SURVEY OF INDIA

TECHNICAL REPORT 1952

PART III—GEODETIC WORK

PUBLISHED BY ORDER OF

THE SURVEYOR GENERAL OF INDIA

PRINTED AT THE OFFICE OF THE GEODETIC & TRAINING CIRCLE
SURVEY OF INDIA, DEHRA DŪN, INDIA, 1953.

Price Six Rupees or Nine Shillings and Six Pence

CONTENTS

CHAPTER III

Levelling—(*concld.*)

CHAPTER IV

Tides

CHAPTER V

Gravity

CHAPTER VI

Computations and Publications

CONTENTS

CHAPTER VI

Computations and Publications—(*concld.*)

Charts and Plates

INTRODUCTION

This report gives a detailed account of the activities of the Geodetic and Training Circle during the period 1st April 1951 to 31st March 1952. The following is a brief review of the contents.

2. *Triangulation and Traverse.*—(Chapter I). The Geodetic triangulation in the Andaman Islands commenced last year was continued. Nine new stations were occupied. The series consists of 27 stations in all, including one Base Centre station.

High Precision traverse with Jäderin invar wires was carried out to provide control for large scale maps of the city of Dehra Dūn. The work was undertaken at the request of the Chairman City Board.

3. *Observatories.*—(Chapter II). The usual meteorological and seismological observations were made and the maintenance and repair of all survey instruments was carried out as usual.

4. *Levelling.*—(Chapter III). No levelling of high precision was carried out during the period under report due to financial stringency.

952 miles of secondary levelling was, however, effected to meet the needs of irrigation and road projects.

5. *Tides.*—(Chapter IV). A standard automatic tide-gauge of U.S.A. pattern was installed at Port Blair. The programme of half-hourly observations at ports remained in abeyance.

6. *Gravity.*—(Chapter V). The normal gravity and deviation of the vertical programme also suffered for lack of funds. The results of some interesting observations made with the Frost and Worden gravimeters are, however, discussed.

It is hoped to observe next year the plumb-line deflections along the North-East Longitudinal Series from Sinaria (in Bihār) to Nojli (near Sahāranpur). These should give much valuable information regarding the compensation of the Himālayas.

DEHRA DŪN,
December, 1952.

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

PERSONNEL OF THE GEODETIC AND TRAINING CIRCLE

Director, Geodetic and Training Circle

	From	To
SHRI B. L. GULATEE, M.A. (CANTAB.), F.R.I.C.S., M.I.S. (INDIA)	1- 4-51 13- 8-51 31-12-51	18- 7-51 13-10-51 31- 3-52
SHRI H. M. CRITCHELL	19- 7-51	12- 8-51
SHRI P. A. THOMAS, M.I.S. (INDIA), A.R.I.C.S. ..	14-10-51	30-12-51

Dy. Director, Geodetic and Training Circle

SHRI B. L. GULATEE, M.A. (CANTAB.), F.R.I.C.S., M.I.S. (INDIA)	31-12-51	2- 3-52
SHRI P. A. THOMAS, M.I.S. (INDIA), A.R.I.C.S. ..	1- 4-51 16-12-51	1-11-51 30-12-51
SHRI E. R. WILSON, B.A., M.I.S. (INDIA)	2-11-51 3- 3-52	15-12-51 31- 3-52

OFFICE OF THE DIRECTOR, GEODETIC AND TRAINING CIRCLE

Ministerial Service

ASSISTANT (FIRST DIVISION)
Shri H. Chatterjee, B.A.

HEAD ACCOUNTANT
Shri Balwant Singh.
13 Clerks
2 Record Keepers.

GEODETIC AND RESEARCH BRANCH

President, Geodetic and Research Branch

SHRI B. L. GULATEE, M.A. (CANTAB.), F.R.I.C.S., M.I.S. (INDIA)	1- 4-51 13- 8-51 31-12-51	18- 7-51 13-10-51 31- 3-52
SHRI H. M. CRITCHELL	19- 7-51	12- 8-51
SHRI P. A. THOMAS, M.I.S. (INDIA), A.R.I.C.S. ..	14-10-51	30-12-51

Class I Service

Shri A. N. Ramanathan, M.A., A.R.I.C.S. (Offg.), Mathematical Adviser.

Geodesy Scholars

Shri P. D. Verma, M.Sc.
Shri P. P. Chatterjee, M.Sc., up to 30-9-51.

COMPUTING AND TIDAL PARTY

(RECORDS AND RESEARCH)

Class I Service

Shri N. D. Joshi, B.A., in charge.

Ministerial Service

5 Clerks.

OBSERVATORY SECTION

Class I Service

Shri R. S. Chugh, M.A., in charge.

Class II Service

Shri S. Vaikuntanathan, M.A.
Shri C. M. Sapru, B.A.

Class III Service

DIVISION I

Shri M. D. Khanduri.

DIVISION II

3 Computers.
3 Instrument Mechanics.
2 Drivers.

TIDAL SECTION

Class I Service

Shri A. N. Ramanathan, M.A., A.R.I.C.S. (Offg.) in charge.

Class II Service

Shri A. C. Dey, M.SC., from 4th Oct. 1951.

Class III Service

DIVISION I (GRADE I)

Shri K. A. P. Mathur, B.SC.
Shri A. K. Banerji, B.SC.
Shri Prem Narain.

DIVISION II

12 Computers.
2 Recorders.

COMPUTING SECTION

Class II Service

Shri C. B. Madan, B.A. (HONS.) in charge.

Class III Service

DIVISION I (GRADE I)

Shri G. S. Tonk, B.A.
Shri K. K. Sawhney, B.A.
Shri O. P. Kukreti, B.SC.
Shri D. N. Basur, M.A.

DIVISION II

8 Computers.

CHART SECTION

Class III Service

DIVISION I (GRADE I)

Shri S. K. Sahai, B.SC.

DIVISION II

5 Draftsmen.

STATISTICAL BRANCH

Class II Service

Shri C. B. Madan, B.A. (HONS.), in charge.

(*a*) STATISTICAL SECTION

Class III Service

DIVISION II

2 Computers.

(*b*) PRESERVATION AND MAINTENANCE SECTION

Class III Service

DIVISION II

2 Computers.

(*c*) LIBRARY

Class III Service

DIVISION II

1 Librarian.

(*d*) PRINTING OFFICE

Class III Service

DIVISION I (GRADE I)

Shri H. H. Williams.

Shri K. P. Bhattacharjee.

DIVISION II

38 Tradesmen.

(*e*) PUBLICATION AND FORMS SECTION

Class III Service

DIVISION II

2 Clerks.
1 Record Keeper.

WORKSHOP SECTION

Class I Service

Shri N. D. Joshi, B.A., in charge.

Class III Service

DIVISION II

17 Tradesmen.

Ministerial Service

1 Clerk.

STORES SECTION

Class I Service

Shri N. D. Joshi, B.A., in charge.

Class III Service

DIVISION II

1 Clerk.
1 Record Keeper.

ESTATE SECTION

Class I Service

Shri N. D. Joshi, B.A., in charge.

DISPENSARY

Dr. J. Sain, M.B.B.S., in charge.

Class III Service

DIVISION II

1 Compounder.

No. 14 PARTY (GEOPHYSICAL AND LEVELLING)

Class I Service

Major C. M. Sahni, B.A., in charge to 1–6–51.

Shri U. D. Mamgain, C.E., B.SC., A.M.I.S., (Offg.), in charge from 1–6–51.

Class II Service

Shri A. K. Bhattacharjee, B.SC. (HONS.).

Class III Service

DIVISION I (GRADE I)

Shri B. P. Rundev.
Shri J. B. Mathur.
Shri J. C. Bhattacharjee, B.A. (HONS.).
Shri S. K. Bose, B.SC.
Shri S. Muthukrishnan, B.A.
Shri Avinash Chandra, B.SC.
Shri S. N. Nandi, B.SC.
Shri M. L. Shadev, B.A.
Shri T. K. Visvanathan, M.A.
Shri J. Narasimhan, B.SC. (HONS.).
Shri P. N. Sanyal, B.A.

