕ mark on it and the other at the distance of 3 feet 1 inch vertically above it.

The station is situated on a high ground surrounded by cultivated land about one mile east of Thoriali village, Pargana Vagad, Kutch State.

6. System of Base Measurement.—The system of measurement was by invar wires in catenary. The Survey of India possesses a number of invar wires 24 metres long with scales 8 cm. long divided to mms. at either end. Nine such wires were obtained in 1914 and two more in 1934. Between the years 1929 and 1937, 10 geodetic bases were measured, but the wires gave considerable trouble on account of their erratic behaviour. Full use was made of the previous experience with them and considerable care was taken in the selection of the good ones for the measurement of this base and in keeping an eye on any sudden changes in length. This was all the more necessary as the observers were quite new to the work.

Wires Nos. 244 and 248 were used for south to north measure and Nos. 252 and 1037 for the reverse direction. Wires Nos. 1038 and 247 were used as sub-standards for daily comparisons of the working wires and No. 245 as the standard for the comparison of the field sub-standards. Comparisons with the field sub-standards were made daily some time before and after the work, in such proportion as to make the mean temperature of comparison the same as the mean temperature at which the bases have been measured. Wire No. 246 was taken as a spare wire for use in the case of a casualty.

The wires were standardized against the Dehra Dūn 24-metre comparator before and after the field season and full details regarding their lengths as well as their coefficients of expansion are given in Chapter VI (Observatories). It will be seen from the results that the wires have held their lengths satisfactorily.

These wires were used with 10 tripods under a tension of 10 kgms. Before the measurement was started, the positions for the tripods were laid out by marks on pegs, accurately aligned and at approximately the correct-intervals. The heights of these pegs were determined by spirit-levelling. During measurement, an assistant measured the heights of the tripods above the pegs but when the rise or fall in a bay exceeded 3½ feet, this was checked by direct levelling between the tops of the tripods.

The measurement of the base was carried out by Mr. U. D. Mamgain and Mr. J. B. Mathur assisted by one Observatory Assistant one computer and 28 *khalāsīs* from 27th October to 22nd November. The average out-turn was 65 bays per day. Temperature ranged from 15°C to 37°C.

7. Results of Base Measurements.—The final results are tabulated below :—

Sec. No. \ Wire	South to North (Fore)		North to South (Back)		Mean value of each section
	No. 244	No. 248	No. 1037	No. 252	
	metres	metres	metres	metres	metres
I	1704·4194	1704·4200	1704·4239	1704·4296	1704·4232
II	1896·3672	1896·3748	1896·3099	1896·3730	1896·3712
III	948·7427	948·7479	948·7470	948·7500	948·7469
Total I to III	4549·5293	4549·5427	4549·5408	4549·5526	4549·5413
IV	1373·8835	1373·8880	1373·8798	1373·8861	1373·8844
V	982·1467	982·1479	982·1428	982·1478	982·1463
VI	2374·3143	2374·3203	2374·3157	2374·3217	2374·3180
Total IV to VI	4730·3445	4730·3562	4730·3383	4730·3556	4730·3487
Sum of two halves	9279·8738	9279·8989	9279·8791	9279·9082	9279·8900

The discrepancy between the south-to-north and north-to-south measures is 1 : 1,300,000.

The measured length of the base is 9279·890 metres. This length is reduced to Indian feet by the following conversion factors.

1 standard yard = 0·914 399 20 metres
1 Indian foot = 0·333 331 886 standard yards.

The reduced length is 30 445·992 Indian feet.

Reduced to spheroid level, the length of the base is 30 445·877 Indian feet or 4·483 5285 log feet.

The lengths of the opening and closing sides of the new triangulation in terms of the new base are tabulated below against the older values. The agreement is satisfactory.

Side	Old value	New value
	log feet	log feet
Chitrod–Kānmer ..	4·812 4064	4·812 3993
Vārār–Sāmatra ..	4·825 5001	4·825 4972

8. Laplace Observations.—Laplace observations were made in pairs at Kānmer H.S. and Chitrod H.S. and at Vārār H.S. and Sāmatra H.S. A detailed narrative account and the results of Laplace observations are given in Chapter IV.

Unfortunately the results at Kānmer H.S. and Chitrod H.S. were not found to be in conformity with each other and have consequently been rejected. The error in the published azimuths derived at Vārār H.S. and Sāmatra H.S. is given below :—

Stations		Astro. Azimuth A to B (1949–50)	Corrn. to reduce Astro. Az. to Geodetic	Geodetic Azimuth	Published Azimuth	Correction to be applied to published Azimuth
A	B					
		° ′ ″	″	° ′ ″	° ′ ″	″
Vārār H.S.	Sāmatra H.S.	13 33 40·7	−1·5	13 33 45·2	13 33 54·6	− 9·4
Sāmatra H.S.	Vārār H.S.	193 32 40·2	−1·5	193 32 38·7	193 32 48·2	− 9·5

9. **Triangulation Observations.**—The observation of triangulation was commenced by Mr. U. D. Mamgain immediately on completion of the base measurement on 23rd November 1949.

The State of Kutch is surrounded on the north, east and south by low lying land which is covered with sea water during the monsoon. This area is known as the Rann of Kutch. On the west it is washed by the sea. To the north of the Rann is a range of broken hills running from east to west. The stations occupied on the eastern end of the series lay in the area between the Rann and the range of hills to the north, while those on the western end were located on hill-tops.

The headquarters of the detachment were established at Chitrod and Mr. S. C. Dhar was sent in advance to post the helio and lampmen. In all 18 stations were occupied, 15 of which were old ones (observed in 1852–58) and three new ones. The new stations are Rahiāda (New) S., Naransar Tarai S. and Thoriali S.

At Mānāba H.S., Sukhpur H.S. and Vārār H.S., the upper mark-stones were destroyed and new upper mark-stones were placed at exactly the same height as the original ones, centred vertically over the lower mark-stones, which were found in tact.

Observations were carried out with a geodetic Tavistock theodolite. Horizontal angles were measured on 8 zeroes with three sets on each zero. Observations were made mostly at night to Argand lamps. At Mānāba, Nara, Charakda and Vārār stations, however, an electric lamp was used and observations were also made during the day to 9-inch helios.

Vertical angles were observed at the time of minimum refraction; two sets were usually taken.

Table I exhibits the old and new triangular errors. It will be seen that the new observations are a considerable improvement on the older ones. The mean length of the side of the triangulation is 13·4 miles and the average triangular error is 0″·72.

TABLE 1.—*Comparative statement of triangular errors (new and old)*

No. of Triangle	Triangle	Triangular Error	
		New value	Old value
		"	"
1	Mānāba, Thoriali, Kānmer	−1·67	
2	Kānmer, Mānāba, Chitrod	−0·21	+0·89
3	Chitrod, Kānmer, Thoriali	+1·00	
4	Chitrod, Thoriali, Mānāba	+0·92	
5	Kānmer, Mānāba, Vandhia	−2·54	
6	Chitrod, Kānmer, Vandhia	+1·19	
7	Chitrod, Mānāba, Vandhia	−1·14	+3·55
8	Chitrod, Vandhia, Bhachāu	−0·99	−2·88
9	Vandhia, Bhachāu, Nara	−0·28	+0·81
10	Bhachāu, Nara, Chitrod	+0·05	
11	Nara, Chitrod, Vandhia	−0·66	−2·03
12	Nara, Bhachāu, Kākarva	+1·42	−2·27
13	Kākarva, Bhachāu, Rahiāda New	+0·24	
14	Rahiāda New, Bhachāu, Sukhpur	+0·31	
15	Rahiāda New, Sukhpur, Jhuran	+0·08	
16	Jhuran, Sukhpur, Charakda	−0·03	−0·11
17	Charakda, Sukhpur, Naran Sar Tarai	−1·12	
18	Charakda, Naran Sar Tarai, Shinaya No. 1	−0·98	
19	Charakda, Shinaya No. 1, Khātrod	−0·46	
20	Charakda, Khātrod, Jhuran	−0·59	−2·36
21	Charakda, Khātrod, Bolādi	−0·58	
22	Khātrod, Bolādi, Jhuran	+1·13	−2·64
23	Bolādi, Jhuran, Charakda	+1·13	−1·70
24	Bolādi, Khātrod, Sāmatra	+0·14	−0·75
25	Khātrod, Sāmatra, Vārār	−0·04	−1·58
26	Sāmatra, Vārār, Bolādi	+0·23	
27	Vārār, Bolādi, Khātrod	+0·41	+0·90

The differences between the old and new horizontal angles are tabulated in Table 2. The differences range from −3″·7 to +4″·9.

TABLE 2.—*Differences between the old and new horizontal angles*

Name of station		Observed angle						Old *minus* New
		Old (1852–53)			New (1949–50)			
		°	′	″	°	′	″	″
Kānmer	H.S.	61	37	46·83	61	37	48·38	−1·55
Chitrod	H.S.	46	07	27·54	46	07	28·04	−0·50
Mānāba	H.S.	72	14	45·40	72	14	44·45	+0·95
Chitrod	H.S.	60	37	34·23	60	37	35·98	−1·75
Mānāba	H.S.	53	53	08·73	53	53	11·28	−2·55
Vandhia	S.	56	29	14·26	56	29	14·65	−0·39
Chitrod	H.S.	88	02	25·08	88	02	23·20	+2·78
Vandhia	S.	40	17	57·05	40	17	59·17	−1·22
Nara	H.S.	51	39	38·76	51	39	38·95	−0·19
Chitrod	H.S.	49	40	29·17	49	40	28·39	+0·78
Vandhia	S.	101	30	47·86	101	30	45·07	+2·09
Bhachāu	H.S.	28	48	47·09	28	48	48·17	−1·08
Vandhia	S.	61	12	49·91	61	12	46·50	+3·41
Bhachāu	H.S.	49	04	22·34	49	04	23·34	−1·00
Nara	H.S.	69	42	48·35	69	42	51·85	−3·50
Bhachāu	H.S.	20	15	35·25	20	15	35·17	+0·08
Nara	H.S.	121	22	27·11	121	22	30·80	−3·69
Chitrod	H.S.	38	21	56·81	38	21	54·81	+2·00
Nara	H.S.	58	10	57·32	58	10	52·41	+4·91
Bhachāu	H.S.	39	06	29·41	39	06	30·55	−1·14
Kākarva	H.S.	82	42	30·48	82	42	30·56	−0·08
Jhuran	H.S.	62	30	14·37	62	30	13·48	+0·89
Sukhpur	H.S.	64	30	41·92	64	30	41·61	+0·31
Charakda	H.S.	52	59	04·90	52	59	06·02	−1·12
Jhuran	H.S.	44	48	08·41	44	48	11·01	−2·60
Charakda	H.S.	78	31	49·22	78	31	40·12	+3·10
Khātrod	H.S.	56	40	05·86	56	40	04·59	+1·27
Charakda	H.S.	42	41	25·59	42	41	24·42	+1·17
Khātrod	H.S.	96	51	45·18	96	51	44·81	+0·37
Bolādi	H.S.	40	26	53·54	40	26	52·36	+1·18
Khātrod	H.S.	40	11	39·32	40	11	40·22	−0·90
Bolādi	H.S.	91	05	58·92	91	05	56·01	+2·91
Jhuran	H.S.	48	42	26·32	48	42	23·55	+1·77
Bolādi	H.S.	50	39	05·38	50	39	03·65	+1·73
Jhuran	H.S.	93	30	33·73	93	30	34·56	−0·83
Charakda	H.S.	35	50	23·63	35	50	21·70	+1·93
Bolādi	H.S.	51	23	31·61	51	23	31·57	+0·04
Khātrod	H.S.	96	02	55·05	96	02	55·80	−0·75
Sāmatra	H.S.	32	33	35·63	32	33	34·03	+1·60
Khātrod	H.S.	39	27	07·78	39	27	07·98	−0·20
Sāmatra	H.S.	72	51	17·71	72	51	17·38	+0·33
Vārār	H.S.	67	41	37·56	67	41	36·16	+1·40
Sāmatra	H.S.	40	17	42·08	40	17	43·35	−1·27
Vārār	H.S.	109	01	33·49	109	01	32·24	+1·25
Bolādi	H.S.	30	40	45·62	30	40	45·45	+0·17
Vārār	H.S.	41	19	55·93	41	19	56·08	−0·15
Bolādi	H.S.	82	04	17·23	82	04	17·02	+0·21
Khātrod	H.S.	56	35	47·27	56	35	47·82	−0·55

10. Heights.—Table 3 shows a comparison of the new values of the heights adjusted to spirit-levelling, with the older values. The agreement on the whole is very satisfactory.

The sides of the geodetic triangulation were on an average about 13 miles long and the stations are mostly located on low bare rocks. The observations for vertical angles were normally taken between 3 and 4 P.M. and it was found that the values of the coefficient of refraction k as derived from reciprocal observations were very irregular and were invariably less than the normal values. They ranged from 0·02 to 0·07 as against the expected value of 0·08. At some low stations (with heights of 100 feet or so), the refraction was even negative. These low values of the coefficient of refraction are no doubt due to large negative values of the lapse rate near the ground surface.

Despite the above, the average triangular errors obtained by taking the mean of the reciprocal observations were very satisfactory being about 2 feet, the maximum being 7·4 feet.

TABLE 3.—*Comparative statement of heights (old and new)*

Serial No.	Name of Station		Old heights (1852–58)	Final heights adjusted to spirit-levelling (1949–50)	Difference (Old − New)
			feet	*feet*	*feet*
1	Kānmer	H.S.	304·5	303·9	+0·6
2	Chitrod	H.S.	490·0	490·4	−0·4
3	Mānāba*	H.S.	..	52·9	..
4	Thorali†	S.	..	114·9	..
5	Vandhia	H.S.	116·4	115·5	+0·9
6	Nara	H.S.	713·0	711·6	+1·4
7	Bhachāu	H.S.	303·7	302·9	+0·8
8	Kākarva	H.S.	465·0	462·9	+2·1
9	Rahiāda New†	S.	..	21·3	..
10	Sukhpur	H.S.	357·2	356·5	+0·7
11	Jhuran	H.S.	626·0	624·1	+1·9
12	Charakda	H.S.	418·5	417·6	+0·9
13	Khātrod	H.S.	1145·0	1144·4	+0·6
14	Bolādi	H.S.	978·0	976·2	+1·8
15	Shinaya No. 1	H.S.	217·0	215·7	+1·3
16	Sāmatra	H.S.	964·0	963·5	+0·5
17	Vārār	H.S.	1128·0	1128·8	−0·8
18	Naransar Tarai†	S.	..	96·7	..

* New mark.
† New station.

11. Connection with Triangulation by Marine Survey.—Chart III shows the Hydrographic triangulation of Kandla, which is based for scale and azimuth on the side Shinaya No. 1 H.S.–Naransar Tarai S. of the Survey of India triangulation.

The hydrographic survey of Kandla and approaches was carried out by the Marine Survey of India simultaneously with the observation of the geodetic triangulation described above and the topographical triangulation in the area carried out by No. 6 Party of the Southern Circle, Survey of India. Hitherto the hydrographic surveys were not extended sufficiently inland to effect proper connection with the primary or topographical triangulation of the Survey of India and the connection of the hydrographic triangulation of Kandla to the geodetic triangulation of the Survey of India is a happy beginning.

The average triangular error of the main triangulation is 3″·2 and that of the Kandla creek triangulation 4″·1. The observing of the Kandla creek triangulation was carried out with Tavistock theodolites, but most of the other stations were observed with Wild T2 theodolites.

Due to mirage, refraction, heat and haze precise observations could only be taken in the morning and evening for about an hour or even less and observations at nearly all stations were made during this brief period. Observations at night were impracticable.

Two short check bases were measured one at Hansthal and the other near Kandla creek.

The length of side F–Bf (near Hansthal) as obtained in terms of the geodetic side Shinaya No. 1 H.S.–Naransar Tarai S. (which in turn is derived from the Mānāba geodetic base) is 12532·25 feet and that in terms of the measured short base is 12531·55. The difference is 0·68 feet or 1 in 18400 (approx.).

Similarly the length of side B–Af (near Kandla creek) as obtained in terms of the Mānāba geodetic base is 4051·05 feet and that in terms of the measured short base is 4050·72 feet. The difference is 0·33 feet or 1 in 12,300 (approx.).

The above checks on the scale of the triangulation are quite satisfactory.

12. Triangulation in the Andamans.—Technical Report 1948–49, Part III, Chapter I, para 5 gives a brief account of the existing triangulation in the Andamans and Nicobar Islands. It has been pointed out there that the existing triangulations both in the Andamans and in the Nicobars are not connected to the Indian triangulation and are only very weakly connected to each other. The triangulations themselves are far from being precise being poorly observed and based on inaccurate base measurements and weakly determined astronomical latitudes and longitudes.

The Government of India has recently ordered an air survey of the Andamans and the Car Nicobars for preparing new maps of

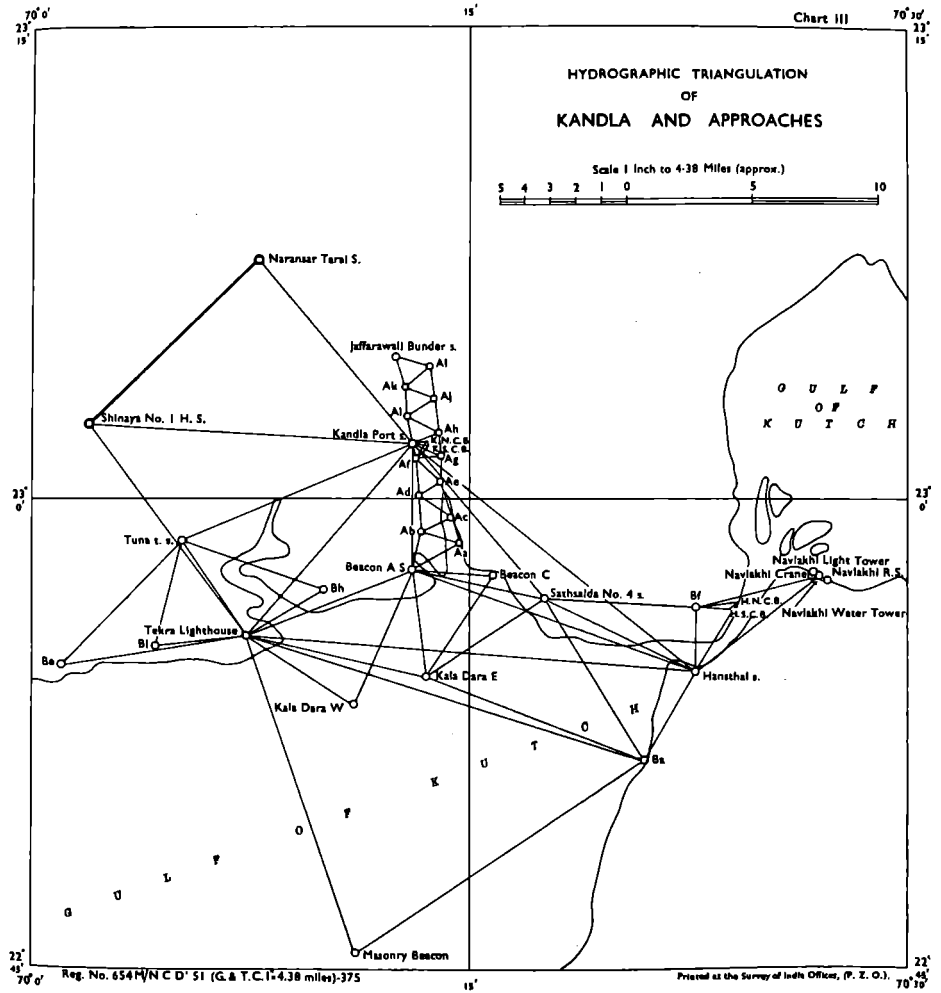


Chart III
HYDROGRAPHIC TRIANGULATION
OF
KANDLA AND APPROACHES
Scale 1 Inch to 4·38 Miles (approx.)
5 4 3 2 1 0 5 10
70° 0'
15'
70° 30'
23° 15'
23° 0'
22° 45'
22° 30'
Naranser Tarsi S.
Jaffarawali Bunder s.
Shinaya No. 1 H. S.
Kandla Port s.
H.N.C.B.
T.S.C.B.
Tuna t. s.
Bescon A S.
Bescon C
Sathsaida No. 4 s.
Navlakhi Light Tower
Navlakhi Crane
Navlakhi R.S.
Navlakhi Water Tower
Tekra Lighthouse
Hansthal s.
Kala Dara E
Kala Dara W
Masonry Beacon
GULF OF KUTCH
Reg. No. 654 H/N C D' 51 (G. & T.C.) 4.38 miles)-375
Printed at the Survey of India Offices, (P. Z. O.).

these islands. A new geodetic framework to provide a basis for these new maps is considered necessary and it is proposed to cover the Andaman Islands with a series of well conditioned triangles to be observed with a geodetic Tavistock theodolite. A precise geodetic base will also be measured and Laplace stations established with an astrolabe.

In the Car Nicobars no triangulation or geodetic base measurement has been planned at present. The area will be covered by traverses which will be suitably controlled by observed astronomical azimuths with scale checked at intervals by short base measurements.

A full account of the new work will be published in the next Technical Report.

CHAPTER II

LEVELLING

BY B. L. GULATEE, M.A. (CANTAB.), F.R.I.C.S., M.I.S. (INDIA)

13. General.—There was a considerable demand for levelling from various authorities during the year under report. Nine detachments took the field in various parts of India, three being employed on levelling of high precision, one on levelling of precision and five on secondary levelling.

One high precision levelling detachment under Mr. J. K. Donald (Surveyor) first levelled the portion Jaleswar (Jellasore) to Balasore in the fore direction and then the line Howrah to Jaleswar in the back direction and then proceeded to Kārwār and observed the line from Kārwār to Hubli in the back direction. The back levelling of the portion from Jaleswar to Balasore was carried out by Mr. A. K. Bhattacharjee during the same season from 16th to 30th June 1950.

The high precision levelling detachment under Mr. B. P. Rundev (Surveyor) carried out the levelling in the back direction from Vizianagram to Vizagapatam and from Vizagapatam to Raipur.

The high precision line from Howrah to Balasore was carried out to test the stability of bench-marks at Howrah relative to Jellasore and Balasore. The other two high precision levelling lines, viz., Kārwār to Hubli and Raipur to Vizianagram form part of the new High Precision Levelling net of India.

The following lines of precision levelling were carried out for the River Surveyor to the Commissioners for the port of Calcutta to provide height datums for his tide-gauges on the Hooghly river :—

(i) Calcutta Mint to King George's Dock,
(ii) Calcutta Mint to Cossipore, and
(iii) Howrah to Purbasthali.

A special river crossing detachment consisting of Messrs. A. K. Bhattacharjee (Class II) and S. Vaikuntanathan (Class II) with 12 *khalāsīs* was formed to carry out levelling across the Hooghly at two places on the line from Diamond Harbour to Dublat where the span of the river was $1\frac{5}{8}$ miles and $1\frac{1}{4}$ miles respectively. This detachment also carried out river crossings at five other places on the line Howrah to Jaleswar.

The secondary levelling detachments were employed as follows :—

(i) One detachment for irrigation projects of Lower and Upper Narbada Divisions in the Madhya Pradesh.

(ii) Two detachments for the Gandak irrigation project of the Government of Bihār.

(iii) One detachment for the Kosi irrigation project, and

(iv) One detachment for the development project of the Port of Kandla.

14. **Summary of out-turn**—The total out-turn of work carried out during the period under report is as follows :—

(*a*)	High Precision Levelling in one direction	654 miles (854 gross)
(*b*)	High Precision Levelling in both directions	27 miles (35 gross)
(*c*)	Precision Levelling in both directions	114 miles
(*d*)	Secondary Levelling ..	1,240 miles

The details are given in Table 12.

15. **Balasore to Howrah.**—Detachment No. 1 under Mr. J. K. Donald (Surveyor) with a recorder and 13 *khalāsīs* left Dehra Dūn for the field on 4th October 1949. Work was commenced from bench-mark No. 78/73 K at Balasore on 8th October 1949 and closed at bench-mark No. 353/79 B at Calcutta Mint on 10th February 1950.

At Jaleswar the work was started from bench-mark No. 244 and was carried to Contai via Mohanpur and Bālighai. From Contai the metalled road to Rasūlpur was followed and then the work was carried along the *bund* on the right bank of the Hooghly.

The country was plain but swampy at places. Streams presented great difficulty all along the coastal area, and part of the work lay in congested industrial area in the vicinity of Calcutta.

For transport, bullock carts were used upto Rasūlpur, from where the work was done along the coast and a country boat had to be permanently engaged.

Connection was made to Kudi Tower Station, to a few standard and embedded bench-marks, and to a few marine bench-marks located on the right bank of the Hooghly.

Weather conditions remained good except for a few days in October 1949 when rains interrupted work for four days. The health of the detachment was good. Vaccination and cholera inoculation were taken by all the personnel of the detachment at Diamond Harbour.

During the course of the work, four big rivers namely Rasūlpur, Haldi, Rūpnārāyan and Damodar had to be crossed. The crossing was done by a special River Crossing Detachment (see para 18).

The revision of the old levelling from Burdwān to Balasore completes two circuits Rānīganj–Burdwān–Howrah–Midnapore–Rānīganj (304 miles) and Midnapore–Howrah–Jellasore–Midnapore (277 miles). See Chart V. Their closure errors are satisfactorily small being +0·132 feet and +0·345 feet respectively.

As mentioned on page 13 of Technical Report 1948–49, Part III, this levelling was carried out in continuation of Burdwān–Howrah line to test the sinkages of the bench-marks in the deltaic region of south Bengal. It was not possible to get an independent connection to mean sea-level at False Point as the old bench-mark of reference of the tidal observatory at False Point has now been destroyed.

The heights of the permanent bench-marks at Burdwān, Kidderpore New Dock Sill, Jaleswar and Balasore as determined from older and new levellings are as follows :—

No.	Brief description	Distance	Published height (Older levelling)	Unadjusted orthometric height from new levelling
		miles	*feet*	*feet*
116/73 M	Type A, Burdwān ..	0·0	93·182	93·182
359/79 B	Kidderpore New Dock Sill ..	81·5	16·175	15·806
90/73 O	E.B.M. Jaleswar ..	237·0	41·973	41·937
78/73 K	S.B.M. Balasore ..	270·1	44·863	44·689

It would be seen that the relative heights of Burdwān, Jaleswar and Balasore have remained unaltered ; the discrepancies being well within the range of levelling errors. The published heights also include significant adjustment corrections, and the apparent change in the height of Kidderpore New Dock Sill is also not conclusively proved. Chart VI shows the changes of heights of old bench-marks on the line Burdwān–Howrah–Jellasore–Balasore, as revealed by present levelling. Their numerical values are given in Table 1.

A comparison with Chart XXXV, of Technical Report 1948–49, Part III shows that changes on the right bank of the Hooghly are much less than those on the left bank near Diamond Harbour, where there were individual sinkages of as much as 1½ feet. On the whole as expected in such alluvial areas the bench-marks between Howrah and Contai have undergone a slight subsidence.

As mentioned in the preceeding Technical Report such sinkages are no proof of the general down warping of the crust.

LEVELLING FROM BURDWĀN TO VIZIANAGRAM

Scale 1 inch = 64 Miles

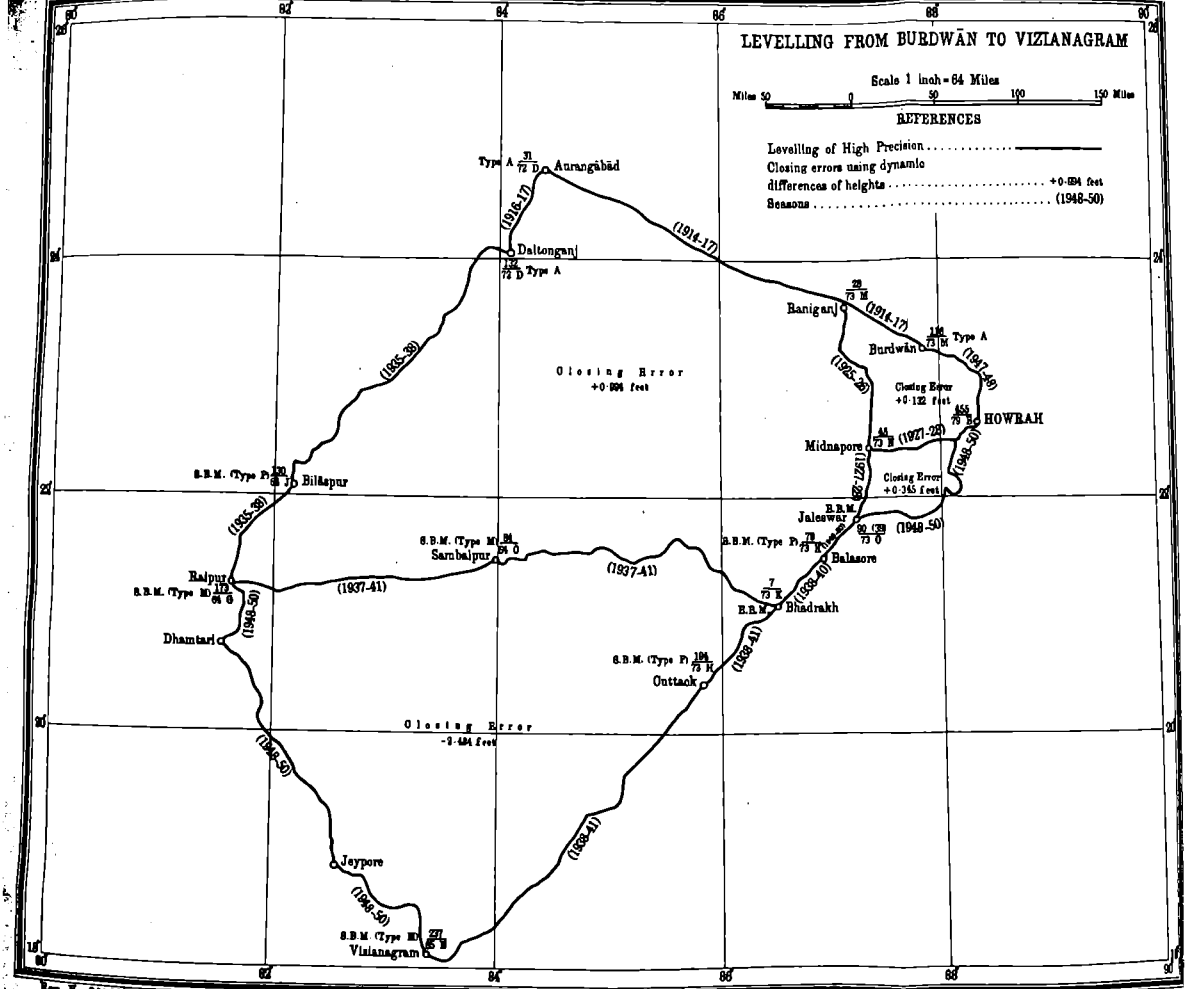
Miles 50 0 50 100 150 Miles

REFERENCES

Levelling of High Precision .....

Closing errors using dynamic differences of heights ..... +0·694 feet

Seasons ..... (1948-50)



Reg. No. 681 M/N O D'51 (O. & T. O. 1" = 64 Miles)-375.

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CHANGES IN HEIGHTS OF BENCH-MARKS

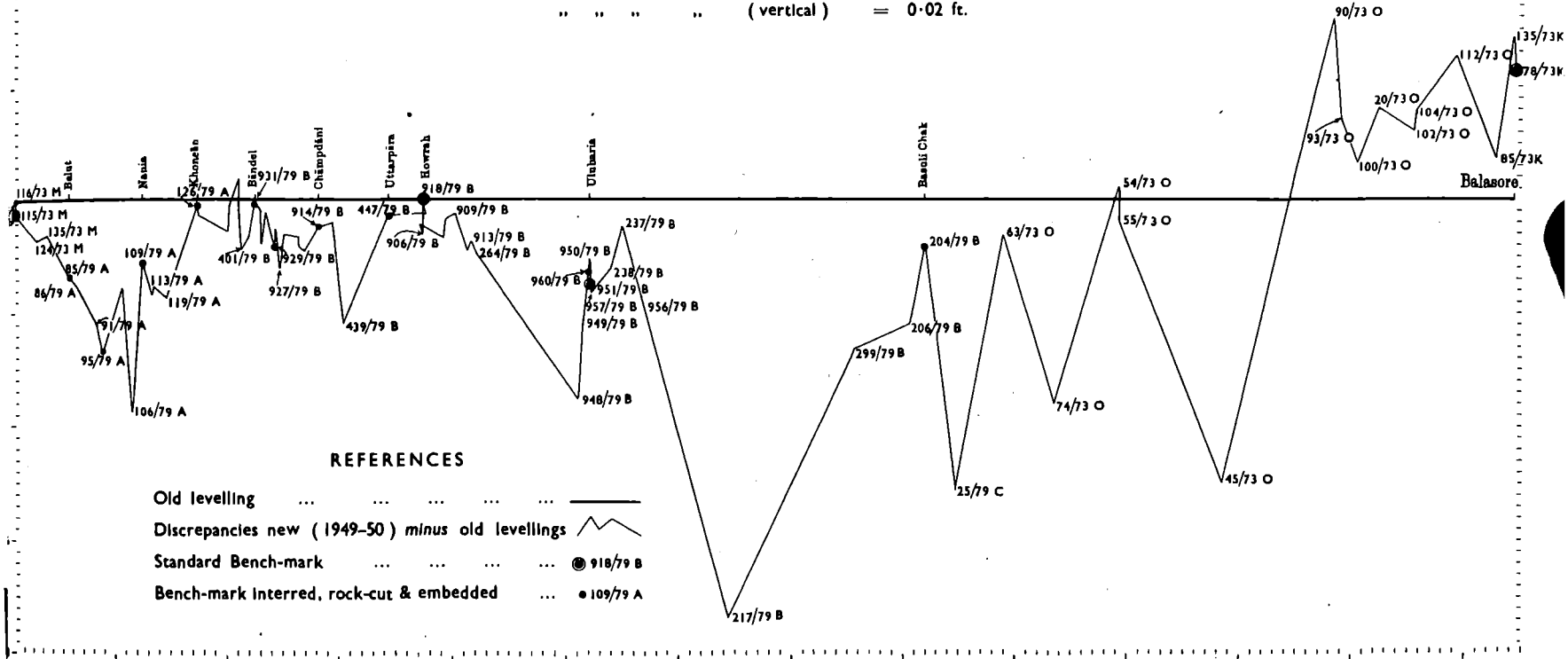
Chart VI

FROM

BURDWĀN TO BALASORE

Scale 1 small division (horizontal) = 2 Miles.

" " " " (vertical) = 0·02 ft.



REFERENCES

Old levelling ... ... ———

Discrepancies new (1949–50) *minus* old levellings ⩘

Standard Bench-mark ... ... ◉ 918/79 B

Bench-mark interred, rock-cut & embedded ... • 109/79 A

Reg. No. 675 M/NCD'51-375.

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TABLE 1.—*Old and new levelling between Burdwān and Balasore*

B.M. No.	Brief Description	Distance from B.M No. 116/73 M at Burdwān	Date of old levelling	Observed heights above (+) or below (—) B.M. No 116/73 M at Burdwān		Discrepancy (New-Old)
				Old levelling	Revised levelling 1947-49	
Sheet 73 M		*Miles*		*feet*	*feet*	*feet*
116	Burdwān, (Type 'A')	0·0	1924–25	0·000	0·000	0·000
138	Coping	1·1	,,	+11·615	+11·596	−0·019
136	Coping	1·0	,,	+10·510	+10·496	−0·014
114	Pillar	0·2	,,	+ 5·332	+ 5·323	−0·009
115	Burdwān, S.B.M. ..	0·0	1913–17	+ 5·118	+ 5·095	−0·023
124	Bridge	4·7	,,	+ 0·248	+ 0·174	−0·074
135 (*127*)	Bridge	7·3	,,	−10·375	−10·438	−0·063
Sheet 79 A						
85	Belut village (Type 'B')	11·7	,,	−19·164	−19·302	−0·138
86	Rasūlpur R.S. ..	12·9	,,	−13·837	−14·036	−0·149
91	Memāri R.S. ..	16·9	,,	−21·860	−22·075	−0·215
95	Memāri, (Type 'A')	17·7	,,	−33·127	−33·394	−0·267
103	Bridge	21·5	,,	−36·208	−36·362	−0·154
106	Step	23·2	,,	−38·238	−38·611	−0·373
109	Naāna village (Type 'B') ..	25·1	,,	−50·030	−50·141	−0·111
112	Pillar	26·6	,,	−47·303	−47·467	−0·164
113	Simlagarh R.S. ..	27·4	,,	−44·261	−44·416	−0·155
119	Pillar	29·9	,,	−49·126	−49·297	−0·171
126	Khonean, (Type 'B')	35·3	,,	−61·423	−61·437	−0·014
127	Culvert	35·4	,,	−62·522	−62·550	−0·028
Sheet 79 B						
392	Bridge	40·4	,,	−64·196	−64·252	−0·056
393	Railway bridge ..	41·0	,,	−64·207	−64·222	−0·015
352	Tribenighāt ..	42·3	,,	−66·170	−66·141	+0·038
399	Well	42·5	,,	−56·628	−56·659	−0·031
401	Culvert	43·3	,,	−58·815	−58·903	−0·088
402	Railway bridge ..	44·1	,,	−62·958	−63·023	−0·065
404	Culvert	45·0	,,	−63·234	−63·241	−0·007
931 (*868*) (*405*) 869	Bāndel, (Type 'B')	45·7	,,	−70·055	−70·061	−0·006
(*348*)	Step	46·4	,,	−59·228	−59·247	−0·019
347	Platform ..	46·7	,,	−62·117	−62·139	−0·022
930 (*407*)	Bridge	46·9	,,	−64·596	−64·673	−0·077
408	Culvert	47·4	,,	−66·309	−66·333	−0·024

(*Continued*)

TABLE 1.—*Old and new levelling between Burdwān and Balasore*—(contd.)

B.M. No.	Brief Description	Distance from B.M. No. 116/73 M at Burdwān	Date of old levelling	Observed heights above (+) or below (−) B.M. No. 116/73 M at Burdwān		Discrepancy (New − Old)
				Old levelling	Revised levelling 1947-49	
Sheet 79B		*Miles*		*feet*	*feet*	*feet*
411	Circuit house ..	48·6	1913–17	−66·305	−66·374	−0·069
929	Chinsura, (Type 'B')	48·9	,,	−65·617	−65·701	−0·084
(*344*)						
410	Base of clock tower..	49·1	,,	−64·157	−64·213	−0·056
028	Step	49·4	,,	−63·554	−63·733	−0·179
(*413*)						
414	Seat of gate ..	49·6	,,	−63·973	−64·032	−0·059
927	Flooring ..	49·9	,,	−66·001	−66·103	−0·102
(*415*)						
416	Culvert	50·6	,,	−66·166	−66·227	−0·061
419	Pavement ..	53·3	,,	−69·569	−69·633	−0·004
420	Step	53·4	,,	−68·138	−68·221	−0·083
421	Flooring ..	54·0	,,	−67·291	−67·393	−0·092
914	Champdāni, (Type 'A')	56·7	,,	−70·732	−70·780	−0·048
(*423*)						
334	Bridge	59·2	,,	−71·253	−71·294	−0·041
439	Coping	61·4	,,	−68·374	−68·592	−0·218
447	Uttarpāra, (Type 'A')	69·0	,,	−74·437	−74·465	−0·028
455	Flooring ..	75·2	,,	−73·038	−73·062*	−0·024
918	Howrah, S.B.M.	74·9	1927–28	−74·411	−74·409*	+0·002
917	Municipal offices ..	75·0	,,	−71·232	−71·264*	−0·032
906	Step	75·2	,,	−74·017	−74·079*	−0·062
453	Post office, Howrah	75·1	,,	−73·867	−73·913	−0·046
920	Plinth	78·5	,,	−77·649	−77·715	−0·066
919	Stone	79·0	,,	−71·892	−71·927	−0·035
909	Sibpur	80·5	,,	−70·889	−70·913	−0·024
458	Sluice	83·0	,,	−75·619	−75·707	−0·088
913	Step	84·0	,,	−77·355	−77·428	−0·073
264	Flooring ..	84·5	,,	−78·068	−78·162	−0·094
948	Railway bridge ..	102·3	,,	−70·331	−70·681	−0·350
949	Railway bridge ..	103·6	,,	−67·612	−67·823	−0·211
959	Step	104·2	,,	−77·192	−77·314	−0·122
960	Ulubāria, (Type 'B')	104·2	,,	−81·138	−81·266	−0·128
950	Canal look ..	104·3	,,	−76·392	−76·493	−0·101
(*246*)						
955	Step	104·4	,,	−81·024	−81·137	−0·113
954	Iron bolt of S.B.M...	104·5	,,	−77·167	−77·312	−0·145
953	E. prism of S.B.M. ..	104·5	,,	−78·326	−78·476	−0·150

(*Continued*)

*Mean value of levelling of 1947-48 and 1948-50.