DIVISION II

10 Computers.

Ministerial Service

2 Clerks.

TRAINING BRANCH

No. 15 PARTY

Class I Service

Shri J. C. Ross, A.R.I.C.S., M.I.S. (INDIA), in charge to 12–10–51.
Major S. K. S. Mudaliar, B.A., A.M.I.E., A.M.I.S. (INDIA), in charge from 13–10–51.
Shri K. Sukhram Singh, B.A. (HONS.).
Shri V. P. Sharma, B.A.
Shri V. Krishnamurthy, M.A., A.R.I.C.S., F.R.G.S. (Offg.).

Officers under instruction

Capt. M. L. Chopra, B.SC., B.E.
Capt. J. P. G. King, B.SC., B.E.
Capt. B. S. N. Murty, B.SC.
Capt. K. L. Khosla, B.SC., B.E., A.M.I.E.
Capt. Partha Rout, B.SC. (ENG.).
Capt. M. M. Datta, B.SC. (HONS.), B.E.
Capt. I. N. Thukral, B.SC.
Capt. S. Choudhuri.
Capt. Y. Ramchandran, B.SC. (MINING).
Capt. Y. L. Khular, B.SC. (ENG.).
Capt. B. Sarin, B.SC.
Shri K. Satyanarayanan, M.A.
Shri V. Rangan, M.A.
1 State trainee.
2 Afghān Officers.

Class II Service

Shri A. K. Bhattacharjee, B.SC. (HONS.), from 1st Oct. 1951.
Shri G. N. Dubey, M.SC.
Shri J. C. Sahgal, B.A.

Officers under instruction

Shri V. Balasubramanyan, M.A.
Shri Hari Singh, B.A.
Shri A. C. Chawla, B.A.
Shri C. M. Sapru, B.A.
Shri T. R. Viswanathan, B.A. (HONS.).
Shri A C. Dey, M.SC.
Shri Mastan Singh B.A.
Shri J. K. Donald, B.SC.
Shri Babu Ram Jain, B.A., B.T.
Shri S. N. Mathur, M.A., LL.B.
Shri Arun Biswas, B.A.
Shri R. Sivaramakrishnan, B.A. (HONS.).
Shri H. D. Gulati, M.A.
4 Burmese Officers.
10 State trainees.

Class III Service

DIVISION I (GRADE I)

Shri Udai Singh.
Shri R. K. Lal.
Shri I. M. Saklani.

Officers under instruction

Shri P. C. Malik, B.A.
14 State trainees.

DIVISION II

1 Plane-tabler.
1 Air Survey Draftsman.
2 Drivers.

Ministerial Service

3 Clerks.
1 Storekeeper.

STORES OFFICE SURVEYS

General Central Service

Class I Service

Shri C. G. Gohani, Dy. Stores Officer.

Class II Service

Shri G. C. Banerjee, B.A., Asst. Stores Officer.
Shri Gurcharan Singh, B.A., Asst. Stores Officer.

Class III Service

DIVISION I

Shri S. P. Ojha, Stores Assistant.
Shri C. S. Pramar, Stores Assistant.
Shri Anant Singh, Stores Assistant.

Ministerial Service

13 Clerks.
1 Assistant storekeeper.
5 Artificers (Carpenters/Packers).

Primary and Secondary Triangulation Series

No.	Name of Series	Season	± m	± p	Instrument
	Primary Series		"	*ft.*	*inches*
5	Calcutta Longitudinal	1864–69	0·360	2·23	36 & 24
6	Great Arc Meridional, Section 24°–30° ..	1835–66	0·708	4·26	36
7*a*	Bombay Longitudinal, East of 75°	1862–63	0·702	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	0·390	1·80	24
11*b*	South Konkan Coast ..	1866–67	0·302	0·77	24
20*a*	North-East Longitudinal, West of 80° ..	1850–51	0·558	1·05	24
22	North-West Himâlaya	1848–53	0·641	2·15	24
23*b*	Gurhâgarh Meridional between 26½°–32½° ..	1859–62	0·362	0·96	24
24	East Coast ..	1848–63	0·606	1·58	24
25	Karâchi Longitudinal	1849–55	0·558	1·88	36
28	Kâthiâwâr Meridional	1852–56	0·990	2·01	18
32	Great Indus ..	1853–61	0·359	1·74	36 & 24
33	Rahûn Meridional ..	1853–63	0·327	1·24	24
34	Assam Longitudinal ..	1854–60	0·570	1·52	24
35	Kutch Coast ..	1855–58	0·986	1·80	18
37	Jogi-Tila Meridional ..	1855–62	0·481	1·67	36 & 24
39	(Kutch) Coast Line ..	1856–60	0·075	1·44	18 & 12
43	Bidar 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
49	Mangalore Meridional	1863–73	0·440	1·14	24
52*a*	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	Bilâspur 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) ..	1889–95	0·418	1·46	12
68	Manipur Longitudinal	1894–99	0·453	1·45	12
69	Makrân Longitudinal ..	1895–97	0·285	0·92	12
72	Great Salween (See 105)	1900–11	0·404	4·28	12
74	Kalât Longitudinal ..	1904–08	0·365	3·15	12
76	North Baluchistân ..	1908–10	0·221	1·82	12
77	Gilgit ..	1909–11	0·443	2·62	12
80	Upper Irrawaddy ..	1909–11	0·596	3·14	12
85	Sambalpur Meridional	1911–14	0·250	1·28	12
103	Chittagong ..	1928–30	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	Dâlbandin ..	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	0·598	1·94	Geodetic Tavistock
111	East-West Bengal boundary ..	1950–51	0·456	0·896	Geodetic Tavistock
112	Andaman ..	1950–52	0·604	2·14	Geodetic Tavistock
	Secondary Series				
1	South Pârasnâth Meridional ..	1836–39	3·308	9·98	18
2	Budhon Meridional ..	1833–43	2·242	7·47	18 & 15
3	Amûa Meridional ..	1834–38	1·647	4·71	18
4	Rangir Meridional ..	1834–41	1·643	7·62	18 & 15
7*b*	Bombay Longitudinal, West of 75° ..	1837–39	0·919	2·24	15
10*a*	Singi Meridional 21°–25°	1860–62	0·723	1·19	18
10*b*	Singi Meridional 19°–21°	1842–46	1·711	1·39	15
11*a*	South Konkan Coast 15½°–19° ..	1842–44	2·425	1·71	15
12	Karâra Meridional ..	1843–45	1·507	3·46	18 & 15
13	North Malûncha Meridional ..	1844–46	1·266	8·69	18 & 15

No.	Name of Series	Season	± m	± p	Instrument
	Secondary Series—*Contd.*		"	*ft.*	*inches*
14	Chendwâr Meridional ..	1844–46	0·841	1·51	36 24 & 18
15	Gora Meridional ..	1845–47	0·073	3·00	15
16	Calcutta Meridional ..	1845–48	1·173	1·52	18
17	South Malûncha Meridional ..	1845–53	1·606	1·40	24 & 18
18	Khânpisura Meridional	1845–48	1·227	2·11	24 & 15
19	Gurwâni Meridional ..	1846–47	1·165	2·57	24 & 18
20*b*	North-East Longitudinal, East of 80° ..	1846–51	0·422	1·41	30, 24 & 15
21	Hurilâong Meridional ..	1848–52	1·502	2·42	24 & 18
23*a*	Gurhâgarh Meridional 24½°–26½° ..	1848–50	1·461	2·09	18 & 15
26	Abu Meridional ..	1851–52	0·617	1·53	18
27	North Pârasnâth Meridional ..	1851–52	0·895	2·10	24
29	Gujarât Longitudinal ..	1852–62	0·859	1·97	18
30	Kâthiâwâr Longitudinal ..	1853	1·481	1·60	18
31	Sâbarmati ..	1853–54	1·348	0·91	18
36	Kashmir Principal ..	1855–60	0·884	2·48	14 Vernier
38	Sambalpur Longitudinal ..	1856–57	0·806	1·48	14 Vernier
40	Kâthiâwâr Meridional No. 1 ..	1858–59	0·930	0·87	18
41	Kâthiâwâr Meridional No. 2 ..	1859–60	1·247	1·39	18
42	Kâthiâwâr Meridional No. 3 ..	1859–60	0·969	3·36	18
47	Kâthiâwâr Meridional No. 4 ..	1863–64	1·164	..	18
48	East Calcutta Longitudinal ..	1863–69	0·379	0·96	24
50	Kumaun and Garhwâl	1864–65	1·742	1·81	14 & 12 Vernier
51	Nâsik ..	1864–65	2·033	0·78	14 & 6
52*b*	Burma Coast 14½°–16°	1876–77	0·327	1·69	24
57	Coimbatore No. 1 ..	1869–71	1·547	2·50	14
59	Cuddapâh ..	1871–72	0·826	1·32	10
60	Hyderâbâd ..	1871–72	1·405	0·78	24 & 7
61	Malabar Coast ..	1872–80	1·532	1·17	14 & 12 Vernier
65	Siam Branch ..	1878–81	3·711	2·65	12
67	Mong Hsat ..	1891–93	3·054	2·71	14, 12 & 10
70	Mandalay Longitudinal	1899–1900	1·696	1·00	8
71	Manipur Meridional ..	1899–1902 & 1915–1916	0·750	2·22	12
73	Kidarkanta ..	1902–03	1·323	2·17	12 & 7
75	"Baluchistân" (Bannu)	1908–09	1·348	2·97	12 & 8
78	Khâsi Hills ..	1909–13	2·038	0·76	8
81	Jaintia Hills ..	1910–11	0·986	0·49	8
82	Bhir ..	1911–12	0·794	2·49	8
83	Rânchi ..	1911–12	1·840	0·61	8
84	Villupuram ..	1911–12	1·184	0·46	8
86	Indo-Russian Connection ..	1912–13	2·700	2·17	6
87	Khandwa ..	1912–13	0·909	1·71	8
88	Ashta ..	1913–14	1·048	1·33	8
89	Buldâna ..	1913–14	0·304	0·08	8
90	Naldrug ..	1913–14	1·465	1·91	8
91	Nâga Hills ..	1913–14	0·913	2·17	12
92	Middle Godâvari ..	1914–15	0·913	0·72	8
93	Kohima ..	1913–15	1·094	1·48	12 & 8
94	Câchâr ..	1914–15	1·077	1·17	12
95	Bombay Island ..	1911–14		..	8
96	Madura ..	1916–17	1·148	1·49	8
97	Bâgalkot ..	1916–17	0·701	1·15	8
99	Rangoon ..	1925–27	1·246	..	12
100	Kurram ..	1927–28	2·096	3·80	3½ Wild
101	Peshâwar ..	1927–28	1·267	5·56	3½ Wild
102	North Wazfristân ..	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

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

1. General.—Due to financial stringency the normal programme of measurement of new bases, the re-observation of secondary triangulation and the establishing of new Laplace stations to strengthen and improve the quality of weak secondary series could not be carried out. The geodetic triangulation of the Andamans, which was only partly observed last year, was, however, completed.

Chart I shows in blue the Primary and in green the Secondary triangulation of India. The measurement of a new geodetic base-line and the insertion of new Laplace stations near Kandla in 1950, have improved the overall accuracy of the Kāthiāwār Meridional Series (No. 28), the Kutch Coast Series (No. 35) and the Kutch Coast-line Series (No. 39). As a consequence these series which were hitherto classed as secondary have now been shown as primary on Chart I. The co-ordinates of the stations of these series have been readjusted.

2. The Andamans Geodetic Triangulation.—The new geodetic triangulation of the Andamans was undertaken last year to provide framework control for the air survey of the islands. The scale of this triangulation is based on the Ferrar Ganj geodetic base-line, which was measured with invar wires in catenary. The datum for latitude, longitude and azimuth is the Chatham Observatory, the co-ordinates of which were determined with a 60-degree astrolabe in November 1950, the initial azimuth being obtained from Polaris observations. The adopted values of the latitude and longitude of the datum and the fundamental azimuth are as follows :—

Latitude 11° 41′ 13″·04

Longitude 92° 43′ 30″·32

Azimuth at Chatham Observatory of Haughton H.S.
= 328° 47′ 19″·7.

The lay-out of the new triangulation consists of 27 stations. Observations were made at 18 stations last year and the remaining 9 stations have been occupied this year (Chart II). Station Jirkatang H.S. occupied last year was revisited this year. It was hoped to observe the new triangulation according to the proposed lay-out given in Chart V of Technical Report 1951, Part III. This was, however, not feasible as the ray Raolunta H.S. to North Reef S. was not visible. It was not possible to establish an intermediate station on this ray and thus improve the lay-out as no suitable site for a station which would be intervisible from both Raolunta H.S. and North Reef S. could be found. The break in the triangulation was, however, avoided by successfully observing the long ray Raolunta H.S.—Saddle Peak H.S. A narrative account of the season's work is given in the following paragraphs.

3. **Narrative.**—The Andamans Geodetic Triangulation Detachment consisting of Mr. U. D. Mamgain, Deputy Superintending Surveyor, in-charge, one Surveyor, one Trig. Computer and 28 *khalāsis* left Dehra Dūn on 22nd November 1951 for Port Blair via Calcutta. The *S.S. Maharaja* was scheduled to leave on 29th November but got delayed and left Calcutta on 6th December. The Bay of Bengal was in the grip of a terrific storm at this time and the ship had, therefore, to deviate considerably westwards for safety and arrived in Port Blair on 11th December, about 3 days late.

About a week was spent in arranging for transport, rations and fresh water. Mr. J. C. Bhattacharjee left by *M.V. Molly* on 19th December for posting heliotropes on Havelock S., N. Button S. and Raolunta H.S. Mr. Mamgain left on 20th December for observations at Jirkatang H.S.

Jirkatang H.S. and Raolunta H.S. are situated on the border of the territory of the hostile Jarwa tribe. Survey personnel working there were provided with armed escort by the Andamans administration. Observations at Jirkatang H.S. were completed on 30th December and the observation party left the same day for Port Blair reaching there on 1st January 1952. Havelock S. was reached on 3rd January by *Molly* and observations there were completed on 5th January. Observations were next made at N. Button S.

Mr. J. C. Bhattacharjee accompanied by Bush Police moved by boat to post the helio squads on Mt. Diavolo H.S., North Reef S. and Saddle Peak H.S. Heliotropers bound for Mt. Diavolo H.S. disembarked at Cuthbert Bay. On their way to the station they came across two empty Jarwa villages. The inhabitants had fled into the jungle and were showing their displeasure by whistling and buttress beating. Heliotroper Gopal Singh, however, proceeded at great personal risk to occupy Mt. Diavolo H.S. and succeeded in showing the helio to N. Button S. The heliotropers at Mt. Diavolo H.S. were not considered quite safe and more Bush Police was arranged through the Divisional Forest Officer Middle Andaman. The Jarwas left the habitation after sometime and seemed to have proceeded to some other locality as no buttress beating was heard afterwards.

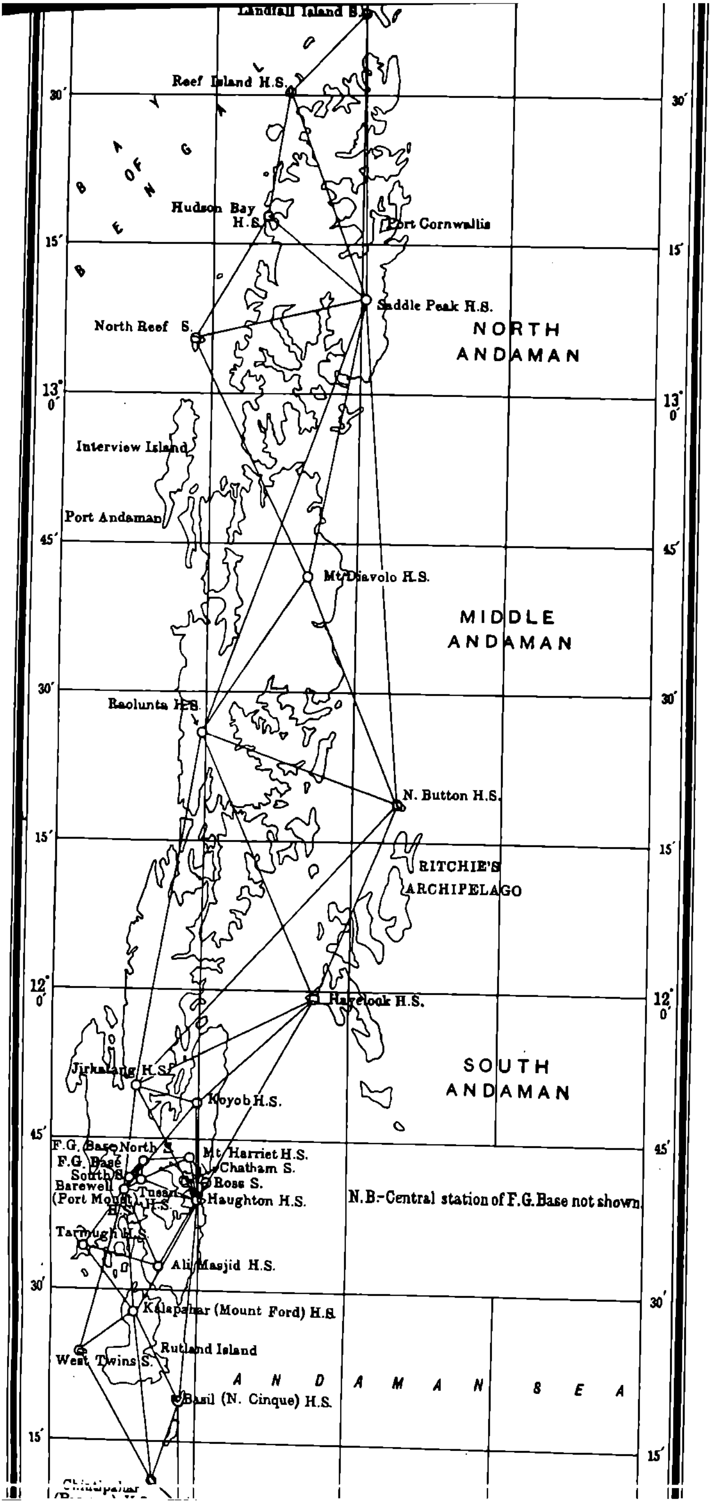
Buttons is an island without fresh water. *M.V. Molly* got delayed in reaching Buttons and fresh water was obtained from sea-water by distillation.