TABLE 1.—*Old and new levelling between Burdwān and Balasore*—(concld.)

B.M. No.	Brief Description	Distance from B.M. No. 116/73 M at Burdwān	Date of old levelling	Observed height above (+) or below (−) B.M. No. 116/73 M at Burdwān		Discrepancy (New−Old)
				Old levelling	Revised levelling 1947-49	
Sheet 79 B		*Miles*		*feet*	*feet*	*feet*
952	W. prism of S.B.M...	104·5	1927–28	−78·318	−78·469	−0·151
951	Ulubāria, S.B.M. ..	104·5	,,	−77·588	−77·736	−0·148
956	Step	104·6	,,	−77·492	−77·654	−0·162
957	Step	104·6	,,	−78·632	−78·796	−0·164
238	Marine Sooket No. 25	108·6	1881–83	−77·689	−77·811	−0·122
237	Flange	110·1	,,	−80·517	−80·566	−0·049
217	Geonkhāli, (Type 'B')	129·0	,,	−77·128	−77·863	−0·735
299	Phulbāria Tower ..	151·5	,,	−78·410	−78·672	−0·262
206	Balughāt I.B. ..	161·5	,,	−76·666	−76·886	−0·220
204	Basuli Chak, (Type 'B')	164·2	,,	−77·849	−77·933	−0·084
Sheet 79 C						
25	Iron pipe ..	169·9	,,	−82·050	−82·560	−0·510
Sheet 73 O						
63	Kedgeree (E.B.M.) ..	178·3	,,	−79·839	−79·900	−0·061
74	Hijli	187·3	,,	−72·868	−73·227	−0·359
54	Contai (E.B.M.) ..	190·1	,,	−55·728	−55·708	+0·020
55	Pillar	190·3	,,	−50·314	−50·353	−0·039
45	Kudi, T.S. ..	217·2	,,	−46·969	−47·465	−0·496
90 (*29*)	Jaleswar, E.B.M. ..	237·0	1927–28	−51·559	−51·241	+0·318
93	Bridge	238·4	,,	−45·930	−45·788	+0·142
100	Muhammad Nagar S.B.M. ..	241·3	,,	−48·565	−48·498	+0·067
20	Bridge	246·5	,,	−65·975	−65·814	+0·161
102	Basta village ..	252·4 ..	,,	−72·751	−72·030	+0·121
104	Brick	252·9	,,	−64·574	−64·418	+0·156
112	Haldipara, E.B.M. ..	259·5	,,	−71·486	−71·234	+0·252
Sheet 73 K						
85	Brick	266·8	,,	−75·086	−75·009	+0·077
135	S.D.O's Office, Balasore	269·2	1938–40	−48·930	−48·645	+0·285
78	Balasore, S.B.M. ..	270·1	1927–28	−48·713	−48·487	+0·226

16. Kārwār to Hubli.—After completing work at Calcutta the detachment under Mr. J. K. Donald (Surveyor) left for Kārwār in Bombay state and commenced work from bench-mark No. 1/48 J on 2nd March 1950. The work was closed on bench-mark 1/48 M at Hubli on 27th April 1950.

The country was very undulating and hilly. As the road passes through dense jungle it was difficult to get bullock-carts for transport and so a motor truck had to be engaged at times. The place was malarious but the health of the detachment remained good.

Connections were made to two trigonometrical stations namely Ramankop H.S. and Guddhumdhur h.s.

The line Kārwār to Hubli has now been levelled thrice, once in 1873–74, a second time in 1907–08 and again in 1949–50. There were certain inexplicably large discrepancies between the two earlier levellings which could only be attributed to mistakes made by the levellers as the bench-marks were mostly on rock. In particular on page 355 Survey of India G.T.S. Vol. XIX, there is a mention of an unexplained large difference of +0·671 feet between bench-marks a/13 and 19 and of a similar error at Hubli. It was suspected that this error could only be due to some mistake by the levellers either of 1873–74 or of 1907–08.

The 1949–50 levelling has revealed that the fault lay with the 1907–08 levellers. Although the bench-marks Nos. a/13 and 19 were found destroyed, a comparison was possible at B.M. No. 44/48 J, which is very close to B.M. No. 19 and this differed by about ½ foot from the 1907–08 value. This bench-mark was not included in the 1873–74 levelling.

Table 2 gives differences between the levels of the various bench-marks as evidenced by levelling at the three epochs in question. Chart VII shows these differences graphically.

Apart from the abnormal local rises and sinkages at a few points such as at bench-marks Nos. 16/48 J, 17/48 J and 21/48 J, there appears to be a sinkage of the area relative to Kārwār. This sinkage becomes more pronounced east of Yellapur.

But the existing evidence cannot be regarded as conclusive as apart from the 1907–08 levelling being suspect, there are no rock-out bench-marks either, east of No. 2/48 I. In fact, EBM. 1/48 M at Hubli at the extreme north end of the area shows actually a rise since 1873–74.

It would thus appear that the data is not sufficient to draw firm quantitative conclusions regarding the stability of this region. For future study, new standard bench-marks have been established at Kārwār and Hubli respectively to supplement the old embedded bench-marks at these places.

TABLE 2.—*Old and new levelling from Kārwār to Hubli*

Bench-marks of the original levelling that were connected in year 1949–50			Distance from Kārwār	Observed heights above (+) and below (—) Kārwār as determined in			Difference in height (Revised–original)		
Topo. No. of bench-marks	Old Nos.	Brief description		i 1873–74	ii 1907–08	iii 1949–50	(ii—i) 1907–08 *minus* 1873–74	(iii—ii) 1949–50 *minus* 1907–08	(iii—i) 1949–50 *minus* 1873–74
			Miles	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*
1/48 J	1	Embedded at Kārwār ..	0·0	0·000	0·000	0·000	0·000	0·000	0·000
48/48 J	..	Engraved on margin cap stone ..	0·1	..	— 4·767	— 4·930	..	—0·163	..
49/48 J	..	Cut on granite stone ..	0·1	..	— 3·067	— 3·071	..	—0·004	..
2/48 J	a/1	Rock	0·2	— 1·105	— 1·156	— 1·161	—0·051	—0·005	—0·056
	2	Cut on mile-stone ..	0·9	+ 85·180	+ 85·152	Destroyed	—0·028	..	..
4/48 J	a/2	Rock	1·3	— 0·721	— 0·780	— 0·801	—0·059	—0·021	—0·080
	3	Cut on mile-stone	1·9	+ 3·175	+ 3·521	Destroyed	+0·346	..	..
6/48 J	a/3	Boulder	2·3	+ 21·546	+ 21·524	+ 21·555	—0·022	+0·031	+0·009
7/48 J	4	Rock	3·3	+137·641	+ 137·538	+ 137·502	—0·103	—0·036	—0·139
8/48 J	a/4	Rock	6·9	— 0·318	— 0·365	— 0·390	—0·047	—0·025	—0·072
9/48 J	5	Rock	10·9	+ 2·593	+ 2·575	+ 2·561	—0·018	—0·014	—0·032
10/48 J	a/5	Rock	12·5	+ 2·800	+ 2·790	+ 2·789	—0·010	—0·001	—0·011
12/48 J	c/5	Bridge Pier	15·2	+ 4·741	+ 4·724	+ 4·705	—0·017	—0·019	—0·036
11/48 J	..	Embedded at Hattikeri ..	15·3	..	+ 6·712	+ 6·668	..	—0·044	..
13/48 J	..	Rock	17·8	..	+ 41·181	+ 41·166	..	—0·015	..
14/48 J	..	Culvert	20·1	..	+ 93·940	+ 93·896	..	—0·044	..
15/48 J	..	Rock	22·0	..	+ 284·210	+ 284·150	..	—0·060	..
16/48 J	g/5	Wheel guard stone	23·8	+ 99·538	+ 99·562	+ 99·732	+0·024	+0·170	+0·194
17/48 J	h/5	Wheel guard stone	24·8	+ 58·688	+ 58·503	+ 58·234	—0·185	—0·269	—0·454
	i/5	Cut on rock	24·8	+ 55·135	+ 55·176	Destroyed	+0·041	..	..

(*Continued*)

TABLE 2.—*Old and new levelling from Kārwār to Hubli*—(contd.)

Bench-marks of the original levelling that were connected in year 1949–50			Distance from Kārwār	Observed heights above (+) and below (−) Kārwār as determined in			Difference in height (Revised–original)		
Topo. No. of bench-marks	Old Nos.	Brief description		i 1873–74	ii 1907–08	iii 1949–50	(ii—i) 1907–08 *minus* 1873–74	(iii—ii) 1949–50 *minus* 1907–08	(iii—i) 1949–50 *minus* 1873–74
			Miles	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*
19/48 J	..	Embedded at Agsur ..	25·2	..	+ 59·541	+ 59·488	..	−0·053	..
20/48 J	..	Stone step	25·3	..	+ 59·403	+ 59·344	..	−0·059	..
21/48 J	6	Wheel gaurd stone	28·0	+ 30·788	+ 30·275	+ 29·811	−0·513	−0·464	−0·977
22/48 J	7	Wheel gaurd stone	29·9	+ 80·158	+ 80·058	+ 79·940	−0·100	−0·118	−0·218
27/48 J	..	Rock	36·1	..	+ 124·912	+ 124·887	. . .	−0·025	..
	9	Cut on culvert	31·7	+ 67·675	+ 67·671	Destroyed	−0·004	..	..
28/48 J	b/11	Rock	38·4	+ 97·613	+ 97·713	+ 97·695	+0·100	−0·018	+0·082
	c/11	Cut on bridge	38·1	+ 101·487	+ 101·377	Destroyed	−0·110	..	..
30/48 J	d/11	Rock	38·8	+ 87·403	+ 87·507	+ 87·487	+0·104	−0·020	+0·084
31/48 J	..	Rock	41·2	..	+ 161·310	+ 161·267	..	−0·043	..
32/48 J	..	Embedded at P.W.D. Stores at Ramanguli	42·4	..	+ 152·933	+ 152·845	..	−0·088	..
36/48 J	..	Rock	50·4	..	+ 674·415	+ 674·369	..	−0·046	..
37/48 J	..	Cess-pool	52·3	..	+1096·384	+1096·320	..	−0·064	..
38/48 J	..	Rock	54·2	..	+1439·993	+1439·926	..	−0·067	..
39/48 J	..	Culvert	54·9	..	+1464·459	+1464·388	..	−0·071	..
40/48 J	..	Culvert	56·8	..	+1563·133	+1563·057	..	−0·076	..
	b/12	Cut on bridge abutment ..	42·0	+ 150·800	+ 150·811	Destroyed	+0·011	..	..
41/48 J	..	Huge boulder	60·3	..	+1798·086	+1798·000	..	−0·086	..
	13	Cut on bridge abutment ..	44·0	+ 167·908	+ 167·922	Destroyed	+0·016	..	..
43/48 J	..	At Forest Office Yellāpur ..	60·4	..	+1778·443	+1778·307	..	−0·136	..

(*Continued*)

TABLE 2.—*Old and new levelling from Kārwār to Hubli*—(contd.)

Bench-marks of the original levelling that were connected in year 1949–50			Distance from Kārwār	Observed heights above (+) and below (−) Kārwār as determined in			Difference in height (Revised–original)		
Topo. No. of bench-marks	Old Nos.	Brief description		i 1873–74	ii 1907–08	iii 1949–50	(ii − i) 1907–08 *minus* 1873–74	(iii − ii) 1949–50 *minus* 1907–08	(iii − i) 1949–50 *minus* 1873–74
			Miles	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*
	a/13	Cut on bridge parapet ..	46·7	+ 168·578	+ 168·588	Destroyed	+0·010	..	..
44/48 J	..	Well	60·5	..	+1769·244	+1768·764	..	−0·520	..
	19	Cut on culvert	59·9	+1776·398	+1777·079	Destroyed	+0·681	..	..
45/48 J	..	Embedded at Yellāpur ..	60·9	..	+1759·927	+1759·827	..	−0·100	..
46/48 J	..	Rock	64·0	..	+1815·700	+1815·618	..	−0·082	..
47/48 J	..	Culvert	65·7	..	+1757·099	+1757·003	..	−0·096	..
1/48 I	..	Culvert	67·7	..	+1722·850	+1722·724	..	−0·126	..
2/48 I	..	Rock	69·9	..	+1770·900	+1770·854	..	−0·046	..
3/48 I	..	Wheel gaurd stone	71·7	..	+1775·139	+1774·993	..	−0·146	..
4/48 I	..	Culvert	74·1	..	+1711·726	+1711·604	..	−0·122	..
7/48 I	..	Culvert	78·9	..	+1773·678	+1773·543	..	−0·135	..
9/48 I	..	Bridge	85·1	..	+1689·169	+1689·042	..	−0·127	..
10/48 I	..	Culvert	87·3	..	+1765·799	+1765·580	..	−0·219	..
11/48 I	..	Embedded at Dastikop ..	88·5	..	+1842·846	+1842·649	..	−0·197	..
12/48 I	..	Dāk bungalow	88·6	..	+1846·586	+1846·374	..	−0·212	..
14/48 I	..	Bridge	89·5	..	+1756·289	+1756·131	..	−0·158	..
46/48 M	..	Culvert	91·5	..	+1847·468	+1847·290	..	−0·178	..
47/48 M	..	Culvert	93·9	..	+1804·538	+1864·368	..	−0·170	..
48/48 M	..	Culvert	95·6	..	+1955·898	+1955·735	..	−0·163	..
49/48 M	..	Culvert	97·4	..	+1940·567	+1940·368	..	−0·199	..

(*Continued*)

TABLE 2.—*Old and new levelling from Kārwār to Hubli*—(concld.)

Bench-marks of the original levelling that were connected in year 1949–50			Distance from Kārwār	Observed heights above (+) and below (−) Kārwār as determined in			Difference in height (Revised–original)		
Topo. No. of bench-marks	Old Nos.	Brief description		i 1873–74	ii 1907–08	iii 1949–50	(ii−i) 1907–08 *minus* 1873–74	(iii−ii) 1949–50 *minus* 1907–08	(iii−i) 1949–50 *minus* 1873–74
			Miles	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*
50/48 M	..	Bridge	100·4	..	+1954·728	+1954·518	..	−0·210	..
52/48 M	..	Bridge	103·3	..	+1977·768	+1977·554	..	−0·214	..
1/48 M	28	Embedded at Hubli	104·0	+2048·200	+2048·893	+2048·698	+0·693	−0·195	+0·498
2/48 M	..	Flooring	104·2	..	+2064·435	+2064·203	..	−0·232	..
3/48 M	..	Flooring	104·3	..	+2067·058	+2066·858	..	−0·200	..

17. **Raipur to Vizagapatam.**—Detachment No. 2 under Mr. B. P. Rundev (Surveyor), with one recorder and 13 *khalāsīs* took up the levelling in the back direction of the high precision line from Vizagapatam to Raipur which was levelled in the fore direction by Mr. H. C. Gupta (Surveyor) in 1947-48. He commenced work at Vizagapatam on 15th October 1949 from Standard Bench-mark No. 91/65 O and followed the B. N. railway line to Vizianagram via. Kottavalasa. Heavy railway traffic caused considerable disturbance in the course of work in this section.

Necessary check-levelling was carried out at Vizianagram. The section from Vizianagram to Raipur followed the Vizianagram–Rayagada road up to Rambhadrampuram whence the line turned to Salur and followed the main road going over the Ghats to Jeypore. From Jeypore the work continued along Jeypore–Nowranganpur road, and thence to Raigarh and joined the forest road at Borai. From Borai it ran along the old cart track to Sihawa via Sitanadi. From Sihawa it followed the old road to Dhamtari.

The Mahānadi river which came in the way was crossed over the weir opposite Rudri Canal Head-works as the river was altogether dry. Thence the work continued to Raipur and closed on standard bench-mark No. 173/64 G (Type P) on 15th May 1950.

For transport, bullock carts were used on a permanent basis except in the section between Salur and Nawrangpur where they could not be had and so motor transport had to be resorted to.

The country was not easy. Section Vizagapatam–Vizianagram which followed the railway line gave trouble due to shimmer which was present from sunrise to sunset. The country between Vizianagram and Dhamtari was rather undulating ; in particular the Ghat section between Salur and Jeypore was very steep.

All bench-marks were previously laid down by the fore-leveller except at a few places where new rock-cut bench-marks were made and connected by the back leveller in fore and back directions. Two trigonometrical stations of Bilaspur Meridional Series, viz., Hathbena H.S. and Sirsi H.S. and five minor stations were also connected by branch-lines.

The country was very malarious and many of the *khalāsīs* suffered but recovered quite quickly. Medical help was available almost all over the area.

Starting with the published height of standard bench-mark No. 173/64 G (Type P) at Raipur, viz., 997·765 feet above M.S.L., this season's levelling gives the height of the standard bench-mark at Vizianagram (B.M. No. 237/65 N) to be 216·811 feet. The published height of this bench-mark as derived by older precision levelling of 1894-95 is 216·130 feet. The discrepancy of 0·681 feet has been adjusted between Raipur and Vizianagram (a distance of 338 miles), each bench-mark receiving a correction proportional to its distance from Raipur.

Similarly accepting the published height of the standard bench-mark at Vizianagram, the closing error at standard bench-mark Vizagapatam (B.M. 71/65 O) is 0·266 feet, and this has been distributed between the portion Vizianagram to Vizagapatam (41 miles).

The closing error of the circuit Bhadrakh-Vizianagram-Raipur-Bhadrakh is —2·484 feet. This large closure error needs critical scrutiny. There are several peculiarities in this circuit. Firstly, part of the line from Bhadrakh to Vizianagram was carried out in 1938–40 by inexperienced and unsteady observers. Again, on both sections of the lines—Raipur to Vizianagram and Vizianagram to Vizagapatam, the route followed was the same as that of the old level lines Nos. 37 and 36 of the first precision level net of India of 1858–1909 (see Chart IV). There are quite a number of bench-marks common to the old and new levellings. The discrepancies especially on the section Raipur–Vizianagram are unduly large. See Table 3.

Thus from embedded bench-mark No. 13/64 H at Gatasili to rock-cut bench-mark No. 11/64H there is a change of level of 0·127 feet, which is increased to 0·208 feet at B.M. 10/63 H. After that there is again a sudden change of 0·232 feet between rock-cut bench-marks Nos. 6/63 H and 5/63 H, the total discrepancy at B.M. 5/63 H between the old and new heights being 0·513 feet. The discrepancy appears to systematically increase still further and becomes about 0·8 feet at rock-cut B.M. 28/65 I and remains so as far as embedded B.M. 77/65 J, when there is a further rise; the discrepancy at B.M. 68/65 J (rock) becoming as large as 1·2 feet, which persists till B.M. 4/65 J on rock. There is then a short fall of half a foot from rock-cut B.M. 49/65 N to rock-cut B.M. 48/65 N.

In the new levelling, there are also large systematic differences between the fore and back levellers.

As the majority of the bench-marks are cut on rock, and the area is not known to be subject to any tectonic activity, the explanation of these large discrepancies can only be found in some unexplained errors in the levellings.

By completion of the levelling from Raipur to Vizagapatam, it is now possible to compute the direct relation between the M.S.L.'s at Bombay and Vizagapatam. This is being done and the result will be included in the next Technical Report.

TABLE 3.—*Old and new (1948–50) levelling from Raipur to Vizianagram*

B.M. Nos.	Brief description	Distance from B.M. No. 173/64 G	Date of original levelling	Observed height above (+) or below (−) B.M. No. 173/64 G		Discrepancy (New–Old)
				Old	New	
		Miles		*feet*	*feet*	*feet*
173/64 G	S.B.M. at Raipur..	0·0	1894–97	0·000	0·000	0·000
66/64 G	E.B.M. at Mana ..	8·5	,,	+ 5·701	+ 5·658	−0·043
55/64 G	E.B.M. at Abhanpur	18·4	,,	+ 68·202	+ 68·188	−0·014
58/64 H	E.B.M. at Darba	23·2	,,	+ 15·441	+ 15·431	−0·010
47/64 H	E.B.M. at Kurud	35·7	,,	+ 10·144	+ 10·134	−0·010
32/64 H	Temple at Dhamtari	48·6	,,	+ 52·941	+ 52·822	−0·119
30/64 H	Step	48·7	,,	+ 48·820	+ 48·786	−0·034
31/64 H	E.B.M. at Dhamtari	48·7	,,	+ 47·785	+ 47·736	−0·049
27/64 H	Temple ..	50·1	,,	+ 57·055	+ 57·007	−0·048
26/64 H	Stone ..	56·2	,,	+ 63·310	+ 63·235	−0·075
21/64 H	Rock ..	63·3	,,	+ 78·584	+ 78·495	−0·089
13/64 H	E.B.M. at Gatasili	94·3	,,	+ 343·065	+ 343·074	+0·009
11/64 H	Rock	98·5	,,	+ 441·226	+ 441·363	+0·137
10/64 H	Rock ..	103·9	,,	+ 424·350	+ 424·565	+0·215
9/64 H	Rock ..	105·3	,,	+ 429·503	+ 429·710	+0·207
7/64 H	E.B.M. at Sihāwa	107·5	,,	+ 427·121	+ 427·329	+0·208
8/64 H	Step ..	107·5	,,	+ 428·401	+ 428·524	+0·123
6/64 H	Rock ..	109·6	,,	+ 464·648	+ 464·920	+0·272
5/64 H	Rock ..	120·3	,,	+ 813·673	+ 814·184	+0·511
4/64 H	Rock ..	122·7	,,	+ 863·124	+ 863·648	+0·524
3/64 H	Rock ..	125·0	,,	+1025·928	+1026·511	+0·583
2/64 H	E.B.M. at Borai ..	128·0	,,	+1089·553	+1090·132	+0·579
1/64 H	Rock ..	129·4	,,	+1082·687	+1083·285	+0·598
1/65 E	E.B.M. at Joringa	140·2	,,	+1160·507	+1161·248	+0·741
28/65 I	Rock ..	143·1	,,	+1197·817	+1198·592	+0·775
26/65 I	E.B.M. at Raigarh	147·5	,,	+1153·042	+1154·440	+0·798
25/65 I	Rock ..	147·6	,,	+1153·304	+1154·098	+0·794
24/65 I	Rock ..	148·1	,,	+1169·186	+1169·986	+0·800
23/65 I	Rock ..	150·8	,,	+1136·377	+1137·173	+0·796
22/65 I	E.B.M. at Bera ..	157·4	,,	+1016·835	+1017·590	+0·755
21/65 I	Rock ..	158·9	,,	+1024·632	+1025·391	+0·759
20/65 I	Rock ..	159·8	,,	+1065·479	+1066·236	+0·757
19/65 I	Rock ..	162·4	,,	+1043·942	+1044·716	+0·774
18/65 I	Rock ..	163·0	,,	+1017·844	+1018·635	+0·791
14/65 I	E.B.M. at Umarkot	165·0	,,	+ 994·634	+ 995·376	+0·742
13/65 I	Rock ..	165·7	,,	+ 994·424	+ 995·163	+0·739
12/65 I	Type 'C' at Dodra	172·2	,,	+ 931·464	+ 932·200	+0·736
11/65 I	E.B.M. at Bijāpur	176·2	,,	+ 959·402	+ 960·099	+0·697
10/65 I	E.B.M. at Dabgaon	186·0	,,	+ 940·752	+ 941·457	+0·705

(*Continued*)

TABLE 3.—*Old and new (1948–50) levelling from Raipur to Vizianagram*—(concld.)

B.M. Nos.	Brief description	Distance from B.M. No. 173/64 G	Date of original levelling	Observed height above (+) or below (−) B.M. No. 173/64 G		Discrepancy (New–Old)
				Old	New	
		Miles		*feet*	*feet*	*feet*
8/65 I	Rock ..	195·0	1894–97	+ 918·484	+ 919·224	+0·740
6/65 I	E.B.M. at Pappadahandi ..	197·4	,,	+ 897·315	+ 898·012	+0·697
4/65 I	E.B.M. at Naurangapur ..	205·8	,,	+ 871·484	+ 872·192	+0·708
3/65 I	Pillar ..	205·9	,,	+ 865·063	+ 864·824	−0·239
2/65 I	E.B.M. at Borigumma ..	218·6	,,	+ 940·395	+ 941·198	+0·803
1/65 I	Rock ..	222·2	,,	+ 914·484	+ 915·262	+0·778
81/65 J	Rock ..	224·0	,,	+ 913·772	+ 914·534	+0·762
80/65 J	Rock ..	229·9	,,	+ 948·270	+ 948·983	+0·713
79/65 J	Rock ..	231·4	,,	+ 950·871	+ 951·625	+0·754
78/65 J	Grave stone ..	232·1	,,	+ 955·760	+ 956·445	+0·685
77/65 J	E.B.M. at Jeypore	232·6	,,	+ 940·807	+ 941·569	+0·762
73/65 J	Rock ..	236·3	,,	+1282·126	+1283·029	+0·903
68/65 J	Rock ..	240·0	,,	+1796·743	+1797·900	+1·157
05/05 J	Rock ..	241·5	,,	+1955·754	+1956·971	+1·217
02/65 J	Rock ..	243·7	,,	+1935·841	+1937·047	+1·206
60/65 J	Rock ..	244·8	,,	+2038·972	+2040·222	+1·250
57/65 J	E.B.M. at Koraput	246·1	,,	+1904·543	+1905·734	+1·191
53/65 J	Rock ..	249·2	,,	+1834·226	+1835·387	+1·161
48/65 J	E.B.M. at Domriput ..	253·7	,,	+1840·094	+1842·133	+1·130
32/65 J	E.B.M. at Doliamba	263·9	,,	+1964·693	+1965·891	+1·198
24/65 J	Stone on bridge ..	269·2	,,	+1870·466	+1871·241	+0·775
15/65 J	E.B.M. at Pottanghi	274·5	,,	+2059·570	+2060·907	+1·337
4/65 J	Rock ..	281·4	,,	+2059·189	+2060·549	+1·360
3/65 J	Stone on bridge ..	281·4	,,	+2060·066	+2060·970	+0·904
101/65 N	E.B.M. at Sunki ..	287·8	,,	+1038·881	+1039·938	+1·057
99/65 N	Rock ..	289·3	,,	+ 951·964	+ 952·955	+0·991
78/65 N	Stone on culvert ..	301·3	,,	− 477·131	− 477·155	−0·024
70/65 N	Flooring ..	301·9	,,	− 485·381	− 484·973	+0·408
74/65 N	E.B.M. at Saluru ..	302·3	,,	− 483·428	− 482·743	+0·685
73/65 N	Step ..	302·4	,,	− 485·510	− 484·982	+0·528
51/65 N	E.B.M. at Gajapatinagaram ..	324·8	,,	− 777·273	− 776·963	+0·310
48/65 N	Rock ..	327·3	,,	− 773·521	− 773·117	+0·404
46/65 N	Stone on culvert ..	330·6	,,	− 792·170	− 791·840	+0·330
22/65 N	Mile-stone ..	338·8	,,	− 773·100	− 771·951	+1·149
23/65 N	Pillar ..	339·5	,,	− 768·230	− 768·067	+0·163
24/65 N	Mile-stone ..	339·8	,,	− 791·808	− 792·548	−0·740
25/65 N	Mile-stone ..	340·8	,,	− 831·766	− 827·294	+4·472
26/65 N	Stone on bridge ..	341·3	,,	− 834·412	− 834·205	+0·207
28/65 N	Stone on bridge ..	342·5	,,	− 829·947	− 829·695	+0·252
31/65 N	Mile-stone ..	343·7	,,	− 770·946	− 771·303	−0·357
33/65 N	Rock ..	345·5	,,	− 758·951	− 758·589	+0·362

TABLE 3(*a*).—*Old and new (1948–50) levelling from Vizianagram to Vizagapatam*

B.M. Nos	Brief description	Distance from B.M. No. 237/65 G	Date of original levelling	Observed height above (+) or below (−) B.M. No. 237/65 G		Discrepancy (New − Old)
				Old	New	
		Miles		*feet*	*feet*	*feet*
237/65 N	S.B.M. at Vizianagram ..	0·0	1894–95	0·000	0·000	0·000
18/65 N	Bridge ..	0·9	,,	− 22·853	− 22·838	+0·015
17/65 N	Bridge ..	1·9	1895–97	− 31·942	− 31·935	+0·007
16/65 N	Bridge ..	2·1	,,	− 36·266	− 36·239	+0·027
15/65 N	Bridge ..	2·9	,,	− 47·994	− 47·961	+0·033
14/65 N	Bridge ..	3·5	,,	− 47·999	− 47·962	+0·037
13/65 N	Bridge ..	4·7	,,	− 78·061	− 78·027	+0·034
12/65 N	Bridge ..	5·8	,,	− 98·172	− 98·147	+0·025
10/65 N	Bridge ..	7·8	,,	−111·339	−111·255	+0·084
9/65 N	Bridge ..	9·0	,,	−116·576	−115·121	+1·455
8/65 N	Bridge ..	9·2	,,	−109·507	−109·467	+0·040
7/65 N	Bridge ..	10·2	,,	− 90·179	− 90·117	+0·062
6/65 N	Platform ..	10·9	,,	− 73·731	− 73·656	+0·075
3/65 N	E.B.M. at Alamanda R.S. ..	11·0	,,	− 73·704	− 73·641	+0·063
2/65 N	Platform ..	11·0	,,	− 73·727	− 73·668	+0·059
68/65 O	Bridge ..	11·6	,,	− 87·620	− 87·540	+0·080
67/65 O	Bridge ..	12·2	,,	− 89·724	− 89·619	+0·105
66/65 O	Bridge ..	12·9	,,	− 66·754	− 66·650	+0·104
65/65 O	Bridge ..	15·6	,,	+ 1·929	+ 2·052	+0·123
64/65 O	Bridge ..	16·9	,,	+ 25·093	+ 25·221	+0·128
63/65 O	Bridge ..	17·8	,,	+ 34·254	+ 34·398	+0·144
62/65 O	Bridge ..	19·1	,,	+ 23·450	+ 23·620	+0·170
60/65 O	Bridge ..	20·1	,,	− 10·633	− 10·463	+0·170
59/65 O	Bridge ..	21·1	,,	− 43·579	− 43·391	+0·188
58/65 O	E.B.M. at Kottavalasa ..	21·4	,,	− 43·683	− 43·498	+0·185
57/65 O	Platform ..	21·5	,,	− 42·755	− 42·611	+0·144
55/65 O	Bridge ..	22·1	,,	− 46·809	− 46·633	+0·176
54/65 O	Bridge ..	22·3	,,	− 53·755	− 53·582	+0·173
52/65 O	Bridge ..	23·8	,,	− 90·058	− 89·897	+0·161
51/65 O	Bridge ..	25·2	,,	−114·101	−113·998	+0·103
50/65 O	Bridge ..	26·5	,,	−128·629	−128·332	+0·297
49/65 O	Bridge ..	27·7	,,	−139·455	−139·297	+0·158
48/65 O	Bridge ..	28·1	,,	−143·890	−143·671	+0·219
47/65 O	Bridge ..	29·4	,,	−152·411	−152·251	+0·160
46/65 O	Bridge ..	29·8	,,	−152·283	−152·142	+0·141
44/65 O	Bridge ..	31·5	,,	−159·577	−159·432	+0·145

(*Continued*)

TABLE 3(*a*).—*Old and new (1948–50) levelling from Vizianagram to Vizagapatam*—(concld.)

B.M. Nos.	Brief description	Distance from B.M. No. 237/65 N	Date of original levelling	Observed height above (+) or below (−) B.M. No. 237/65 N		Discrepancy (New − Old)
				Old	New	
		Miles		*feet*	*feet*	*feet*
43/65 O	E.B.M. at Simhachalam ..	32·7	1895–97	−137·285	−137·096	+0·189
42/65 O	Platform ..	32·7	,,	−147·371	−147·210	+0·161
41/65 O	Platform ..	32·8	,,	−147·262	−147·078	+0·184
40/65 O	Bridge ..	33·7	,,	−161·338	−161·166	+0·172
38/65 O	Bridge ..	35·9	,,	−160·075	−159·908	+0·167
37/65 O	Bridge ..	37·3	,,	−196·195	−196·044	+0·151
71/65 O	S.B.M. at Vizagapatam ..	40·1	1909–10	−196·292	−196·074	+0·218
75/65 O	Type 'C' at Vizagapatam ..	40·4	,,	−195·137	−194·916	+0·221
74/65 O	Flooring ..	40·5	,,	−196·042	−195·843	+0·199
73/65 O	Plinth ..	40·8	,,	−188·380	−188·201	+0·179
72/65 O	Statue of Queen Victoria at Vizagapatam ..	41·1	,,	−198·615	−198·474	+0·141

18. River Crossing Detachment.—In season 1948–49, in the course of levelling from Diamond Harbour to Dublat and Howrah to Jellasore, Mr. B. P. Rundev had to cross the rivers Damodar, Rūpnārāyan, Rasulpur, Haldi, Bartala and Gahattaganj, which were $\frac{3}{8}$, $\frac{3}{8}$, $\frac{1}{4}$, $\frac{5}{8}$, $1\frac{5}{8}$ and $1\frac{1}{2}$ miles in width respectively. Fortunately only the first four of these crossings occurred in the Primary level net ; the last two rivers which were unduly wide came in the branch-line executed for the Port Commissioners of the Port of Calcutta.

The problem of transferring level heights across a wide river in the absence of bridges is beset with considerable difficulties and entails the use of special methods. Even rivers of a $\frac{1}{4}$ mile width can introduce great inaccuracy unless special precautions are taken. Particularly important is the selection of a suitable site with due regard to length of crossing, asymmetry, height of water and so on. Other things being equal, the aim should be that the selected site gives the highest elevation of the ray above the water. But there are so many factors involved that the balance of advantage can only be assessed after considerable experience.

Some experimental work was done on the Jumna river near Kalsi (about 35 miles away from Dehra Dūn) and much time and

thought was expended on the relative merits of the various methods. It was not considered advisable to entrust the work to the levellers who were running the lines. A separate detachment comprising of Messrs. A. K. Bhattacharjee and S. Vaikuntanathan and 12 *khalāsīs* was formed.

Details of the methods used and a critical resume of the results obtained will be given in the next Technical Report.

19. **Calcutta Mint to King George's Dock and to Cossipore.**—A report was received from the River Surveyor for the Port of Calcutta that standard bench-mark No. 985/79 B situated near No. 3 Gate, King George's Dock was found damaged and that it was necessary to reconnect it by levelling after it had been repaired. In connection with this work, opportunity was taken to establish two additional bench-marks in the vicinity of $\frac{\text{H.R.S.}}{\text{B.M.}}$ B.M. No. 80 which is the bench-mark of reference of the tidal observatory at King George's Dock, so that a check could be maintained in future on its stability; also the standard bench-mark near the old Power-house of Cossipore was reconnected.

Messrs. A. K. Bhattacharjee and S. Vaikuntanathan took up this line both in fore and back directions on 14th February 1950 from the inscribed B.M. No. 359/79 B near Hastings Bridge, Kidderpore. The levelling was carried out in 2-mile sections first from the above B.M. near Hastings Bridge to King George's Dock and then from the B.M. on Hastings Bridge to B.M. No. 353/79 B at Calcutta Mint. Due to heavy traffic in Calcutta area the progress of levelling was only between 2 and $2\frac{1}{2}$ miles per day. The work was completed on 24th February 1950.

Levelling was then started from S.B.M. at Calcutta Mint towards Cossipore. This line was done in 2-mile sections, both in the fore and back directions and by the same two observers. The line was closed on type M bench-mark near the old Power-house Cossipore which was, however, found to be in a damaged condition. Two new inscribed bench-marks have been established in its vicinity. The type M bench-mark at Cossipore Docks was found to be in a very good condition and was also connected en route.

The instrument used on both these lines was Zeiss Level MK III No. 5741.

Table 4 gives the difference between heights by old and new levellings of all old bench-marks connected by the new levelling. The discrepancies are small and indicate that the relative heights of bench-marks in the vicinity of Howrah have not altered.

TABLE 4.—*Old and new levelling from Calcutta Mint to King George's Dock and to Cossipore*

B.M. Nos.	Description	Distance from 353/79 B at Calcutta	Date of old levelling	Observed heights above (+) or below (—) B.M. No. 353/79 B at Calcutta Mint		Discrepancy (New–Old)
				Old levelling	Revised levelling 1949–50	
		Miles		*feet*	*feet*	*feet*
	Calcutta Mint to King George's Dock					
Sheet 79 B						
353	Calcutta Mint, (Type B) ..	0·0	1936–37	0·000	0·000	0·000
994	Howrah, (Type M)	0·2	,,	— 0·265	— 0·255	+0·010
897	Stone ..	0·4	,,	+ 3·094	+ 3·095	+0·001
992	Stone step ..	0·6	,,	+ 1·958	+ 1·961	+0·003
991	Stone plinth ..	1·0	,,	+ 3·573	+ 3·563	—0·010
990	Stone ..	1·0	,,	+ 0·755	+ 0·750	—0·005
31	Stone pavement ..	1·7	,,	+ 1·066	+ 1·088	+0·022
989	Plinth ..	1·9	,,	+ 6·031	+ 6·031	0·000
988	Step	2·3	,,	+ 3·664	+ 3·680	+0·016
355	Step	3·1	1894–95	+ 4·293	+ 4·258	—0·035
356	Step	3·5	,,	+ 4·269	+ 4·310	+0·041
357	Pavement ..	4·1	,,	+12·886	+12·872	—0·014
359	Kidderpore New Dock ..	5·6	,,	— 0·837	— 0·796	+0·041
358	Kidderpore New Dock	5·7	,,	— 0·837	— 0·798	+0·039
	Calcutta Mint to Cossipore					
353	Calcutta Mint, (Type B) ..	0·0	1926–27	0·000	0·000	0·000
902*	Cossipore, (Type M)	3·1	,,	+ 4·135	+ 4·107	—0·028
900*	Lock coping stone	2·2	,,	— 0·036	— 0·032	+0·004

* Secondary levelling bench-marks.

20. Howrah to Purbasthali.—In 1929–30 a line of secondary levelling was carried out from Uttarpara to Kalna, at the request of the Commissioners for the Port of Calcutta to determine the heights of the special types of bench-marks built by them along the west bank of the Hooghly river.

These bench-marks consist of a stone monolith 10 inches square and 2 feet high, the upper 3 inches which project above ground-level being dressed to the form of a frustum of a pyramid terminating in a square of 3-inch side. The lower 1 foot 9 inches is built in a masonry platform 3 feet 4 inches square and 3 feet high. It is surrounded by a masonry wall $3\frac{1}{3}$ feet square, 10 inches thick and 1 foot high. The inner enclosure is filled in with earth to a height of about 9 inches above the top surface of the monolith.

These special bench-marks were established to provide permanent height datums for the tide-gauge stations.

Recent levellings carried out from Howrah to Diamond Harbour and Dublat had revealed sinkages of local bench-marks which were quite significant in magnitude and the Port Commissioners considered that it would be worthwhile relevelling the line from Uttarpara to Kalna as well and further to extend it to Purbasthali.

Of late, it has been decided that Kidderpore New Dock Sill B.M. 359/79 B shall be the datum in terms of which all heights for the use of Commissioners for the Port of Calcutta will be reduced. It was, therefore, considered desirable that the revision levelling be carried out from Howrah instead of from Uttarpara and that the entire line should be observed to a higher precision than before.

The work was undertaken towards the end of February 1950 by Mr. S. Vaikuntanathan (Class II) using a C.T.S. Geodetic Level with parallel plate attachment and a pair of invar staves.

The levelling was commenced from standard bench-mark No. 918/79 B at Howrah and closed on bench-mark No. 318/79 A (concrete block) at Purbasthali.

The first 8 miles were carried out by Mr. S. Vaikuntanathan himself both in the fore and back directions. Then he was joined by Mr. A. K. Bhattacharjee (Class II) and the next 16 miles were levelled in sections of 4 miles each, Mr. Bhattacharjee observing in the fore direction and Mr. Vaikuntanathan in the back direction. After that Mr. M. M. Sobti (Trig. Computer) replaced Mr. Vaikuntanathan.

Table 5 gives the list of bench-marks common to the new levelling and high precision levelling carried out in 1947–48 from Burdwān to Howrah. The differences are fairly small and consistent.