Observation to Saddle Peak H.S. from N. Button S. could not be completed due to bad weather. These were completed later. The observation party then left for Raolunta H.S. via Long Island and arrived there on 16th January. The weather now deteriorated and visibility became poor due to haze and clouds. The ray to North Reef S. from Raolunta H.S. could not be observed as the stations are not intervisible. Observations to Saddle Peak were hampered by clouds and haze and were finally completed on 22nd January. Mt. Diavolo H.S. was next occupied on 25th January. At Mt. Diavolo the Jarwa villagers showed signs of very recent occupation and precautionary measuros had to be taken to safeguard the movement of the personnel. This was especially necessary as the Jarwas were reported to have attacked a village near Tirhut about this time. Bad weather delayed observation on Mt. Diavolo H.S. Water here was originally brought from about 6 miles but a reconnaissance revealed a nearer source of supply and this enabled the heliotropers to camp at the peak and lessened their vulnerability to attacks from the hostile tribes. After completing observations at Mt. Diavolo H.S. on 2nd February, the observation party returned to the base camp to wait for a boat from Port Blair to convey them to Saddle Peak. Boats in Port Blair became scarce at this time due to the visit to that port of some Indian Naval ships. Boat *Molly* came up with heliotropers on 6th February. The observation party was left at Saddle Peak and Mr. J. C. Bhattacharjee took the boat to put heliotropes on Landfall Island S., Reef Island S. and Hudson Bay H.S. Camp was moved to Saddle Peak top on 8th February. Here work was delayed due to bad weather and could only be completed on 19th February, the 57-mile ray to N. Button S. proving the most difficult to observe.

Boat *Elsa* had in the meantime been arranged to shift the observation party from Saddle Peak to North Reef via Buttons. North Reef was reached on 22nd February.

Observations on North Reef S. were completed on 23rd February and on Hudson Bay H.S. on 25th February. Some delay occurred at Hudson as the ray to Reef Island H.S. was getting obstructed by a tree on a distant ridge. The tree was located and cleared sufficiently to carry out observations between the stations. Hudson Bay H.S. is close to a village inhabited by the Oongis, an aboriginal tribe of the Andamans. These are friendly people, some of them being employed by the Forest Department. They know this part of the Andamans very well and were useful as guides. In their small boats they venture out into the open sea and move from island to island collecting coco-nut and fish which are their staple diet.

Reef Island H.S. was reached on 26th February. There is no fresh water in this island. Heliotropers here were posted on 10th February with rations and 88 gallons of water in two 44-gallon drums. Leakage in one of the water drums was discovered later and



Landfall Island S.
Reef Island H.S.
B A Y O F B E N G A L
Hudson Bay H.S.
Port Cornwallis
Saddle Peak H.S.
North Reef S.
NORTH ANDAMAN
Interview Island
Port Andaman
Mt. Diavolo H.S.
MIDDLE ANDAMAN
Raolunta H.S.
N. Button H.S.
RITCHIE'S ARCHIPELAGO
Havelock H.S.
SOUTH ANDAMAN
Jirkatang H.S.
Koyob H.S.
F.G. Base North S.
F.G. Base South S.
Barewell (Port Mount) H.S.
Tusan H.S.
Mt. Harriet H.S.
Chatham S.
Ross S.
Haughton H.S.
N.B.-Central station of F.G. Base not shown.
Tarmugh H.S.
Ali Masjid H.S.
Kalapahar (Mount Ford) H.S.
Rutland Island
West Twins S.
Basil (N. Cinque) H.S.
A N D A M A N S E A
30′
15′
13° 0′
45′
12° 0′

the men ran short of fresh water. There were, however, enough coco-nut trees in the island and water from these solved their problem. One shell-collecting boat which happened to pass that way also replenished supplies to some extent.

Landfall Island S. was reached on 27th February. Heliotropers here were posted on 10th February with rations and fresh water in two drums. They found themselves in a difficult situation one day when one of their 44-gallon drums of water tied to a tree (near the coast) by rope was swept away by a high tidal wave. They had nearly finished all other fresh water and none was available in the island. They had, however, been shown how to distil sea-water for their requirements which they managed to do successfully.

Boat *Elsa* had been with the observation party now for nearly thirteen days and the crew had exhausted their rations. Booking of the boat was extended up to 5th March and the party sailed for Mayapur (North Andaman) where rations for the crew and Bush Police were drawn by special arrangement with the Supply Officer. The services of a wireless detachment supplied by the Superintendent of Police enabled the observation party to keep contact with Port Blair and other wireless stations and thus greatly facilitated the making of administrative arrangements.

The party left Mayapur for Buttons on 1st March to observe the ray N. Button H.S.—Saddle Peak H.S. Bad weather prevailing over the Andaman seas at the time delayed the observations. The weather cleared up considerably after the rain on 2nd March, and observations on this ray were completed on 3rd March. *Elsa* was then signalled to collect heliotropers from Saddle Peak H.S. and Mt. Diavolo H.S. The personnel of the observation party reached Port Blair on 5th March.

Triangulation observations were hampered considerably by the unpredictable weather in the Andamans, but wireless communication kept the wastage of time due to other sources to a minimum. Sometime was, of course, lost when boats or labour were not available.

Special precautions were taken to protect personnel of the detachment against malaria by regularly administering Paludrine. Mosquito nets were supplied to *khalāsīs*. The heliotropers suffered from some sickness due to lack of fresh vegetables after their prolonged stay on uninhabited island stations like Buttons and N. Reef. The Senior Medical Officer at Port Blair was good enough to supply some multi-vitamin tablets and anti-mosquito cream which were found useful. There was no case of sickness requiring admission in hospital but some vegetarian *khalāsīs* developed night-blindness in the later part of the season which was soon cured on reaching Port Blair. The personnel suffered much from tick and leach bites which developed into boils.

4. **Tidal Observatory at Port Blair.**—On arrival at Port Blair on 11th December 1951, it was learnt that the foundation structure

of the tidal observatory at the Aberdeen Jetty had been swept away by cyclone. A visit to the Aberdeen Jetty on 12th December confirmed this. The Executive Engineer was at that time planning to drive piles deep into the sea-bed to support the observatory building. In view of the cyclonic conditions that often prevail in the sea around Port Blair, it was considered advisable to shift the site to a more protected place. A suitable site was reconnoitred and found at the south end of Phœnix Bay. This place is more suitable from administrative point of view also as the offices of the Marine Department which are to look after the observatory are all situated around this area. Deep sea water is quite close to the site and it is much less exposed than Aberdeen Jetty. The Chief Commissioner gave top priority to the construction and procurement of material and fixed 15th February 1952 as the target date for the completion of the observatory. Mr. J. C. Bhattacharjee was specially instructed to keep in touch with the progress of construction. Wooden piles of *mahua*, a special variety of wood, which grows on the sea coast, 20 to 25 feet long were driven deep into the sea-bed leaving about 12 feet above the ground on which the floor rests. The building was finally ready by the 23rd March and the tide-gauge was erected on the 27th March (see Chapter IV, para 24).