Table 6 gives the comparative statement of the differences in heights of bench-marks on this line which are common to the 1929-30 levelling and the new levelling. Although some of the Port Commissioner's bench-marks have changed their height, the amount of the change is generally small.

TABLE 5.—*Comparison of common bench-marks connected in 1947–48 and in 1950 on line Howrah to Purbasthali*

B.M. No.	Description	Distance from B.M. No. 359/79 B	Observed height above (+) or below (−) B.M. No. 359/79 B at Kidderpore New Dock		Discrepancy (New–Old)
			(Old) H.P. levelling 1947–48	(New) Revised levelling 1950	
Sheet 79 B		*Miles*	*feet*	*feet*	*feet*
359	Kidderpore New Dock ..	0·0	0·000	0·000	0·000
918	Howrah, (Type 'M') ..	6·7	+ 2·972	+ 2·972*	0·000
870	Stone	13·1	+ 7·748	+ 7·772	+0·024
(*326*)					
447	Uttarpara, (Type 'A') ..	13·6	+ 2·909	+ 2·931	+0·022
906(S)	Konnagar bathing ghāt ..	17·2	+ 1·026	+ 1·063	+0·037
(*330*)					
850(S)	Railway bridge ..	23·4	+ 8·298	+ 8·367	+0·069
855(S)	Stone	23·5 ..	+ 9·334	+ 9·401	+0·067
854(S)	Coping	23·6	+10·723	+10·789	+0·066
853(S)	Coping	23·7	+10·570	+10·640	+0·070
334	Bridge	24·3	+ 6·080	+ 6·156	+0·076
914(S)	Champadāni, (Type 'A')..	26·6	+ 6·594	+ 6·651	+0·057
(*428*)					
421	Flooring	30·0	+ 9·991	+10·036	+1·045
420	Step	30·6	+ 9·153	+ 9·208	+0·055
419	Stone	30·7	+ 7·741	+ 7·797	+0·056
927(S)	Flooring	35·2	+11·271	+11·311	+0·040
(*415*)					
926(S)	Step	35·7	+13·641	+13·672	+0·031
(*413*)					
410	Base of pedestal ..	36·1	+13·161	+13·205	+0·044
929(S)	Chinsura, (Type 'B') ..	36·2	+11·673	+11·712	+0·039
(*344*)					
352	Tribenighāt, (Type 'B') ..	46·2	+11·233	+11·181	−0·052

* From levelling of 1947–48.

TABLE 6.—*Old and new levelling from Howrah to Purbasthali*

B M. No.	Brief description	Distance from B.M. No. 359/79 B	Date of old levelling	Observed height above (+) or below (−) B.M. No. 359/79 B at Kidderpore New Dock		Discrepancy (New−Old)
				Old levelling (Secondary)	Revised levelling 1950	
Sheet 79 B		*Miles*		*feet*	*feet*	*feet*
359	Kidderpore New Dock	0·0	1881–83	0·000	0·000	0·000
447	Uttarpāra (Type A)	13·6	1913–17	+ 2·953*	+ 2·918	−0·040
906(S) (*330*)	Stone ..	17·2	1929–30	+ 1·071	+ 1·050	−0·021
907(S)	P.C.B.M. No. 1 (Type M)	18·6	,,	+ 1·043	+ 0·919	−0·124
909(S)	P.C.B.M. No. 3 ..	20·7	,,	+ 7·118	+ 7·096	−0·022
910(S)	P.C.B.M. No. 4 ..	22·1	,,	+ 5·933	+ 5·822	−0·111
911(S)	P.C.B.M. No. 5 ..	23·2	,,	+ 4·942	+ 4·962	+0·020
912(S)	P.C.B.M. No. 6 ..	26·2	,,	+ 3·881	+ 3·872	−0·009
913(S)	P.C.B.M. No. 7 ..	26·1	,,	+ 1·863	+ 1·024	−0·039
914(S)	Champādāni (Type 'A')	26·7	,,	+ 6·648	+ 6·638	−0·010
916(S)	P.C.B.M. No. 8 ..	27·1	,,	+ 9·109	+ 9·095	−0·014
917(S)	P.C.B.M. No. 9 ..	28·0	,,	+ 7·918	+ 7·928	+0·010
918(S)	P.C.B.M. No. 10 ..	29·4	,,	+ 3·144	+ 3·004	−0·140
919(S)	P C.B.M. No. 11 ..	30·4	,,	+ 2·338	+ 2·272	−0·066
922(S)	Cement platform ..	31·5	,,	+ 8·701	+ 8·703	+0·002
921(S)	Step	31·5	,,	+ 3·420	+ 3·438	+0·018
920(S)	Step	31·5	,,	+ 5·453	+ 5·465	+0·012
925(S)	Stone flooring ..	32·1	,,	+ 9·651	+ 9·644	−0·007
924(S)	Stone flooring ..	32·2	,,	+10·068	+10·115	+0·047
923(S)	Stone	32·2	,,	+10·223	+10·234	+0·011
927(S) (*415*)	Flooring ..	35·2	,,	+11·291	+11·298	+0·007
414	Seat of gate ..	35·5	,,	+13·343	+13·368	+0·025
928(S) (*413*)	Step	35·7	,,	+13·695	+13·659	−0·036
410	Base of pedestal ..	30·1	,,	+13·159	+13·192	+0·033
929(S) (*344*)	Chinsura (Type 'B')	36·2	,,	+11·691	+11·699	+0·008
411	Slab	36·5	,,	+11·022	+11·036	+0·014
408	Culvert	37·9	,,	+11·022	+11·070	+0·048
930(S) (*407*)	Plinth	38·4	,,	+12·699	+12·714	+0·015
347	Coping	38·6	,,	+15·198	+15·246	+0·048
860(S) (*348*)	Step	38·9	,,	+18·091	+18·130	+0·039
931(S) (*405*)	Bāndel (Type 'B')..	39·6	,,	+ 7·271	+ 7·311	+0·040
933(S)	P.C.B.M. No. 18 ..	41·5	,,	+14·928	+14·945	+0·017
934(S)	P.C.B.M. No. 19 ..	42·7	,,	+ 2·354	+ 2·379	+0·025

(*Continued*)

* Value obtained from old H.P. levelling.

TABLE 6.—*Old and new levelling from Howrah to Purbasthali*—(concld.)

B.M. No.	Brief description	Distance from B M 359/79 B	Date of old levelling	Observed height about (+) or below (−) B.M. No 359/79 N at Kidderpore New Dock		Discrepancy (New − Old)
				Old levelling (Secondary)	Revised levelling 1950	
Sheet 79B		*Miles*		*feet*	*feet*	*feet*
350	Marble plaque ..	43·0	1929–30	+16·900	+16·913	+0·013
936(S) (*351*)	Step	44·5	,,	+22·088	+22·234	+0·146
931(S)	Bridge	45·1	,,	+24·078	+24·017	−0·061
932(S)	Stone coping ..	45·6	,,	+19·282	+19·221	−0·061
935(S)	P.C.B.M. No. 20 ..	43·5	,,	+15·349	+15·605	+0·256
937(S) (*352*)	Tribenighāt, (Type 'B')	46·3	,,	+11·133	+11·168	+0·035
291(S)	Bridge	49·4	,,	+27·805	+27·712	−0·093
Sheet 79 A						
269(S)	P.C.B.M. No. 21 ..	50·2	,,	+ 2·051	+ 1·887	−0·164
270(S)	P.C.B.M. No. 22 ..	51·8	,,	+14·688	+14·747	+0·059
295(S)	Bridge	54·5	,,	+15·775	+15·647	−0·128
271(S) (*12*)	Step	55·5	,,	+17·210	+17·263	+0·053
272(S) (*13*)	Marble slab ..	55·5	,,	+17·468	+17·483	+0·015
273(S)	P.C.B.M. No. 24 ..	56·8	,,	+ 3·549	+ 3·544	−0·005
274(S) (*14*)	Marble slab ..	57·4	,,	+ 7·126	+ 7·095	−0·031
17	Balagarh, (Type 'B')	60·1	,,	+ 7·352	+ 7·357	+0·005
299(S)	Stone	62·8	,,	+17·266	+17·064	−0·202
300(S)	Bridge	64·3	,,	+18·328	+18·237	−0·091
275(S)	P.C.B.M. No. 25 ..	64·0	,,	+ 6·466	+ 6·504	+0·038
276(S)	P.C.B.M. No. 26 ..	67·0	,,	+ 4·361	+ 4·324	−0·037
277(S)	P.C.B.M. No. 27 ..	70·2	,,	+ 8·764	+ 8·657	−0·107
278(S)	Step ..	75·7	,,	+ 26·345	+26·292	−0·053
279(S)	Pavement ..	76·4	,,	+23·637	+23·570	−0·067
280(S)	Flooring, Kalna ..	77·7	,,	+24·933	+24·973	+0·040
281(S) (*25*)	Flooring ..	77·7	,,	+25·876	+25·853	−0·023
308(S)	Culvert	81·8	,,	+21·943	+21·819	−0·124
309(S)	Concrete block ..	82·3	,,	+24·242	+24·120	−0·122
311(S)	Bridge	84·7	,,	+24·361	+24·352	−0·009
312(S)	Concrete block ..	86·3	,,	+23·878	+23·766	−0·112
315(S)	Stone coping, Nabadwip R.S. ..	91·3	,,	+23·941	+24·822	+0·881

21. **Kosi Levelling.**—Secondary levelling in the Kosi area of Bihār was carried out from Kishanganj in Purnea district to Harpur in Darbhanga district for the purpose of providing height control for Kosi Irrigation Project (See Chart VIII).

Detachment No. 3 consisting of Messers R. K. Gupta and J. Narasimham as levellers with 13 *khalāsīs* commenced work on the 15th October 1949 from B.M. No. 27/72 N at Kishanganj, and detachment No. 4 consisting of Messrs Avinash Chandra and T. K. Vishvanathan as levellers and 13 *khalāsīs* commenced work from Pratāpganj on 17th October.

It was originally intended that No. 4 levelling detachment would commence work from Diwānganj T.S. (Latitude 26° 16′ 49″·97, longitude 86° 54′ 21″·55), a geodetic station of N.E. Longitudinal Series. The height of the original tower was 20 feet, but when it was visited by a levelling detachment in April 1934, the height was found to be 14 feet, the upper six feet having crumbled away and the mark-stone at a height of about 12 feet was connected by spirit-levelling.

When visited by No. 4 levelling detachment in 1949 the pillar was found to be only 5 feet high with a mark-stone, having a circle and dot cut on it on the top, which was connected by levelling. Apparently this was not the mark connected by levelling detachment in 1934. Hence the work was commenced from bench-mark No. G.T.S.
59/72J ○ on stone which was found on check-levelling to B.M.
have maintained its height satisfactorily.

The two detachments effected a connection at Mahachanda on 14th December. Thereafter detachment No. 4 was transferred to Gandak area, and detachment No. 3 continued levelling towards Purnea. The work was finally closed on B.M. 136 PP/72 J at Harpur on 8th June 1950.

The levelling was carried out both in the fore and back directions in sections of 8 miles, each section being sub-divided into 4 sub-sections of 2 miles each. These sub-sections were levelled first by the fore-leveller in the morning and in the afternoon till the 8-mile section was completed. The back leveller then followed the same procedure of observation for the 8-mile section from the opposite direction, levelling in the afternoon the sections done in the morning by the fore leveller and vice versa. This was done to ensure that the two observers observed the same sections under different atmospheric conditions.

The routes generally available were cart-tracks, mule and foot-paths which remained under knee-deep stagnant water and mire at many places till the beginning of November. The country is fairly plain and open but is full of water channels, a few of which only are bridged. Boats are not easily available. The only means of land transport is bullock carts obtainable either directly through the

villagers or through the help of local officials. In the area ravaged by the Kosi river, there existed no road or track except foot-paths zigzagging through thick forests of high grass interspersed with unfordable water channels. No transport was available. Local cultivators were persuaded with great difficulty to act as labourers for shifting the camp from place to place.

Apart from a standard bench-mark at Purnea No. 348/72 O and a primary protected bench-mark at Harpur T.S.—No. 136/72 J, a number of inscribed bench-marks on railways and road culverts were also connected. A few tower stations, viz., Masaldanga T.S., Mānikpur T.S. and Mohania T.S. of the North Maluncha Meridional Series were included in the levelling.

The whole area of this project is highly malarious. There were some cases of dysentery also.

As would appear from Chart VIII the levelling work in the Kosi area, described above comprises two closed circuits, viz :—

(i) Kishanganj – Raghopur – Srinagar – Sara Bathna –Kishanganj and

(ii) Raghopur – Srinagar – Madhipura – Tribeniganj – Mahachanda– Raghopur,

and the two branch lines from Madhipura to Harpur T.S. and Tribeniganj to Diwānganj.

The first closed circuit yielded an error of $-0{\cdot}120$ feet over a distance of 126 miles and the second $+\ 0{\cdot}088$ feet in 110 miles.

As usual the published height of old bench-marks at Kishanganj, Purnea and Harpur have been retained, and the new levelling has been adjusted on to these values. The corrections applied to the various sections are as follows:—

Purnea to Kishanganj (51 miles) $+\ 0{\cdot}204$ feet, Kishanganj to Sara Bathna (83 miles) $-\ 0{\cdot}051$ feet, Srinagar to Harpur (110 miles) $-\ 0{\cdot}429$ feet, Diwānganj to Raghopur (45 miles) $+\ 0{\cdot}145$ feet and Madhipura to Tribeniganj (19 miles) $-0{\cdot}029$ feet.

In 1946–47 No. 9 Party, Eastern Circle, Survey of India carried out some tertiary levelling for providing height control for their surveys in the area and connected some bench-marks of the old high precision levelling line 151 B. This line was run after the Bihār earthquake in 1934–36. Unfortunately no permanent bench-marks were established on this line and bench-marks connected by tertiary levelling were mostly on edges of wells. The heights of some of these bench-marks as derived by the tertiary levelling were significantly different from their heights by the 1934–36 levelling and consequently some of them were included in the new secondary levelling. The results are given in Table 7 and indicate that the levelling carried out by No. 9 Party correctly detected the changes in the heights of these bench-marks, which being on wells were liable to disturbance.

TABLE 7.—*Showing old and new values of bench-marks on line 151 B*

Topo. No. of Bench-mark	Brief description	Distance from initial B.M.	Observed height above initial bench-marks			Discrepancy		Orthometric Height			Difference (1949–50) *minus* (1946–47)
			Old 1934–36	E.C. 1946–47	G.T.C. 1949–50	(E.C. *minus* Old) (5—4)	(G.T.C. *minus* E.C.) (6—5)	1934–36	1946–47	1949–50	
1	2	3	4	5	6	7	8	9	10	11	12
		Miles	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*
59/72 J	Stone	0·0	0·000	0·000	0·000	0·000	0·000	203·201	203·201	203·201	0·000
58/72 J	Well in Bhawanipur	0·5	+ 2·290	+ 2·298	+ 2·310	+ 0·008	+ 0·012	205·402	205·499	205·513	+ 0·014
97/72 N	Well in Madhubani	4·1	+ 3·108	+ 3·095	+ 3·113	− 0·013	+ 0·018	206·330	206·296	206·330	+ 0·034
96/72 N	Well in Jiwachhpur	4·6	+ 4·882	+ 4·890	..	+ 0·008	..	208·107	208·091	..	..
95/72 N	Well in Jiwachhpur	4·7	+ 4·328	+ 4·279	+ 4·309	− 0·049	+ 0·030	207·554	207·480	207·526	+ 0·046
94/72 N	Well in Belāganj ..	6·9	+ 6·206	+ 5·855	..	− 0·351	..	209·445	209·055	..	..
93/72 N	Well in Belāganj ..	7·0	+ 5·202	+ 5·035	+ 5·057	− 0·167	+ 0·022	208·441	208·236	208·274	+ 0·038
87/72 N	Well in Nāthpur Arāzi	11·4	+ 7·036	+ 6·979	..	− 0·057	..	210·299	210·179	..	..
84/72 N	Well near Madhura	13·3	+ 5·916	+ 7·799	..	+ 1·883	..	209·199	210·999	..	..
83/72 N	Well in Thalha ..	14·6	+ 3·925	+ 3·922	..	− 0·003	..	207·208	207·122	..	..
82/72 N	Well in Gauria ..	15·6	+ 2·951	+ 2·844	..	− 0·107	..	206·239	206·044	..	..
128/72 J	Stone	0·0	0·000	0·000	0·000	0·000	0·000	..	..	..	..
127/72 J	Well	0·4	− 6·644	− 7·055	− 7·105	− 0·411	− 0·050	..	..	..	..
126/72 J	Bridge	1·0	− 4·211	− 4·148	..	+ 0·063	..	..	..	..	..
123/72 J	Bridge	3·7	− 4·775	− 4·767	..	+ 0·008	..	..	..	..	..

22. Gandak Levelling.—The secondary levelling in the Gandak project area of Bihār (see Chart IX) was carried out by four detachments to meet the requirements of the Gandak Irrigation Project. Detachment No. 4 consisted of two surveyors Messrs. Avinash Chandra and T. K. Vishvanathan and 13 *khalāsis*, and detachment No. 5 consisted of two surveyors—Messrs. S. Muthukrishnan and D. V. Verma and 13 *khalāsis*. The other two detachments were provided by No. 9 Party of Eastern Circle.

(*a*) *Line I—Padrauna–Muzaffarpur.*—After closing the line Diwānganj–Kishanganj in Kosi area on type B bench-mark at Mahachanda on the 30th November 1949, detachment No. 4 moved over to Gandak area and after doing some check-levelling near Muzaffarpur commenced work from S.B.M. 221 PP/72 F on the 9th December 1949.

The instruments used were Level No. 17783 Wild, Model No. 2 and a pair of Committee pattern staves Nos. 038 A and 038 B.

The system of levelling followed was the same as for Kosi levelling described on page 35.

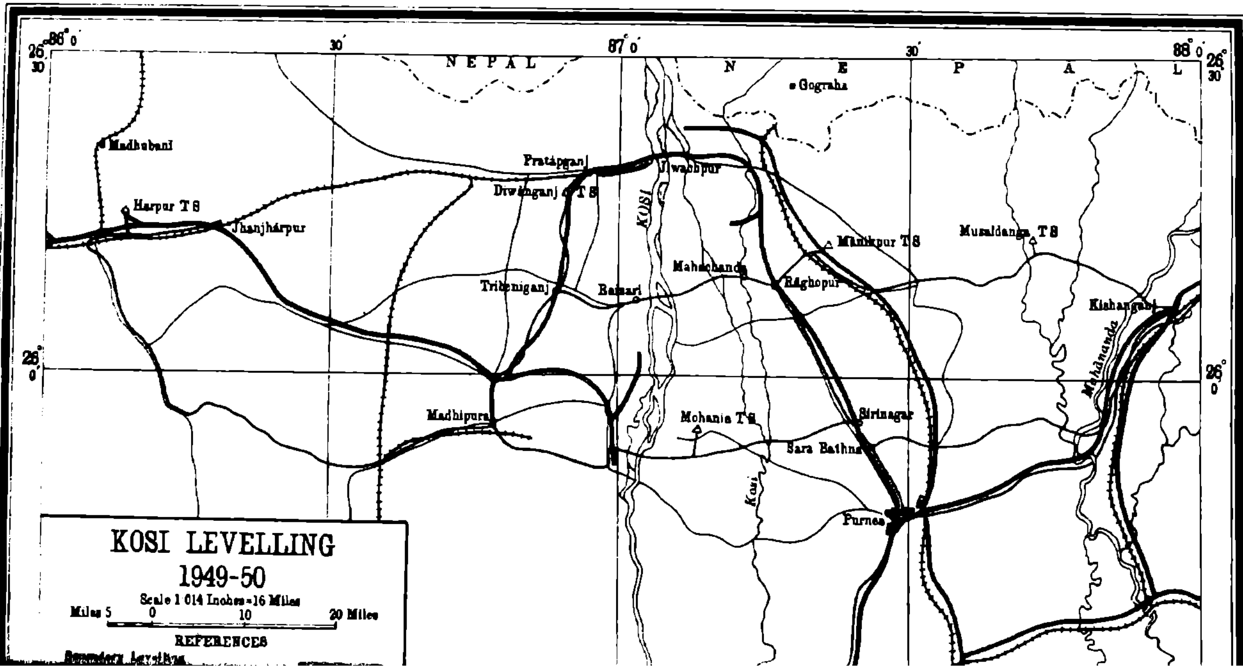
The route followed was the motor road from Muzaffarpur to Hājīpur, thence after crossing the river Gandak over O.T. Railway bridge across to Sonpur along the motor road to Raghunathpur via Chāpra and Gangapur Siswan where junction was effected with detachment No. 5 on type 'B' bench-mark on the 18th February 1950.

Type 'B' bench-marks were established at Karhani, Bhagwānpur, Sarai, Sonpur, Nayagaon, Dighwāra, Sāntha, Mānjhi Ghāt, Gangapur Siswan and Raghunathpur and Type 'M' bench-marks at Hājīpur and Chāpra. These were constructed according to Survey of India specifications under the directions of Superintending Engineer, Gandak Circle, Patna.

Detachment No. 5 started check-levelling at Bagaha on 24th October 1949, connecting bench-marks Nos 52, 139, 140 PP, 141 and 142/72 A and the line continued up to east bank of river Gandak. But since the railway bridge over Gandak at this place was found washed away, the line had to be closed on an inscribed bench-mark on east bank, and the line started afresh from Chhitauni Ghāt R.S. on west bank of Gandak. The bench-marks on the two banks could not be connected as the personnel available had no experience of levelling across rivers. It was, therefore, decided to continue the line to Padrauna where check-levelling was done again connecting bench-marks Nos. 88 to 92, 95, 96/63 N and 152/72 B. The results of check-levelling are tabulated in Table 12.

The results show that bench-marks Nos. 89, 91, 92, 95 and 96/63 N are in order and bench-marks Nos. 88, 90/63 N and 152/72 B have been disturbed. It was, therefore, decided to reduce the heights in terms of bench-mark No. 89/63 N.

The instrument used was Zeiss Level No. 5733 Model No. III with Invar staves Nos. 121 and 122.

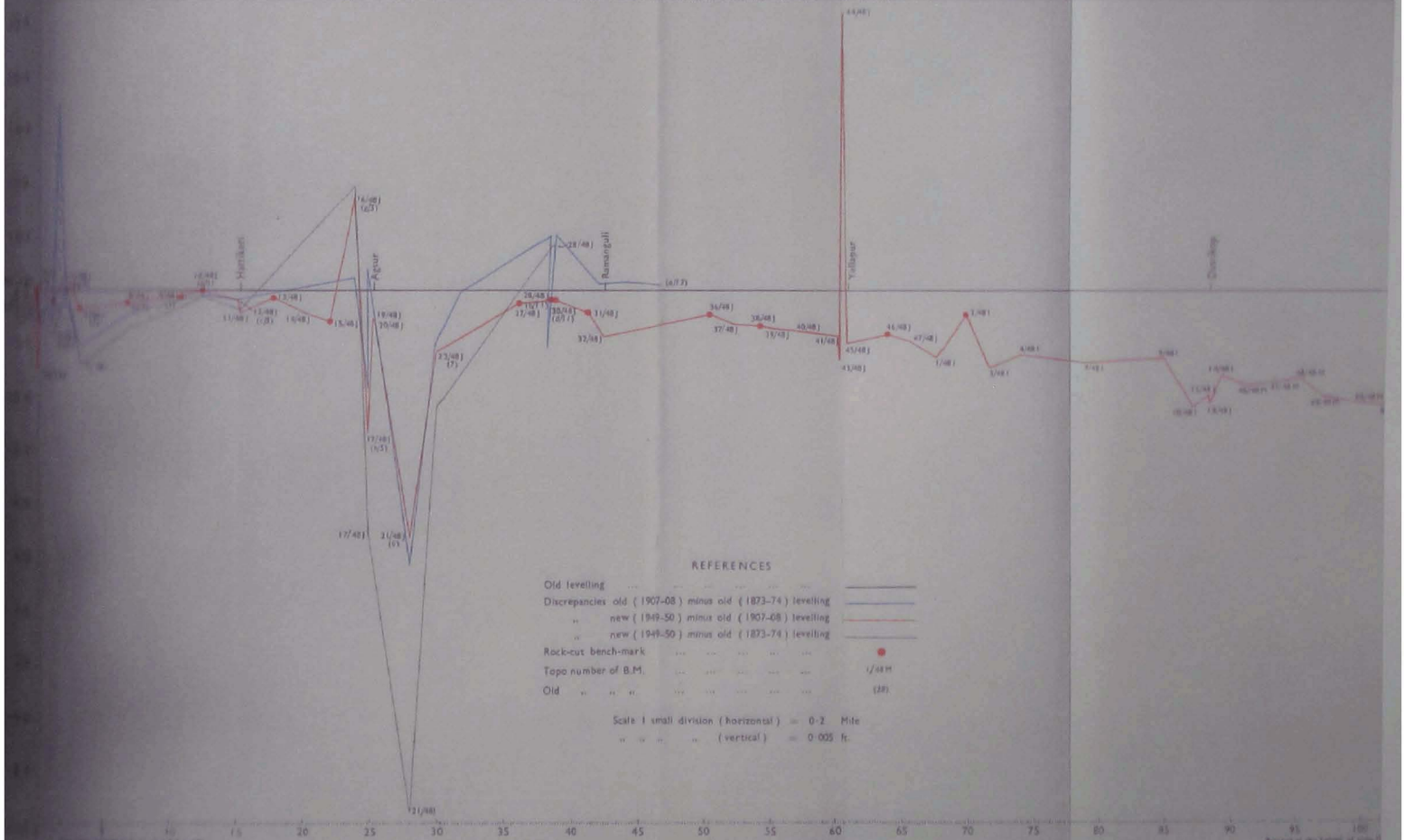


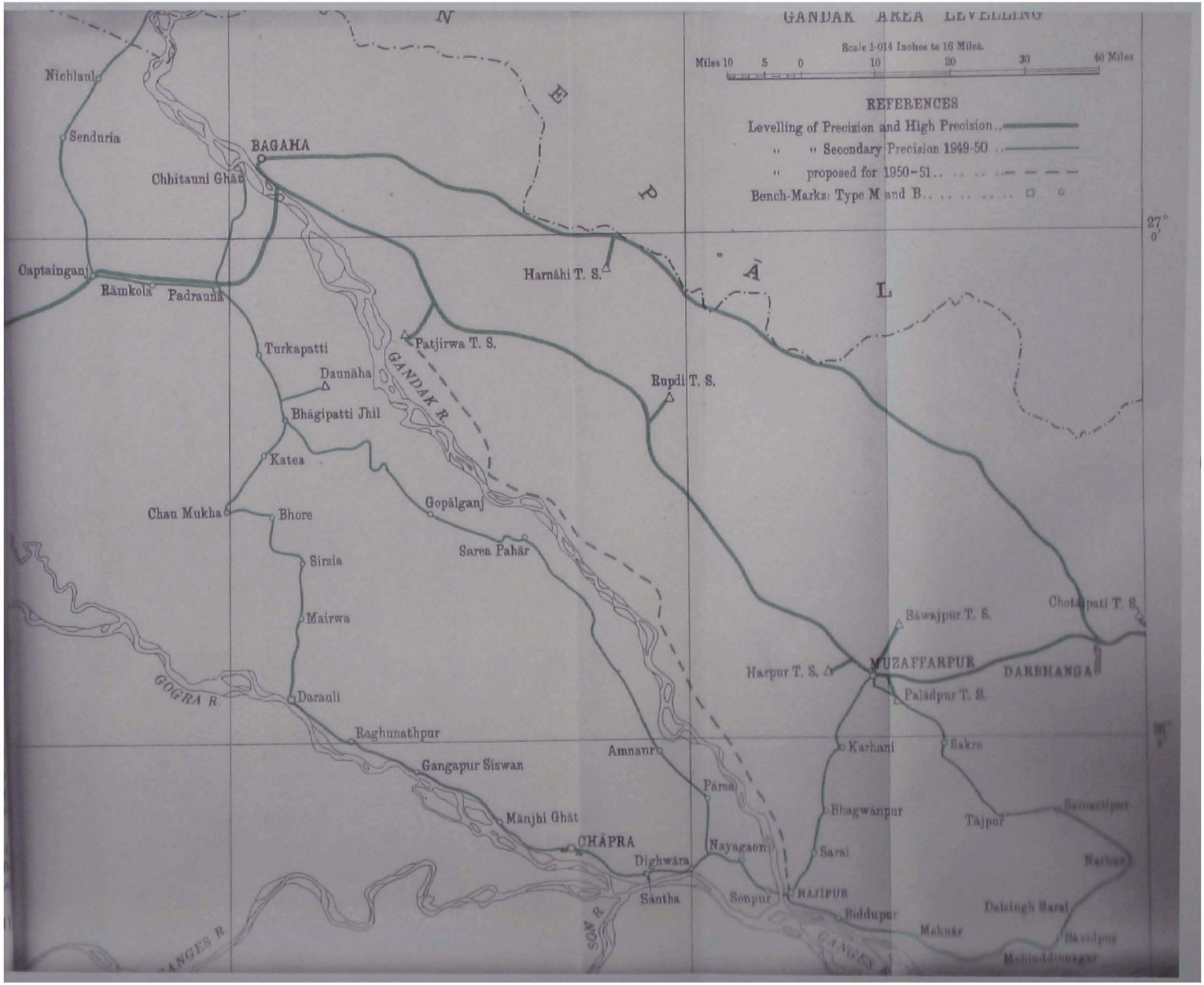
KOSI LEVELLING
1949-50
Scale 1 014 Inches=16 Miles
Miles 5 0 10 20 Miles
REFERENCES
NEPAL
N E P A L
Gograha
Madhubani
Harpur T S
Jhanjharpur
Pratapganj
Diwanganj T S
Jiwachpur
KOSI
Triveniganj
Mahachanda
Raghopur
Manikpur T S
Musaldanga T S
Kishanganj
Mahananda
Madhipura
Mohania T S
Srinagar
Sara Bathna
Kosi
Purnea
86° 0'
87° 0'
88° 0'
30'
26° 30
26° 0

OLD AND NEW LEVELLING

FROM

KĀRWĀR TO HUBLI




GANDAK AREA LEVELLING
Scale 1·014 Inches to 16 Miles.
Miles 10 5 0 10 20 30 40 Miles
REFERENCES
Levelling of Precision and High Precision
" " Secondary Precision 1949-50
" proposed for 1950-51
Bench-Marks: Type M and B
N
E
P
A
L
27° 0'
Nichlaul
Senduria
BAGAHA
Chhitauni Ghāt
Captainganj
Rāmkola
Padrauna
Harnāhi T. S.
Turkapatti
Patjirwa T. S.
Daunāha
GANDAK R.
Rupdi T. S.
Bhāgipatti Jhil
Katea
Gopālganj
Chau Mukha
Bhore
Sarea Pahār
Sirsia
Mairwa
GOGRA R.
Darauli
Raghunathpur
Gangapur Siswan
Amnaur
Pārsa
Mānjhi Ghāt
CHAPRA
Dighwāra
Nayagaon
Santha
SON R.
Sonpur
HAJIPUR
Biddupur
Mahnār
Sawajpur T. S.
Chotāpati T. S.
Harpur T. S.
MUZAFFARPUR
DARBHANGA
Palādpur T. S.
Karhani
Sakra
Bhagwānpur
Tājpur
Sarsastipur
Sarai
Narhan
Dalsingh Sarai
Bāsidpur
Mohiuddinnagar
GANGES R.
GANGES

The line was continued from Padrauna to Raghunathpur along the motor road via Turkapatti, Katea, Bhore, Mairwa and Darauli effecting junction with detachment No. 4 at Raghunathpur type 'B' bench-mark.

Type 'B' bench-marks were established at Turkapatti, Bhāgipatti Jhil, Katea, Chau Mukha, Bhore, Sirsia, Mairwa and Raghunathpur and type 'M' bench-marks at Padrauna and Darauli. These were also constructed under the direction of the Superintending Engineer, Gandak Circle, Patna, according to Survey of India specifications.

The discrepancy between the heights of type 'B' bench-mark at Raghunathpur obtained independently by the two detachments was 0·632 feet.

The total distance from Padrauna to Muzaffarpur is about 200 miles and for purposes of computations and adjustment of error this portion of the line has been treated as a single continuous line from Padrauna to Muzaffarpur and the portion Padrauna to Chhitauni Ghāt R. S. as a branch line. The closing error of 0·611 feet, which is the excess of reduced height of S.B.M. No. 221 PP/72 F over its published height has been distributed proportionate to distance.

For transport detachment No. 4 had to engage bullock carts and detachment No. 5 had the use of a jeep, which the Superintending Engineer, Gandak Circle Patna, very kindly placed at their disposal. Food stuff and vegetables, etc., could be procured without much difficulty in the area.

The health of the detachment was good throughout but for occasional cases of malaria. Few sporadic cases of cholera, plague and small pox were reported in the area and later these broke out in an epidemic form in some localities. All the precautionery measures for appropriate inoculations of the personnel were taken in good time.

(*b*) *Line II—Muzaffarpur to Hājīpur.*—After effecting junction at Raghunathpur on Gandak priority I line on 18th February 1950, detachments Nos. 4 and 5 moved over to priority II line to meet the requirements of the Gandak Irrigation Project.

Detachment No. 4 commenced work from the standard bench-mark at Muzaffarpur on 25th February 1950, the stability of which having been already ensured by check-levelling while working on priority I line.

The route followed was the motor road from Muzaffarpur to Pusa up to about the 12th mile stone and then southwards along the cart-track to Shakra–Faridpur, thence along the road via Tājpur–Samastipur and Narhan R.S. to Dalsing Sarai, where junction was effected with detachment No. 5 at type 'B' bench-mark on the 14th April 1950.

Since the type 'B' bench-marks at Tājpur and Narhan and type 'M' at Samastipur had not been constructed when the detachment

passed working through these places, the detachment had to proceed with the work leaving three inscribed bench-marks at each of these places. After effecting junction with detachment No. 5 at Dalsing Sarai each one of these permanent bench-marks was connected to the group of the three inscribed bench-marks of the main-line.

These permanent bench-marks were constructed according to Survey of India specification under the direction of the Superintending Engineer, Gandak Circle, Patna.

Detachment No. 5 commenced work on the line from Type 'M' bench-mark at Hājīpur on the 28th February 1950 and working along unmetalled road from Hājīpur to Dalsing Sarai via Biddupur, Mehnār, Baghra, Mohiuddinnagar and Bāxidpur effected junction with detachment No. 4 on the 14th April 1950 at type 'B' bench-mark at Dalsing Sarai.

Type 'B' bench-marks were established at Biddupur, Mehnār, Baghra, Bāxidpur and Dalsing Sarai and type 'M' bench-mark at Mohiuddinnagar.

After completing the line upto Dalsing Sarai, detachment No. 5 moved over to Ramkola to Commence work on line from Captainganj to Tribeni Ghāt.

For transport, bullock carts were used by detachment No. 4 and the jeep with its trailer by detachment No. 5.

Health of the detachments remained satisfactory.

The closed circuit taken from standard bench-mark 221 PP/72 F at Muzaffarpur to type 'M' bench-mark at Hājīpur and from Hājīpur to Muzaffarpur via Dalsing Sarai and Samastipur yielded an error of 0·069 feet in a distance of about 152 miles and this has been distributed proportionate to the distance.

Captainganj to Tribeni Ghāt :—After effecting connection with detachment No. 4 at Dalsing Sarai detachment No. 5 proceeded to Captainganj and carried out further check-levelling on the old line 151 B. Connection to the new type 'M' bench-mark was from B.M. No. 102/63N and levelling was carried forward to Tribeni Ghāt.

From Senduria to Nichlaul levelling was carried out exactly on the alignment of the canal and permanent marks such as culverts, wells have been chosen for bench-marks. From Nichlaul levelling was done cross country and only trees were available for making bench-marks. The levelling closed on type 'M' bench-mark at Tribeni Ghāt on 10th June 1950.

For transport, the detachment had to depend solely on bullock-carts. In Nepal, the non-availability of carts due to harvest time, and the non-existence of any roads except cart-tracks which were rendered unsafe for the movement of carts due to setting in of monsoon made camp shifting really difficult.

The health of the detachment was fairly good during the period.

OLD and NEW LEVELLING
From
BAGAHA TO PURNEA

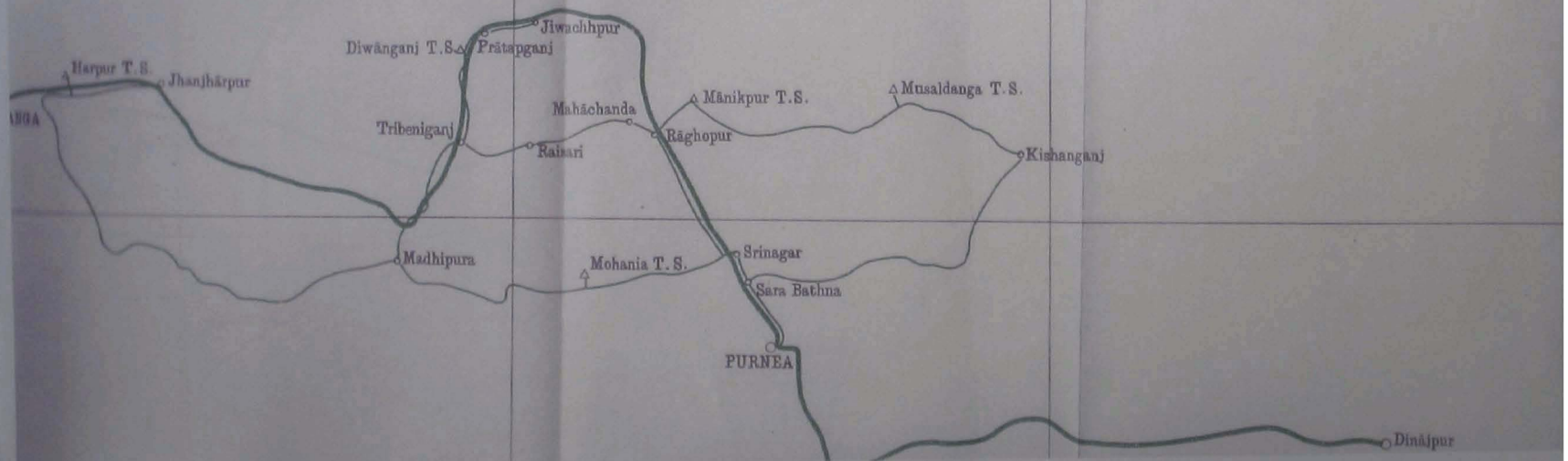
Scale 1·014 Inches to 16 Miles.

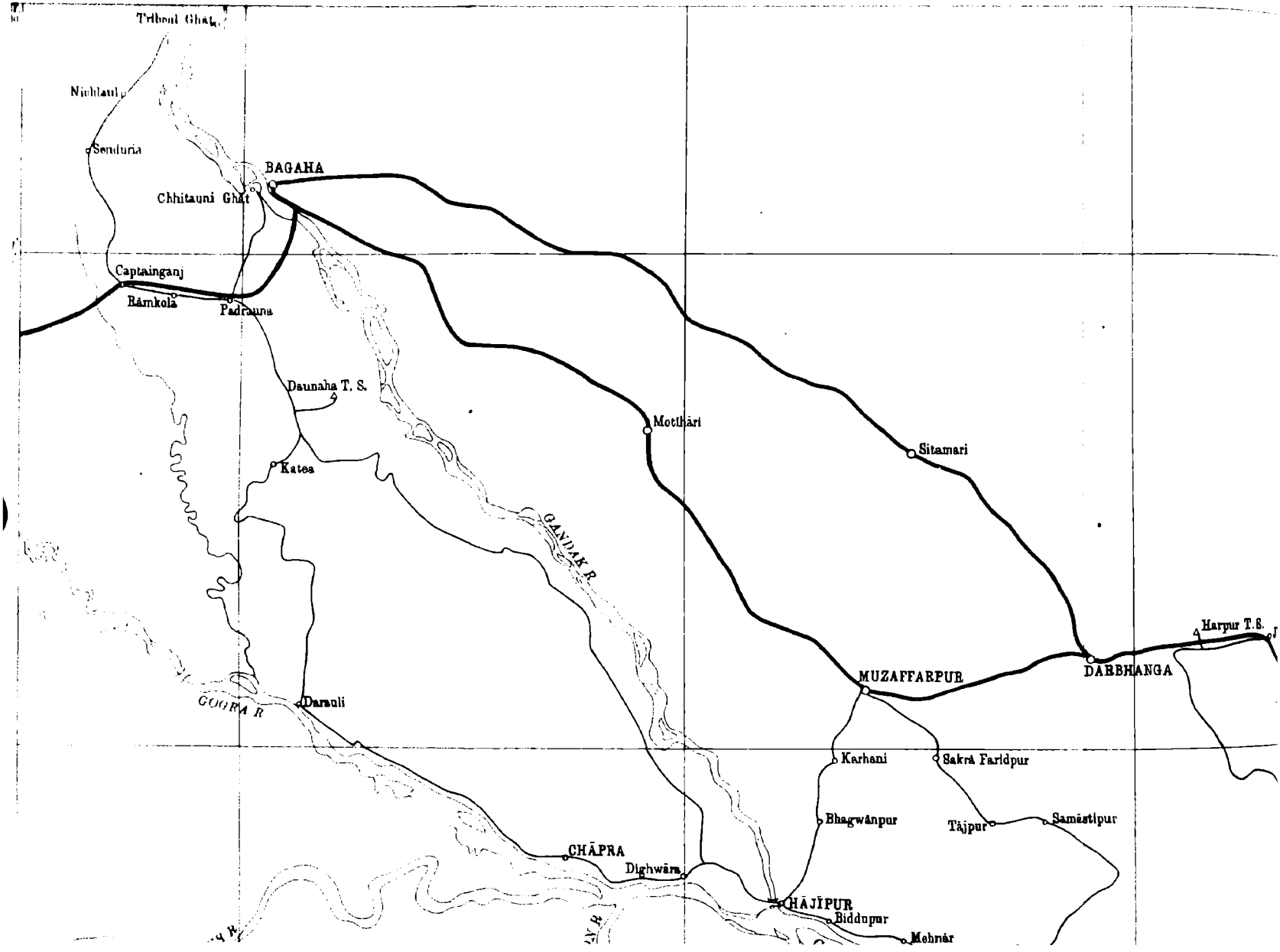
Miles 10 5 0 10 20 30 40 M

REFERENCES

Levelling of Precision and High Precision .....