Training was given to an observer deputed by the Engineer and Harbour-master for the maintenance of tide-gauge. Determination of zero of the gauge and fixing of the level of the bedplate by precise levelling with respect to two type C bench-marks in the Marine Department compound was completed on 26th March. A final check for zero, etc., was made on 27th March and the same evening the detachment embarked the *S.S. Maharaja* and arrived in Calcutta on 31st March.

The Indian Navy Survey Ship *Investigator* arrived in Port Blair on 23rd March. The data for the geodetic triangulation of 1950–51 was already with them and this enabled them to start their own survey of the coast and sea-bed around Port Blair. The observer of the Tidal Observatory was instructed to supply the tidal information to the Commander of the survey ship when asked for by him.

5. **Interpretation of G.T. Stations on Photographs.**—Photographs of the Andaman Islands were taken to the field to pinpoint the G.T. stations. All the station marks were correctly located on the photographs with the help of white 'T' marks made on the ground in the long radial clearings, which were recognizable on the photographs. The clearings had been carried out to ensure intervisibility of the stations.

6. **Dehra Dūn City High Precision Traverse.**—In 1949, the Chairman City Board, Dehra Dūn requested for the provision of precise traverse for the purpose of framework control for the proposed 16-inch survey of the civil station and 64-inch survey of the city and congested areas.

The City Board's requirements consisted of 20 to 40 permanent traverse stations, suitably placed, per square mile.

The permanent traverse stations consisted of a brass plug with a fine vertical cut mark embedded in cement concrete filled in a pit, dug in ground, of size about 18 inches × 15 inches and depth about 18 inches. The brass plugs were kept about 3 inches below the level of the ground to avoid the possibility of their being disturbed by outside agencies. Later, the City Board was advised to construct pillars, 2 feet square at base and 2 feet high, the upper 4 inches being dressed to the form of a frustum of a pyramid terminating in a square of 4-inch side, over each of these stations. The top of this pillar will have another brass plug embedded in it similar to the one embedded below, and centred exactly over the lower one. In addition, close to and around each of these permanent traverse stations, a number of brass plugs have been embedded in the compound and outer walls of buildings so as to enable these stations to be exactly relaid should these stations get disturbed at a future date.

The field work was started on 13th March 1950 and completed by 27th May 1950. Co-ordinates of 47 stations are tabulated in Table 1 which includes all the 21 permanent traverse stations built by the City Board, Dehra Dūn.

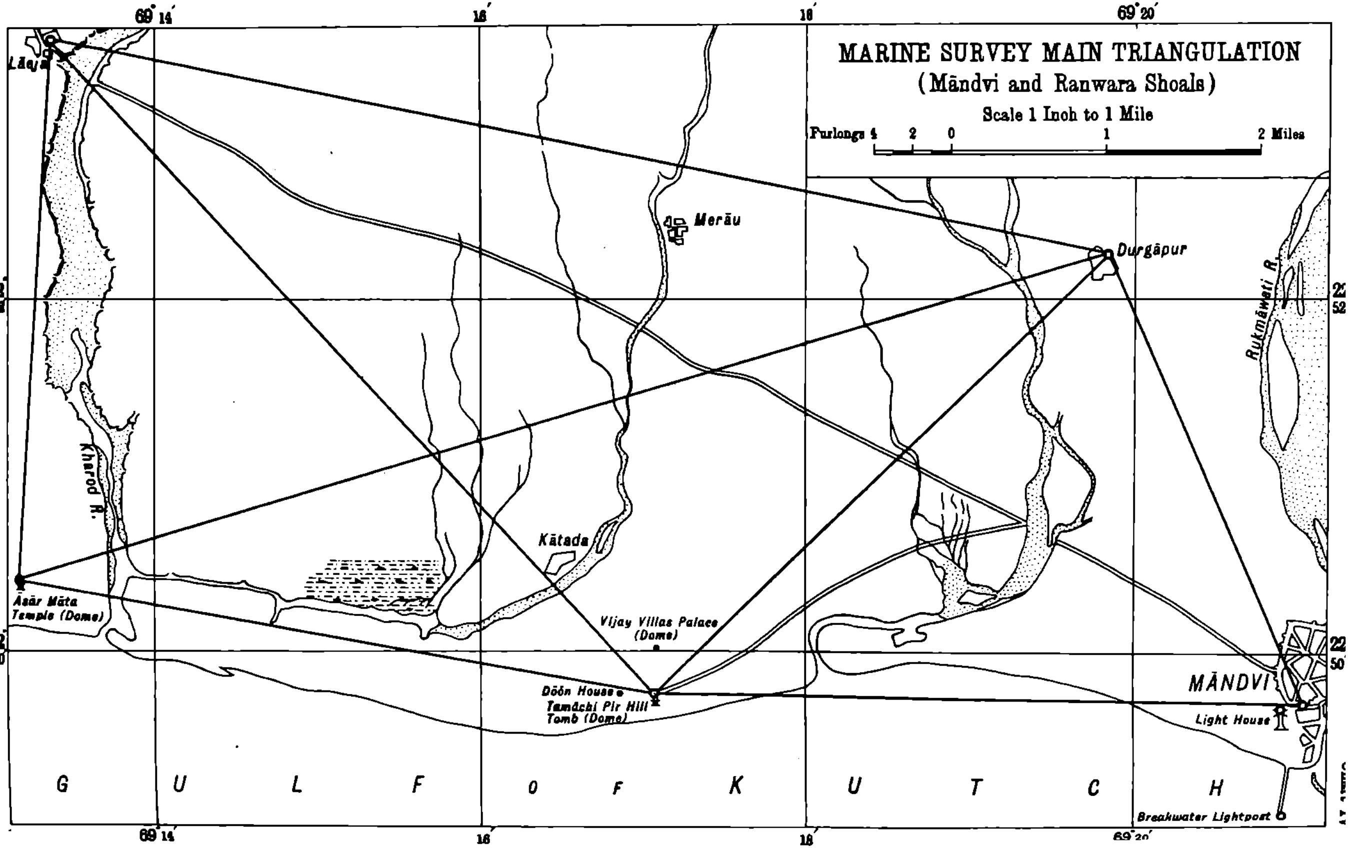
The traverse emanated from Dālanwāla Satellite S. and proceeded towards north up to Jākhan along the Rispana, crossing the Dehra Dūn–Rājpur road to Anārwāla and closing on Dālanwāla Satellite S. via Nayāgaon, Dubhālwāla, and the new clock tower (Chart III).

For linear measurements between traverse stations, Jädrin wires and equipment were used ; 24-metre wires Nos. 243 and 244 and 72-metre wire No. 231 were used as field wires and measured in catenary. The 24-metre wires used in the field were standardized against the standard wire No. 247 and the field 72-metre wire was standardized by measuring three 24-metre legs with the 24-metre wires. Due to the undulating nature of the ground and the built up areas, it was not possible to carry out continuous linear measures and hence some of the legs of the traverse were measured by triangulation.

All angular measurements were made with a Geodetic Tavistock theodolite. The traverse angles were observed on two zeroes and on both faces. At three stations, astronomical azimuths were observed from Polaris.

The closing discrepancy of the closed circuit of traverse was as follows :—

Northing	Easting	Height	Total length of traverse
Yds.	*Yds.*	*feet*	*Yds.*
~~5·0~~ 0·5	0·6	1·6	16,400



Reg. No. 169 D/M.C. '32 (G. & T.C. 1" - 1 Mile.)-300.

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

During 1951, the circuit from Dālanwāla Satellite S. going southwards round the southern limits of Dehra Dūn Municipality and back to the new clock tower was taken up. For this only linear measurements have been completed for about 13 legs and no angular measurements have been made as yet.

Further details of this work will be given in the next Technical Report.

Seventeen of the permanent traverse stations have been connected by secondary levelling. The results are given in Table 2.

7. **Marine Survey Triangulation in Māndvi and Ranwara Shoals.**—At the request of the Ministry of Transport, the Marine Survey of India carried out the survey of Māndvi and Ranwara Shoals with a view to selecting a site for the building of a light-house on the Ranwara Shoal. Triangulation was carried out to provide framework control for this survey (Chart IV).

After an exhaustive reconnaissance of the area, only one old geodetic station, i.e., Māndvi S. was recovered intact. The other two geodetic stations, viz., Asār Māta H.S. and Traghari H.S. were found in a damaged condition. In both cases the original structures had fallen down and it was not possible to ascertain whether the lower stones, marked with a circle and dot, were in their original positions. It appears that there has been a considerable drift of sand since 1859, when these stations were established, and it is possible that the lower stones may have been displaced from their positions.

Geodetic intersected points Asār Māta Temple, Tamāchi Pir and Rāval Pir were found in good condition, but reports from local authorities revealed that extensive repairs had been carried out to the buildings and it was, therefore, necessary to verify that their positions agreed with their published co-ordinates.

The length of the ray Māndvi S.—Tamāchi Pir was checked by means of a Hunter Short Base of 4 chains. The triangulation was, then based on the value of this side and the azimuth at Māndvi S. of Tamāchi Pir as published in Triangulation Pamphlet 41 F, viz., 90° 42′ 47″ (measured south by west). In addition to Māndvi S., Durgāpur S. (a new station), Tamāchi Pir hill tomb, Asār Māta Temple dome, and Lāeja tower station were occupied and formed stations of the main series, from which a number of other stations and points have been fixed.

The results of the 1949–50 topographical triangulation in the area carried out by Southern Circle, Survey of India were received by the Marine Survey after the completion of the hydrographic survey and could not be utilized. The following stations and points of the G.T. and topographical triangulation were connected,

M.S.I. letter	Name of station	G.T. (Survey of India)	Topo. triangu-lation (Survey of India)	Marine Survey Triangu-lation	G.T. *minus* M.S.	Topo. *minus* M.S.
		° ′ ″	° ′ ″	° ′ ″	″	″
B	Māndvi Light-house	Lat. (N) .. Long. (E) ..	22 49 40·07 69 20 53·69	22 49 41·04 69 20 53·56	.. ..	—·07 +·13
C	Tamachi Pir Hill Tomb (Dome)	Lat. (N) 22 49 44·90 Long. (E) 69 17 04·67	.. ..	22 49 45·00 69 17 04·57	—·10 +·10	.. ..
D	Asār Māta Temple (Dome)	Lat. (N) 22 50 23·31 Long. (E) 69 13 09·64	.. ..	22 50 23·44 69 13 09·53	—·13 +·11	.. ..
F	Lāeja Tower Station	Lat. (N) 22 53 28·19 Long. (E) 69 13 21·71	.. ..	22 53 28·33 69 13 21·71	—·14 ·00	.. ..
T	Rāval Pir (Dome)	Lat. (N) 22 48 50·66 Long. (E) 69 23 26·57	.. ..	22 48 50·74 69 23 26·40	—·08 +·17	.. ..
E	Dōōn House (Tamachi Pir h.s.)	Lat. (N) .. Long. (E) ..	22 49 45·40 69 16 51·55	22 49 45·50 69 16 51·37	.. ..	—·10 +·18
F	Vijay Villas Palace (Dome)	Lat. (N) .. Long. (E) ..	22 50 00·73 60 17 05·76	22 50 00·88 69 17 05·68	.. ..	—·15 +·08

The above discrepancies are satisfactory.

8. **Triangulation in Nepāl.**—Due to disturbances in Nepāl, the proposed scheme of strengthening the topographical triangulation by effecting a connection at Bulākipur T.S. and Sināria T S. (see Technical Report 1948–49, part III, page 4) could not be carried out. It is hoped to undertake this work during the next year.

TABLE 1.—*Stations of the Dehra Dūn City Traverse*

Grid I

Origin $\begin{cases} \lambda_0 & 32° \ 30' \\ L_0 & 68 \ \ 00 \end{cases}$

Serial No.	Station or Point	Easting *Grid yards*	Northing *Grid yards*	Height (Top) *feet*
1	Dālanwāla Satellite S. in Col. Brown School ..	4 055 871·44	786 118·13	2222·7
2	North of Raipur road in Rispana near electric pole ..	4 055 913·23	786 360·67	2227·1
3	East bank of Rispana near Nālāpāni road, west of cremation ground ..	4 056 391·97	787 451·07	2277·9
4	West bank of Rispana near wall of Chirya Mandi ..	4 056 274·41	788 060·41	2313·5
5	East bank of Rispana on a wall near lime kiln ..	4 056 232·78	788 831·30	2354·5
6	West bank of Rispana near an isolated hut ..	4 056 304·95	789 509·20	2387·8
7	East bank of Rispana on embankment wall ..	4 056 532·87	789 955·94	2415·1
8	East bank of Rispana on high ground near Jākhan village	4 056 823·70	790 321·43	2443·9
9	On canal near flour mill of Jākhan	4 056 585·27	790 420·62	2471·6
10	On canal road near culvert in Jākhan	4 056 595·60	790 525·29	2478·5
11	In cultivated land, south of canal in Jākhan ..	4 056 905·88	790 997·66	2502·2
12	On canal road about 8 metre from A.I.D. Pillar in Jākhan	4 056 983·79	791 247·37	2517·1
13	In cultivated land between canal and Rājpur road ..	4 056 676·36	791 232·16	2572·4
14	On east side of Rājpur road near culvert in Body Guard	4 056 498·25	791 247·57	2570·4
15	In guava garden of Mukand Lal, west of Rājpur road	4 056 452·30	791 311·49	2568·8
16	Near Hoshiar Singh's house in Anārwāla village ..	4 055 580·80	791 382·92	2547·1
17	North of isolated house of Hav. Rameshwar in Nayāgaon	4 055 364·34	790 915·69	2493·0
18	Near water reservoir and School in Nayāgaon ..	4 055 102·81	790 560·95	2464·5
19	In cultivated land near Kishan Lal's house in Nayāgaon	4 055 059·26	790 248·80	2444·1
20	On road near Guman Singh's house in Nayāgaon ..	4 054 930·80	790 342·68	2449·2
21	Near *papita* tree south of ruin of huts in Nayāgaon	4 054 814·49	790 023·26	2416·3
22	In cultivated land on top of slope near electric line in Nayāgaon	4 054 632·86	789 806·51	2386·7

(*Continued*)

TABLE 1.—*Stations of the Dehra Dūn City Traverse*—(contd.)

Grid I

Origin $\begin{cases} \lambda_0 & 32^\circ\ 30' \\ L_0 & 68\ \ 00 \end{cases}$

Serial No.	Station or Point	Easting *Grid yards*	Northing *Grid yards*	Height (Top) *feet*
23	NW. corner of cultivated land near *nāla* and 'K' quarters of Hāthībarkala Survey Estate ..	4 054 012·93	789 636·78	2293·0
24	SW. corner of land on top over *nāla* near 'K' quarters of Hāthībarkala Survey Estate ..	4 054 513·46	789 627·88	2287·7
25	West end of barren land at junction of *nāla* and Bindāl	4 054 281·56	789 494·24	2280·6
26	On east corner of cultivated land on west bank of Bindāl	4 054 321·09	790 103·19	2273·9
27	On south of cantonment road near pine trees and bridge	4 054 190·04	789 175·10	2287·9
28	SW. corner of cultivated land on east bank of Bindāl	4 053 996·70	788 902·78	2255·7
29	South corner of cultivated land on east bank of Bindāl opposite to firing area	4 053 703·38	788 620·40	2252·1
30	East bank of Bindāl under a *shīsham* tree south of a *kachcha* house in Dubhālwāla	4 053 832·80	788 029·42	2197·9
31	East bank of Bindāl at its bend S. of G.E.'s office ..	4 053 612·76	787 877·11	2192·0
32	On high ground on east bank of Bindāl near foot-path–Dubhālwāla to Chānd Bāgh	4 053 575·89	787 342·63	2180·1
33	On flat ground in Dubhālwāla, north of temple ..	4 053 562·61	787 080·18	2215·2
34	West end of flat land near temple	4 053 486·85	787 041·74	2213·8
35	East end of flat land near Mr. John's house ..	4 053 770·61	786 989·67	2216·6
36	NW. of Guru Nanak's High School near prayer room	4 053 517·27	786 618·73	2195·6
37	New clock tower near General Post Office ..	4 054 039·74	786 154·83	2277·0
38	W. end of parade ground near Rājpur road ..	4 054 349·40	786 438·88	2217·5
39	In parade ground near fountain	4 054 519·32	786 397·75	2225·3
40	East end of parade ground near cement road ..	4 054 813·40	786 177·45	2221·4

(*Continued*)

TABLE 1.—*Stations of the Dehra Dūn City Traverse*—(concld.)