" Secondary Precision 1949-50 .....




Tribeni Ghat
Nichlaul
Senduria
BAGAHA
Chhitauni Ghat
Captainganj
Rāmkolā
Padrauna
Daunaha T. S.
Motihāri
Sitamari
Katea
GANDAK R.
Harpur T.S.
MUZAFFARPUR
DARBHANGA
GOGRA R.
Daraulī
Karhani
Sakrā Faridpur
Bhagwānpur
Tājpur
Samastipur
CHĀPRA
Dighwāra
HĀJĪPUR
Biddupur
Mehnār

(c) *Line III.*—A line of levels from Dighwāra to Bhāgipatti along the south-west bank of the Gandak was run by two detachments of 11 Party.

The first detachment commenced work on 18th December 1950 from the reference pillar of the new Type 'B' bench-mark at Bhāgipatti on the Padrauna–Muzaffarpur's secondary levelling line described above. No check-levelling was carried out at Bhāgipatti as the bench-mark had only recently been built and could not have been disturbed.

The instruments used were Watt pattern level No. 402 (Cooke Troughton & Simms, Ltd.) and tertiary levels No. C.T.S. 34307 and Committee pattern wooden staves Nos. 06 B and 040 B. The system of levelling followed was simultaneous double levelling, the discrepancy between the two levellers at any station being limited to 0·007 feet. The maximum permissible discrepancy between the middle wire reading and the mean of the three wire readings was 0·003 feet. The length of the shot was kept within 7 chains. The route followed was the unmetalled road from Bhāgipatti to Jalalpur R.S., thence to Gopālganj via Sasamusa R.S. and then on the unmetalled road along the south-west bank of the Gandak to Sonwalia village where junction was effected with the second detachment on 12th January 1950.

The second detachment commenced work from type 'B' bench-mark at Dighwāra on the Padrauna–Muzaffarpur secondary levelling line on 10th December 1949. No check-levelling was carried out as the bench-mark had only recently been built. Moreover a branch-line was run from Dighwāra to connect the new Type 'B' bench-mark at Nayagaon on the Padrauna–Muzaffarpur secondary levelling line. Working along the unmetalled road along the west bank of the Gandak via Amnaur the detachment effected junction with the detachment working from Bhāgipatti on 12th January 1950 at Sonwalia village.

The instruments used were tertiary levels Nos. C.T.S. 34236 and 34252 and the staves were of Committee pattern, viz., Nos. 16 A and 16 B.

The line yielded a closing error of-0·705 over a distance of 107 miles and this has been distributed proportionate to distance. The probable accidental error computed from the formula 0·6745 works out to 0·0042 feet per mile.

In addition to the above lines a secondary levelling line from Hājīpur to Patjirwa along the NE. bank of the Gandak is contemplated to be run by Eastern Circle in 1950–51.

23. **Height of Standard Bench-mark at Purnea.**—The secondary levelling carried out in the Kosi and Gandak areas described in paras 21 and 22 above, and the old levelling of 1934–36 between Bagaha and Dinājpur have been shown on Chart X.

In the discussion of the results of the levelling carried out in 1934–36 after the Bihār earthquake in Geodetic Report, 1936,

Chapter VIII, it is concluded that the heights of Bagaha and Dinājpur were not seriously disturbed by the 1934 earthquake but that in between permanent bench-marks had undergone serious changes of height as shown in the table below :—

TABLE 8.—*Old and new levelling from Bagaha to Purnea*

Bench-marks of the original levelling that were connected during the revisionary operations			Distance from starting bench-mark	Difference between orthometric height, above (+) or below (−) the starting bench-mark			Difference (revision − original). The sign + denotes that the height was greater at the time (1934) than when originally levelled
No.	Degree sheet	Description		Date of original levelling	From published heights	From revision 1934	
			miles		*feet*	*feet*	*feet*
Revision of part of line 71 (Gorakhpur–Purnea)							
51	72 A	E.B.M. at Bagaha R.S. ..	0·0	1920–21	0·000	0·000	0·000
5	,,	Bakwa T.S. ..	13·9	1870–72	− 6·089	− 6·269	−0·180
4	72 B	Patjirwa T.S. ..	44·6	,,	− 30·294	− 30·713	−0·419
25	,,	S.B.M., Motihari ..	75·0	1909–10	− 72·876	− 74·509	−1·633
18	,,	Rūpdi ..	79·2	1870–72	− 77·105	− 81·692	−4·587
8	72 F	Harpur T.S. ..	131·5	,,	−114·478	−115·205	−0·727
52	,,	S.B.M. Muzaffarpur	128·0	1909–10	−115·589	−116·301	−0·712
14	,,	Sāwajpur T.S. ..	138·0	1870–72	−115·500	−117·848	−2·348
16	,,	Palādpur T.S. ..	134·3	,,	−116·776	−118·644	−1·868
246 (*56*)	,,	E.B.M. at Darbhanga R.S. ..	166·3	1920–21	−135·508	−137·436	−1·928
347 (*49*)	,,	Chotsipati T.S. ..	170·5	1870–72	−135·978	−137·156	−1·178
136 (*11*)	72 J	Harpur T.S. ..	180·2	,,	−128·635	−130·620	−1·985
344(*168*)	72 Q	E.B.M. at Purnea R.S. ..	319·6	1899–1900	−165·076	−165·325	−0·249
348(*177*)	,,	S.B.M. at Purnea ..	323·0	1930–31	−169·378	−169·911	−0·533

A direct connection of Bagaha and Purnea by the new secondary levelling which followed a different route from the 1934–36 one, would have afforded a very valuable check on the old levelling but this was not possible. The iron bridge over the Gandak near Bagaha was found to have been washed away, so the levelling from Muzaffarpur could only be taken to the south bank of the river opposite Bagaha.

On the eastern end levelling from Purnea could be carried only up to Harpur after the detachment had been in the field for about 9 months and due to bad weather conditions it became impossible to take any further observations. Consequently Harpur could not be connected to Muzaffarpur.

The following table gives the observed difference of height between Padrauna and Muzaffarpur and that between Harpur and Purnea by the new and old levellings :—

From	To	Distance	Observed difference of height			Difference	
			By 1870–72 and 1930–31 levelling	By 1934–36 levelling	By 1949–50 Sec. levelling	(6—4)	(6—5)
1	2	3	4	5	6	7	8
		miles	*feet*	*feet*	*feet*	*feet*	*feet*
B.M. No. 89/63 N at Padrauna	B.M. No. 221 PP/72 F at Muzaffarpur	197·25	..	−105·494	−105·319	..	+0·175
B.M. No. 348 PP/72 O at Purnea	B.M. No. 136 PP/72 J at Harpur	131·01	+40·593	+ 40·098	+ 39·725	−0·868	−0·373

The new levelling confirms the difference of height between Padrauna and Muzaffarpur as obtained by the 1934–36 levelling, but indicates a rise in the height of Purnea relative to Harpur T.S. As a results of the 1934–36 levelling corrections of −0·712, −1·928 and −0·533 feet were applied to the pre-earthquake heights of S.B.M. Muzaffarpur, Harpur T.S. and S.B.M. Purnea. The new levelling shows that these corrections were justified although the magnitude of the correction applied to the height of S.B.M. Purnea was possibly on the lower side. This, however, cannot be regarded as conclusive and for adjustment of the present secondary levelling the post earthquake height of the standard bench-mark at Purnea has been accepted. The check-levelling (see Table 12) shows that inscribed bench-marks at these places have maintained their heights relative to the permanent bench-marks since 1936.

24. **Narbada Levelling.**—Secondary levelling in Madhya Pradesh was carried out to provide height control for the Upper and Lower Narbada Division of C.W.I.N.C. in connection with different irrigation projects, the work being extra departmental and paid-for.

Lines from Bir (G.I.P. Rly.) to village Chikdaria and from Timurni (G.I.P. Rly.) to Makrai were run for the Lower Narbada Division, and line from Hoshangābād to Jubbulpore was run for the Upper Narbada Division.

One line of about 26 miles starting from Jubbulpore was run to connect Ballār H.S. to determine the error in the trigonometrical height of this station.

The levelling was carried out by a detachment under Mr. S. N. Nandi (Surveyor), assisted by Mr. M. L. Sahdev (Surveyor) and 13 *khalāsīs* which left Dehra Dūn on the 15th October 1949 and reached Bir on the 17th October. The work was started on the 19th October from B.M.146/55 B and closed on a new type 'B' bench-mark at Chikdaria on 8th November 1949.

On the 11th November 1949 the detachment took up the levelling of the other branch-line from Timurni to Makrai. The work was commenced from B.M. No. 196/55 F at Timurni and closed on a new type 'M' bench-mark at Makrai.

The detachment then moved to Hoshangābād and started work there on 13th December 1949 from B.M. 87 PP/55 F and closed on type 'M' B.M. No. 104/55 M at Jubbulpore on 3rd June 1950. After doing some check-levelling at Jubbulpore, the levelling was carried to Ballār H.S. This line was completed on 29th June 1950. After doing further check-levelling at Jubbulpore the detachment returned to Dehra Dūn on the 11th July 1950.

Wild Level No. 21201, Model II and Committee pattern wooden staves Nos. 020 A and 020 B were used.

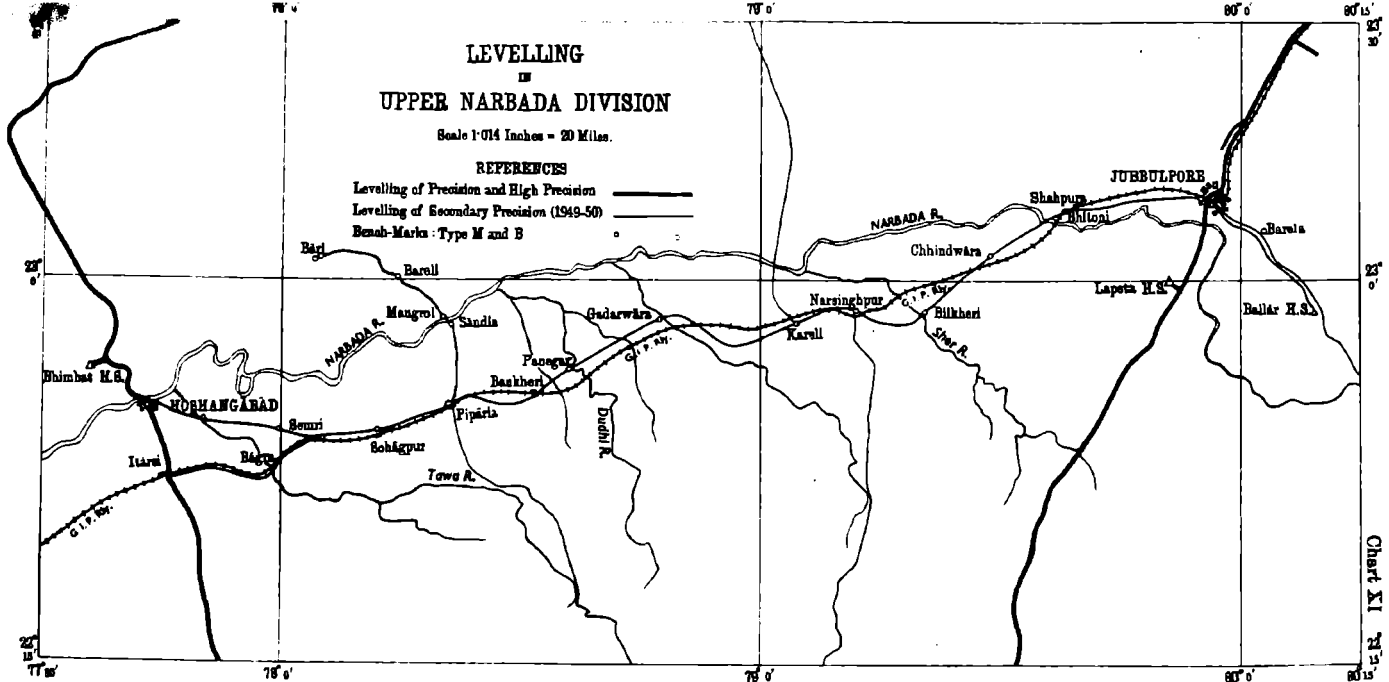
The system of work was the same as for the Kosi and Gandak area secondary levelling (see paras 21 and 22).

Route followed on the lines from Bir to Chikdaria and Timurni to Makrai was mainly cart-tracks and foot-paths. The country was on the whole undulating and very often the route lay through jungle and long grass. Several small streams had also to be crossed on the way. Means of transport throughout were bullock-carts.

The route followed from Hoshangābād to Jubbulpore was along the old Bombay road which was in a motorable condition up to Narsinghpur but from there onwards the road was in a very bad condition with bridges and culverts in many cases broken and rivers Narbada, Dudhi and others being unbridged. The country was ~~no~~ the whole plain.

The route followed from Jubbulpore to Ballār H.S. was along the metalled road leading to Mandla. The major portion of this line was through hills. Means of transport were bullock-carts up to the middle of January 1950 after which the detachment secured a motor vehicle with driver from the Executive Engineer, Upper Narbada Division C.W.I.N.C., Jubbulpore.

Connections were made to Baodiya H.S. and Anjania Khurd H.S. in sheet 55 B and to Ballār H.S. in sheet 64 B. In addition to connecting the various Type 'B' and 'M' bench-marks which had been constructed by the C.W.I.N.C., the detachment inscribed a number of bench-marks on railway or road culverts, bridges and other suitable places. Connection was also made to B.M. No. 258/55 F at railway bridge over Tawa River of the levelling line carried out in 1948–49.



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The area is highly malarious and the members of the detachment including the levellers were often laid down with fever. In the first two or three months the *khalāsīs* were constantly attacked by malaria and at one time the whole of the squad was laid down. The progress of the detachment suffered much on account of this, as the local coolies were not able to hold the staves or run the chain properly. Immediate relief could not be given to the sick persons as the detachment was poorly equipped with medicines. Sick persons were, however, promptly sent to Government dispensaries wherever they were available.

The closing error of levelling at Jubbulpore (S.B.M. 104/55 M) with the starting datum at Hoshangābād (B.M. 87 PP/55 F) was −0·262 feet in a distance of 168 miles. For the sake of adjustment the main-line has been broken up into two parts, viz., Hoshangābād–Semri–Itārsi and Semri–Jubbulpore.

A small circuit composed partly of this year's and partly last year's secondary levelling (Hoshangābād–Semri–Itārsi–Hoshangābād) is also formed. This has a closing error of −0·111 feet in 51 miles. This has been adjusted first taking the portion Hoshangābād–Itārsi as unchanged. An error of −0·3 feet in 142 miles has then been adjusted in the main-line from Semri to Jubbulpore.

25. **Height Control for Bargi Dam Project.**—In order to provide planimetric and height control for the Bargi Dam Project surveys No. 1 Party carried out some triangulation in 1948–49. During the course of this triangulation heights of a number of stations were refixed. The new heights showed considerable differences from their old values. The difference, (new−old), ranged from + 16 to + 37 feet. Both the new and the old heights were examined. It was found that whereas the new heights by No. 1 Party were closely in terms of spirit-levelled values, the computation of old heights (of 1873–74 and 1917–18) were faulty. On recomputation of the old heights the differences between the new and old values were considerably reduced to an average of about 13 feet. It was estimated that the recomputed old heights required to be increased by about 6 feet in order to bring them into terms of spirit-levelled values, thus reducing the discrepancy to 7 feet.

To confirm that the old heights which were in terms of the G.T. stations Kotāli H.S., Banori H.S., Kūsam Bara H.S. and Ballār H.S. did require an increase of about 6 feet, a line of levelling was run from Jubbulpore to Ballār H.S. The height of Ballār H.S. by spirit-levelling has been found to be greater than its trigonometrical value by 5 feet. The average discrepancy between the old and new heights is now 8 feet, a greater part of which is to be attributed to the old heights. The results are tabulated below.

Sheet	Station		New height by No. 1 party 1948–49	Old height	Observer and date of old triangulation	Recomputed value of old height	Old height in terms of spirit-level values	Discrepancy	
								New *minus* old (3–4)	New *minus* old (3–7)
1	2		3	4	5	6	7	8	9
			feet	*feet*		*feet*	*feet*	*feet*	*feet*
64 B/1	Bakra	h.s.	1830	1814	D. Khadilkar, 1917–18	1818	1823	16	7
,,	Nauri	h.s.	1824	1808	,,	1811	1816	16	8
,,	Koduari	h.s.	1630	1614	,,	1617	1622	16	8
,,	Maldongri	h.s.	1809	1793	,,	1796	1801	16	8
64B/6	Joratoria	h.s.	1693	1677	,,	1679	1684	16	9
55 N/13	Dudhia	h.s.	1724	1691	,,	1713	1718	33	6
,,	Chaura	h.s.	1703	1666	G. C. Depree 1873–74	1689	1694	37	9
,,	Sidh No. 2	h.s.	1530	1500	,,	1517	1522	30	8

26. Kandla Levelling.—Secondary levelling in Kutch was carried out for the following purposes :—

(i) To provide height control for tertiary levelling and triangulation carried out in the area by units of the Southern Circle, Survey of India,

(ii) To provide bench-marks of reference to the tide-gauges,

and (iii) To provide height datums for the hydrographic Survey of Lakes for taking down water by pipes to Kandla port.

The entire job was carried out at the request of the Development Commissioner for the Port of Kandla and was paid for by him.

A detachment under Mr. C. L. Puri (Surveyor) assisted by a computer and 13 *khalīsīs* left Dehra Dūn on the 10th October 1949. After a month the computer fell sick and was replaced by Mr. S. K. Bose (Surveyor).

The portion of old level line No. 104 (Viramgām to Tatta) of 1874 from B.M. No. 54/41 I (type C) at Lunwa village to B.M. No. 64/41 I (type B) at Anjār was first revised. The work was commenced on 20th October 1949 and after connecting old bench-marks Nos. 58, 59, 60, 61, 62, 63 of sheet 41 I it was completed on 30th October 1949. The results are given in Table 9 and show that except for bench-mark No. 58/41 I the heights of the rest of the bench-marks did not undergo any change.

TABLE 9.—*Old and new levelling between Lunwa and Anjār*

No. of Bench-mark	Brief description	Height by old levelling published 1874	Unadjusted ortho-metric height by new levelling 1949–50	Diff. Old *minus* new	Height accepted	Remarks
		feet	*feet*	*feet*	*feet*	
54/41 I	On rock (Type C) at Lunwa ..	141·110	..	..	..	Intact.
58/41 I	G.T.S. (Type B) at ←□→ Pasura .. A.D. 1874	77·278	76·931	+0·345	76·929	Disturbed.
59/41 I	On plinth of Satti ..	93·806	93·827	−0·021	93·806	Intact.
60/41 I	On culvert ..	98·599	98·633	−0·034	98·599	,,
61/41 I	Plinth of temple ..	111·098	111·135	−0·037	111·098	,,
62/41 I	Parapet of well ..	130·378	130·415	−0·037	130·378	,,
63/41 I	On culvert ..	139·988	140·024	−0·036	139·988	,,
64/41 I	G.T.S. (Type B) at ←□→ Anjār .. A.D. 1874	204·671	204·676	−0·005	204·671	,,
69/41 E	Type 'B' at Chānd-roda ..	204·980	205·010	−0·030	204·980	Intact.
66/41 E	On rock ..	195·587	..	..	..	
68/41 E	G.T.S. On rock .. ▪ □ → A.D. 1874	194·664	194·664	0·000	194·664	Intact.
64/41 E	On rock ..	229·743	229·738	+0·005	229·743	,,
56/41 E	On rock at Ratnāl ..	392·008	..	..	..	
57/41 E	On rock ..	382·030	382·011	+0·019	382·030	Intact.

Levelling was then started from B.M. No. 8 at Bhīmāsar on 1st November 1949 and was closed on B.M. No. 64/41 I at Anjār on 3rd December 1949. During the course of this levelling trigonometrical stations Rohar Miti s. Shinaya No. 1 H.S., Shinaya No. 2 h.s., Antarjāl NE. s. and Naransar s. were connected. A small branch-line was run to connect Anjār Fort s.

After that a line was started from B.M. No. 22 at Antarjāl on 4th December 1949 and was closed on B.M. No. 15 at Galpadar on 20th December 1949. The trigonometrical station connected by this line were Barapur Tower s., Kirnia s. and Khāri Rohar S.

Again another line was commenced from B.M. No. 49 near Khāri Rohar on 11th January 1950 and was closed on a B.M. at Khori creek near the Khori creek tide-pole on 26th January 1950. Three 'type B' reference bench-marks for tide-gauges at Kandla were also connected by this line.

Before closing the work some more levelling was carried out to provide height datums for hydrographic survey of the lakes.

For this purpose one line was started from Anjār on 20th December 1949 from B.M. No. 64/41 I and was closed on 10th January 1950 on B.M. No. 64/41 I and another line was started from B.M. No. 64/41 I on 27th January 1950 and was closed on B.M. No. 107 PP/41E on 10th March 1950.

Some 'type B' and rock-cut old bench-marks were connected in this line.

Table 10 give the heights of all the triangulation stations and other permanent bench-marks connected during the course of the levelling described above.

TABLE 10.—*Heights of triangulation stations and other permanent marks in Kutch connected by secondary levelling in 1949–50*

Observer's No. of bench-mark	Brief description	Height above M.S.L.	Observer's No. of bench-mark	Brief description	Height above M.S.L.
		feet			*feet*
39/A	G.T.S. (Type B) □ at Warsa-		27/A	Overseer bungalow..	158·564
	B.M. 1949 medi ..	110·638	30/A	At Mezhpur ..	145·674
45/H	○ mark on concrete near Tekra tide-pole ..	10·206	60	Type 'B' at Viri ..	227·767
			64	Type 'B' at Khedoi	257·796
			67	Type 'B' at Mathoda	279·920
			68	Type 'B' at Chāndroda ..	204·980
47/A	Type 'B' at Kidana	57·085			
53/A	Type 'B' on Kandla road ..	7·378	88	Type 'B' at Satapur	195·497
			95	Type 'B' at Tapar	118·413
54/A	Type 'B' on Kandla road ..	8·489	104	Type 'B' Dudhai ..	133·554
55	Type 'B' at Dharamsala Kandla ..	10·939	139	Type 'B' at Jhuran	151·259
			149	Type 'B' at Lodai	116·150
			167	Type 'B' at Rudar Mata ..	98·768
56	Type 'B' at Kandla	11·501			
57	Type 'B' at Kandla	11·779			
58	B.M.□ at Jetty ..	14·285	45/B	Barapur tower s.	75·895
			48	Kirnia s.	22·819
85	Top of iron near Khori creek ..	11·257	50	Khari Rohar s.	36·011
51/A	Type 'B' at Khori Rohar ..	29·056	11/X	Miti Rohar s.	70·901
			12	Naransar ..	97·795
11/A	Type 'B' at Morwadar ..	69·605	19/A	Antarjāl NE. s.	05·593
			24/B	Shinaya No. 1 H.S.	215·725
11/Z	Type 'B' at Miti Rohar ..	29·896	25	Shinaya No. 2 h.s.	185·910
			34/A	Anjār Fort s.	266·309
15/A	Type 'B' at Galpadar	62·180			
20/A	Type 'B' at Kandla	87·603	137/I	Jhuran H.S.	624·073
20/C	Type 'B' at Kandla	52·385			
21/A	At pipe Antarjāl ..	90·459			
22	On rock ..	97·756			

The Instrument used was Zeiss Level No. 1633 Model II which was later replaced by level No. SO34318 (due to the axis of the former becoming loose and Invar staves No. 31, 32.

The levelling was carried out in fore and back directions by 4-mile sections as for Kosi levelling described in para 21. Strong breeze generally interfered with the work.

The area of levelling was heterogeneous mixture of topographical details being marshy, sandy, hilly, plain and undulating places.

For transport, bullock-carts were used except where railways could be made use of for shifting camps.

Difficulty was experienced in connecting the tide-poles. Several creeks had to be crossed and the line had to be taken through the swampy rann. The work, in marshy areas could only be done at low tide and connections to tide-pole at neap tide periods, which resulted in some loss of time.

Health of the detachment was not good. One of the officers suffered from the attack of typhoid for about a month towards the end of the field.

27. **Levelling in Navi Wat and Navlakhi Areas.**—Secondary levelling in these areas was carried out (i) to establish reference bench-marks for tide-gauges and (ii) for connecting the zero of the tide-poles fixed in Navi Wat and Navlakhi.

A detachment consisting of Mr. G. S. Tonk (Surveyor), one computer and 10 *khalāsīs* reached Vāndhia on 5th March 1950 and after doing check-levelling between Vāndhia and Shikārpur commenced work from B.M. 43/41 I at Vāndhia. The levelling closed on a new bench-mark built at Navi Wat consisting of a 2-inch thick stone slab, 12 inches by 8 inches, embedded on top of a masonry pillar 3 feet square and 1½ feet high. The whole rests on a cement concrete foundation 2 feet deep.

After completing the branch-line to Navi Wat, check-levelling was again carried out between Vāndhia and Amliāra as the check-levelling to Shikārpur was not quite satisfactory.

The orthometric heights of the bench-mark of reference and of the zero of the tide-pole at Navi Wat are as follows :—

1. G.T.S. ○ B.M.	embedded at Navi Wat	+10·163 *feet*
2. Zero of the tide-pole at Navi Wat		−14·011 ,,

Mr. G. S. Tonk then returned to Dehra Dūn. He was replaced by Mr. S. K. Bose (Surveyor). The detachment then proceeded to Navlakhi area.

At Navlakhi 3 'type B' bench-marks had been constructed as bench-marks of reference for the tide-pole there. Connections were effected to these as well as to an old tide-pole attached to passenger jetty after check-levelling from Dudhia to Jhijhura.

The heights of these bench-marks and the zero of the tide-pole are given below :—

1. Bench-mark Type 'B' near Passenger Jetty		10·682	*feet*
2. ,, ,, at Post office } Navlakhi		11·231	,,
3. ,, ,, at Port office } Navlakhi		12·921	,,
4. Zero of tide-pole attached to Passenger Jetty		−14·798	,,

The instruments used for levelling in the Navi Wat area were Zeiss level No. SO 34508 Model II and wooden staves Nos. 011A and 011B and those used in Navlakhi levelling were Zeiss level No. SO 34318 Model and invar staves Nos. 30 and 31.

The levelling was done in both the fore and back directions by the same observer. Every endeavour was made that the back levelling was done in the evening for sections which were observed in the morning and vice versa.

The line from Vāndhia to Navi Wat was carried along the cart-track up to Janghi Dak bungalow and thence along the marshes and small creeks (the banks of which were dangerously slippery and the crossing of which was only possible during neap tides) to Navi Wat. The line from Jhijhura to Navlakhi was carried through the fields up to Lavanpur and thence along the railway line up to Navlakhi. The area was plain.

For transport, bullock-carts were generally employed. Country craft and ordinary boats were also used.

The health of the detachment was good.

28. Progress of New Level Net.—The levelling under report has added 27 miles of complete levelling (both directions) and about 654 miles in one direction only to the total mileage of the new high precision level net.

Out of an estimated total of 15,800 miles, the total mileage of this level net completed to date is 11781 miles.

TABLE 11.—*Tabular statement of out-turn of work, season 1949–50*

Detachments and lines levelled	Dates	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*				
H.P. Levelling Detachment.										
Line No. 75 (Kendrapāra to Howrah) portion Balasore to Jaleswar (Fore)	11–10–49 to 22–10–49	27	2	29	268	266	404	..	1	33
Line No. 75, portion Jaleswar to Balasore (Back))	17–6–50 to 4–7–50	27	14	41	254	230	302	..	2	33
Line No. 75 (Kendrapāra to Howrah) portion Jaleswar to Howrah (Back)	23–10–49 to 12–2–50	165	75	240	1,574	1,702	2,393	..	7	255
Branch-line of Line No. 129 (Kolhāpur to Mangalore) portion Kārwār to Hubli (Back)	2–3–50 to 28–6–50	104	19	123	6,722	5,200	2,437	1	9	173
Line No. 124 Vizianagram to Raipur (Back)	7–11–49 to 7–5–50	344	90	434	13,031	14,486	6,770	6	31	325
Line No. 126 (Vizianagram to Rajahmundry) portion Vizagapatam to Vizianagram (Back)	15–10–49 to 6–11–49	41	16	57	609	607	580	2	5	53
Secondary Levelling Detachment.										
Line Purnea to Kishanganj	31–12–49 to 6–1–50 and 10–1–50 to 9–2–50	51	12	63	422	400	765	..	2	45

* This column includes check-levelling and relevelments also.

(*Continued*)

TABLE 11.—*Tabular statement of out-turn of work. season 1949–50.*—(contd.)

Detachments and lines levelled	Dates	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*				
Secondary Levelling Detachment.										
Line Kishanganj to Sarabathna	15–10–49 to 12–12–49 and 15–12–49 to 30–12–49	79	23	102	629	636	1,232	..	7	91
Line Srinagar to Harpur T.S.	17–2–50 to 23–3–50 and 8–4–50 to 8–6–50	116	23	139	961	934	1,635	..	11	115
Line Pratāpganj to Raghopur	17–10–49 to 3–12–49 and 13–12–49 to 14–12–49	45	14	59	378	405	694	..	3	66
Line Madhipura to Tribeniganj	24–3–50 to 5–4–50	19	2	21	161	132	249	..	1	20
Line Padrauna to Chitaunighāt	Oct. 49 to Nov. 49	21	4	25	180	192	256	..	2	27
Line Padrauna to Muzzaffarpur	Dec. 49 to Feb. 50	197	49	246	1,383	1,436	2,583	..	24	248
Line Muzzaffarpur to Hajipur	Mar. 50 to April 50	113	23	136	728	774	1,402	..	16	149
Line Captainganj to Tribeniganj	May 50 to June 50	54	21	75	413	345	596	..	11	43
Line Hoshangābād to Jubbulpore	13–12–49 to 8–7–50	168	155	323	5,391	4,155	3,548	1	24	261
Line Timurni to Makrai	14–11–49 to 10–12–49	28	10	38	1,225	647	558	..	1	31

* This column includes check-levelling and relevelments also.

(*Continued*)

TABLE 11.—*Tabular statement of out-turn of work, season 1949–50.*—(contd.)

Detachments and lines levelled	Dates	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-out	Others	
		Mls.	*Mls.*	*Mls.*	*feet*	*feet*				
Secondary Levelling Detachment.										
Line Bīr to Chikdaria	19–10–49 to 10–11–49	24	3	27	875	840	516	..	4	18
Line Bhimasar to Anjār	20–10–49 to 3–12–49	30	48	78	969	752	658	1	10	24
Line Anjār to Galpādar	4–12–49 to 20–12–49	13	4	17	175	263	274	..	2	7
Line Khari Rohar to Khori Creek	11–1–50 to 26–1–50	11	1	12	51	72	145	..	7	3
Line Anjār to Chandroda	20–12–49 to 10–1–50	30	6	36	783	784	566	..	3	6
Line Anjār to Ratnāl	27–1–50 to 18–2–50	40	8	48	622	520	580	..	3	10
Line Kanaiyabe to Bhūj	20–2–50 to 10–3–50	36	5	41	1,522	1,119	796	2	3	11
Line Jhijhura to Navlakhi	6–4–50 to 23–4–50	10	5	15	50	63	184	..	4	8
Sub-branch Barapara to Tekra Tide pole	11–3–50 to 18–3–50	7	..	7	105	41	86	..	..	1
Tidal and Levelling Detachment.										
Lines Vāndhia to Navi Wāt, Vandhia to Shikarpur and Vandhia to Almiāra	5–3–50 to 13–4–50	21	13	34	78	148	315	..	3	7

(Continued)

* This column includes check-levelling and relevelments also.

TABLE 11.—*Tabular statement of out-turn of work, season 1949–50.*—(concld.)

Detachments and lines levelled	Dates	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*				
Precision Levelling Detachment.										
Line Howrah to Purbasthali	25–2–50 to 1–6–50	89	29	118	1,165	1,134	1,473	..	3	173
Line Calcutta Mint to King George's Dock	14–2–50 to 21–2–50	6	1	7	82	121	126	..	2	23
Line Calcutta Mint to Cossipore	21–2–50 to 24–2–50	4	1	5	27	28	52	..	2	10

* This column includes check-levelling and relevelments also.

TABLE 12.—*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			Differences (check − original). The sign + denotes that the height was greater and the sign − less in 1949–50 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1949–50	
			miles		*feet*	*feet*	*feet*
		At Bālāsore on line No. 121					
78	73 K	S.B.M. at Bālāsore ..	0·0	1938-40	0·000	0·000	0·000
138	,,	On stone ..	0·0	,,	− 2·067	− 2·066	+0·001
140	,,	On veranda ..	0·1	,,	− 4·138	− 4·152	−0·014
92	,,	Embedded B.M. ..	1·0	,,	+ 14·435	+ 14·427	−0·008
143	,,	On I.B. veranda ..	1·1	,,	+ 18·174	+ 18·165	−0·009
144	,,	On parapet ..	1·3	,,	+ 17·222	+ 17·229	+0·007
135	,,	In S.D.O.'s Office ..	2·2	,,	− 0·217	− 0·153	+0·064
		At Calcutta on line No. 74 B					
353	79 B	At Calcutta Mint ..	0·0	1947-48	0·000	0·000	0·000
994	,,	Howrah bridge ..	0·2	,,	− 0·262	− 0·258	+0·004
992	,,	Strand ware-house ..	0·3	,,	+ 1·956	+ 1·953	−0·003
991	,,	At M.M. Office ..	0·7	,,	+ 3·568	+ 3·554	−0·014
990	,,	Abdul Ghani Fort ..	0·8	,,	+ 0·752	+ 0·742	−0·010
089	,,	North Brook's statue	1·5	,,	+ 6·043	+ 6·029	−0·014
988	,,	Canning's statue ..	1·8	,,	+ 3·671	+ 3·654	−0·017
364	,,	Outram's statue ..	2·6	,,	+ 2·672	+ 2·669	−0·003
368	,,	S.B.M. at D.E.C.'s Office ..	3·2	,,	+ 2·104	+ 2·094	−0·010
		At Kārwār on line No. 129					
1	48 J	Embedded at Kārwār ..	0·0	1886-87	0·000	0·000	0·000
48	,,	On cap stone ..	0·0	,,	− 4·767	− 4·928	−0·161
49	,,	On granite ..	0·5	,,	− 3·067	− 3·072	−0·005
		At Hubli on line No. 129					
1	48 M	Embedded at Hubli	0·0	1907-08	0·000	0·000	0·000
2	,,	Municipal borough ..	0·2	,,	+ 15·542	+ 15·503	−0·039
3	,,	On hospital flooring	0·3	,,	+ 18·165	+ 18·157	−0·008
		At Vizagapatam on line No. 126					
72	65 O	Plinth ..	0·00	1909-10	0·000	0·000	0·000
73	,,	Plinth ..	0·50	,,	+ 10·235	+ 10·272	+0·037
74	,,	Floor ..	0·34	,,	+ 2·573	+ 2·635	+0·062
75	,,	Type (C) ..	0·01	,,	+ 3·478	+ 3·561	+0·083
71	,,	S.B.M. (P) ..	0·34	,,	+ 2·323	+ 2·404	+0·081

(Continued)

TABLE 12.—*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 1949-50 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Orginal levelling	Check-levelling 1949–50	
			miles		*feet*	*feet*	*feet*
		At Vizianagram on line No. 126					
35	65 N	Stone ..	0·00	1938-40	0·000	0·000	0·000
225	,,	Furlong stone ..	0·49	,,	+ 1·136	+ 1·126	−0·010
226	,,	Step ..	0·63	,,	+ 8·811	+ 8·817	+0·006
227	,,	Flooring ..	0·73	,,	+ 10·834	+ 10·862	+0·028
228	,,	Bridge ..	0·93	,,	+ 28·939	+ 28·973	+0·034
230	,,	Culvert ..	1·24	,,	+ 9·408	+ 9·405	−0·003
234	,,	Iron bolt ..	1·41	,,	+ 29·860	+ 29·869	+0·009
235	,,	Stone prism ..	1·41	,,	+ 29·356	+ 29·363	+0·007
236	,,	Stone prism ..	1·41	,,	+ 29·328	+ 29·336	+0·008
237	,,	S.B.M. (Type M) ..	1·41	,,	+ 30·230	+ 30·247	+0·008
175	,,	Bridge ..	0·00	,,	+ 9·330	+ 9·321	−0·015
239	,,	Bridge ..	0·09	,,	+ 7·907	+ 7·916	+0·009
		At Raipur on line No. 118					
180	64 G	Bridge ..	0·00	1935-36	0·000	0·000	0·000
179 (43)	,,	Coping of platform	0·21	1937-38	+ 1·747	+ 1·743	−0·004
178 (79)	,,	Culvert ..	0·45	,,	− 12·604	− 12·614	−0·010
177 (45)	,,	Pavement ..	1·18	,,	+ 10·120	+ 10·116	−0·004
175 (46)	,,	Step ..	1·60	,,	+ 15·294	+ 15·285	−0·009
176 (77)	,,	Step ..	1·69	,,	+ 17·024	+ 17·013	−0·011
170	,,	Step ..	1·84	,,	+ 17·011	+ 16·987	−0·024
174 (76)	,,	Step ..	2·01	,,	+ 25·744	+ 25·766	+0·022
171	,,	Culvert ..	2·24	,,	+ 29·306	+ 29·169	−0·137
237	,,	Culvert ..	3·29	,,	+ 21·161	+ 21·061	−0·090
48	,,	Stone ..	3·36	,,	+ 24·320	+ 24·319	−0·001
173 (75)	,,	S.B.M. ..	3·81	,,	+ 40·544	+ 40·480	−0·064
172 (73)	,,	Culvert ..	4·34	,,	+ 40·973	+ 41·020	+0·047
		At Kishanganj on line No. 76 A					
29	72 N	Rly. bridge ..	0·00	1899-1900	0·000	0·000	0·000
28	,,	Rly. bridge ..	2·96	,,	+ 5·784	+ 5·748	−0·030
27	,,	Rly. bridge ..	3·78	,,	+ 3·726	+ 4·320	+0·594
30	,,	Rly. bridge ..	2·75	,,	− 6·203	− 6·150	+0·044
113	72 O	Rly. bridge ..	3·64	,,	− 7·579	− 7·578	+0·001
114	,,	Embedded at Kanki R.S. ..	4·04	,,	− 7·706	− 7·852	−0·146
115	,,	Rly. bridge ..	6·13	,,	− 11·349	− 11·648	−0·299

(*Continued*)

TABLE 12.—*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 less in 1946–49 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1948–49	
			miles		*feet*	*feet*	*feet*
		At Purnea on line No. 151 B					
348 PP	72 O	S.B.M. at Purnea ..	0·00	1934-36	0·000	0·000	0·000
347	,,	Culvert ..	0·36	,,	+ 1·080	+ 1·089	+0·009
346	,,	Culvert ..	1·36	,,	− 1·770	− 1·777	−0·007
344	,,	Embedded at Purnea R.S. ..	3·45	,,	+ 4·567	+ 4·581	+0·014
345	,,	Bridge ..	3·79	,,	+ 3·843	+ 3·859	+0·016
		At Harpur on line No. 151 B					
136 PP	72 J	Mark stone of Hârpur T.S. ..	0·00	1934-36	0·000	0·000	0·000
134	,,	In temple ..	0·44	,,	+ 2·268	+ 2·269	+0·001
133	,,	On step ..	2·61	,, ..	+ 2·686	+ 2·724	+0·038
131	,,	On culvert ..	3·94	,,	+ 2·832	+ 2·935	+0·103
130	,,	On bridge ..	5·26	,,	+ 0·806	+ 0·940	+0·134
129	,,	On milestone ..	5·98	,,	+ 3·311	+ 4·162	+0·851
128	,,	In temple ..	7·29	,,	+ 7·449	+ 7·485	+0·036
127	,,	On well ..	7·68	,,	+ 0·805	+ 0·380	−0·425
138	,,	On bridge ..	5·25	,,	+ 0·813	+ 0·921	+0·108
		At Diwanganj on line No. 151 B					
59	72 J	On stone ..	0·00	1934-36	0·000	0·000	0·000
58	,,	On well ..	0·53	,,	+ 2·290	+ 2·310	+0·020
97	72 N	On well ..	3·76	,,	+ 3·108	+ 3·113	+0·005
95	,,	On well ..	4·43	,,	+ 4·328	+ 4·309	−0·019
93	,,	On well ..	6·95	,,	+ 5·202	+ 5·057	−0·145
		At Muzaffarpur on line No. 151 B					
221 PP	72 F	S.B.M. ..	0·00	1934-36	0·000	0·000	0·000
222	,,	Stone step ..	0·14	,,	− 0·989	− 0·995	−0·006
223	,,	Stone step ..	0·22	,,	− 2·147	− 2·170	−0·023
224	,,	Bridge ..	1·41	,,	+ 0·091	+ 0·095	+0·004
220	,,	Plinth ..	0·03	,,	− 1·887	− 1·896	−0·009
209	,,	Stone seat ..	0·49	,,	+ 3·830	+ 3·758	−0·072
210	,,	Bridge ..	1·10	,,	+ 0·093	− 0·058	−0·151
207	,,	Culvert ..	1·30	,,	− 1·462	− 1·479	−0·017
203	,,	Culvert ..	2·10	,,	− 1·023	− 1·041	−0·018
202	,,	Culvert ..	3·24	,,	− 1·174	− 1·210	−0·036
201	,,	Culvert ..	4·39	,,	− 4·541	− 4·636	−0·095

(*Continued*)

TABLE 12.—*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 1949–50 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1949–50	
			miles		*feet*	*feet*	*feet*
		At Padrauna on line No. 151 B					
89	63 N	Step ..	0·00	1934-36	0·000	0·000	0·000
90	,,	Well ..	1·01	,,	− 1·063	− 1·532	−0·469
91	,,	Bridge ..	2·35	,,	+ 0·971	+ 0·989	+0·018
92	,,	Plinth ..	3·08	,,	− 0·236	− 0·203	+0·033
95	,,	Culvert ..	7·70	,,	− 7·671	− 7·599	+0·072
96	,,	Culvert ..	8·74	,,	− 7·844	− 7·767	+0·077
88	,,	Well ..	1·18	,,	− 0·030	− 0·341	−0·311
152	72 B	Bridge ..	2·73	,,	+ 1·049	+ 1·022	−0·027
		At Captainganj on line No. 151 B					
102	63 N	Culvert ..	0·00	1934-36	0·000	0·000	0·000
98	,,	Well ..	5·35	,,	− 3·797	− 3·966	−0·169
96	,,	Culvert ..	8·58	,,	− 9·644	− 9·639	+0·005
95	,,	Bridge ..	9·64	,,	− 9·471	− 9·477	−0·006
92	,,	Bridge ..	14·33	,,	− 2·036	− 2·103	−0·067
91	,,	Bridge ..	15·06	,,	− 0·829	− 0·891	−0·062
104	,,	Culvert ..	3·46	,,	− 5·602	− 5·643	−0·041
		At Jubbulpore on line No. 60 A					
101	55 M	(Type B) at Jubbulpore ..	0·00	1908-09	0·000	0·000	0·000
102	,,	R.M.S. office ..	0·26	,,	+ 8·041	+ 8·062	+0·021
103	,,	In court ..	0·45	,,	− 3·327	− 3·295	+0·032
104	,,	(Type M) at Jubbulpore ..	1·46	,,	− 12·434	− 12·472	−0·038
105	,,	On plinth ..	0·79	,,	+ 9·875	+ 13·553	+3·678
106	,,	In circuit house ..	0·70	,,	+ 13·378	+ 13·386	+0·008
100	,,	On platform ..	0·20	,,	+ 18·170	+ 18·214	+0·044
107	,,	In Cantt. board office	1·75	,,	+ 8·618	+ 8·628	+0·010
109	,,	On bridge ..	4·49	,,	− 53·655	− 53·693	−0·038
110	,,	On culvert ..	6·55	,,	− 76·750	− 76·731	+0·019
98	,,	On parapet ..	2·21	,,	+ 2·491	+ 2·521	+0·030
97	,,	On parapet ..	3·40	,,	− 25·806	− 25·763	+0·043
96	,,	On parapet ..	5·51	,,	− 59·799	− 59·749	+0·050
95	,,	On parapet ..	7·43	,,	− 61·379	− 61·315	+0·064
170	64 A	On parapet ..	9·79	,,	− 67·891	− 67·757	+0·134

(*Continued*)

TABLE 12.—*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 1948-49 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1948-49	
			miles		*feet*	*feet*	*feet*
		At Jubbulpore on line No. 60 A					
169	64A	Type 'B' at Deori R.S. ..	10·29	1908-09	− 74·033	− 73·643	+0·390
168	,,	On platform ..	10·40	,,	− 68·336	− 68·370	−0·034
167	,,	On parapet ..	11·48	,,	− 71·478	− 71·098	+0·380
		At Tawa River Bridge on line No. 115 A					
258	55 F	On bridge ..	0·00	1948-49	0·000	0·000	0·000
259	,,	On bridge ..	0·04	,,	− 43·740	− 43·732	+0·008
257	,,	On culvert ..	0·65	,,	− 6·327	− 6·318	+0·009
		At Hoshangābād on line No. 115					
87	55 F	S.B.M. ..	0·00	1935-37	0·000	0·000	0·000
86	,,	Supplementary mark ..	0·00	,,	− 0·668	− 0·664	+0·004
85	,,	Supplementary mark ..	0·00	,,	− 0·675	− 0·677	−0·002
83	,,	Step ..	0·11	,,	+ 4·311	+ 4·314	+0·003
82	,,	Flooring ..	0·53	,,	+ 12·671	+ 12·688	+0·017
88	,,	Flooring ..	0·05	,,	+ 0·890	+ 0·893	+0·003
89	,,	Plinth ..	0·16	,,	− 0·533	− 0·540	−0·007
90	,,	Plinth ..	0·45	,,	− 1·715	− 1·719	−0·004
		At Bīr on line No. 115 A					
144	55 B	Culvert ..	0·00	1948-49	0·000	0·000	0·000
145	,,	Flooring ..	0·67	,,	− 5·444	− 5·455	−0·011
146	,,	Type B ..	0·15	,,	− 17·638	− 17·650	−0·012
147	,,	Culvert ..	0·85	,,	− 27·754	− 27·759	−0·005
		At Timurni on line No. 115 A					
197	55 F	Culvert ..	0·00	1948-49	0·000	0·000	0·000
196	,,	Flooring ..	0·50	,,	+ 13·389	+ 13·396	+0·007
195	55 B	Coping ..	0·05	,,	+ 13·159	+ 13·374	+0·215
194	,,	Culvert ..	0·69	,,	+ 18·917	+ 18·931	+0·014
193	,,	Culvert ..	0·50	,,	+ 26·768	+ 26·790	+0·022

(*Continued*)

TABLE 12.—*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 1948–49 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1948–49	
			miles		*feet*	*feet*	*feet*
At Lunwa–Anjār on line No. 104							
54	41 I	Rock (Type C) ..	0·00	1921-24	0·000	0·000	0·000
58	,,	Slab (Type B) ..	4·39	,,	− 63·839	− 64·189	−0·350
59	,,	Plinth ..	9·04	,,	− 47·304	− 47·294	+0·010
60	,,	Culvert ..	13·04	,,	− 42·508	− 42·489	+0·019
61	,,	Temple ..	14·10	,,	− 30·007	− 29·986	+0·021
62	,,	Well ..	16·13	,,	− 10·726	− 10·707	+0·019
63	,,	Culvert ..	17·56	,,	− 1·111	− 1·097	+0·014
64	,,	Stone slab ..	19·51	,,	+ 63·572	+ 63·554	−0·018
At Dudhai on line No. 104							
146	41 J	Type B ..	0·00	1921-24	0·000	0·000	0·000
147	,,	Stone ..	4·99	,,	− 32·726	− 32·853	−0·127
149	,,	Type B ..	4·78	,,	− 36·747	− 36·781	−0·034
At Vāndhia on line No. 104							
43	41 I	Step ..	0·00	1921-24	0·000	0·000	0·000
42	,,	Type B ..	3·90	,,	− 25·506	− 25·498	+0·008
45	,,	Type B ..	7·65	,,	− 18·439	− 18·401	+0·038
At Ratnāl on line No. 104							
56	41 E	Rock ..	0·00	1921-24	0·000	0·000	0·000
57	,,	Rock ..	2·53	,,	− 10·039	− 10·057	−0·018

TABLE 13.—*List of triangulation stations connected by spirit-levelling, season 1949–50*

Degree Sheet No.	Name of station	Height above mean sea-level		Difference (Lev.—Trian.)	REMARKS
		Spirit-levelling	Trian-gulation		
		feet	*feet*	*feet*	
65 I	Hathbena H.S. Lat. 19° 51′ 42·34 Long. 82 01 25·96	2600	2600	0	Upper mark-stone.
65 I	Sirsi H.S. Lat. 19° 19′ 39·21 Long. 82 28 16·57	2302	2302	0	Top of rectan-gular pillar.
64 H	Jhuriamari h.s. Lat. 20° 09′ 17·80 Long. 81 56 19·11	2062	2065	− 3	Ground level (Rock-in-situ).
65 I	Sargoli h.s. Lat 19° 31′ 09·94 Long. 82 17 38·36	2128	2127	+ 1	Rock-in-situ.
65 I	Kantha Hill mark Lat. 19° 28′ 02·56 Long. 82 22 41·30	2152	2147	+ 5	Intersected point (top).
65 I	Hirli No. 1 h.s. Lat. 19° 13′ 37·08 Long. 82 32 06·91	2114	2117	− 3	Top (Rock-in-situ).
65 J	Athri h.s. Lat. 18° 47′ 30·30 Long. 82 42 44·69	3274	3281	− 7	Upper mark-stone.
72 G	Kamtaul T.S. Lat. 25° 59′ 11·38 Long. 85 19 0·69	200	198	+ 2	Upper mark-stone.
72 A	Upasai T.S. Lat. 27° 04′ 56·05 Long. 84 01 28·63	314	313	+ 1	Upper mark-stone.
72 B	Daunaha T.S. Lat. 26° 42′ 16·85 Long. 84 13 21·91	271	271	0	Ground level.

(*Continued*)

TABLE 13.—*List of triangulation stations connected by spirit-levelling, season 1949–50*—(concld.)

Degree Sheet No.	Name of station	Height above mean sea-level		Difference (Lev.–Trian.)	REMARKS
		Spirit-levelling	Trian-gulation		
		feet	*feet*	*feet*	
72 N	Musaldanga T.S. Lat. 26° 13′ 01″·80 Long. 87 42 33·81	170	172	− 2	Height refers to ⊙ cut on mark-stone 9 feet above ground level mark.
72 N	Manikpur T.S. Lat. 26° 12′ 16″·49 Long. 87 21 13·43	193	204	−11	S.L. height refers to ⊙ mark whose height above ground level mark-stone could not be ascertained. Trig. height refers to upper mark-stone.
72 O	Mohania T.S. Lat. 25° 54′ 44″·44 Long. 87 08 27·79	151	153	− 2	Height refers to ⊙ cut on mark-stone 14 feet below the top of the square tower.
55 B	Baŏdiya H.S. Lat. 22° 02′ 48″·53 Long. 76 28 24·37	1047	1047	0	Upper mark.
55 B	Anjānia Khurd H.S. Lat. 22° 12′ 12″·74 Long. 76 25 26·48	959	957	+ 2	Upper mark.
64 B	Ballār H.S. Lat. 22° 56′ 27″·69 Long. 80 10 38·52	2135	2130	+ 5	Upper mark-stone.
44 E	Jhuran H.S. Lat. 23° 21′ 37″·81 Long. 69 59 0·25	624	626	− 2	Upper mark.
41 I	Shinaya No. 1 H.S. Lat. 23° 02′ 25″·44 Long. 70 01 57·32	216	219	− 3	Lower mark.
41 I	Shinaya No. 2 h.s. Lat. 23° 02′ 46″·82 Long. 70 03 41·05	186	189	− 3	Upper mark.

CHAPTER III

GRAVITY

BY B. L. GULATEE, M.A. (CANTAB.), F.R.I.C.S., M.I.S. (INDIA)

29. Summary.—Gravity reductions for all the 77 gravimeter stations at approximately 10-mile intervals established in Madhya Pradesh area mentioned in the last year's report, were carried out and gravity anomalies have been derived on the various hypotheses of Hayford's Compensation and Heiskanen's Regional Compensation.

In addition to the above, re-observations were made at the five gravity stations established by Dr. G. P. Woollard as part of his World net at Delhi in January 1949 (*see* Technical Report 1948–49, Part III, Chapter III, para 24).

30. Value of *g* at Palam Airport.—In January 1949 Dr. G. P. Woollard established five stations at Delhi with Worden gravimeter. These stations were also occupied by the Survey of India with the Frost gravimeter to tie them up with Dehra Dūn. The results were as follows :—

Place	Values of *g* by Frost gravimeter	Values of *g* by Worden gravimeter
	gals	*gals*
Willingdon Air Port ..	979·1359	979·1352
Imperial Hotel	·1363	·1364
Surveyor General's Office ..	·1456	·1459
Palam Road Junction ..	·1317	·1320
Palam Air Port	979·1321	979·1424

It will be seen that there is good agreement between the Frost and Worden gravimeter values at all stations except at Palam Air Port, where there is a large difference of 10 mgals between the two instruments.

In order to find out the reason for this discrepancy, all the five stations were re-occupied in August 1949 with the Frost gravimeter. The instrument reproduced its original values and it appears certain that the discrepancy is due to a booking error in the Worden gravimeter readings.

The repeat observations were carried out by Mr. S. Vaikuntanathan (Class II) under the personal supervision of the Director, Geodetic and Training Circle from 24th to 29th August 1949.

31. **Reduction and interpretation of gravity anomalies in the Nagpur area.**—Gravity reductions for all the stations observed with the Frost gravimeter in the Nāgpur area of Madhya Pradesh (1947-48) have now been carried out on seven hypotheses. The results are given in Tables 1 to 4.

Charts XV and XVI show the Bouguer and Isostatic anomalies respectively. On the latter chart, the older contours drawn on the basis of pendulum stations are shown by dotted lines. A comparison with the new contours is of interest. Gravimeter observations confirm the zero contour and the 20-mgals contour passing through sheets 64 B and 55 O. The older 20-mgals contour in sheet 55 N, however, appears to be wrong and requires a considerable shift upwards. Gravimeter observations are based on pendulum station Seoni as datum. Pendulum stations at Nāgpur and Amgaon were also connected by the gravimeter and checked satisfactorily. It would be desirable to cover the remaining portion of sheet 55 N with further gravimeter stations to delineate this contour and the apparently higher contours below it in greater detail.

There is a pocket of large positive anomalies of 55 mgals or so which was missed by the pendulum observations, as they were too far apart.

The Bouguer anomalies are all negative and on the whole small. Chart XVII shows the section on line AB from which it would appear that the anomalies display a progressive increase in this direction.

The anomalies are on the whole closely related to geology. They are computed on the assumption of the average density of the rocks being 2·67. The Deccan trap in sheet 55N has an average density much higher than this (about 2·9 or so). The more positive Bouguer anomalies in this area are presumably due to this cause. The variations in the thicknesses of the trap will also influence the anomalies considerably.

The south-west corner of Sheet 64 C appears to be of interest. On transition from the alluvium to the gneisses the anomalies show a progressive trend.

A further discussion will follow when the various gaps in this area have been filled by observations and a more comprehensive picture becomes available.

32. **Magnetic anomalies.**—Magnetic vertical force observations were also carried out in conjunction with the gravimeter observations with magnetic V.F. variometers No. 19134 and 19135. The former was used at the base station and the latter at the field stations. Scale values of the instruments were determined from time to time and the results obtained were steady. The values adopted for the two instruments were 26·5 and 19·0 gammas respectively.

Table 5 gives magnetic anomalies computed with reference to Jubbulpore magnetic repeat station. The observed values have

Jubbulpore
(68)

Chart XVI

79° 80° 81°

23°

22°

21°

Narsinghpur
(221)

HAYFORD'S ANOMALIES

$g - \gamma_{CH}$

Scale 1·014 Inches = 16 Miles.

Miles 10 5 0 10 20 30 Miles

Contour interval .....5 mgals.

Gravity stations .....

Seoni (Dorawa)
(67)

Amgaon
(66)

Nagpur
(237)

A

B

NOTE. 1. Dotted lines show Hayford's Anomalies due to older pendulum values.

2. Figures in brackets near the names of pendulum stations relate to the number of the old pendulum stations.

Reg. No. 604 M/W C D'51 (G. & T. C. 1·014" = 16 Miles)-375.

Printed at the Survey of India Offices (P.E.O.)

Modified Bouguer ($g-\gamma_B$) Anomaly

Section on AB

Scale 1·014 Inches = 16 Miles.

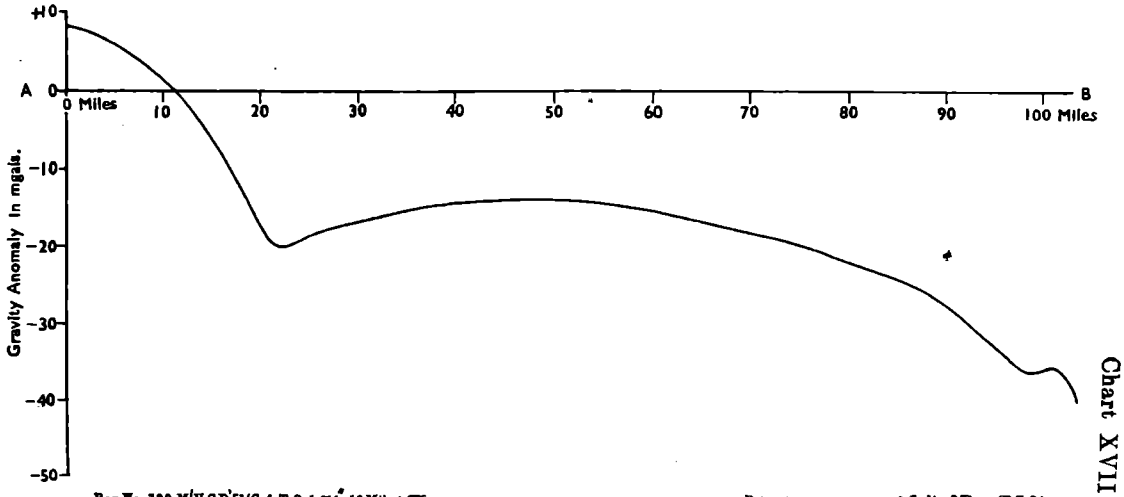


Chart XVII

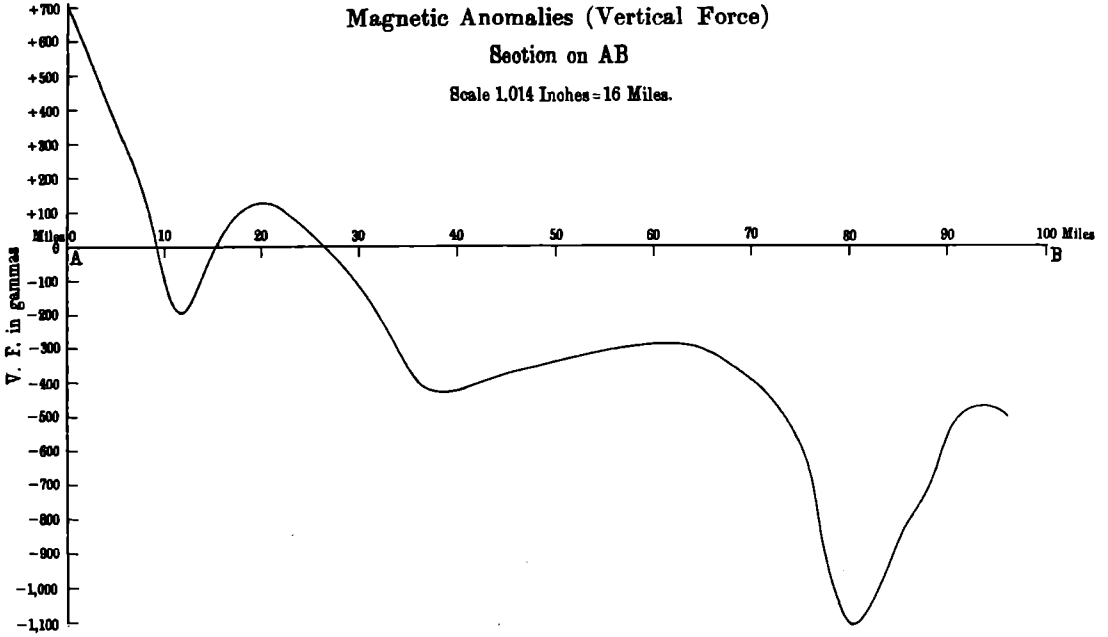
Reg. No. 700 M/N.O.D/51(G & T.O. 1·014=16 Miles)-375.

Printed at the Survey of India Offices (P.Z.O.).

Magnetic Anomalies (Vertical Force)

Section on AB

Scale 1.014 Inches = 16 Miles.



Reg. No. 701 M/N.O.D. 51 (G. & T.C. 1014-16 Miles)-375.

Printed at the Survey of India Offices (P.Z.O.).

CHART XIX

been corrected for closure, diurnal and latitude variations. The latitude variations were derived from the generalised V.F. charts of the Earth's field published by the United States Coast and Geodetic Survey, 1945.

At station No. G/9 (Sheet 64 C), a very large anomaly of -1900γ was obtained. This is purely a local phenomenon and has been ignored in the drawing of contours of magnetic anomalies (Chart XVIII).

The strong magnetic lows are possibly connected with iron ore or manganese ore formations having reverse polarization due to thermal and mechanical processes or they might be produced by remanent magnetisation in the neighbouring rocks.

The range ot anomalies is considerable as is inevitable in a regional survey like the one under discussion as certain stations must be burdened with large local effects. The stations marked by crosses denote magnetically disturbed areas where the anomalies change by over 100 gammas in a distance of a few yards.

In sheet 55 N, the stations are mainly located on trap and display a very large variation in the magnetic anomalies. Large positive magnetic and gravity anomalies are expected in trap areas.

On the meridian of 80° near latitude 21°, there is a steady increase in the anomalies on crossing the junction between the Dharwars and gneisses.

Chart XIX shows the magnetic variation along the section AB. As with gravity, the magnetic anomalies show a steady decrease in this direction except at the end, where the transition from alluvium to gneisses is accompanied by an increase.

TABLE 1.—*Gravi*

No.	Stations in Sheet 55 N	Height	Latitude	Longitude	g (observed value)	HE $g-\gamma_A$	HE $g-\gamma_B$	HE Modifie $g-\gamma_B$
		feet	° ′ ″	° ′ ″	*gals*	*mgals*	*mgals*	*mgals*
1	G 1 ..	2077	22 26 11	79 33 51	978·6502	+63·6	− 8·0	− 3·
2	G 2 ..	1859	36 04	48 37	·6843	+66·8	+ 2·7	+ 5·
3	G 3 ..	2084	36 14	44 00	·6724	+75·8	+ 4·0	+ 8·
4	G 4 ..	2004	35 59	36 45	·6709	+67·0	− 2·0	+ 0·
5	G 5 ..	1899	16 45	32 54	·6472	+53·8	−11·6	− 8·
6	G 6 ..	2027	05 35	33 04	·6220	+52·4	−17·6	−14·
7	G 7 ..	1594	26 43	49 34	·6848	+52·2	− 2·7	+ 0·
8	G 8 ..	1500	17 59	48 58	·6615	+29·2	−22·5	−20·
9	G 9 ..	1737	10 05	41 33	·6458	+44·3	−15·5	−13·
10	G 10 ..	1567	17 26	56 17	·6549	+29·5	−24·5	−21·
11	G 11 ..	1545	26 04	57 40	·6711	+34·7	−18·5	−16·
12	G 12 ..	1586	08 18	48 16	·6515	+37·7	−16·9	−14·
13	G 13 ..	1654	15 42	43 23	·6523	+37·0	−20·0	−17·
14	G 14 ..	1761	02 20	42 45	·6368	+45·6	−15·0	−12·
15	G 15 ..	1739	01 37	49 39	·6382	+45·7	−14·2	−10·
16	G 16 ..	1151	22 01 24	79 59 29	978·6681	+20·5	−19·1	−16·
	Mean with regard to sign					+47·2	−12·6	− 9·
	Mean without regard to sign					47·2	13·4	11·
	Range					55·3	28·5	29·

* Topographical reduction up to zone O.

Note :—All observed values of 'g' are in terms of Seoni Pendulum Station (g = 978·622 gal

Anomalies

MERT'S FORMULA					INTERNATIONAL FORMULA				
Hayford's compensation 113·7 km.	HEISKANEN'S REGIONAL COMPENSATION				Hayford's compensation 113·7 km.	HEISKANEN'S REGIONAL COMPENSATION			
	40 km.	60 km.	80 km.	100 km.		40 km.	60 km.	80 km.	100 km.
mgals	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*
+44·8	+47·2	+43·2	+39·4	+36·1	+27·1	+29·5	+25·5	+21·7	+18·4
+53·7	+55·3	+52·3	+49·4	+46·4	+36·0	+37·6	+34·6	+31·7	+28·7
+55·5	+57·2	+54·0	+51·0	+48·0	+37·8	+39·5	+36·3	+33·3	+30·3
+50·0	+51·7	+48·0	+44·8	+41·8	+32·3	+34·0	+30·3	+27·1	+24·1
+40·8	+42·7	+38·8	+35·2	+31·8	+23·1	+25·0	+21·1	+17·5	+14·1
+33·0	+34·6	+30·5	+27·0	+23·9	+15·3	+16·9	+12·8	+ 9·3	+ 6·2
+46·7	+48·6	+45·6	+42·6	+39·7	+29·0	+30·9	+27·9	+24·9	+22·0
+26·1	+28·1	+25·3	+22·5	+19·6	+ 8·4	+10·4	+ 7·6	+ 4·8	+ 1·9
+33·9	+35·5	+32·3	+29·3	+26·3	+16·2	+17·8	+14·6	+11·6	+ 8·6
+22·5	+24·8	+22·4	+19·8	+16·9	+ 4·8	+ 7·1	+ 4·7	+ 2·1	− 0·8
+30·5	+32·6	+30·3	+27·5	+24·6	+12·8	+14·9	+12·6	+ 9·8	+ 6·9
+31·0	+33·0	+30·3	+27·4	+24·4	+13·3	+15·3	+12·6	+ 9·7	+ 6·7
+29·3	+31·3	+28·1	+25·3	+22·2	+11·6	+13·6	+10·4	+ 7·6	+ 4·5
+34·0	+35·6	+32·3	+29·0	+25·9	+16·3	+17·9	+14·6	+11·3	+ 8·2
+31·9	+33·4	+30·9	+28·1	+25·6	+14·2	+15·7	+13·2	+10·4	+ 7·9
+25·1	+27·1	+25·4	+23·0	+20·5	+ 7·4	+ 9·4	+ 7·7	+ 5·3	+ 2·8
+36·8	+38·7	+35·6	+32·6	+29·6	+19·1	+21·0	+17·9	+14·9	+12·0
36·8	38·7	35·6	32·6	29·6	19·1	21·0	17·9	14·9	12·0
33·0	32·4	31·6	31·2	31·1	33·0	32·4	31·6	31·2	31·1

TABLE 2.—*Grav*

No.	Stations in Sheet 55 O	Height	Latitude	Longitude	g (observed value)	H		
						$g-\gamma_A$	$g-\gamma_B$	Modifi $g-\gamma$
		feet	° ′ ″	° ′ ″	*gals*	*mgals*	*mgals*	*mga*
17	G 1 ..	1067	21 14 46	79 08 03	978·6232	+15·7	−20·0	−14
18	G 2 ..	870	09 05	23 29	·6278	+ 7·4	−22·5	−19
19	G 3 ..	835	09 25	39 07	·6260	+ 2·1	−26·7	−23
20	G 4 ..	871	09 03	31 53	·6319	+11·6	−18·4	−14
21	G 5 ..	905	08 30	12 38	·6233	+ 6·9	−24·2	−21
22	G 6 ..	975	18 20	04 07	·6229	+ 3·2	−30·4	−26
23	G 7 ..	917	13 19	11 21	·6286	+ 8·5	−23·1	−19
24	G 8 ..	980	18 23	13 53	·6285	+ 9·3	−24·5	−21
25	G 9 ..	915	14 09	18 05	·6261	+ 5·0	−26·5	−23
26	G 10 ..	1020	08 56	04 55	·6158	+ 9·6	−25·5	−22
27	G 11 ..	1186	22 38	23 18	·6177	+13·5	−26·4	−17
28	G 12 ..	1060	23 46	15 45	·6291	+12·7	−24·1	−20
29	Tirora ..	908	24 49	55 08	·6366	+ 4·0	−27·2	−23
30	G 17 ..	955	40 56	58 20	·6573	+12·5	−20·4	−17
31	G 19 ..	1521	49 20	40 41	·6435	+43·3	−09·1	− 7
32	G 20 ..	1793	56 13	43 00	·6355	+53·7	−08·0	− 8
33	G 21 ..	885	31 10	54 08	·6471	+ 5·7	−24·8	−21
34	G 22 ..	1089	47 28	54 03	·6622	+23·3	−14·2	−10
35	G 23 ..	888	12 09	47 36	·6323	+10·5	−20·1	−16
36	G 24 ..	1090	39 57	40 45	·6525	+21·4	−16·2	−12
37	G 25 ..	1083	39 15	48 06	·6484	+17·4	−19·9	−17
38	G 26 ..	1136	30 59	30 57	·6372	+19·7	−19·4	−10
39	G 27 ..	1034	31 03	43 22	·6353	+ 8·2	−27·4	−23
40	G 28 ..	1023	24 03	30 36	·6285	+ 7·5	−27·7	−24
41	G 29 ..	937	04 04	39 18	·6243	− 4·9	−37·2	−33
42	G 30 ..	862	22 20	50 10	·6383	+ 3·0	−25·8	−22
43	G 31 ..	944	15 39	27 53	·6212	+ 1·3	−31·2	−27
44	G 32 ..	863	14 15	38 41	·6320	+ 6·0	−23·7	−20
45	G 34 ..	854	21 04 08	79 49 34	978·6356	+18·9	−10·2	− 1
	Mean with regard to sign					+12·3	−22·6	−1
	Mean without regard to sign					12·7	22·6	1
	Range					58·6	29·4	2

* Topographical reduction up to zone O.

Note :—All observed values of 'g' are in terms of Seoni Pendulum Station (g= 978·622 gt

Anomalies

MERT'S FORMULA					INTERNATIONAL FORMULA				
Hayford's compensation 113·7 km.	HEISKANEN'S REGIONAL COMPENSATION				Hayford's compensation 113·7 km.	HEISKANEN'S REGIONAL COMPENSATION			
	40 km.	60 km.	80 km.	100 km.		40 km.	60 km.	80 km.	100 km.
mgals	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*
+15·2	+16·8	+16·0	+14·5	+12·2	− 2·5	− 0·9	− 1·7	− 3·2	− 5·5
+11·6	+12·9	+12·6	+11·4	+ 9·6	− 6·1	− 4·8	− 5·1	− 6·3	− 8·1
+ 6·5	+ 7·7	+ 7·4	+ 6·4	+ 4·4	−11·2	−10·0	−10·3	−11·3	−13·3
+14·6	+15·9	+15·6	+14·6	+12·6	− 3·1	− 1·8	− 2·1	− 3·1	− 5·1
+ 9·9	+11·4	+10·7	+ 9·4	+ 7·5	− 7·8	− 6·3	− 7·0	− 8·3	−10·2
+ 6·8	+ 8·5	+ 7·5	+ 5·8	+ 3·6	−10·9	− 9·2	−10·2	−11·9	−14·1
+12·0	+13·6	+12·9	+11·4	+ 9·5	− 5·7	− 4·1	− 4·8	− 6·3	− 8·2
+11·6	+13·2	+12·4	+10·9	+ 8·7	− 6·1	− 4·5	− 5·3	− 6·8	− 9·0
+ 8·3	+ 9·9	+ 9·3	+ 7·8	+ 5·8	− 9·4	− 7·8	− 8·4	− 9·9	−11·9
+ 9·1	+10·7	+ 9·8	+ 8·2	+ 6·2	− 8·6	− 7·0	− 7·9	− 9·5	−11·5
+11·0	+12·5	+11·6	+10·0	+ 7·8	− 6·7	− 5·2	− 6·1	− 7·7	− 9·9
+13·9	+15·4	+14·3	+12·7	+10·6	− 3·8	− 2·3	− 3·4	− 5·0	− 7·1
+ 8·1	+ 9·4	+ 9·0	+ 7·7	+ 5·9	− 9·6	− 8·3	− 8·7	−10·0	−11·8
+18·5	+20·6	+19·5	+17·9	+15·8	+ 0·8	+ 2·9	+ 1·8	+ 0·2	− 1·9
+35·0	+36·2	+34·2	+31·9	+28·9	+17·3	+18·5	+16·5	+14·2	+11·2
+38·1	+39·1	+36·4	+34·0	+31·0	+20·4	+21·4	+18·7	+16·3	+13·3
+12·1	+13·7	+13·2	+11·8	+ 9·8	− 5·6	− 4·0	− 4·5	− 5·9	− 7·9
+26·9	+28·6	+27·2	+25·4	+22·8	+ 9·2	+10·9	+ 9·5	+ 7·7	+ 5·1
+13·3	+14·7	+14·2	+13·0	+11·2	− 4·4	− 3·0	− 3·5	− 4·7	− 6·5
+24·1	+25·9	+24·4	+22·6	+20·3	+ 6·4	+ 8·2	+ 6·7	+ 4·9	+ 2·6
+18·7	+20·4	+19·4	+17·7	+15·7	+ 1·0	+ 2·7	+ 1·7	0·0	− 2·0
+18·9	+20·1	+19·2	+17·7	+15·7	+ 1·2	+ 2·4	+ 1·5	0·0	− 2·0
+ 9·6	+11·1	+10·6	+ 9·2	+ 7·1	− 8·1	− 6·6	− 7·1	− 8·5	−10·6
+ 8·8	+10·2	+ 9·3	+ 8·1	+ 6·1	− 8·9	− 7·5	− 8·4	− 9·6	−11·6
− 1·4	+ 0·1	− 0·4	− 1·5	− 3·3	−19·1	−17·6	−18·1	−19·2	−21·0
+ 9·0	+10·5	+10·0	+ 8·7	+ 7·0	− 8·7	− 7·2	− 7·7	− 9·0	−10·7
+ 3·5	+ 5·1	+ 4·7	+ 3·3	+ 1·5	−14·2	−12·6	−13·0	−14·4	−16·2
+ 9·5	+10·6	+10·4	+ 9·2	+ 7·5	− 8·2	− 7·1	− 7·3	− 8·5	−10·2
+21·7	+22·8	+22·4	+21·2	+19·4	+ 4·0	+ 5·1	+ 4·7	+ 3·5	+ 1·7
+14·0	+15·4	+14·6	+13·1	+11·1	− 3·7	− 2·3	− 3·1	− 4·0	− 6·6
14·1	15·4	14·6	13·2	11·3	7·9	7·2	7·3	7·8	9·0
39·5	39·0	36·8	35·5	34·3	39·5	39·0	36·8	35·5	34·3

TABLE 3.—*Gravi*

No.	Stations in Sheet 64 B	Height	Latitude	Longitude	g (observed value)	H E $g-\gamma_A$	$g-\gamma_B$	Modifie $g-\gamma_B$
		feet	° ′ ″	° ′ ″	*gals*	*mgals*	*mgals*	*mgal*
46	G 1 ..	1483	22 30 41	80 02 53	978·6876	+40·4	−10·7	− 8·(
47	G 2 ..	1438	25 38	06 21	·6696	+23·4	−26·1	−23·(
48	G 3 ..	1674	24 41	17 18	·6489	+26·1	−31·6	−28·(
49	G 4 ..	1170	15 28	03 40	·6735	+13·0	−27·3	−24·(
50	G 5 ..	1633	22 48	26 29	·6491	+24·3	−32·0	−28·(
51	G 6 ..	1918	14 18	16 07	·6233	+34·3	−31·7	−28·(
52	G 7 ..	1661	15 23	29 28	·6449	+30·5	−26·7	−24·(
53	G 8 ..	1106	07 39	03 52	·6701	+11·7	−26·4	−23·(
54	G 9 ..	1905	10 02	15 22	·6205	+34·8	−30·8	−28·(
55	G 10 ..	2001	08 06	22 53	·6208	+46·1	−22·8	−19·(
56	G 11	1829	22 06 10	80 32 54	978·6239	+35·1	−28·0	−25·(
	Mean with regard to sign					+29·1	−26·7	−23·(
	Mean without regard to sign					29·1	26·7	23·(
	Range					34·4	21·3	20·(

* Topographical reduction up to zone O.