Grid I

Origin $\begin{cases}\lambda_0 & 32° \ 30' \\ L_0 & 68 \ \ 00\end{cases}$

Serial No.	Station or Point	Easting *Grid yards*	Northing *Grid yards*	Height (Top) *feet*
41	NE. of parade ground near *purāna nāla*	4 054 896·71	786 241·34	2227·2
42	On foot of N. pillar of main gate of G.B. on Raipur road	4 055 083·40	786 321·12	2242·0
43	On Raipur road near Police Station	4 055 265·23	786 347·62	2244·6
44	On Raipur road near crossing of Nehru road ..	4 055 482·92	786 337·98	2244·0
45	Near yellow building on Raipur road	4 055 631·16	786 313·37	2243·2
46	Near gate of No. 22 Raipur road	4 055 785·82	786 331·26	2235·0
47	A.I.D. pillar on the Sahasradhara road over canal near Jākhan (near traverse station No. 11) ..	4 056 988·15	791 254·84	..

TABLE 2.—*Heights of traverse pillars connected by spirit-levelling*

Traverse Pillar No.	Brief description by Levellers	Spirit-level heights	Precise traverse heights	Spirit-level *minus* Traverse height
		feet	*feet*	*feet*
8	On high ground near Rispana *nadi* about ¼ mile S. of Jākhan ..	2446·0	2443·9	+2·1
9	On canal near flour mill of Jākhan	2472·9	2471·6	+1·3
11	In cultivated land about 100 feet E. of canal and NE. of Jākhan ..	2503·0	2502·2	+0·8
13	At SE. corner of a mango garden N. of Jākhan	2573·1	2572·4	+0·7
14	At S. end of E. parapet of culvert near F.S. No. 3 between milestones 4 and 5	2570·5	2570·4	+0·1
16	Near Hoshiar Singh's house in Anārwāla village	2547·8	2547·1	+0·7
17	In cultivated land of Kulman Singh in Nayāgaon village and about 2½ furlongs N. of water reservoir	2493·4	2493·0	+0·4
18	Near water reservoir in Nayāgaon village	2466·0	2464·5	+1·5
20	On the foot-path Nayāgaon–Hāthībarkala about 1½ furlongs S. of water reservoir in Nayāgaon ..	2448·5	2449·2	−0·7
22	About 320 feet SSW. of an electric post on the foot-path Nayāgaon–Hāthībarkala	2386·1	2386·7	−0·6
25	In cultivated land about 100 feet N. of the junction of *khāla* (Bhuriwāla) and Bindāl	2278·7	2280·6	−1·9
27	On NE. edge of New Cantonment road about 1 furlong N. of Bindāl bridge	2287·6	2287·9	−0·3
28	1½ furlongs S. of Military Dairy Farm and about 2 furlongs SW. of Bindāl bridge	2255·1	2255·7	−0·6
29	On Shri Kundan Singh Thakur's land and opposite to firing area..	2251·1	2252·1	−1·0
32	On E. bank of Bindāl *nāla* and SE. of M.E.S. stores	2178·4	2180·1	−1·7
34	On E. bank of Bindāl *nāla* in the high grounds of Dubhālwāla ..	2213·2	2213·8	−0·6
36	On NW. corner of Guru Nanak's School at Chakhuwāla ..	2193·4	2195·6	−2·2

CHAPTER II

OBSERVATORIES

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

9. **General.**—The following are the main items of work carried out by the Observatories during the period under report :—

(i) Comparison and maintenance of standards of length,

(ii) Meteorological and seismological observations,

(iii) Maintenance and adjustment of delicate scientific instruments such as geodetic theodolites, geodetic levels, Astrolabe, Frost Gravimeter, etc.,

(iv) Maintenance of clocks and batteries,

(v) Test, calibration and repair of survey instruments and calculating machines,

(vi) Research and experiments, and

(vii) Instruction of officers in precise traversing, astronomical observation and the use of short bases.

10. **Establishment of a standard base-line in India.**—The Indian geodetic triangulation is controlled for scale by 18 base-lines. Of these 10 were measured in the last century in terms of foot standards of length and 8 have been measured in the last 20 years with modern metric equipment.

The Finnish Geodetic Institute have now evolved a comparator based on interference of light known as the Vaisäla comparator. This enables a standard base-line to be established with very high precision and the International Association of Geodesy has recommended that one such standard base-line should be established in every country to serve as a basis for geodetic measurements. The cost of the project is rather heavy and it has not been possible yet to implement it in India.

11. **Meteorological and Seismological Observations.**—The usual meteorological observations at 08½ and 17½ hours 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 were sent to the Director, Regional Meteorological Centre, New Delhi.

The Omori seismograph was in operation throughout the year. It was cleaned and reset on 7th July 1951. Data of earthquake records was supplied to the Director-General of Observatories for publication in the monthly Seismological Bulletins. 45 earthquakes in all were recorded during the period under report, out of which 39 were of slight intensity, 4 were of moderate intensity and 2 of great intensity.

The work on the construction of the new Seismological Observatory is in hand and the building of the Magnetic Observatory is expected to be taken up very shortly.

12. Test, Calibration and Repairs of Instruments.—This directorate now controls the issue, procurement and allotment of all precision instruments of the department. As far as possible, the precision instruments are repaired in the Observatory workshops.

During the year under report, 367 surveying instruments were repaired. They consisted of 10 glass arc theodolites, 41 vernier theodolites, 55 levels, 24 barometers, 45 calculating machines, 2 stereo comparators, projectoscopes and various other survey instruments. The tide predicting machine, the seismograph, the Shortt and Riefler clocks, and other geodetic instruments were attended to and kept in working order.

339 instruments of various kinds were tested and calibrated. The H.S.B. tapes were calibrated in catenary against bays 1–6 of the 24-metre comparator. Comparisons were also made of 100-foot steel tapes and crinoline chains in flat on the mural base. The other items calibrated include invar staves, 10-foot steel tapes, barometers (aneroids and Paulins), theodolites, levels, chronometers, watches and clocks.

The new National H.R.O. wireless receiving sets are being tried for getting time signals emitted from stations other than Rugby.

13. Twist in Bilby Towers.—The tall steel Bilby towers have recently been brought into use by the Geodetic Branch for control surveys. They are 100 feet or more in height and comprise two independent units—the outer portion supports the observer and the surveying instrument is placed on the inner tower. Experimental observations on them were undertaken to investigate the amount of error arising from the twists of the tower due to heating by the rays of the sun. Twists of amplitudes up to 1½ minutes of arc in an interval of 2½ hours were recorded.

To study this twist in greater detail, 4 days' observations on the tower, and 2 days' comparative observations on the ground were made at Dehra Dūn. The temperature variations ranged up to 17° F. Half-hourly observations were made to two sharp objects, about a mile away from the tower and approximately at the same elevation as the tower. The comparative observations on the ground were done on two hot days inside an observatory tent with a view to finding how the observations of directions were affected due to lateral heating, and these revealed practically no variation in direction throughout the day.

An analysis of the results leads to the following conclusions :

(i) Appreciable errors due to twists are present especially in hot months,

(ii) Excepting for an hour or two in the early mornings and/or late evenings, no day observations with the tower are free from this error,

(iii) The errors due to this cause are erratic, and

(iv) Night observations are almost free from errors due to this cause.

14. Magnetic Observations.—To test the hypothesis that enhanced daily magnetic variations should occur in areas between magnetic and geographic equators, observations at some stations in South India were taken in 1948–49 and the results are discussed in Technical Report 1950, Part III, Chapter VI. The range of H was found to be maximum at Kodaikanal and Tinnevelly which are nearer to the magnetic equator than the other stations observed at. This has been further confirmed by an analysis of the data for Kodaikanal observatory for September by Dr. Egedal. He found the main lunar term to be $(4 \cdot 4 \pm 0 \cdot 58)$ sin $(2t + 167)\ \gamma$. This is about four times as great as that at Colāba.