Note :—All observed values of 'g' are in terms of Seoni Pendulum Station (g = 978·622 gals

Anomalies

MERT'S FORMULA					INTERNATIONAL FORMULA				
Hayford's compensation 113·7 km.	HEISKANEN'S REGIONAL COMPENSATION				Hayford's compensation 113·7 km.	HEISKANEN'S REGIONAL COMPENSATION			
	40 km.	60 km.	80 km.	100 km.		40 km.	60 km.	80 km.	100 km.
mgals	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*
+38·5	+40·4	+37·9	+35·4	+32·6	+20·8	+22·7	+20·2	+17·7	+14·9
+23·0	+25·0	+22·6	+20·1	+17·4	+ 5·3	+ 7·3	+ 4·9	+ 2·4	− 0·3
+18·1	+20·2	+17·5	+14·6	+11·7	+ 0·4	+ 2·5	− 0·2	− 3·1	− 6·0
+19·4	+21·8	+19·7	+17·1	+14·6	+ 1·7	+ 4·1	+ 2·0	− 0·6	− 3·1
+18·2	+20·5	+17·2	+14·1	+11·3	+ 0·5	+ 2·8	− 0·5	− 3·6	− 6·4
+17·3	+19·3	+16·4	+13·7	+10·8	− 0·4	+ 1·6	− 1·3	− 4·0	− 6·9
+23·6	+25·4	+21·9	+18·5	+15·3	+ 5·9	+ 7·7	+ 4·2	+ 0·8	− 2·4
+18·9	+21·1	+19·1	+16·7	+13·8	+ 1·2	+ 3·4	+ 1·4	− 1·0	− 3·9
+17·3	+19·1	+16·3	+13·7	+10·9	− 0·4	+ 1·4	− 1·4	− 4·0	− 6·8
+26·5	+28·0	+24·5	+21·3	+18·2	+ 8·8	+10·3	+ 6·8	+ 3·6	+ 0·5
+22·5	+24·1	+19·6	+15·9	+12·5	+ 4·8	+ 6·4	+ 1·9	− 1·8	− 5·2
+22·1	+24·1	+21·2	+18·3	+15·4	+ 4·4	+ 6·4	+ 3·5	+ 0·6	− 2·3
22·1	24·1	21·2	18·3	15·4	4·6	6·4	4·1	3·9	5·1
21·2	21·3	21·6	21·7	21·8	21·2	21·3	21·6	21·7	21·8

TABLE 4.—*Gravity*

No.	Stations in Sheet 64 C	Height	Latitude	Longitude	g (observed value)	HEL $g-\gamma_A$	HEL $g-\gamma_B$	HEL Modified $g-\gamma_B$ *
		feet	° ′ ″	° ′ ″	*gals*	*mgals*	*mgals*	*mgals*
57	G 1 ..	1065	21 55 17	80 03 31	978·6645	+15·4	−21·3	−17·5
58	G 2 ..	1040	56 28	09 30	·6659	+13·1	−22·7	−20·0
59	G 3 ..	1883	58 00	16 10	·6169	+41·7	−23·2	−20·6
60	G 4 ..	2049	58 11	29 26	·6026	+42·8	−27·7	−25·2
61	G 5 ..	998	48 28	02 52	·6646	+16·0	−18·3	−14·7
62	G 6 ..	995	48 34	12 05	·6583	+ 9·4	−25·0	−21·2
63	G 7 ..	1959	52 32	20 27	·6083	+46·0	−21·5	−17·2
64	G 8 ..	1927	52 19	33 21	·5948	+29·7	−36·7	−34·3
65	G 9 ..	924	39 54	01 04	·6504	+12·8	−19·0	−15·4
66	G 10 ..	909	37 36	12 42	·6473	+ 1·7	−29·6	−26·2
67	G 11 ..	951	37 34	19 40	·6476	+ 6·0	−26·7	−23·2
68	G 12 ..	1046	39 20	27 13	·6479	+13·4	−22·6	−21·3
69	G 13 ..	946	29 01	03 51	·6397	+ 6·4	−26·2	−23·0
70	G 14 ..	1010	27 40	11 51	·6296	+ 3·5	−31·3	−27·6
71	G 15 Sakoli (P.P.B.M.)	864	05 13	00 28	·6139	− 2·9	−32·5	−28·7
72	G 16 ..	994	21 16	00 20	·6348	+13·7	−20·3	−17·2
73	G 17 ..	1064	20 21	12 15	·6106	− 2·8	−30·5	−35·5
74	G 18 ..	1019	45 09	21 16	·6518	+ 8·6	−26·5	−24·6
75	G 19 ..	944	11 51	11 24	·6040	−12·1	−44·6	−41·0
76	G 20 ..	858	04 44	09 09	·6024	−14·6	−44·2	−40·7
77	G 21 ..	980	21 10 54	80 00 26	978·6289	+17·2	−16·5	−12·7
	Mean with regard to sign					+12·6	−27·4	−24·3
	Mean without regard to sign					15·7	27·4	24·2
	Range					60·6	28·1	28·3

* Topographical reduction up to zone O.

Note :—All observed values of 'g' are in terms of Seoni Pendulum Station (g = 978·622 gals).

Anomalies

MERT'S FORMULA					INTERNATIONAL FORMULA				
Hayford's compensation 113·7 km.	HEISKANEN'S REGIONAL COMPENSATION				Hayford's compensation 113·7 km.	HEISKANEN'S REGIONAL COMPENSATION			
	40 km.	60 km.	80 km.	100 km.		40 km.	60 km.	80 km.	100 km.
mgals	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*
+21·4	+23·4	+22·0	+19·9	+17·3	+ 3·7	+ 5·7	+ 4·3	+ 2·2	− 0·4
+20·3	+22·3	+20·5	+18·3	+15·7	+ 2·6	+ 4·6	+ 2·8	+ 0·6	− 2·0
+22·0	+23·4	+21·0	+18·4	+15·6	+ 4·3	+ 5·7	+ 3·3	+ 0·7	− 2·1
+20·3	+21·1	+17·3	+14·3	+11·0	+ 2·6	+ 3·4	− 0·4	− 3·4	− 6·7
+21·6	+23·8	+22·5	+20·8	+18·4	+ 3·9	+ 6·1	+ 4·8	+ 3·1	+ 0·7
+15·6	+17·6	+16·0	+14·0	+11·6	− 2·1	− 0·1	− 1·7	− 3·7	− 6·1
+22·8	+24·0	+21·4	+18·9	+16·1	+ 5·1	+ 6·3	+ 3·7	+ 1·2	− 1·6
+ 9·1	+ 9·8	+ 6·1	+ 3·3	+ 0·5	− 8·6	− 7·9	−11·6	−14·4	−17·2
+19·7	+21·8	+20·8	+19·3	+17·1	+ 2·0	+ 4·1	+ 3·1	+ 1·6	− 0·6
+ 8·5	+10·6	+ 9·5	+ 7·9	+ 5·5	− 9·2	− 7·1	− 8·2	− 9·8	−12·2
+13·3	+15·6	+14·0	+12·1	+ 9·4	− 4·4	− 2·1	− 3·7	− 5·6	− 8·3
+19·2	+20·6	+18·5	+16·1	+13·7	+ 1·5	+ 2·9	+ 0·8	− 1·6	− 4·0
+ 8·4	+ 9·7	+ 8·9	+ 7·6	+ 6·0	− 9·3	− 8·0	− 8·8	−10·1	−11·7
+ 5·3	+ 7·1	+ 5·8	+ 4·2	+ 2·0	−12·4	−10·6	−11·9	−13·5	−15·7
+ 0·1	+ 1·5	+ 0·7	− 0·6	− 2·8	−17·6	−16·2	−17·0	−18·3	−20·5
+15·1	+16·5	+15·7	+14·5	+12·5	− 2·6	− 1·2	− 2·0	− 3·2	− 5·2
− 4·3	− 2·8	− 4·0	− 5·5	− 7·7	−22·0	−20·5	−21·7	−23·2	−25·4
+15·7	+17·3	+15·1	+13·0	+10·4	− 2·0	− 0·4	− 2·6	− 4·7	− 7·3
−10·0	− 8·6	− 9·7	−11·3	−13·5	−27·7	−26·3	−27·4	−29·0	−31·2
−11·6	−10·5	−11·5	−12·8	−14·6	−29·3	−28·2	−29·2	−30·5	−32·3
+17·0	+18·4	+17·7	+16·4	+14·5	− 0·7	+ 0·7	0·0	− 1·3	− 3·2
+11·9	+13·5	+11·8	+ 9·0	+ 7·6	− 5·8	− 4·2	− 5·8	− 7·8	−10·1
14·3	15·5	14·2	12·8	11·2	8·3	8·0	8·0	8·7	10·2
34·4	34·5	34·0	33·6	33·0	34·4	34·5	34·0	33·6	33·0

TABLE 5.—*Magnetic Anomalies*

No.	Station	Latitude	Longitude	Height	Magnetic Anomalies*
	SHEET 55 N	° ′ ″	° ′ ″	*feet*	*gammas*
1	G 1 ..	22 26 11	79 33 51	2077	+ 706
2	G 2 ..	36 04	48 37	1859	− 414
3	G 3 ..	36 14	44 00	2084	− 249
4	G 4 ..	35 50	36 45	2004	− 256
5	G 5 ..	16 45	32 54	1899	− 387
6	G 6 ..	05 35	33 04	2027	− 323
7	G 7 ..	26 43	49 34	1594	− 357
8	G 8 ..	17 59	48 58	1500	− 100
9	G 9 ..	10 05	41 33	1737	+ 240
10	G 10 ..	17 26	56 17	1567	− 344
11	G 11 ..	26 04	57 40	1545	− 704
12	G 12 ..	08 18	48 16	1586	− 283
13	G 13 ..	15 42	43 23	1654	+ 37
14	G 14 ..	02 20	42 45	1761	− 125
15	G 15 ..	01 37	49 39	1739	− 274
16	G 16 ..	22 01 24	79 59 29	1151	− 215
	SHEET 55 O				
17	G 1 ..	21 14 46	79 08 03	1067	− 656
18	G 2 ..	09 05	23 29	870	− 495
19	G 3 ..	09 25	39 07	835	− 308
20	G 4 ..	09 03	31 53	871	− 394
21	G 5 ..	08 30	12 38	905	− 547
22	G 6 ..	18 20	04 07	975	− 522
23	G 7 ..	13 19	11 21	917	− 521
24	G 8 ..	18 23	13 53	980	− 631
25	G 9 ..	14 09	18 05	916	− 540
26	G 10 ..	08 56	04 55	1020	− 448
27	G 11 ..	22 38	23 18	1186	− 855
28	G 12 ..	23 46	15 45	1069	−1147
29	Tirora ..	24 49	55 08	908	− 439
30	G 17 ..	40 56	58 20	955	− 474
31	G 19 ..	49 20	40 41	1521	− 362
32	G 20 ..	56 13	43 00	1793	− 454
33	G 21 ..	31 10	54 06	885	− 429
34	G 22 ..	47 28	54 03	1089	− 328
35	G 23 ..	12 09	47 36	888	− 554
36	G 24 ..	39 57	40 45	1090	− 381
37	G 25 ..	39 15	48 06	1083	− 299
38	G 26 ..	30 59	30 57	1136	− 405
39	G 27 ..	31 03	43 22	1034	− 845
40	G 28 ..	24 03	30 36	1023	− 507
41	G 29 ..	04 04	39 18	937	− 509
42	G 30 ..	22 20	50 10	862	− 718
43	G 31 ..	15 39	27 53	944	− 393

* With respect to Jubbulpore Magnetic Repeat Station.

TABLE 5.—*Magnetic Anomalies*—(concld.)

No.	Station	Latitude	Longitude	Height	Magnetic Anomalies*
	SHEET 55 O	° ′ ″	° ′ ″	*feet*	*gammas*
44	G 32 ..	14 15	38 41	863	— 462
45	G 34 ..	21 04 08	79 49 34	854	— 512
	SHEET 64 B				
46	G 1 ..	22 30 41	80 02 53	1483	+ 77
47	G 2 ..	25 38	06 21	1438	— 99
48	G 3 ..	24 41	17 18	1674	+ 65
49	G 4 ..	15 28	03 40	1170	— 33
50	G 5 ..	22 48	26 29	1633	— 23
51	G 6 ..	14 18	16 07	1918	— 76
52	G 7 ..	15 23	29 28	1661	— 206
53	G 8 ..	07 39	03 52	1106	— 207
54	G 9 ..	10 02	15 22	1905	— 128
55	G 10 ..	08 06	22 53	2001	— 21
56	G 11 ..	22 06 10	80 32 54	1829	— 11
	SHEET 64 C				
57	G 1 ..	21 55 17	80 03 31	1065	— 262
58	G 2 ..	56 28	09 30	1040	— 312
59	G 3 ..	58 00	16 10	1883	— 173
60	G 4 ..	58 11	29 26	2049	— 115
61	G 5 ..	48 28	02 52	998	— 382
62	G 6 ..	48 34	12 05	995	— 261
63	G 7 ..	52 32	20 27	1959	— 116
64	G 8 ..	52 19	33 21	1927	— 220
65	G 9 ..	39 54	01 04	924	—1910
66	G 10 ..	37 36	12 42	909	— 295
67	G 11 ..	37 34	19 40	951	— 334
68	G 12 ..	39 20	27 13	1046	— 323
69	G 13 ..	29 01	03 51	946	— 127
70	G 14 ..	27 49	11 51	1010	— 351
71	G 15 Sakoli (P.P.B.M.)	05 13	00 28	864	— 491
72	G 16 ..	21 16	00 20	994	—1137
73	G 17 ..	20 21	12 15	1064	— 574
74	G 18 ..	45 09	21 16	1019	— 227
75	G 19 ..	11 51	11 24	944	— 564
76	G 20 ..	04 44	09 09	858	— 576
77	G 21 Pendulum station ..	10 54	00 26	980	— 423
..	Amgaon ..	21 31	28 ..	1032	— 464
..	Jamri h.s. (No. 94 P.P.B.M.) ..	12 21	01 54	1716	— 991
..	Sitapur (No. 31 P.P.B.M.)	21 24 51	80 19 26	1241	— 589

* With respect to Jubbulpore Magnetic Repeat Station.

CHAPTER IV

DEVIATION OF THE VERTICAL

BY B. L. GULATEE, M.A. (CANTAB.), F.R.I.C.S., M.I.S. (INDIA)

33. General.—Deflections of the vertical in both components were measured at four stations in Kutch. These furnished very useful information about deflections in an area where no astronomical observations had been carried out before.

These stations were also made into Laplace stations.

34. Narrative of the Season's Work.—The detachment consisting of Mr. J. B. Mathur (Surveyor), one recorder and 12 *khalāsīs* commenced observations for Laplace at Kānmer on 22nd October and after observing for two nights proceeded to Chitrod for similar observations. After helping in the base-measurement, the detachment then proceeded to Vārār H.S. and Sāmatra H.S. and completed the observations on 7th December 1949.

Observations were made with a large 45-degree prismatic astrolabe. Two nights' observations were taken at Kānmer and one nights' at the other three stations. Greenwich time was obtained from Rugby 09 : 55 and 17 : 55 G.M.T. signals. The "demi-definitive" corrections of the Bulletin Horaire have been applied to the times of emission. Observations for personal equation were made at Dehra Dūn before and after the field work.

35. Personal Equation.—The personal equation was determined at Dehra Dūn before and after field work with the following results :—

Before field		After field	
Date	Personal equation	Date	Personal equation
	s		s
27th September 1949 ..	+0·39	19th December 1949 ..	+0·31
29th September 1949 ..	+0·32	21st December 1949 ..	+0·27
2nd October 1949 ..	+0·26	23rd December 1949 ..	+0·22
	s		s
MEAN..	+0·32	MEAN..	+0·27

36. Details of the Laplace Stations.—The following table gives the details of the Laplace corrections. The stations were observed in pairs, Kānmer H.S. and Chitrod H.S. forming one pair and Sāmatra H.S. and Vārār S. the other.

Details of the Laplace corrections

Station	Kānmer H.S.	Chitrod H.S.	Vārār H.S.	Sāmatra H.S.
	° ′ ″	° ′ ″	° ′ ″	° ′ ″
Geodetic latitude = λg	23 23 51·40	23 23 30·87	23 20 33·25	23 09 48·71
Geodetic longitude = Lg	70 52 40·46	70 41 03·81	69 33 35·81	69 30 47·64
Astronomical latitude = λa	23 23 46·69	23 23 27·63	23 20 28·07	23 09 44·45
Probable error ..	± 0·58	± 0·66	±0·49	± 0·87
Astronomical Longitude = La	70 52 42·68	70 41 06·75	69 33 36·45	69 30 43·30
Probable error ..	± 0·40	± 0·27	± 0·24	± 0·47
Correction to reduce astronomical azimuth to geodetic = −[(La−Lg)+3·2] × sin λg	−2·2	−2·4	−1·5	−1·5

Station A	Station B	Astronomical azimuth at A of B with *p.e.*	Correction to reduce astro. azimuth to geodetic	Geodetic azimuth = Ag	Published geodetic azimuth
		° ′ ″	″	° ′ ″	° ′ ″
Kānmer H.S.	Chitrod H.S.	88 12 28·3 ±0·4	−2·2	88 12 26·1	88 12 38·2
Chitrod H.S.	Kānmer H.S.	268 07 57·4 ±0·4	−2·4	268 07 55·0	268 08 01·6
Vārār H.S.	Sāmatra H.S.	13 33 46·7 ±0·4	−1·5	13 33 45·2	13 33 54·6
Sāmatra H.S.	Vārār H.S.	193 32 40·2 ±0·4	−1·5	193 32 38·7	193 32 48·2

It will be seen from the above table that convergence between the azimuth at Kānmer of Chitrod H.S. and the reverse azimuth Chitrod H.S. to Kānmer differs from the correct value by 5″·5. The reason for this discrepancy is not known but it is suspected that while observing azimuth the lamp used as the reference mark got shifted without the observer noticing it. As the results for these two stations are doubtful they have been rejected.

The results at Sāmatra S. and Vārār S. are satisfactory and the azimuth given in the second table has been used in computing the co-ordinates of the new Geodetic Triangulation in Kutch, Chapter I, see para 8.

37. **Geoid in Kutch.**—Table 1 gives the deflections at the four stations. It will be seen that their magnitudes are comparatively small.

These results have been used to extend the charts of the geoid and the compensated geoid in India. (Charts XXII and XXIII). A closed contour of 40 feet is indicated in the Kutch area. Observational data in this region and to the south of it is rather meagre. It is proposed to observe in the near future some deflection stations in Saurashtra in conjunction with the reobservation of geodetic triangulation that has to be carried out there, and it is hoped that these will give a more detailed picture of the geoid in this locality.

38. **Hayford Deflections.**—To date observations for determining the deviation of the vertical have been made at 1,210 stations. By 1940, deflections on Hayford's isostatic system assuming the depth of compensation as 113·7 kms., had been computed at about 900 stations. Due to lack of personnel it has not been possible to continue these computations during the war period and in the post-war period so far.

39. **Future Geoidal Programme.**—Chart XXIV shows the geoidal sections. Although a number of reliable sections are now available for drawing a fairly accurate picture of the geoid, there are several areas for which knowledge of the geoid is either totally lacking or too meagre. These regions are the foot of the Himālayas from Darjeeling to Srinagar in Kashmir, the Assam, Kutch, Saurashtra and the Western Coast from Mangalore to Cape Comorin. There are also some other weak sections which need strengthening. In the next two or three years it is proposed to run a meridional section from Dohad to Deesa and a longitudinal section from Bhavnagar to Porbandar. It is hoped to continue work as opportunity arises.

DEFLECTION STATIONS

TABLE 1

Serial No.	Sheet No.	Observed at	Height in feet	International Spheroid Deflections		Calculated Deflections Hayford System		Calculated Deflections Uncompensated Topography	
				Meridian	P.V.	Meridian	P.V.	Meridian	P.V.
				"	"	"	"	"	"
1207	41 E	Vårår H.S.		− 2·9	− 1·1				
1208	41 E	Sårnatra H.S.		− 2·1	− 1·2				
1209	41 I	Kånmor H.S.		− 2·3	+ 1·0				
1210	41 I	Chitrod H.S.		− 0·8	+ 1·6				

DEFLECTIONS 1949–50

EVEREST'S SPHEROID							Serial No.
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections			
				Meridian	P.V.		
° ′ ″	° ′ ″	° ′ ″		"	"		
A 23 20 28·07	A 69 33 36·45	A 13 33 46·7	Sårnatra H.S.	− 5·2	+ 3·5	1207
G 23 20 33·28	G 69 33 35·81	G 13 33 45·2				
A 23 09 44·45	A 69 30 48·30	A 103 32 40·2	Vårår H.S.	− 4·3	+ 3·6	1208
G 23 09 48·71	G 69 30 47·64	G 103 32 38·7				
A 23 23 46·60	A 70 52 42·08			− 4·7	+ 4·0	1209
G 23 23 51·40	G 70 52 40·46					
A 23 23 27·63	A 70 41 06·75			− 3·2	+ 5·6	1210
G 23 23 30·87	G 70 41 03·81					

(*b*) *By touring tidal detachment of the Survey of India.*— A series of 31 days' systematic observations on tide-pole was carried out by a tidal detachment, under Mr. G. S. Tonk (Surveyor), at each of the ports, Navlakhi (Standard Port) and Navi Wat (Secondary Port) in the Gulf of Kutch. The observations consisted, as usual, of readings at intervals of every half-hour during both day and night, and also at the times of high and low waters. The work was executed at the request of the Development Commissioner, Kandla port, for the purpose of obtaining up-to-date tidal information in the neighbourhood of the Kandla area in connection with its development.

The detachment which, apart from the officer-in-charge, comprised of 4 class III and 6 class IV personnel left Dehra Dūn for the field on 7th January 1950 and returned to the Headquarters, after completion of programme on 13th April 1950. Due to various reasons, no other port could be visited during the season for such observations.

41. Harmonic Analysis.—The field observations that had been carried out at Port Okha, Mandvi, Porbandar and Bhavnagar during the 1948–49 season were harmonically analysed, during the recess in 1949, by the Admiralty Method. The results of this analysis, together with the comparative values of the tidal constants that have hitherto been accepted as standard, are given in Table 1(*a*).

It will be seen that while no significant changes in the constants have taken place in the case of Port Okha and Porbandar in the course of the last half a century or so, considerable changes have occurred in the case of Bhavnagar. The latter has presumably been due to some natural changes in the harbour, like the formation of a bar in the Bhavnagar Creek, about which a reference was made already in a previous Report (Technical Report 1947, Part III) while discussing the accuracy of predictions for this port. The value of Z_0 has also changed considerably at this port. A proposal is now in hand to instal an automatic tide-gauge in the main stream, outside the entrance of the Creek, and obtain systematic observations for a period of not less than a year for purposes of intensive analysis and derivation of fresh constants for future standard predictions for the port.

The comparisons at Mandvi show that the "inferred" constants for this port published in the Admiralty Tide-Tables Part II, are not good enough. These "inferred" constants can now be replaced by the more reliable constants as derived from the new observations.

The observations carried out at Navlakhi and Naviwat during the last season have not yet been analysed. Their results will be published in the next Technical Report.

At the request of the Kandla Port authorities, the harmonic analysis of two series of 29 days' observations taken at the Port during 1949, was also carried out by the Admiralty method. The constants derived were used in the preparation of tidal predictions for the port for 1949–50 that were required to be supplied in connection with the port's development project. The mean values of the

constants obtained from the two series are given in Table 1(*b*). The old constants published in the Admiralty and Indian Ocean Tide-Tables Part II are also included in the Table for comparison. The agreement is very satisfactory.

Some data of 15 and 29 days' observations, executed by the Marine Survey Department in the course of their Hydrographic Surveys, have also been analysed. The constants derived from these observations are tabulated in Table 1(*c*).

An important request for the special harmonic analysis of short period observations at the Saugor sandheads (about 40 miles seaward of Saugor at the mouth of the Hooghly River) has been received from the Calcutta Port Commissioners, and this analysis is now in progress. The results are to be used for the preparation of tidal predictions for Lower Saugor which have been asked for by the Central Waterways Irrigation and Navigation Research Station, Poona, in connection with the construction of a tidal model for the Hooghly River.

42. Tide-Tables.—During the year under report, the preparation of the annual Tide-Tables for the Indian Ocean ports for 1950 was completed and that for the years 1951 and 1952 was continued. Preliminary computations for the tidal predictions for 1953 were also taken up.

The "Tide-Tables of the Indian Ocean 1950" and the separate pamphlets for Bombay and the Rangoon River for the year 1950 were published in the month of August. The tidal pamphlet for the Hooghly River was published in November.

The Tide-Tables relating to the year 1951 are now in the press in various stages of printing. Proofs of predictions for 52 ports (out of a total of 67 that are to be included in the Tide-Tables of the Indian Ocean) have already been examined and passed for printing.

Advance tidal predictions for 17 ports for the year 1951 were despatched (in accordance with the standing arrangements for exchange of official predictions between nations) to the Hydrographic Departments of Britain, the United States and Portugal, in August 1949. Advance predictions for 3 ports for 1951 were also supplied, as usual, to the Royal Indian Navy, during the same month.

Also, special predictions for Kandla port for the latter part of the year 1949 and for the full year 1950 were prepared and supplied to the port authorities on payment.

The total realization from the sale of Tide-Tables (exclusive of the Agents' Commission) during the year under report amounted to Rs. 5,299/13/-. The sum received up-to-date on account of paid for work done during the year, as well as the Royalties amounted to Rs. 1,850/-.

43. Corrections to Predictions.—Empirical corrections, based on the observations of recent years in each case, were as before, applied to the 1952 predictions for Karachi, Navlakhi, Bhavnagar, Bombay (A.B.), Vizagapatam, Chandbali and Rangoon. The

corrections were the same as those applied to the 1951 predictions (see Technical Report 1948, Part III), except in the case of Vizagapatam and Rangoon where the values were slightly revised. These revised values for Vizagapatam and Rangoon are given in Tables 2 and 3 respectively.

In respect of Dublat (Saugor) and Kidderpore, the empirical corrections for the 1952 predictions were worked out as before, but were not applied. The intention is to change the entire method of predictions for the above ports, commencing with the 1952 Tide-Tables and use modern (1948) observations for the revised method. These empirical corrections are, therefore, not reproduced in this report.

44. **Accuracy of Predictions.**—Tables 4–11 give details of the discrepancies between the predicted and observed tides, during the year 1949, at the ports at which "actuals" were observed, and Table 12 gives the greatest errors in the predicted heights of low waters at these ports during the same year. It may be observed that, in general, the quality of the predictions has remained practically the same as in the previous years in each case.

The case of the Hooghly River ports, viz., Calcutta, Diamond Harbour and Saugor, requires special mention. From a recent levelling (1949) along the river banks, it has appeared that the tidal bench-marks of reference at these stations had all undergone considerable changes in their accepted heights due either to individual and/or regional subsidence or to local faulty levelling. The gauges having been set in relation to these faulty bench-marks, the recorded "actuals" have been wrong for some years. The figures tabulated in Tables 8–10 are thus burdened with inaccuracies from this source and should not be regarded as merely representing errors in the predictions.

For the (P–A) discrepancies to present a true state of affairs regarding the quality of the predictions, the importance of preserving the reference bench-mark and of keeping timely track of any alteration in its height by periodical check-levelling, cannot be over emphasized. In addition the zeros of the respective gauges should, of course, be kept adjusted to the reference bench-marks throughout.

45. **Prediction Methods.**—With a view to overhauling the older methods of tidal prediction and analysis followed in the Department especially those relating to riverain ports, Mr. A. N. Ramanathan, Deputy Superintending Surveyor, was sent on deputation abroad to undergo a course of advanced studies at the Liverpool Observatory and Tidal Institute, Birkenhead. He proceeded early in January 1950 and is expected to be back by the middle of May. Soon after his return it is proposed to take up the introduction, by gradual stages, of modern improved methods in all our future analysis and prediction work with a view to achieving maximum possible accuracy in our Tide-Tables.

The Liverpool method of reverain predictions has already been outlined briefly in the last year's Technical Report. The analysis for the harmonic shallow water constituent for Rangoon is being completed by Mr. Ramanathan at Liverpool and also among other things the special methods of analysis and predictions that are proposed to be followed in the case of the Hooghly River ports are being studied by him.

The following is a list of the methods that will be adopted for the Hooghly ports, viz., Saugor, Diamond Harbour and Kidderpore. The observed data proposed to be used for the analysis are those of the year 1948 for each of these ports. In the final results of the analysis, due allowance will be made for changes in datums and subsidence of bench-marks.

(*a*) *Saugor :*

(i) Carry out a normal Harmonic analysis for primary constituents (as for an open sea port) by Liverpool Institute's intensive method.

(ii) Using as many of the above components as the machine provides, obtain the "primary" prediction for the port for the same year (1948) and obtain the (P—A) differences.

(iii) Analyse these (P—A) difference for harmonic shallow water constituents. If the residuals, after the first H.S.W.C. analysis, are large, analyse these residuals for a second approximation. Combine the first and second approximation results and obtain the final set of H.S.W.C.

(iv) For predicting any future year, obtain the primary prediction for that year from the machine using the normal constituents as used in (ii) above, and to this apply the shallow water corrections that will be obtained separately from the machine by special methods and improvisations.

(*b*) *Diamond Harbour :—*

(i) Using the primary predictions for Saugor for 1948 as in (*a*) (ii) above, obtain the differences between these Saugor predictions and the observations at Diamond Harbour for the year 1948.

These differences are bound to be large because of the time interval and height differences between the tidal occurrences at the two ports, and in order to reduce the size of these differences for any easy analysis, it might be necessary to apply some suitable time and height corrections every month or fortnight

(or even more often) to the Saugor basic predictions to get a first approximation to the Diamond Harbour predictions and then take out the differences between the thus obtained values and the Diamond Harbour "actuals" for further analysis.

(ii) Analyse these differences for H.S.W.C. as in (*a*) (iii) above and obtain the H.S.W.C. constants :

(iii) For predicting for any future year, obtain the Saugor primary predictions for that year as in (*a*) (ii), and then apply the same corrections as were used vide (*b*) (*i*) sub-para above, to obtain basic first approximation predictions for Diamond Harbour. To these will be applied the shallow water corrections that will be obtained separately from the machine by using the H.S.W.C. constants derived in (*b*) (ii) above.

(*c*) *Kidderpore :—*

The procedure in this case is exactly similar to that of Diamond Harbour. The primary predictions, here again, are those of the deep water tides at Saugor, and corrections are made to these Saugor basic predictions to obtain the required predictions at Kidderpore.

It is hoped to introduce the above methods for the Hooghly River predictions, commencing with the 1952 Tide-Tables.

46. Miscellaneous.—Though the tide-predicting machine has remained in working order throughout the year, it has been giving some errors due to the worn-out crank pins and slots in the T-pieces. In addition, the gear wheel of the M_6 component happened to go out of order due to its wear, causing slight inaccuracies in some prediction curves. Action is in hand to effect the necessary repairs to the worn-out parts as early as possible.

TABLE 1(*a*).—*Harmonic Tidal constants derived from 29 days' observations*

Serial No.	Place and position (with description of the Tide-pole site)	Period and Central day of observations	Level of Zero of Tide-pole below: Chart datum (or Zero of predictions)	Level of Zero of Tide-pole below: B.M. of reference	Harmonic Constants	Constituents: M_2	S_2	N_2	K_2	K_1	O_1	P_1	M_4	MS_4	Z_0 (Height of local MSL. above chart datums)	Description of B.M. of reference
			feet	*feet*		*Indian Standard Time (05h 30m fast on G.M.T.)*									*feet*	
1	PORT OKHA* Lat. 22° 28′ N.; Long. 69° 05′ E. (about 100 yards SE. of the old tide-gauge site)	29 days			Old 1874–75 & 1904–05 H ft.	3·68	1·16	0·86	0·32	1·43	0·70	0·42	0·12	0·04	6·67	G.T.S. embedded □ in masonry B.M underneath A a railway siding inside the Port Compound about 100 yards south of the gate opening to the Indian Resthouse compound.
					g°	008	041	343	038	066	065	086	150	173		
		12–11–48	8·99	21·14	New 1948 H ft.	3·64	1·10	0·94	0·30	1·37	0·65	0·45	0·11	0·02	6·84†	
					g°	011	040	340	040	064	061	064	108	166		
2	PORBANDAR* Lat. 21° 38′ N.; Long. 69° 37′ E. (at Asmavathi Ghât near Shiva Temple and at the bend of the Creek)	29 days			Old 1893–94 & 1900–02 H ft.	2·13	0·78	0·51	0·21	1·16	0·57	0·34	0·03	0·02	5·02	Marine Survey B.M.† cut on the south face of the sea wall.
					g°	313	349	293	349	056	053	056	164	250		
		30–1–49	2·95	24·75	New 1949 H ft.	2·16	0·78	0·52	0·22	1·37	0·58	0·45	0·02	0·02	5·07†	
					g°	312	350	298	350	056	054	056	172	220		
3	BHAVNAGAR* Lat. 21° 48′ N.; Long. 72° 09′ E. (about 10 feet north of the old tide-gauge site)	29 days			Old 1889–94 H ft.	11·04	3·51	2·44	0·87	2·34	0·98	0·68	0·88	0·66	10·74	G.T.S. a dressed ○ block of B.M stone 154 yards SW. of the site of the old tide-gauge observatory, situated near the Steam Ferry Incline.
					g°	149	197	126	193	101	089	105	181	232		
		4–3–49	0·07	40·50	New 1949 H ft.	10·25	3·20	2·45	0·86	2·54	1·10	0·84	0·08	0·68	20·47†	
					g°	144	190	117	190	090	070	090	190	237		
4	MANDVI Lat. 22° 50′ N.; Long 69° 21′ E. (at the south end of the break water pier)	29 days		Unknown	Inferred Adm. T.T. Part II H ft.	4·2	1·6			1·4	0·7				8·5‡	Iron base of beacon at end of break water, chart datum being 20·00 ft. below this base.
					g°	357	034			072	069					
		19–12–48	1·39	23·87	New 1948 H ft.	4·08	1·16	0·84	0·32	1·46	0·72	0·48	0·14	0·06	8·5‡	Mark T, situated on the SW. side of the south verandah of the customs.
					g°	043	079	010	079	075	079	075	233	278		

* Standard Ports. † Derived from 29 days' observations and corrected for seasonal variations. ‡ Provisional value.

TABLE 1(*b*).—*Harmonic Tidal constants derived from 29 days' observations*

Serial No.	Place and position (with description of the Tide-pole site)	Period and Central day of observations	Level of Zero of Tide-pole below: Chart datum (or Zero of predictions)	Level of Zero of Tide-pole below: B.M. of reference	Harmonic Constants	Constituents: M_2	S_2	N_2	K_2	K_1	O_1	P_1	M_4	MS_4	Z_0 (Height of local M.S.L. above chart datums)	Description of B.M. of reference
			feet	*feet*		*Indian Standard Time (05h 30m fast on G.M.T.)*									*feet*	
1	KANDLA Lat. 23° 02′ ; Long. 70° 14′ E.	29 days 15–11–30	..	..	Old 1930 H ft. g°	7·65 062	2·40 111	1·59 036	0·65 111	1·55 094	0·76 075	0·48 094	0·43 004	0·33 071	12·30	Cut on the top of the south wall of pier.
	(At Kandla Timber Jetty)	2 Series of 29 days with central days 4–9–49 and 4–10–49	0·00	26·99	New 1949 H ft. g°	7·44 065	2·29 108	1·67 046	0·62 108	1·66 092	0·73 074	0·55 092	0·44 011	0·32 049	12·34*	

* Corrected for seasonal variations.

TABLE 1(*c*).—*Harmonic Tidal constants derived from 15 or 29 days' observations*

Serial No.	Place and position with description of the Tide-pole site)	Period and Central day of observations	Level of Zero of Tide-pole below: Chart datum (or Zero of prediction)	Level of Zero of Tide-pole below: B.M. of reference	Harmonic Constants	Constituents: M_2	S_2	N_2	K_2	K_1	O_1	P_1	M_4	MS_4	Z_0 (Height of local MSL. above chart datums)	Description of B.M. of reference
			feet	*feet*		*Indian Standard Time (05h 30m fast on G.M.T.)*									*feet*	
1	BHATKAL Lat. 13° 58′ N.; Long. 74° 32′ E.	15 days 4-2-49	2·60	147·78	H ft. g°	1·17 325	0·53 016	0·20 309	0·14 016	0·80 058	0·25 049	0·26 058	0·05 118	0·03 286	2·54	(M.S. of *g.*) situated on the eastern side of a lodge surrounding the lighthouse.
2	MALPE Lat. 13° 21′ N.; Long. 74° 41′ E.	15 days 12-12-48	1·70	62·22	H ft. g°	1·48 810	0·46 358	0·24 277	0·12 358	0·86 048	0·46 058	0·28 048	0·04 082	0·03 032	3·67	B.M. M.S.I. 1948 cut on the top step at the base of the lighthouse.
3	MANGALORE Lat. 13° 52′ N.; Long. 74° 50′ E.	29 days 1-4-49	2·70	13·05	H ft. g°	1·26 326	0·41 015	0·29 301	0·11 015	0·94 061	0·37 056	0·31 061	0·09 081	0·01 091	3·25	Set on the floor of the Port Office.
4	SACRAMENTO SHOAL Lat. 16° 36′ N.; Long. 82° 19′ E.	29 days 1-4-48	5·10	11·78	H ft. g°	1·38 244	0·58 283	0·28 226	0·15 283	0·35 350	0·12 328	0·11 350	0·10 326	0·09 160	1·78	The top of 1¼″ diameter iron rod cemented into the ground, situated on the south-west bank of URUDHA GAUTAMI river, approximately 1·4 miles to the east-north-east of Sacramento lighthouse.
	Harmonic Tidal constants derived from short period observations															
			feet	*feet*		*Time Meridian: 6h 30m fast on G.M.T.*									*feet*	
5	PORT REFUGE (Cocos Island)* Lat. 12° 05′ S.; Long. 96° 53′ E.	15 days 11-4-44	2·20	12·31	H ft. g°	0·90 140	0·30 199	0·23 131	0·08 199	0·37 264	0·31 224	0·12 264	0·03 301	0·02 007	2·29	B.M. 1944 at the NW. corner of the shed near the root of Direction Island Pier.

* Observations carried out during the last war by the Eastern Fleet Hydrographic Office, Naval HQ., Colombo.

TABLE 2.—*Corrections applied to the predicted times and heights at Vizagapatam for 1952*

Month	H.W.		L.W.	
	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*
January ..		0·2		0·0
February ..		0·4		0·2
March ..		0·2		0·0
April ..		0·2		0·0
May ..		0·0		0·0
June ..	−20	0·0	−20	− 0·2
July ..		0·0		− 0·2
August ..		0·0		− 0·2
September ..		0·0		− 0·2
October ..		0·2		0·0
November ..		0·0		0·0
December ..		0·0		0·0

The corrections have been based on (P — A) differences of the years 1945–49.

TABLE 3.—*Corrections applied to the predicted times and heights at Rangoon for 1952*

Month	H.W.		L.W.	
	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*
January ..	— 20	0·0	0	0·0
February ..	— 16	0·0	0	— 0·2
March ..	— 14	0·2	— 8	— 0·2
April ..	— 16	0·2	— 14	— 0·2
May ..	— 16	0·2	— 16	— 0·2
June ..	— 20	0·2	— 23	0·1
July ..	— 25	0·2	— 26	— 0·2
August ..	— 30	0·2	— 22	— 0·4
September ..	— 26	0·0	— 16	— 0·5
October ..	— 24	0·0	— 9	— 0·3
November ..	— 19	0·0	— 2	— 0·2
December ..	— 14	0·0	6	— 0·2

The corrections have been based on (P — A) differences of the years 1947–49.

TABLE 4.—*Mean errors E_1* and E_2* for 1949*

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PERIOD 1949	MEAN ERRORS (Predicted − Actual)												Number of errors exceeding			
	E_1								E_2				30 *minutes* in time		0·7† *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		3·1		0·2	3·5			0·2	13·5	0·2	15·8	0·2	2	1	0	0
16–31		3·9		0·4	7·2			0·2	9·8	0·4	12·9	0·3	1	0	0	0
Feb. 1–15		0·1		0·1	5·4			0·1	12·2	0·2	12·1	0·1	1	0	0	0
16–28		12·3		0·3	5·4			0·1	17·5	0·3	13·6	0·2	4	1	0	0
Mar. 1–15	Observations not reliable.															
16–31																
April 1–15																
16–30																
May 1–15																
16–31																
June 1–15																
16–30																
July 1–15																
16–31																
Aug. 1–15																
16–31																
Sept. 1–15																
16–30																
Oct. 1–15																
16–31																
Nov. 1–15																
16–30																
Dec. 1–15																
16–31																
TOTALS..	−	19·4	−	1·0	21·5	−	−	0·6	53·0	1·1	54·4	0·8	8	2	0	0
MEANS..	− 4·8		− 0·2		+ 5·4		− 0·2		13·2	0·3	13·6	0·2				

* E_1 is with regard to sign : E_2 is without regard to sign.
† One-tenth of the mean range of the ordinary spring tides.

TABLE 5.—*Mean errors E_1* and E_2* for 1949*

BHAVNAGAR

PERIOD 1949	MEAN ERRORS (Predicted – Actual)												Number of errors exceedi		
	E_1								E_2				30 *minutes* in time		1· *feet* hei
	H.W. Time		H.W. Height		L.W. Time		L.W. Height		H.W. Time Ht.		L.W. Time Ht.		H.W.	L.W.	H.W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*			
	+	–	+	–	+	–	+	–							
Jan. 1–15	4·2		0·5		1·9		0·4		5·8	0·5	4·3	0·6	0	0	1
16–31		1·2		0·0		1·9	0·3		5·2	0·6	6·3	0·5	0	0	3
Feb. 1–15	0·2		0·6			0·5	0·5		5·9	0·6	4·7	0·6	0	0	2
16–28		11·1		0·2	0·4		0·5		12·2	0·6	22·5	0·7	0	5	1
Mar. 1–15		7·8	0·4		9·8		0·9		8·6	0·6	31·4	0·9	0	6	1
16–31		17·1		0·2		4·3	0·5		17·1	0·3	21·3	0·8	0	5	0
April 1–15		1·6	0·1			4·4	0·6		8·4	0·2	25·6	0·8	0	8	0
16–30		19·0		0·2		1·7	0·6		19·3	0·6	16·3	0·8	3	1	1
May 1–15		5·9		0·0		12·1	0·5		7·3	0·5	19·6	0·6	0	5	0
16–31		9·1		0·6	2·3		0·6		11·7	0·9	13·9	0·6	2	0	4
June 1–15		7·7		0·6		3·3	0·8		10·1	0·9	20·5	0·8	0	3	6
16–30		9·3	0·2		6·2		0·6		13·1	0·5	18·1	0·9	0	4	0
July 1–15	0·3		0·1		4·7		0·6		7·5	0·4	9·1	1·2	0	0	0
16–31		1·8	0·2			1·4		0·7	6·0	0·3	14·7	1·1	0	1	0
Aug. 1–15	1·5		0·1			4·1		0·3	6·7	0·3	11·4	0·5	0	0	0
16–31		0·3		0·6		4·0		0·3	5·9	0·7	15·0	0·6	0	2	3
Sept. 1–15	2·7		0·4		4·5		0·3		6·1	0·5	10·7	0·6	0	0	1
16–30	0·2		0·5			2·6		0·0	13·5	0·5	21·0	1·1	1	3	1
Oct. 1–15	3·3		0·0		8·5		0·8		9·9	0·5	17·5	0·9	0	3	0
16–31		0·9	0·1		8·4			0·3	7·8	0·6	14·1	0·6	0	3	3
Nov. 1–15		2·5	0·2			3·6	0·4		11·6	0·4	11·8	0·5	0	0	0
16–30	0·3		0·3			5·5		0·4	7·1	0·5	15·7	0·9	0	0	0
Dec. 1–15	3·3		0·1		7·7			0·2	9·3	0·3	9·0	0·4	0	0	0
16–31	7·6		0·4		1·6			0·1	8·8	0·7	12·9	0·6	0	1	2
TOTALS ..	23·6	95·3	4·2	2·4	56·0	49·4	8·9	2·3	224·9	12·5	366·9	17·6	6	50	29
MEANS ..	– 3·0		+ 0·1		+ 0·9		+ 0·8		9·4	0·5	15·3	0·7			

* E_1 is with regard to sign : E_2 is without regard to sign.
† The mean range of the greatest ordinary spring-tides is 31·5 ft.

TABLE 6.—*Mean errors E_1* and E_2* for 1949*

BOMBAY (APOLLO BANDAR)

PERIOD 1949	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		6·9		0·1		3·6		0·1	11·9	0·3	8·7	0·2	2	1	0	0
16–31		2·3		0·4		3·5		0·0	5·1	0·2	8·0	0·3	0	0	0	0
Feb. 1–15		2·9	0·4		1·5		0·1		11·7	0·2	9·5	0·2	0	2	0	0
16–28		5·6		0·1		1·9	0·1		7·2	0·2	10·3	0·3	0	1	0	0
Mar. 1–15		2·7		0·3		0·1		0·1	8·6	0·4	10·7	0·3	1	1	0	0
16–31		1·3		0·5	0·6			0·3	8·5	0·5	7·2	0·4	0	0	1	1
April 1–15		1·6		0·6	2·1			0·3	9·6	0·6	9·4	0·4	0	0	6	1
16–30	0·7			0·1	1·7		0·1		9·4	0·1	10·0	0·3	0	1	0	0
May 1–15	1·5			0·3	7·1		0·1		11·3	0·4	11·7	0·3	0	3	0	0
16–31		3·5		0·3		0·4		0·3	9·8	0·4	11·5	0·4	1	3	5	1
June 1–15	2·3			0·6	3·7			0·4	9·0	0·7	7·7	0·4	0	0	5	4
16–30		6·2		0·1		4·2		0·2	10·8	0·3	10·8	0·2	0	1	0	0
July 1–15	2·1			0·4	9·0			0·2	6·9	0·4	11·0	0·3	0	0	0	0
16–31	3·5			0·5	10·5			0·6	12·5	0·5	15·3	0·6	0	1	2	4
Aug. 1–15	0·9			0·5	16·5			0·3	9·5	0·5	16·9	0·3	0	2	0	0
16–31	1·9		0·0		5·8			0·1	12·5	0·3	19·8	0·2	2	5	0	0
Sept. 1–15	7·2			0·1	16·0			0·1	10·6	0·2	20·5	0·3	1	6	0	0
16–30	8·6		0·2		9·0		0·1		11·9	0·3	14·5	0·3	1	4	0	0
Oct. 1–15	2·1			0·0	12·4		0·1		7·6	0·2	15·0	0·3	1	3	0	0
16–31	5·5		0·0		4·8			0·1	11·1	0·3	12·7	0·3	2	3	0	0
Nov. 1–15	5·2		0·0		5·1		0·1		7·3	0·2	8·1	0·3	0	0	0	0
16–30		1·4		0·1		2·5		0·2	7·9	0·3	10·6	0·4	1	1	0	0
Dec. 1–15	1·6			0·2	1·9			0·1	9·4	0·4	9·7	0·3	0	1	1	0
16–31		2·0		0·1		4·5		0·0	7·8	0·3	12·2	0·3	1	5	0	0
TOTALS ..	43·1	36·4	0·6	5·3	107·7	20·7	0·7	3·4	227·9	8·2	281·8	7·6	13	44	20	11
MEANS ..	+	0·3	−	0·2	+	3·6	−	0·1	9·5	0·3	11·7	0·3				

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

TABLE 7.—*Mean errors E_1* and E_2* for 1949*

VIZAGAPATAM

PERIOD 1949	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 Ht.		L.W. Time Ht.					
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*	H.W.	L.W.	H.W.	L.W.
	+	−	+	−	+	−	+	−								
Jan. 1–15		0·1	0·2			0·1	0·2		0·1	0·2	0·1	0·3	0	0	1	1
16–31	0·5			0·2	2·3			0·1	1·4	0·2	3·1	0·2	0	1	0	0
Feb. 1–15	1·2			0·3	1·6			0·4	1·2	0·3	1·9	0·4	0	0	2	4
16–28	2·2			0·2	0·7			0·3	2·4	0·2	1·3	0·3	0	0	0	1
Mar. 1–15	5·7			0·2	1·9			0·3	6·3	0·2	3·1	0·3	2	0	0	0
16–31	0·2			0·2	0·3			0·2	0·2	0·2	1·2	0·2	0	0	0	1
April 1–15		0·0		0·1	2·8		0·0		3·4	0·2	2·8	0·1	0	0	1	0
16–30		1·1	0·0			0·3		0·1	3·4	0·2	3·9	0·3	1	1	0	0
May 1–15	2·7			0·2	1·5			0·1	5·0	0·3	3·9	0·2	0	0	1	1
16–31	3·5			0·3	2·1			0·2	6·8	0·3	2·7	0·3	1	0	2	0
June 1–15	0·7			0·3	3·0			0·1	3·8	0·3	5·0	0·3	0	0	5	3
16–30	0·8			0·2	1·5			0·1	4·6	0·2	3·4	0·2	0	0	0	0
July 1–15	3·0			0·3	3·1			0·0	8·6	0·3	3·3	0·2	2	0	5	0
16–31	1·0			0·0	1·8			0·0	2·5	0·1	2·3	0·1	1	0	0	0
Aug. 1–15	1·2		0·1		0·0		0·2		1·2	0·1	0·0	0·2	0	0	0	1
16–31	0·1		0·1		0·2		0·1		0·1	0·1	0·2	0·1	0	0	0	0
Sept. 1–15	2·3		0·3		1·4		0·5		3·4	0·3	3·2	0·5	0	0	0	10
16–30	1·0		0·2		1·7		0·2		1·1	0·5	1·7	0·5	0	0	11	11
Oct. 1–15	3·1		0·4		2·4		0·4		3·1	0·4	2·4	0·4	0	0	7	9
16–31	0·5			0·3	0·8			0·2	0·5	0·4	2·7	0·5	0	0	9	10
Nov. 1–15		0·2		0·2	0·5			0·1	1·5	0·2	0·5	0·1	0	0	0	1
16–30		0·0		0·0	0·6		0·1		0·0	0·2	0·6	0·2	0	0	1	0
Dec. 1–15	1·9			0·1	1·3			0·0	1·9	0·1	1·9	0·2	0	0	0	0
16–31	2·0		0·1			1·0	0·1		2·2	0·2	1·5	0·3	0	0	0	1
TOTALS ..	33·6	1·4	1·4	3·1	31·5	1·4	1·8	2·2	64·7	5·7	52·7	6·4	7	2	45	54
MEANS ..	+ 1·3		− 0·1		+ 1·3		− 0·0		2·7	0·2	2·2	0·3				

* E_1 is with regard to sign : E_2 is without regard to sign.
† One-tenth of the mean range of the ordinary spring-tides.

TABLE 8.—*Mean errors E_1* and E_2* for 1949*

CALCUTTA (KIDDERPORE)

PERIOD 1949	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 Ht.		L.W. Time Ht.		H.W.	L.W.	H.W.	L.W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	−	+	−	+	−	+	−								
Jan. 1–15		0·6		0·2	7·9		0·2		10·1	0·4	10·1	0·5	1	1	0	1
16–31		5·4		0·3		5·0	0·1		14·2	0·4	9·6	0·6	0	2	0	1
Feb. 1–15		3·0		0·3	3·6		0·1		10·0	0·5	13·2	0·5	0	5	1	1
16–28		3·3		0·4		1·0	0·4		10·5	0·7	12·7	0·6	0	8	7	5
Mar. 1–15	2·6			0·2	5·3		0·3		9·3	0·3	12·2	0·4	2	2	1	0
16–31		3·8		0·2	2·6		0·4		12·2	0·5	11·7	0·5	2	2	3	3
April 1–15	5·2			0·5		1·4	0·4		12·3	0·6	17·2	0·4	2	4	1	0
16–30	7·8			1·2	16·2			0·2	12·7	1·2	18·3	0·4	2	4	18	1
May 1–15	11·3			1·1	2·6		0·0		14·2	1·1	19·5	0·3	4	4	15	0
16–31	5·2			0·5	12·7		0·1		10·1	0·5	14·6	0·4	0	2	5	0
June 1–15	3·1			0·5		3·0		0·1	12·6	0·6	8·8	0·3	0	0	4	1
16–30		2·9		0·3	5·6		0·2		12·5	0·5	10·9	0·5	0	1	2	6
July 1–15	3·6			0·4		1·2	0·1		13·0	0·5	14·9	0·4	1	2	0	0
16–31		2·9		0·2	0·1		0·1		14·5	0·5	13·7	0·4	2	2	3	0
Aug. 1–15	5·2			0·1	5·6		0·5		10·8	0·3	12·8	0·5	0	2	0	5
16–31	0·2			0·0	0·8		0·4		13·2	0·3	19·4	0·5	1	4	0	1
Sept. 1–15	3·1		0·4		11·1		1·0		9·6	0·5	13·3	1·0	0	3	4	13
16–30	0·2		0·1			1·0	0·5		10·6	0·3	12·8	0·5	1	3	0	1
Oct. 1–15		3·0	0·5		4·0		0·8		10·4	0·6	15·1	0·8	1	2	8	8
16–31		3·0	0·4		2·7		0·9		11·0	0·6	18·5	0·9	0	4	2	13
Nov. 1–15		3·3	0·6		6·6		1·2		10·6	0·7	7·8	1·2	0	0	7	22
16–30		0·2	0·1			1·7	0·7		9·2	0·4	13·8	0·8	0	4	0	11
Dec. 1–15		6·5	0·7		4·4		0·9		12·1	0·7	13·1	0·9	1	1	7	9
16–31		1·9	0·6		4·4		0·7		9·6	0·6	16·4	0·7	0	5	3	9
TOTALS ..	47·5	40·0	3·4	6·4	96·1	14·3	10·0	0·3	275·3	13·3	330·4	14·0	20	62	91	111
MEANS ..	+ 0·3		− 0·1		+ 3·4		+0·4		11·5	0·6	13·8	0·6				

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

TABLE 9.—*Mean errors E_1* and E_2* for 1949*

DIAMOND HARBOUR

PERIOD 1949	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 Ht.		L.W. Time Ht.		H.W.	L.W.	H.W.	L.W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	–	+	–	+	–	+	–								
Jan. 1–15	2·0			0·6	15·9			0·1	10·7	0·6	16·1	0·6	0	4	5	2
16–31		5·0		0·7	4·6			0·6	10·5	0·7	9·1	0·9	0	0	9	13
Feb. 1–15	1·4			0·8	13·1			0·6	7·4	0·8	15·5	0·7	1	5	9	9
16–28		6·6		0·8	4·5			0·6	14·6	1·0	8·1	0·7	1	1	11	5
Mar. 1–15		2·5		0·7	9·5			0·6	11·5	0·8	14·3	0·6	1	2	6	6
16–31		12·9		0·7	1·7			0·5	21·5	0·7	10·6	0·7	6	1	7	2
April 1–15	0·7			1·1		2·5		0·4	14·7	1·1	16·7	0·5	2	4	14	2
16–30		7·1		1·5	14·6			0·6	13·2	1·5	18·1	0·6	1	4	21	3
May 1–15	1·4			1·5	9·1			0·8	13·4	1·5	17·3	0·8	4	4	19	8
16–31		10·9		1·0	13·9			0·5	13·8	1·0	16·2	0·8	2	3	11	5
June 1–15		15·0		0·8		8·0		0·7	15·7	0·8	12·7	0·8	2	2	7	8
16–30		14·3		0·7	2·7			0·5	15·7	0·7	11·2	0·6	4	0	10	3
July 1–15		8·2		0·6		0·3		0·7	12·2	0·7	14·2	0·8	2	1	5	8
16–31		6·0	0·1		6·5			0·5	11·1	0·4	10·2	0·6	0	2	4	6
Aug. 1–15	4·2			0·2	16·8			0·4	7·7	0·3	19·6	0·6	0	5	1	3
16–31	2·3			0·0	9·5			0·6	12·4	0·6	15·5	0·6	1	4	4	2
Sept. 1–15		1·0		0·4	20·4			0·4	8·2	0·5	21·4	0·5	0	8	3	1
16–30	0·5			0·6	15·6			1·0	13·3	0·6	18·3	1·0	0	4	8	13
Oct. 1–15		6·1		0·7	17·8			0·5	14·0	0·8	21·1	0·6	4	6	9	3
16–31		0·0		0·9	11·6			1·1	11·0	0·9	17·5	1·1	1	4	9	14
Nov. 1–15		5·4		0·8	13·8			0·4	9·3	0·8	14·6	0·6	0	3	8	2
16–30		3·3		0·8	8·2			0·9	7·9	0·8	16·3	0·9	0	2	9	15
Dec. 1–15		2·8		0·6	11·3			0·5	8·0	0·6	15·5	0·8	0	0	8	8
16–31		2·9		0·4	10·9			0·8	8·5	0·5	14·6	0·9	0	4	1	13
TOTALS ..	12·5	110·0	0·1	16·9	232·0	10·8	–	14·3	286·5	16·7	361·7	17·1	32	73	198	153
MEANS ..	– 4·1		– 0·7		+ 9·2		– 0·6		11·9	0·8	15·1	0·7				

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

TABLE 10.—*Mean errors E_1* and E_2* for 1949*

SAUGOR (DUBLAT)

PERIOD 1949	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. Ht.		L.W. Ht.		H.W.	L.W.	H.W.	L.W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	−	+	−	+	−	+	−								
Jan. 1–15		6·3		0·1		0·3	0·3		6·7	0·3	6·4	0·4	0	0	0	0
16–31		8·0		0·2		3·8		0·1	8·3	0·3	7·1	0·5	0	0	0	2
Feb. 1–15		0·3		0·2		0·4		0·1	6·8	0·4	9·4	0·2	0	1	0	0
16–28		6·1		0·1		5·5	0·1		7·0	0·5	8·2	0·4	0	1	2	0
Mar. 1–15		0·0		0·2	1·3			0·0	10·2	0·3	7·7	0·3	1	1	0	0
16–31		11·9		0·1		9·5		0·1	14·4	0·2	13·7	0·4	4	1	0	3
April 1–15		2·6		0·4		6·7		0·0	11·9	0·4	17·7	0·4	1	2	0	0
16–30		5·2		0·9	3·2			0·4	9·1	0·9	11·5	0·4	1	1	12	0
May 1–15		3·4		0·8		4·4		0·6	13·3	0·9	13·1	0·6	1	1	12	7
16–31		4·1		0·4		1·5		0·2	10·7	0·5	9·5	0·3	1	0	4	0
June 1–15		4·9		0·4		6·0		0·4	6·2	0·4	9·9	0·5	0	0	2	0
16–30		6·1		0·0		2·3	0·1		10·7	0·3	9·3	0·3	0	0	0	0
July 1–15		0·2		0·2		0·7		0·5	8·9	0·4	8·8	0·5	0	0	0	4
16–31		3·2	0·4		1·0			0·0	9·0	0·5	9·8	0·5	0	1	1	5
Aug. 1–15	3·2		0·1		6·1			0·0	9·4	0·2	10·2	0·4	1	0	0	0
16–31		2·1	0·4			4·0	0·1		11·0	0·5	13·6	0·4	1	3	3	0
Sept. 1–15		6·1	0·1			0·6	0·1		9·1	0·4	7·2	0·4	0	0	1	1
6–30		3·5	0·1			7·6		0·3	12·0	0·4	13·8	0·4	2	2	0	1
Oct. 1–15		7·9		0·1		2·5		0·0	15·9	0·4	12·1	0·4	4	3	0	0
16–31		4·2		0·5		6·2		0·7	14·4	0·5	10·8	0·7	1	0	4	13
Nov. 1–15		8·1		0·7		3·1		0·4	9·7	0·7	6·2	0·5	0	0	4	3
16–30		10·0		0·5		8·8		0·8	11·1	0·5	10·3	0·8	1	0	3	9
Dec. 1–15		9·1		0·5		4·0		0·5	9·6	0·5	8·3	0·6	0	0	4	1
16–31		4·8		0·3		1·5		0·7	9·5	0·4	10·7	0·7	0	0	0	5
TOTALS ..	3·2	124·1	1·1	6·6	11·6	79·6	0·7	5·8	244·9	10·8	243·3	11·0	19	17	52	54
MEANS ..		− 5·0		− 0·2		− 2·8		− 0·2	10·2	0·4	10·1	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 1949*

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PERIOD 1949	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	13·5			0·1		0·2		0·2	15·1	0·2	11·7	0·4	1	1	0	1
16–31	3·5		0·1			14·2		0·5	8·0	0·2	15·1	0·5	0	0	0	3
Feb. 1–15	5·4		0·2			1·9		0·3	12·9	0·6	13·1	0·5	0	1	1	2
16–28		0·1	0·3			7·6		0·3	9·8	0·3	11·9	0·4	0	0	0	2
Mar. 1–15	1·4		0·1		2·4			0·2	9·7	0·4	17·6	0·5	2	2	0	1
16–31		7·4	0·4			6·5		0·0	12·2	0·4	11·1	0·4	1	1	0	0
April 1–15	2·2		0·2		2·0		0·1		8·6	0·6	20·1	0·5	0	2	3	1
16–30		1·0		0·4	8·9			0·1	10·0	0·5	11·8	0·7	0	2	2	3
May 1–15	3·1			0·1	4·9		0·5		6·4	0·6	15·1	0·6	0	2	2	4
16–31	2·3			0·4	13·7		0·0		6·0	0·6	13·7	0·5	0	0	6	2
June 1–15	0·4		0·2		6·6		0·1		6·8	0·3	9·7	0·5	0	0	1	2
16–30	6·1			0·1	17·1			0·1	9·9	0·3	17·1	0·8	0	1	0	5
July 1–15	1·2			0·1	10·9		0·3		7·2	0·3	14·5	0·7	0	0	0	4
16–31	6·8		0·4		13·0			0·3	9·5	0·4	13·0	0·6	0	2	0	4
Aug. 1–15	4·7		0·0		10·6		0·4		9·0	0·3	13·3	0·5	0	1	0	2
16–31	6·7		0·2		8·8		0·2		9·5	0·6	10·9	0·4	2	1	0	0
Sept. 1–15	3·3			0·1	7·1		0·4		7·2	0·4	8·5	0·6	0	0	0	1
16–30	12·1		0·3			0·7		0·5	13·4	0·7	9·8	0·5	0	0	1	1
Oct. 1–15	0·1			0·2	3·1		0·3		7·0	0·4	4·9	0·4	0	0	0	0
16–31	5·6		0·1		0·4			0·8	9·8	0·3	9·2	0·8	0	0	0	5
Nov. 1–15	3·9			0·5	6·0			0·4	10·0	0·6	7·5	0·4	0	0	2	1
16–30	4·9			0·1		4·4		1·1	7·3	0·5	13·5	1·1	0	0	0	8
Dec. 1–15	0·1			0·0		8·5		0·3	6·2	0·5	8·5	0·4	0	0	0	0
16–31		1·8	0·1			8·4		0·9	9·7	0·5	15·6	0·9	0	1	1	5
TOTALS ..	87·3	10·3	2·6	2·1	115·5	52·4	2·3	6·0	221·2	10·5	296·7	13·6	6	17	19	57
MEANS ..	+	3·2	+	0·0	+	2·6	−	0·2	9·2	0·4	12·4	0·6				

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

TABLE 12.—*Greatest differences between the predicted and actual heights of Low Water during 1949*

Port	Predicted *minus* actual	Date	REMARKS
Aden ..	— 0·8	September 20 and 21	
Bhavnagar ..	— 2·6	July 27 and October 24	A bar has formed in the channel which obstructs the flow of water to the Tide-pole, thereby affecting all tides below 9 ft. The mean range of the ordinary spring tides at this port is 31·5 ft.
Bombay .. (Apollo Bandar)	— 1·2	July 26	
Vizagapatam ..	— 1·7	October 27	
Calcutta .. (Kidderpore)	— 2·1	November 1	Riverain port.
Diamond Harbour ..	— 2·2	October 28	Do.
Dublat (Saugor) ..	— 2·0	October 28	Do.
Rangoon .. (Monkey Point)	— 2·1	April 23	Do. Tidal registrations are at Monkey Point about 1½ miles down the river.

CHAPTER VI

OBSERVATORIES

BY B. L. GULATEE, M.A. (CANTAB.), F.R.I.C.S., M.I.S. (INDIA)

47. Standards of Length.—The length of the 4-metre invar bar has been determined in terms of the 1-metre nickel bar, and 8 invar wires have been standardized in the 24-metre comparator in preparation for geodetic base measurement in Kutch. The bars and wires have maintained their previous lengths very satisfactorily. Details of the observations are given below. The observers were Messrs. V. P. Sharma and A. K. Bhattacharjee.

The 4-metre invar bar has been measured in 4 sections which are reduced to a common temperature of 24°·3 C. This bar has three sets of graduations on it—one on its edge A, the other on edge B and the third on Baros plugs in the centre. The details of comparison with the 1-metre nickel bar are given below.

(*a*) Invar 4-m (Baros plugs) *minus* Nickel 1-m.—
First metre (*0 to 1*) *of invar bar.*

Date	Temperature	A. K. B.	V. P. S.
17-10-49	$T_I = 23°{\cdot}66$ C $T_N = 23°{\cdot}66$ C	−0·2550 mm. ·2541 ·2546 ·2572 ·2543 ·2502 ·2507 ·2515	−0·2554 mm. ·2552 ·2543 ·2568 ·2552 ·2495 ·2519 ·2528
	Mean	−0·2535 mm.	−0·2539 mm.

Reputed length of nickel at 23°·66 C = 1 m. + 0·3126 mm. (derived from N.P.L. certificate 1947)
Observed invar *minus* nickel = − 0·2537 mm.
∴ Length of invar at 23°·66 C = 1 m. + 0·0589 mm.

The expansion equation of invar is
$L_T = L_0 (1 + 0{\cdot}000\,001\,450t - 0{\cdot}000\,000\,000\,5t^2)$
which gives the length of this section of the invar bar at 24°·3 to be = 1 m. + 0·0598 mm.

Second metre (1 to 2) of invar bar.

Date	Temperature	A. K. B.	V. P. S.
16–10–49	$T_1 = 23°{\cdot}82$ C $T_N = 23°{\cdot}80$ C	−0·2623 mm. ·2618 ·2647 ·2619 ·2661 ·2637 ·2660 ·2653	−0·2623 mm. ·2621 ·2662 ·2636 ·2660 ·2640 ·2658 ·2641
	Mean	−0·2640 mm.	−0·2642 mm.

Reputed length of nickel = 1 m. + 0·3144 mm.
Observed invar *minus* nickel = − 0·2641 mm.
Length of the invar at 23°·82 C = 1 m. + 0·0503 mm.
∴ Length of the invar at 24°·3 C = 1 m. + 0·0510 mm.

Third metre (2 to 3) of invar bar.

Date	Temperature	A. K. B.	V. P. S.
15–10–49	$T_1 = 23°{\cdot}66$ C $T_N = 23°{\cdot}64$ C	−0·2593 mm. ·2614 ·2641 ·2637 ·2628 ·2604 ·2601 ·2616	−0·2597 mm. ·2614 ·2633 ·2622 ·2638 ·2601 ·2607 ·2631
	Mean	−0·2617 mm.	−0·2618 mm.

Reputed length of nickel = 1 m. + 0·3123 mm.
Observed invar *minus* nickel = − 0·2617 mm.
Length of the invar at 23°·66 C = 1 m. + 0·0506 mm.
∴ Length of invar at 24°·3 C = 1 m. + 0·0515 mm.

Fourth metre (3 to 4) of invar bar.

Date	Temperature	A. K. B.	V. P. S.
14–10–49	$T_1 = 23°{\cdot}30$ C $T_N = 23°{\cdot}29$ C	−0·2523 mm. ·2531 ·2503 ·2524 ·2537 ·2532 ·2525 ·2550	−0·2521 mm. ·2522 ·2523 ·2507 ·2550 ·2537 ·2530 ·2553
	Mean	−0·2528 mm.	−0·2530 mm.

Reputed length of nickel = 1 m. + 0·3079 mm.
Observed invar *minus* nickel = − 0·2529 mm.
Length of the invar at 23°·30 C = 1 m. + 0·0550 mm.
∴ Length of the invar at 24°·3 C = 1 m. + 0·0564 mm.

Combining the four sections of the invar bar we get the total length of the bar (Baros plugs) as 4 m. + 0·2187 mm. at 24°·3 C. 1939 standardizations gave this length to be 4000·2243 millimetres. The bar has accordingly shortened by 0·006 mm. or 1·5/M in 10 years. This shows that it has more or less reached a stable condition, as in its early days, it exhibited an increase of 5/M in 10 years.

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

Date	A. K. B.	V. P. S.
19–10–49	+0·0036 mm. + ·0025 − ·0015 + ·0008	+0·0033 mm. + ·0016 + ·0010 − ·0005
Mean	+0·0014 mm.	+0·0014 mm.
	General mean	= +0·0014 mm.

Length of 4-m invar (Baros plugs) at 24°·3 C = 4 m. + 0·2187 mm.
Length of 4-m invar Edge B at 24°·3 C = 4 m. + 0·2201 mm.
and length of 4-metre invar Edge B at 28° C = 4 m. + 0·2411 mm.

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

Date	A. K. B.	V. P. S.
19–10–49	+0·0014 mm. + ·0048 − ·0018 + ·0004	+0·0021 mm. + ·0004 − ·0011 − ·0005
Mean.	+0·0013 mm.	+0·0002 mm.
	General mean	+0·0008 mm.

(*d*) 4-m Nickel-steel *minus* 4-m Invar Baros plugs.—

Date	Temperature	A. K. B.	V. P. S.
9-11-49	T_I = 17°·58 C T_{NS} = 17°·58 C	+0·3411 mm. ·3427 ·3452 ·3413 ·3402 ·3404 ·3385 ·3367 ·3377 ·3388	+0·3452 mm. ·3392 ·3478 ·3415 ·3383 ·3411 ·3378 ·3377 ·3366 ·3371
	Mean	+0·3403	+0·3402
	Accepted mean	+0·3402 mm.	

Accepted length of 4-m invar bar at 24°·3 C = 4 m. + 0·2187 mm.
Length of 4-metre invar bar at 17°·58 C = 4 m. + 0·1802 mm.
Observed nickel-steel *minus* invar at 17°·58 C = + 0·3402 mm.
Length of 4-m nickel-steel at 17°·58 C = 4 m. + 0·5204 mm.
Coefficient of expansion of nickel-steel = + ·000 007, 52 per °C.
∴ Length of this bar at 24°·3 C = 4 m. + 0·7225 mm.

Its length during 1934 standardization was found to be 4 m. + 0·7325 mm. and its Reputed Length in 1914 (N.P.L. Certificate) was 4 m. + 0·7423 mm.

These figures show that the 4-m nickel-steel has been shortening by 0·01 mm. in 20 years or at the rate of 1/8 M per year.

48. Coefficients of Expansion of 24-metre Invar Wires.—The invar wires for geodetic base measurement were obtained a long time ago and the coefficients of expansion for some of them were determined from short samples of the wires. Previous work with them had made it abundantly clear that the coefficients as supplied by the makers were not applicable and it was essential to determine them either in the 24-m. comparator or in the field. During the Kandla base measurement, a length of 240 metres was laid on in the field on a flat bit of ground. Its ends were marked by brass plugs embedded in cement. It was measured with all the wires in use at two different temperatures.

The following table gives the values for the coefficients as derived in this way. For comparison the previously accepted values of 1934 have also been given. It will be seen that during these 15 years when no work has been done with them, a considerable change has occurred in their temperature coefficients. For some of the wires, even the sign has changed.

Increase in mms. per 24 metres per 1°C.

Season \ Wire Nos.	244	247	248	252	1037	1038
Nov. 1949 ..	−·0092	−·0149	−·0132	−·0138	−·0091	−·0078
1933–34 ..	+·0058	−·0009	−·0028	−·0050	·0000	+·0012

49. **Lengths of Wires.**—In the year 1931–32, although no base was actually measured, all the wires for some unaccountable reason showed abnormal changes of length amounting in an extreme case to as much as 1/10,000. During the measurement of some bases in 1932–33 also some of the wires changed by 1/60,000 or so. To avoid the uncertainties caused by such large changes, the lengths of all the wires which were taken to the field were determined against the 24-metre comparator at Dehra Dūn before and after the measurement of the Kandla base. In the field, daily comparisons were done with the substandard and a close watch was kept to ensure that the two wires of each pair maintained their relative length.

The length of the 24-metre comparator was determined in October with the help of the 4-metre Invar bar and is shown in Plate XXV.

The resulting lengths of the seven wires pre and post field season are tabulated below :—

Millimetres in excess of 24 metres at 28° C.

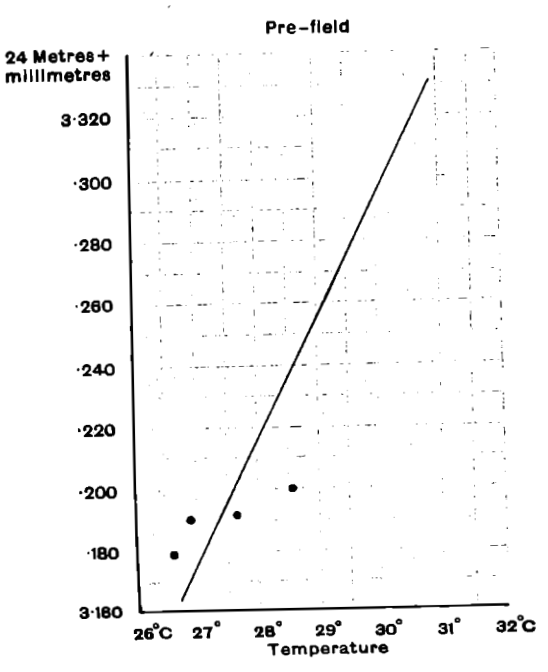
Date \ Wire Nos.	245	244	247	248	252	1037	1038
October ..	+0·99	−2·42	+1·56	+1·75	+3·19	+0·79	+0·77
December ..	+1·05	−2·44	+1·37	+1·67	+3·11	+0·77	+0·81
Mean ..	+1·02	−2·43	+1·47	+1·71	+3·15	+0·78	+0·79

It will be seen that the wires have held their lengths very satisfactorily in the field. Their mean value has been accepted for the final reduction of the base.

The largest change 0·19 mm. has been exhibited by wire No. 247. This wire was slightly kinked at one end in 1933 due to the wireman slipping while crossing a *nāla*, resulting in a shortening of its length by 0·08 mm. After that it showed rather large changes of length. It was deliberately included this field season to see whether ill-treatment causes only temporary instability in these wires. Actual results have shown that although the wire received a maltreatment 16 years ago, it still shows not only large changes in its length but also in its temperature coefficient (vide table in para 48). It is now being rejected for future use.

Another point, to which it is worthwhile drawing attention is that in the past, the field standards have sometimes changed much more than working wires. The standard wire selected was No. 245.

Length of 24 – metre Comparator, 1949



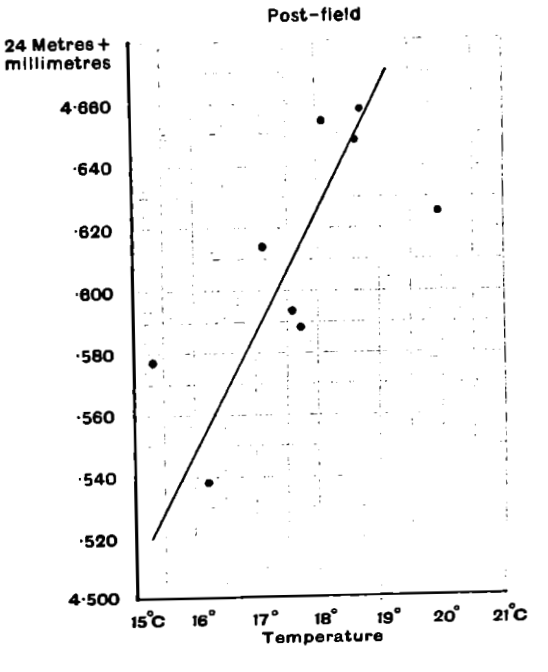


Plate XXV

Reg. No. 702 M/M O.D. 51 (G. & T. O.)-375.

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It was used for the comparison of substandard 1037 only four times during the field season. Neither this nor the substandard 1037 shows a markedly greater change than the working wires.

50. Magnetic Observations.—It has been known for some time that the diurnal variations of the horizontal force of the earth's magnetism are enhanced in the areas between the magnetic and geographic equators. Thus, at Kodaikanal Observatory, range is about double that at Alibag. This augmentation is of so great an interest as to warrant observations being carried out in different regions of the world near the magnetic equator. With this end in view, a Committee was convened by the International Association of Terrestrial Magnetism and Electricity at the Oslo Assembly in 1948 to promote observations of daily variation of the horizontal magnetic force between and near the geographic and magnetic equators. It put forth the scheme that observations of the range of the daily variation of H should be carried out at a series of stations about 150 km. apart lying in a north-south line outside and between the geographic and geomagnetic equators with a station of reference on the geomagnetic or on the geographic equator.

The Committee's proposal for these observations in India was considered at the meeting of the Central Board of Geophysics and it was agreed that the Geodetic Branch of the Survey of India should be entrusted with this work.

Chart XXVI shows the stations which were selected for these special observations. They are Guntakal, Bangalore, Tinnevelly and Galle (in Ceylon) with Kodaikanal as the reference station. Galle is off the meridian of Kodaikanal, but it was considered advisable to include it as it is situated in a latitude on which the observations should be of much value.

Three Quartz Horizontal Magnetometers Nos. 17, 18 and 32 belonging to the International Association of Terrestrial Magnetism were received in India for the purpose. A detachment consisting of Mr. S. Vaikuntanathan and 2 *khalāsis* started from Dehra Dūn for field work on the 9th May and returned on the 20th August, 1950. Although the observations were made subsequent to the period covered by this report, the results have been included as they are of immediate interest. Details of observations are as follows :—

At Kodaikanal observatory which was chosen as the reference station, simultaneous observations were made for three days both at the beginning and the close of the field work.

To get the maximum range, observations in the field were carried out during the periods in which H attains its maximum and minimum values. In India, the maximum usually occurs between 11-30 and 12-30 hrs., Indian standard time (5½ hours ahead of Greenwich) and the minimum occurs either in the morning between 5-45 and 7-00 hrs. or in the evening between 17-00 and 18-30 hours.

The Q.H.Ms. accordingly were observed at 3 specified times (6, 12 and 18 hours) in a day and simultaneously, values were

observed at Kodaikanal reference station. A single observation lasted 10 to 14 minutes. The routine of observation was to read two of the three Q.H.Ms. at a time. This involved six observations each day—three with one instrument and three with another almost immediately after it (one in the morning, one in the noon and one in the evening). A minimum of three days observations were made at each station, No. 32 being used for all the three days, No. 17 for two days and No. 18 for only one day.

The Q.H.Ms. 32 and 17 were found to agree between themselves very well while the values obtained with Q.H.M. No. 18 was always on the higher side by about 10 gammas.

The constants for the three instruments for a torsion of 2π are as follows :—

No. 17. $H = 9{\cdot}14718 - \log \sin\phi + 0{\cdot}000172_5\ t - 0{\cdot}0002\ H \cos\phi$
No. 18. $H = 9{\cdot}15017 - \log \sin\phi + 0{\cdot}000172\ t - 0{\cdot}0002\ H \cos\phi$
No. 32. $H = 9{\cdot}14947 - \log \sin\phi + 0{\cdot}000160\ t - 0{\cdot}0002\ H \cos\phi$,

where t is the temperature in degrees centigrade, ϕ is the observed deviation angle and H is the horizontal magnetic force.

The results obtained at the 5 stations are shown in Tables 1 and 2.

A scrutiny of the results reveals that as expected the ranges are maximum at Kodaikanal and Tinnevelly which are nearer to the magnetic equator than the other stations observed at. Galle and Guntakal have about the same mean range.

It is also interesting to note that the mean range at Kodaikanal decreased by as much as 33γ in a period of a fortnight commencing from 5th June 1950.

A comparison of columns 13 and 14 of Table 1 reveals that for Kodaikanal, the range as derived from Q.H.M. observations agrees almost perfectly with that obtained from self-recording magnetic variometers, which is very satisfactory.

The observed ranges tabulated in this table have to be further corrected for such effects as the declination of the sun, sun spot numbers and the age of the moon to get the final value for the variation of the range with the geographical latitude. This has been done at the Geographical Section of the Danish Meteorological Institute, Copenhagen under the supervision of Dr. J. Egedal.

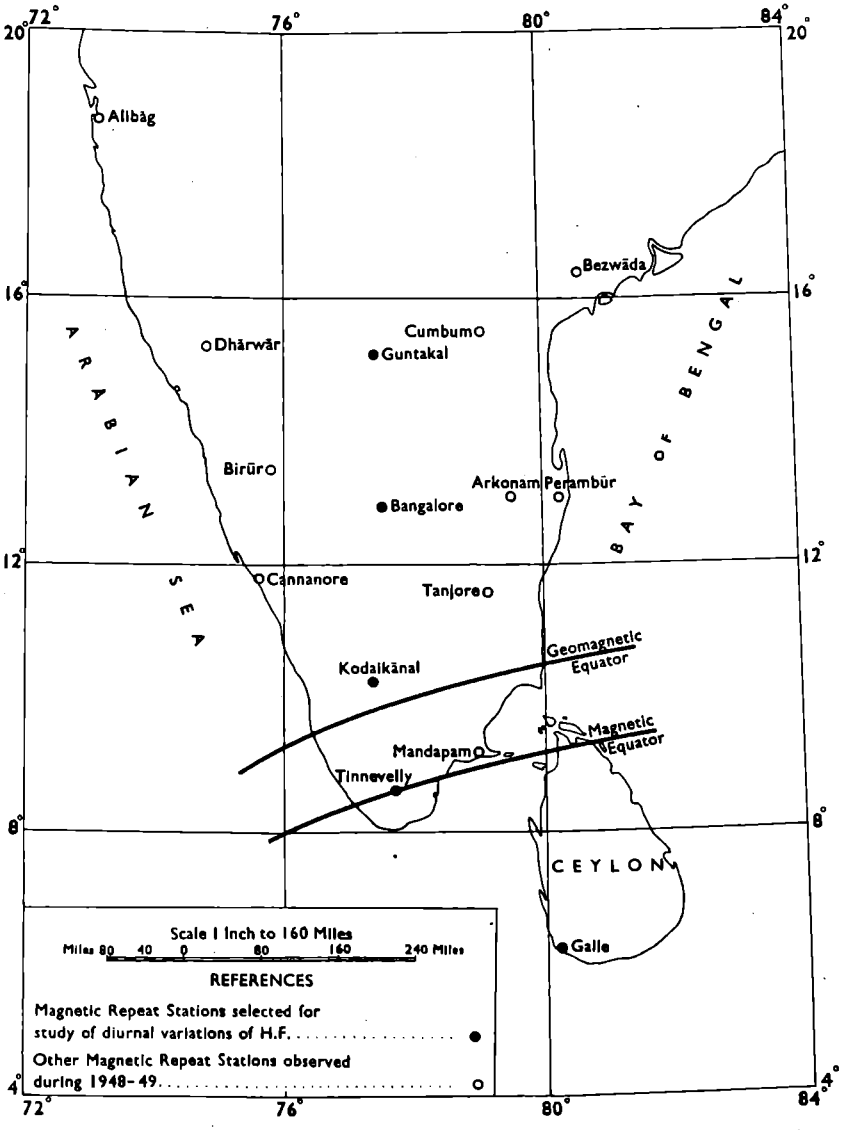
The following table gives the final results :—

Reference station : Kodaikanal (Lat. 10°·2 N., Long. 77°·5 E.)
Magnetic equator = 8°·7 N. ; Geomagnetic equator = 9°·7 N.

Year	1950			
Date	July 31–Aug. 2	July 9–12	June 5–8	June 18–20
Station	Guntakal	Bangalore	Tinnevelly	Galle
Latitude	15°·2 N.	13°·0 N.	8°·7 N.	6°·0 N.
Longitude	77°·4 E.	77°·6 E.	77°·6 E.	80°·2 E.
Ratio	0·74	0·82	1·12	0·86

Chart XXVI

STATIONS OBSERVED WITH Q.H.M s.



Reg.No. 704 M/N.O.D'51(G.& T.O.1°= 160 Miles)-375.

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The observations revealed that the mean maximum range in India was 106 γ as against 116 γ at Huancayo and 124 γ at Togoland.

One more station Mandapam (Latitude 9°·3 N., Longitude 79°·1 E.) was also observed, as it happened to be a repeat station. Although it is not located on the meridian of the stations chosen for special study, the observations on it are of interest, as it is quite close to the Magnetic Equator. Table 3 shows the results. It would be seen that the observed range of variation of H is very large and comparable to that at Tinnevelly.

51. **Observations at Repeat Stations.**—The three Q.H.Ms. employed for measurements in the equatorial belt were also compared with the Kew Pattern instruments in use at Dehra Dūn as well as at Alibag magnetic observatory. The results will be discussed in the next Technical Report.

In addition to the above comparisons, declination and horizontal force were observed at 9 other repeat stations, viz., Mandapam (see para 50 above), Tanjore, Perambur, Arkonam, Cannanore, Birur, Dharwar, Cumbun and Bezwada (See Chart XXVI). The revised isogonic lines south of latitude 16° drawn as a result of these observations will be given in the next Technical Report.

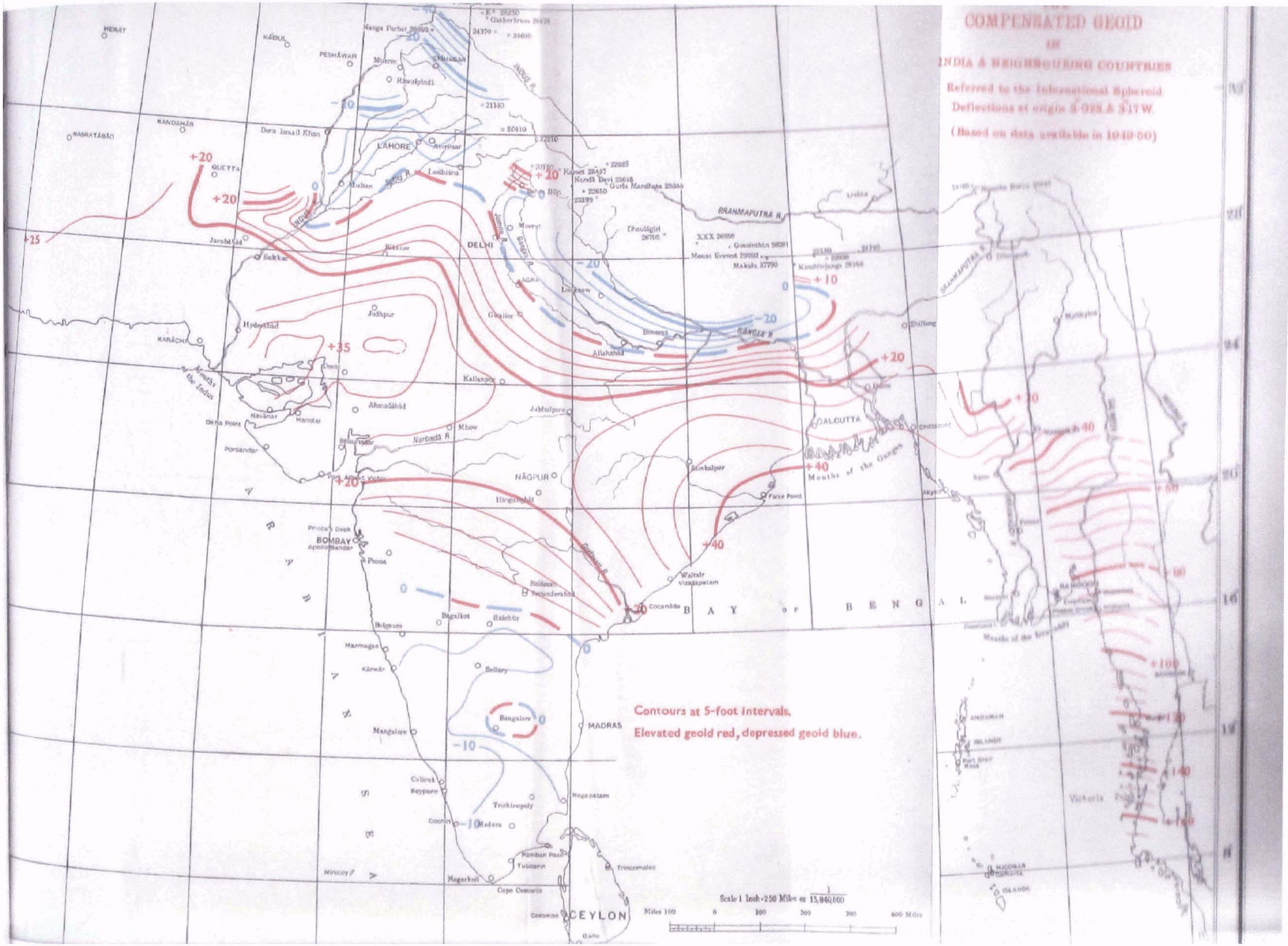
52. **Meteorological and Seismological Observations.**—The usual meteorological observations at 8½ hrs. and 17½ hrs. in place of 8 hrs. and 17 hrs. have been taken throughout the year. The meteorological data for Dehra Dūn have been supplied to various local civil and military offices. The original Meteorological monthly records have been sent to the Director, Regional Meteorological Centre, New Delhi.

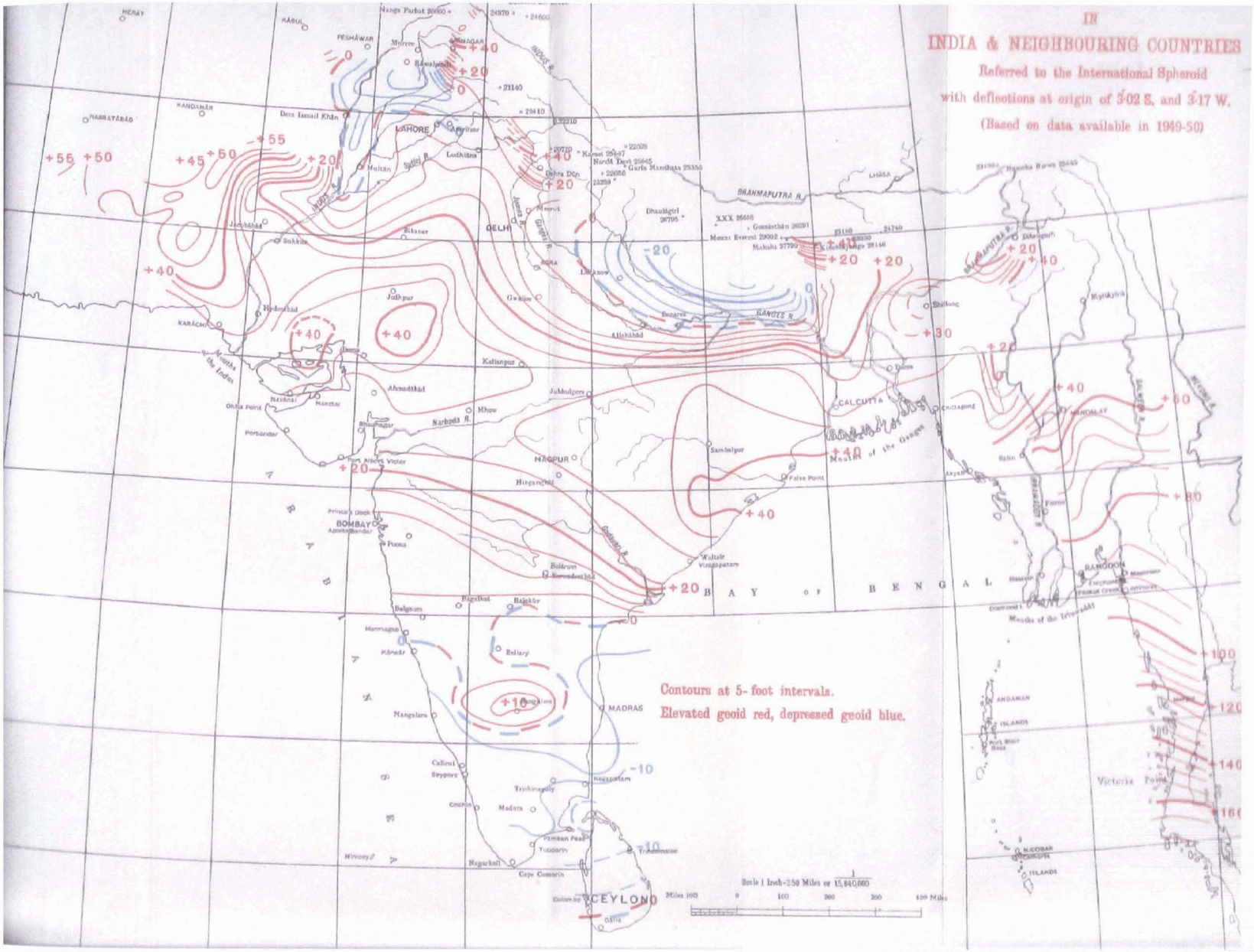
The Omori Seismograph was in operation throughout the year and worked satisfactorily. The earthquakes recorded at this observatory are published in the monthly Seismological Bulletin under the direction of the Director General of Observatories.

53. **The Riefler Clock.**—The Riefler electric clock has been functioning throughout the year. Adjustment of Shortt clock has been taken up. Renewals of Caustic Soda cells have been received. The rating of the clocks and chronometers has been done by hearing the B.B.C. time pips on an ordinary wireless receiver.

54. **Test, Calibration and Repairs of Instruments.**—During the period under report 356 instruments of various kinds were tested and calibrated. The calibration of Hunter Short Base tapes was carried in catenary against bays 1–6 of 24-metre comparator. The other instruments calibrated were invar staves, standard steel 10-foot tape, barometers aneroids and Paulins, theodolites, levels, chronometers, watches and many other precision instruments.

Repairs to 336 surveying instruments were carried out. The instruments for repairs were, theodolites (glass arcs, verniers), levels, calculating machines, barometers, tapes, crinoline chains,


COMPENSATED GEOID
IN
INDIA & NEIGHBOURING COUNTRIES
Referred to the International Spheroid
Contours at 5-foot intervals.
Elevated geoid red, depressed geoid blue.
Scale 1 Inch=250 Miles or 1/15,840,000
BAY OF BENGAL
ARABIAN SEA
CEYLON
DELHI
LAHORE
CALCUTTA
BOMBAY
MADRAS
NĀGPUR
KARĀCHI
QUETTA
KANDAHĀR
HERĀT
KĀBUL
PESHĀWAR
BRAHMAPUTRA R.
GANGES R.
INDUS R.
Mouths of the Ganges
Mouths of the Indus
ANDAMAN ISLANDS
NICOBAR ISLANDS


IN
INDIA & NEIGHBOURING COUNTRIES
Referred to the International Spheroid
with deflections at origin of 3·02 S. and 3·17 W.
(Based on data available in 1949-50)
Contours at 5-foot intervals.
Elevated geoid red, depressed geoid blue.
Scale 1 Inch=250 Miles or 1/15,840,000
Miles 100 0 100 200 300 400 Miles
BAY OF BENGAL
ARABIAN SEA
CEYLON
DELHI
LAHORE
BOMBAY
MADRAS
CALCUTTA
RANGOON
NAGPUR
KARACHI
Nanga Parbat 26660
24370
24600
21140
20410
20720
22020
Kamet 25447
Nanda Devi 25645
Garhi Mandhata 25355
22050
23379
Dhaulagiri 26795
XXX 25655
Gosainthan 26291
Mount Everest 29002
Makalu 27790
Kinchinjunga 28146
+55
+50
+45
+60
+20
+40
-20
+30
+10
-10
0

staves, clocks, watches, chronometers, binoculars, prismatic compasses, magnetic box compasses, clinometers, stereoscopes, magnetometers, etc.

55. Miscellaneous.—

(i) Various field detachments of Geodetic and Training Circle were supplied with instruments, and equipments for the field season 1949–50.

(ii) All delicate instruments installed in observatories and store were maintained in good condition and adjustment.

(iii) Star Almanac 1951 was compiled and published.

(iv) Preliminary computations of Manaba base-line, geodetic triangulation and astrolabe work in Kutch were carried out.

(v) Practice observations were carried out in Geodetic Base measurement by young officers in Dehra Dūn and a part of City Traverse of Dehra Dūn was carried out with Invar Base measuring equipment.

(vi) Annual examination of all surveying instruments of units and detachments at the close of field work was carried out.

TABLE 1.—*Diurnal variation of the Horizontal Magnetic Force derived from Q.H.M. observations.*

Serial No.	Date	Name of station	Latitude	Longitude	Q.H.M. No.	Observed Values of H.F. in gammas						Maximum diurnal variation at field station in gammas	Maximum† diurnal variation at Kodaikanal in gammas
						Time* I.S.T.	H.F.	Time* I.S.T.	H.F.	Time* I.S.T.	H.F.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
			° ′	° ′									
1	25–5–50	Kodaikanal	10 13·8	77 27·7	32	06 17	39328	12 45	39445	17 57	39352		
	,,	Observatory	..	..	32	06 35	39328	..	..	..	..	124	129
	,,	,,			17	06 54	39321	13 04	39418	18 21	39352		
	26–5–50	,,			32	06 38	39328	12 45	39418	17 53	39314	104	104
	,,	,,			17	06 18	39333	13 00	39405	18 11	39325		
	27–5–50	,,			32	06 49	39317	11 39	39402	17 44	39344	86	84
	,,	,,			17	06 28	39316	12 01	39386	18 07	39344		
	28–5–50	,,			32	06 15	39281	12 44	39270	17 50	39232		
	,,	,,			18	06 37	39285	12 58	39285	17 31	39252	53	48
	,,	,,			..	..	..	..	..	18 10	39237		
2	5–6–50	Tinnevelly	8 43·7	77 42·95	32	06 45	39875	11 59	39956	17 53	39860	113	99
	,,	,,			17	07 04	39873	12 21	39972	18 08	39859		
	6–6–50	,,			32	06 08	39887	11 57	39968	17 32	39842	142	129
	,,	,,			17	06 26	39887	12 12	39974	17 52	39832		
	7–6–50	,,			32	06 11	39860	11 47	39945	18 27	39868	102	85
	,,	,,			18	06 30	39877	12 10	39962	18 41	39875		
	8–6–50	,,			32	06 10	39873	11 55	39947	18 10	39886	82	80
	,,	,,			17	06 28	39867	12 12	39949	18 26	39884		
3	18–6–50	Galle	6 01·8	80 12·2	32	06 12	39739	11 58	39798	17 38	39745	67	76
	,,	,,			17	06 32	39731	12 12	39793	17 57	39738		
	19–6–50	,,			32	06 08	39746	11 50	39790	17 44	39750	46	54
	,,	,,			17	06 28	39744	12 06	39787	17 58	39747		
	20–6–50	,,			32	06 15	39760	11 55	39792	17 58	39748	56	65
	,,	,,			18	06 35	39769	12 15	39807	18 18	39758		

* I.S.T. means Indian Standard Time (5½ hours ahead of Greenwich Mean Time).

† From Table 2.

(contd.)

TABLE 1.—*Diurnal variation of the Horizontal Magnetic Force derived from Q.H.M. observations*—(concld.).

Serial No.	Date	Name of station	Latitude	Longitude	Q.H.M. No.	Observed Values of H.F. in gammas						Maximum diurnal variation at field station in gammas	Maximum† diurnal variation at Kodaikanal in gammas
						Time* I.S.T.	H.F.	Time* I.S.T.	H.F.	Time* I.S.T.	H.F.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
4	9-7-50	Bangalore	12 58·7	77 35·4	32	06 36	40215	11 47	40257	17 38	40213	50	70
	,,	,,			17	06 53	40214	12 04	40259	17 59	40209		
	10-7-50	,,			32	06 10	40220	11 58	40279	18 00	40199	85	73
	,,	,,			17	06 25	40217	12 13	40267	18 16	40194		
	11-7-50	,,			32	06 17	40230	11 58	40301	17 58	40223	88	115
	,,	,,			18	06 36	40235	12 17	40311	18 13	40230		
	12-7-50	,,			32	06 14	40186	12 10	40196	17 55	40162	46	70
	,,	,,			17	06 33	40177	12 28	40196	18 13	40150		
5	31-7-50	Guntakal	15 10·8	77 22·95	32	06 02	39803	11 56	39858	18 04	39822	50	58
	,,	,,			17	06 20	39808	12 10	39851	18 19	39816		
	1-8-50	,,			32	06 15	39813	11 54	39860	18 19	39815	51	80
	,,	,,			17	06 31	39809	12 10	39851	18 40	39813		
	2-8-50	,,			32	06 18	39814	11 50	39871	18 07	39809	83	117
	,,	,,			18	06 35	39826	12 07	39890	18 20	39807		
6	10-8-50	Kodaikanal Observatory	10 13·8	77 27·7	32	06 27	39316	12 04	39362	17 53	39313	85	87
	,,				17	06 44	39318	12 21	39376	18 11	39291		
	11-8-50	,,			32	06 24	39326	12 19	39361	18 03	39307	66	64
	,,	,,			17	06 43	39327	12 36	39365	18 18	39299		
	12-8-50	,,			32	06 23	39336	12 21	39379	18 06	39317	75	67
	,,	,,			18	06 47	39339	12 36	39392	18 25	39333		

* I.S.T. means Indian Standard Time ($5\frac{1}{2}$ hours ahead of Greenwhich Mean Time).
† From Table 2.

TABLE 2.—*Diurnal variation of the Horizontal Magnetic Force at Kodaikanal Observatory derived from self-recording magnetic variometers.*

Serial No.	Date	Name of station	Latitude	Longitude	Q.H.M. No.	Values of H.F. in gammas at reference station Kodaikanal Observatory, derived from magnetograms					
						Time I.S.T.	H.F.	Time I.S.T.	H.F.	Time I.S.T.	H.F.
			° ′	° ′							
1	25–5–50	Kodaikanal	10 13·8	77 27·7	32	06 17	39315	12 45	39442	17 57	39345
	,,	Observatory			32	06 35	39313	..	..	..	..
	,,	,,			17	06 54	39315	13 04	39425	18 21	39340
	26–5–50	,,			32	06 38	39320	12 45	39420	17 53	39316
	,,	,,			17	06 18	39318	13 00	39419	18 11	39325
	27–5–50	,,			32	06 49	39313	11 39	39395	17 44	39349
	,,	,,			17	06 28	39311	12 01	39390	18 07	39345
	28–5–50	,,			32	06 15	39265	12 44	39270	17 50	39225
	,,	,,			18	06 37	39263	12 58	39273	17 31	39227
	,,	,,			..	..	..	..	..	18 10	39228
2	5–6–50	Tinnevelly	8 43·7	77 42·95	32	06 45	39223	11 59	39312	17 53	39221
	,,	,,			17	07 04	39220	12 21	39319	18 08	39220
	6–6–50	,,			32	06 08	39241	11 57	39307	17 32	39189
	,,	,,			17	06 26	39241	12 12	39314	17 52	39185
	7–6–50	,,			32	06 11	39219	11 47	39303	18 27	39237
	,,	,,			18	06 30	39220	12 10	39304	18 41	39234
	8–6–50	,,			32	06 10	39334	11 55	39314	18 10	39254
	,,	,,			17	06 28	39334	12 12	39313	18 26	39250
3	18–6–50	Galle	06 01·8	80 12·2	32	06 12	..	11 58	39361	17 38	39288
	,,	,,			17	06 32	..	12 12	39358	17 57	39285
	19–6–50	,,			32	06 08	39285	11 50	39339	17 44	39293
	,,	,,			17	06 28	39285	12 06	39337	17 58	39293
	20–6–50	,,			32	06 15	39305	11 55	39360	17 58	39295
	,,	,,			18	06 35	39310	12 15	39357	18 18	39298

NOTE :—The results for col. 14 in Table 1 are derived from this table.

(*contd.*)

TABLE 2.—*Diurnal variation of the Horizontal Magnetic Force at Kodaikanal Observatory derived from self-recording magnetic variometers*—(concld.).

Serial No.	Date	Name of station	Latitude	Longitude	Q.H.M. No.	Values of H.F. in gammas at reference station Kodaikanal Observatory, derived from magnetograms					
						Time I.S.T.	H.F.	Time I.S.T.	H.F.	Time I.S.T.	H.F.
			° ′	° ′							
4	9–7–50	Bangalore	12 58·7	77 35·4	32	06 36	39232	11 47	39302	17 38	39236
	,,	,,			17	06 53	39237	12 04	30296	17 59	39238
	10–7–50	,,			32	06 10	39245	11 58	39296	18 00	39223
	,,	,,			17	06 25	39247	12 13	39287	18 16	39223
	11–7–50	,,			32	06 17	39249	11 58	39359	17 58	39266
	,,	,,			18	06 36	39251	12 17	39364	18 13	39270
	12–7–50	,,			32	06 14	39251	12 10	39260	17 55	39196
	,,	,,			17	06 33	39239	12 28	39266	18 13	39197
5	31–7–50	Guntakal	15 10·8	77 22·95	32	06 02	39252	11 56	39310	18 04	39263
	,,	,,			17	06 20	39253	12 10	39309	18 19	39263
	1–8–50	,,			32	06 15	39259	11 54	39329	18 19	39257
	,,	,,			17	06 31	39249	12 10	39323	18 40	39256
	2–8–50	,,			32	06 18	39254	11 50	39330	18 07	39249
	,,	,,			18	06 35	39256	12 07	39363	18 20	39246
6	10–8–50	Kodaikanal Observatory	10 13·8	77 27·7	32	06 27	39233	12 04	39281	17 53	39220
	,,				17	06 44	39236	12 21	39307	18 11	39230
	11–8–50	,,			32	06 24	39246	12 19	39279	18 03	39222
	,,	,,			17	06 43	39248	12 36	39284	18 18	39220
	12–8–50	,,			32	06 23	39254	12 21	39299	18 06	39232
	,,	,,			18	06 47	39239	12 36	39298	18 25	39239

NOTE:—The results for col. 14 in Table 1 are derived from this table.

TABLE 3.—*Diurnal range of H at Mandapam** (*Latitude 9° 16′ ·8, Longitude 79° 07′ ·8*)

Observations in India for the Committee to promote observations of daily variation of the Horizontal Magnetic Force between and near the Geographical and Magnetic Equators

Date	Q.H.M. No.	Values of H.F. in gammas at selected Field Repeat Stations							Values of H.F. in gammas at reference station Kodaikanal Observatory derived from Magnetograms						
		Time† I.S.T.	H.F.	Time† I.S.T.	H.F.	Time† I.S.T.	H.F.	Maximum Diurnal variation at field station	Maximum Diurnal variation at Kodaikanal Observatory	Time† I.S.T.	H.F.	Time† I.S.T.	H.F.	Time† I.S.T.	H.F.
31-5-50	32	06 26	40062	11 52	40177	17 54	40069	123	105	06 26	39327	11 52	39430	17 54	39339
,,	17	06 43	40054	12 10	40165	18 14	40065			06 43	39325	12 10	39429	18 14	39335
1-6-50	32	06 10	40080	11 39	40184	17 26	40048	155	119	06 10	39235	11 39	39323	17 26	39209
,,	17	06 30	40077	12 00	40203	17 45	40057			06 30	39236	12 00	39328	17 45	39213
2-6-50	32	06 15	40076	11 51	40123	17 40	40063	82	67	06 15	39227	11 51	39277	17 40	39219
,,	18	06 35	40069	12 09	40145	17 59	40075			06 35	39226	12 09	39283	17 59	39216
3-6-50	32	06 18	40066	11 52	40185	18 45	40060	128	118	06 18	39220	11 52	39328	16 45	39234
,,	17	06 36	40061	12 09	40188	17 00	40070			06 36	39227	12 09	39338	17 00	39234
							Mean	122	101						

* This station is situated on the banks of the sea shore.

† I.S.T. means Indian Standard Time (5½ hours ahead of Greenwich time).

CHAPTER VII

COMPUTATIONS AND PUBLICATIONS

BY B. L. GULATEE, M.A. (CANTAB.), F.R.I.C.S., M.I.S. (INDIA)

56. Adjustment of Topographical Triangulation in India.— A reference was made in the previous report to the immensity of the task involved in the systematic examination, compilation and adjustment of the huge mass of topographical triangulation in India (about 3½ lakhs of points) and it was pointed out that the work would take 30 computers nearly 30 years to complete. Although a start has been made, the progress is likely to be seriously hampered by the lack of trained staff.

During the period under report, one pamphlet No. 54 A, covering one degree square, was completed in Block No. 1 and one pamphlet No. 47 F was prepared in Block No. 2. See Technical Report, 1948–49, Part III, para 84 and charts XXIX and XXX. Further work is in progress in these blocks.

Some preliminary compilation in 1/M sheets 48 and 58 has been carried out in the Southern Circle, but the data has not yet been examined and adjusted.

57. Triangulation data in Irāq and Irān.—The triangulation data in Irāq and Irān comprises the following :—

(i) Data of the triangulation carried out by the Survey Party of the Mesopotamia Expeditionary Force of World War I in south and west Irān.

(ii) Data of primary, secondary and tertiary triangulation of the Irāq Survey Department.

(iii) Data of Paiforce triangulation, 1941–43, mostly by Indian Field Survey Companies.

(iv) Data of triangulation linking Irāq to India executed in 1944.

(v) Data of triangulation carried out by the Anglo-Irānian Oil Company.

As already mentioned in the previous report, the data described above, some of which is on different spheroids, have all been brought into one terms by adjustment and made mutually consistent. Details of the various triangulations are given in Technical Report 1947, Part III, Chapter V.

The rectangular co-ordinates on Lambert Orthomorphic Conical Projection of all points are being compiled in pamphlets, each pamphlet containing data falling in an area of one degree of latitude

by one degree of longitude. In cases where data is sparse a larger area has been included in one pamphlet. The details of the adjustment carried out are given in the preface to each pamphlet. Out of an estimated total of about 80 pamphlets, 22 have so far been published.

58. **Computations of results of field work.**—Observations of geodetic triangulation and base measurement in Kutch (see Chapter I) have been computed in the Computing Office.

Results of the following levelling lines executed during the period under report were also worked out :—

(*a*) *Levelling of High Precision*

(i) Balasore to Howrah
(ii) Kārwār to Hubli
(iii) Raipur to Vizianagram and Vizianagram to Vizagapatam.

(*b*) *Precise levelling*

(i) Howrah to Purbasthali
(ii) Calcutta Mint to Cossipore
(iii) ,, ,, ,, King George's Dock.

(*c*) *Secondary Levelling*

(i) Kosi area
(ii) Gandak area
(iii) Narbada area
(iv) Kutch area
(v) Connections to Tidal stations at Navi Wat and Navlakhi.

A narrative account of these level lines and the discussion of results is given in Chapter II.

Besides the above, deflections and gravity anomalies have been computed at new stations and the charts of the Geoids (Chapter IV) and Gravity Anomalies (Chapter III) have been revised.

59. **Technical Papers.**—An account of the geodetic work of the Survey of India has been published from 1921 to 1940 in the annual Geodetic Reports, and since 1947 in the annual Technical Reports, the publication having been in abeyance from 1940 to 1947 due to the difficulties created by World War II. In addition to this annual account, research work carried out on specific problems or accounts of methods and processes relating to particular subjects have been dealt within two series of papers, viz., the Professional Papers and Departmental Papers. The former were intended for wide distribution to foreign survey institutions libraries, universities and distinguished scientists interested in the subject matter of the paper, and the latter were meant primarily for the use of the departmental officers and other Government of India Departments interested in the progress of the Survey of India.

It has unfortunately not been possible to publish any Professsional Paper ever since World War II broke out and only one Departmental Paper has been issued recently since that date.

With a view to stimulating thought and encouraging research on departmental methods and problems and to making the results of such research widely available in the department a third series of Papers known as "Technical Papers" have been initiated. The first paper of this series is entitled "Towards a National Survey" and emphasizes the need of a close liasion between the Survey of India and the State (Provincial) Survey Departments, which carry out local and cadastral surveys for revenue and settlement purposes, to avoid duplication of effort. It is recommended that all officers employed in the State Survey Departments should be Survey of India trained, that the Survey programmes of the State Survey Departments should be executed in consultation with and in accordance with the methods and technique and with the same class of instruments as are in use in the Survey of India.

The second paper "Value of Gravity at Dehra Dūn" gives the history of the various determinations of the value of gravity at Dehra Dūn which is the National Base Station for India and stresses the need for a highly precise value, since all the previous values are widely discrepant.

The third paper bears the title "Levelling in India, Past and Future". This paper brings home the fact that India is very backward as regards levelling compared with European and American countries. A chart is included which shows in striking contrast the levelling carried out in the U.S.A. and in India. The U.S.A. level net (1936–38) consists of more than 150,000 bench-marks distributed along about 107,000 miles of first order and 155,000 miles of second order levelling whereas the total mileage of levelling in India is less than 15,000 miles with a total of 16,000 bench-marks about 14,000 of which are of non-permanent nature. It is pointed out that it is beyond the capacity of the Survey of India to bring up the progress of levelling in India to the standard of other advanced countries and consequently the active co-operation of State Governments and the Engineering Departments in filling up the large gaps which exist is sought. To ensure uniformity it is suggested that all agencies carrying out levelling for local purposes should work in terms of the National Datum and their levelling should be tied on to the National framework of High Precision Levelling, and should be carried out to the standards of accuracy and with the class of instruments employed in the Survey of India. This appeal has since met with some response and a number of State Governments have deputed their officers for training in the Survey of India.

The fourth paper "Mount Everest—Its name and height", which has been issued after the period covered by this report throws light on a subject, which has been a matter of great controversy in the past and about which several misconceptions are

current to-day. The accepted height of 29,002 feet for this peak was derived from older observations which were incomplete in many respects. The Survey of India proposes to extend the triangulation to within about 40 miles of the peak so that reliable observations can be made for a precise determination of its height. Until these are carried out, the traditional value will have to be adhered to.

60. **Other Publications.**—The following are the other publications which were seen through the press :—

1. Technical Report 1948–49, Part III—Geodetic Work.
2. Levelling Pamphlets for 1/M Sheets 65 and 74.
3. Grid data triangulation pamphlets in Irāq and Irān, six in number.
4. Spherical and grid triangulation pamphlet for sheet 73 M (at press).
5. Secondary levelling pamphlet No. 55.

LIST OF IMPORTANT GEODETIC PUBLICATIONS AND CONTRIBUTIONS BY OFFICERS OF THE SURVEY OF INDIA

(A) Publications.

No.	*Name of Book*	*Details*
1.	G.T.S. Vol. II	History and General Description of the Reduction of the Principal Triangulation. Dehra Dūn, 1879. *Price Rs. 10-8.*
2.	G.T.S. Vol. IX	Telegraphic Longitudes. During the years 1875–77 and 1880–81. Dehra Dūn, 1883. *Price Rs. 10-8.*
3.	G.T.S. Vol. X	Telegraphic Longitudes. During the years 1881–82, 1882–83 and 1883–84. Dehra Dūn, 1887. *Price Rs. 10-8.*
4.	G.T.S. Vol. XI	Astronomical Latitudes. During the period 1805–1885. Dehra Dūn, 1890. *Price Rs. 10-8.*
5.	G.T.S. Vol. XV	Telegraphic Longitudes. From 1885 to 1892 and the Revised Results of Vols. IX and X: also the Simultaneous Reduction and final Results of the whole Operations. Dehra Dūn, 1893. *Price Rs. 10-8.*
6.	G.T.S. Vol. XVI	Tidal Observations. From 1873 to 1892 and the Methods of Reduction. Dehra Dūn, 1901. *Price Rs. 10-8.*
7.	G.T.S. 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.*
8.	G.T.S. Vol. XVIII	Astronomical Latitudes. From 1885 to 1905 and the deduced values of Plumb-line Deflections. Dehra Dūn, 1906. *Price Rs. 10-8.*
9.	G.T.S. Vol. XIX	Levelling of Precision in India. From 1858 to 1909. Dehra Dūn, 1910. *Price Rs. 10-8.*
10.	Records of the Survey of India, 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.*

No.	*Name of Book*	*Details*
11.	Geodetic Report 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.*
12.	Geodetic Report 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.*
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15.	Geodetic Report 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.*
16.	Geodetic Report Vol. VI	1929–30. Computations and Publication of data. Observatories. Tides. Gravity. Triangulation. Levelling. Research and Technical Notes. Dehra Dūn, 1931. *Price Rs. 3.*
		Supplement. Indian Deflection and Gravity stations. Dehra Dūn, 1931. *Price Rs. 1-8.*
17.	Geodetic Report 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.*

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18.	Geodetic Report Vol. VIII	1931–32. Computations and Publication of data. Observatories. Tides. Gravity. Triangulation. Levelling. Research and Technical Notes. Dehra Dūn, 1933. *Price Rs. 3.*
19.	Geodetic Report 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.*
20.	Geodetic Report 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.*
21.	Geodetic Report 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.*
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25.	Geodetic Report 1938	Triangulation and Levelling. Deviation of the Vertical. Gravity. Computing Office and Tidal Section. Observatories. Dehra Dūn, 1939. *Price Rs. 3.*
26.	Geodetic Report 1939	Levelling. Gravity. Computing Office and Tidal Section. Observatories. Research and Technical Notes. Dehra Dūn, 1940. *Price Rs. 3.*
27.	Geodetic Report 1940	Levelling. Deviation of the Vertical Gravity. Computing Office and Observatories. Dehra Dūn, 1945. *Price Rs. 2,*

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28.	Technical Report, Part III, Geodetic Work 1947	Triangulation in the Neighbouring Countries of India. Levelling. Gravity. Deviation of the Vertical. Computations and Publications. Tides. Observatories. Dehra Dūn, 1948. *Price Rs. 4.*
29.	Technical Report, Part III, Geodetic Work 1948–49.	Triangulation. Levelling. Gravity. Deviation of the Vertical. Tides. Observatories. Computations and Publications. Research and Technical Notes. Dehra Dūn, 1950. *Price Rs. 4.*
30.	Technical Report, Part III, Geodetic Work 1949–50	Triangulation. Levelling. Gravity. Deviation of the Vertical Tides. Observatories. Computations and Publications. Dehra Dūn, 1951. *Price Rs. 4.*
31.	Professional Paper No. 10	Pendulums. The Pendulum Operations in India, 1903–07, by Maj. G. P. Lenox-Conyngham, R.E. Dehra Dūn, 1908. *Price Rs. 2-8.*
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36.	Professional Paper No. 28	Triangulation. The Readjustment of the Indian Triangulation, by Maj. G. Bomford, R.E. Dehra Dūn, 1938. *Price Rs. 4-8.*
37.	Professional Paper No. 29	Magnetic. Magnetic Anomalies, by B. L. Gulatee, M.A. (Cantab.). Dehra Dūn, 1938. *Price Rs. 1-8.*
38.	Professional Paper No. 30	Gravity. Gravity Anomalies and the Figure of the Earth, by B. L. Gulatee, M.A. (Cantab.). Dehra Dūn, 1940. *Price Rs. 3.*
39.	War Research Series Pamphlet No. 9	The Trans-Persia Triangulation 1941–44. (linking Irāq and India), by J. de Graaff Hunter, C.I.E., SC.D., F.R.S. and B. L.

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		Gulatee, M.A. (Cantab.), with an Appendix "The Persia–India Connection", by Maj. P. A. Thomas, I.E. *Price Rs. 2.*
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41.	Technical Paper No. 2	Value of Gravity at Dehra Dūn, by Mr. B. L. Gulatee, M.A. (Cantab.). Dehra Dūn, 1948.
42.	Technical Paper No. 3	Levelling in India, Past and Future, by, Mr. B. L. Gulatee, M.A. (Cantab.). Dehra Dūn, 1949.
43.	Technical Paper No. 4	Mount Everest, its Name and Height, by Mr. B. L. Gulatee, M.A. (Cantab.). Dehra Dūn, 1950.
44.	Technical Paper No. 5	Geodetic and Geophysical aspects of the earthquakes in Assam, by Mr. B. L. Gulatee, M.A. (Cantab.), F.R.I.C.S., M.I.S. (IND.). Dehra Dūn, 1951.
45.	.. ..	Question Papers set at the Intermediate Examination of the Institution of Surveyors (India) in 1950. Dehra Dūn, 1950. *Price As. -/8 -*

(B) Articles on Geodetic Subjects.

1.	.. ..	The Indian Geoid and Gravity Anomalies, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. and Capt. G. Bomford, R.E. (Bulletin Géodésique, No. 29, Jan.–March 1931, pages 20, 21, Paris).
2.	.. ..	Construction of the Geoid, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. and Capt. G. Bomford, R.E. (Bulletin Géodésique, No. 29, Jan.–March 1931, pages 22–26, Paris).
3.	.. ..	*†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).

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4.	.. ..	*Stokes's Formula in Geodesy, by B. L. Gulatee, M.A. (Cantab.). (Nature, 20th Feb., 1932).
5.	.. ..	†"Crustal Warpings" discussing the gravity work of the Survey of India, by Maj. E. A. Glennie, D.S.O., R.E. (The Observatory January and April 1933).
6.	.. ..	‡Figure of the Earth, by B. L. Gulatee, M.A. (Cantab.), (Gerlands Beiträge, Bd. 38, H. 3/4, S.426, 1933).
7.	.. ..	§Deflection of the Plumb-Line, by B. L. Gulatee, M.A. (Cantab.), (Hydrographic Review, Vol. X, No. 2, Nov. 1933, pages 182–189).
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11.	.. ..	††Crustal Warping in the United States, by Lt.-Col. E. A. Glennie, D.S.O., R.E. (Gerlands Beiträge Zur Geophysik, Vol. 46, pp. 193–197, 1936).
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§ Obtainable from the International Hydrographic Bureau, Monte-Carlo, Monaco.
‖ Obtainable from Messrs. Dulau & Co., 37 Soho Sqaure, London, W. or Messrs. Harrison & Sons, St. Martin's Lane, London, or The Royal Society at Burlington House, London.
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		(Philosophical Transactions, Royal Society, Series A, Vol. 234, 1935).
10.	.. ..	*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).
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13.	.. ..	Geophysical Prospecting for Manganese, by B. L. Gulatee, M.A. (Cantab.), (Journal of Scientific and Industrial Research, Vol. III, No. 12, June 1945, pp. 543–554).
14.	.. ..	Standards of Length, by B. L. Gulatee, M.A. (Cantab.), (Journal of Scientific and Industrial Research, Vol. IV, No. 8, Feb. 1946, pp. 453–59).
15.	.. ..	Standards of Measurement, by B. L. Gulatee, M.A. (Cantab.), (Journal of Scientific and Industrial Research, Vol. V, No. 3, Sept. 1946, pp. 104–05).
16.	.. ..	Angular Corrections for the Lambert Orthomorphic Conical Projection, by B. L. Gulatee, M.A. (Cantab.), (Empire Survey Review, Vol. VIII, No. 62, Oct. 1946, pp. 311–14).
17.	.. ..	Secular Variation of Magnetic Declination in India, by B. L. Gulatee, M.A. (Cantab.), (Science and Culture, Vol. XII, No. 5, Nov. 1946, pp. 215–17).
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19.	.. ..	The Hunter Shutter Eye-Piece for Longitude and Azimuth, by J. de Graaff Hunter, C.I.E., Sc.D., F.R.S. (Empire Survey Review, Vol. IX, No. 63, Jan. 47, pp. 20–24).

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