The Indian Meteorological Department* arranged further observations in 1951 at Cape Comorin, Pālamcottah and Sankaranāyinarkovil with Q.H.M. and B.M.Z. instruments. The diurnal range of H in South India near the inter-equatorial region is quite large and was of the order of 135γ in March 1951 and 80γ in June-July 1950.

In connection with the above, it is of interest to record the following two resolutions passed at the 1951 meeting of the International Union of Geodesy and Geophysics at Brussels :—

(i) "The Association of Terrestrial Magnetism and Electricity expresses its thanks to the Geodetic and Research Branch, Survey of India, for important magnetic observations obtained in southern India".

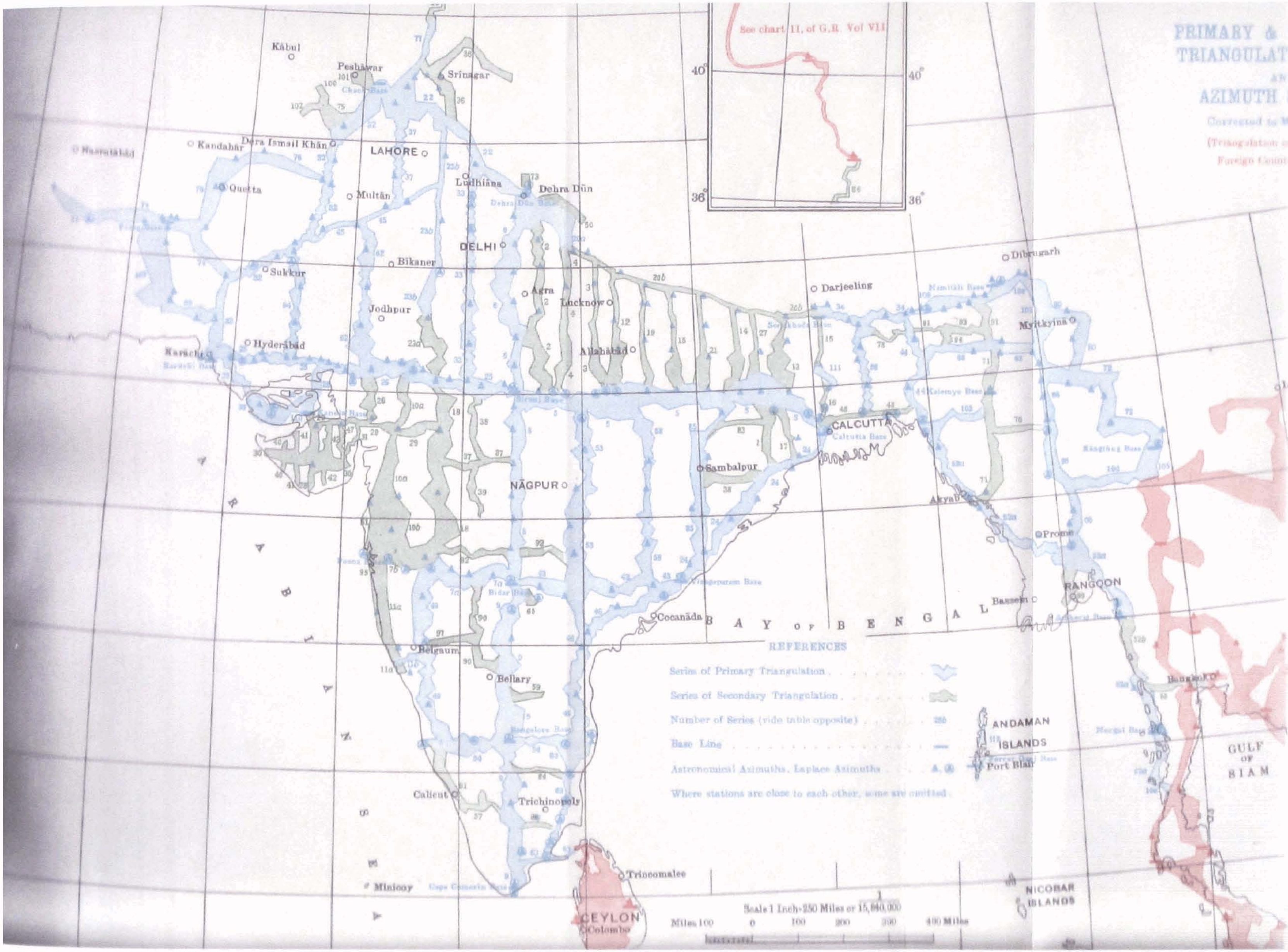
(ii) "The Association of Terrestrial Magnetism and Electricity recommends that a magnetic observatory be established at the magnetic equator in the northern hemisphere, for instance at Tinnevelly, India, and that the desirability of establishing a magnetic observatory where the geographic and magnetic equators coincide (Jarvis Island) be examined".

15. Observations at Magnetic Repeat Stations.—The normal programme of 5-yearly observations at magnetic repeat stations has been in abeyance since 1945 for want of suitable personnel. The field observations have to be corrected for diurnal variation by comparative observations at an observatory. It has not been possible to restart the Dehra Dūn Magnetic Observatory, but a start

* Diurnal Magnetic Variation in Equatorial Regions by Pramanik and Narayanan. The Indian Journal of Meteorology and Geophysics, Vol. 3, No. 3, July 1952.

can be made with the observation of the 5-yearly programme in areas dependent on the Alibag and Kodaikanal observatories. Observations at 13 repeat stations in South India were made last year and although no observations could be carried out during the period under report, it is intended to continue the programme next year. It is also proposed to undertake some observations in the Rāniganj and Jharia Coalfields for the use of mining engineers. No magnetic data exists in these areas at present.

The magnetic declination observed last year at Kodaikanal observatory (See Tech. Report 1951, Part III, Chapter II) is doubtful.



PRIMARY &
See chart II, of G.R. Vol VII
REFERENCES
Series of Primary Triangulation
Series of Secondary Triangulation
Number of Series (vide table opposite)
Base Line
Astronomical Azimuths, Laplace Azimuths
Where stations are close to each other, some are omitted.
Scale 1 Inch=250 Miles or 15,840,000
Miles 100 0 100 200 300 400 Miles
Kābul
Peshāwar
Srinagar
Kandahār
Dera Ismail Khān
LAHORE
Quetta
Multān
Ludhiāna
Dehra Dūn
DELHI
Bikaner
Sukkur
Agra
Lucknow
Jodhpur
Hyderābad
Karāchi
Allahābād
Darjeeling
Dibrugarh
Myitkyina
CALCUTTA
Sambalpur
NĀGPUR
Akyab
Prome
RANGOON
Bassein
Cocanāda
BAY OF BENGAL
Belgaum
Bellary
Calicut
Trichinopoly
Trincomalee
CEYLON
Colombo
Minicoy
ANDAMAN ISLANDS
Port Blair
NICOBAR ISLANDS
GULF OF SIAM
Bangkok
A R A B I A N S E A

CHAPTER III

LEVELLING

BY U. D. MAMGAIN, B.SC., A.M.I.S. (INDIA)

16. **General.**—No levelling of high precision could be carried out during the period under report for lack of funds and only four detachments were employed on secondary levelling. Two of these detachments first completed the levelling required for the Bhākra Dam Project and then proceeded to the Bombay state and carried out levelling for the roads project in the Ratnāgiri district of Bombay state. The third detachment was employed on secondary levelling for the Chambal Irrigation Project and the fourth on the Son Canal Project. The cost of all the levellings was paid for by the state governments at whose request the work was carried out.

17. **Summary of out-turn.**—The total out-turn of secondary levelling carried out was 952 miles.

18. **Secondary Levelling for Bhākra Dam Project.**—To complete the work of providing height control for the Bhākra Dam Project two detachments carried out secondary levelling in the Punjāb.

Detachment No. 1 consisting of Shri S. Muthukrishnan (Surveyor), Shri V. N. Oberoi (Topo. Computer) and 13 *khalāsis* left Dehra Dūn on the 17th October 1951 and commenced work from B.M. No. 83PP/53 H (Type P) at Delhi after the necessary check-levelling.

The instrument used was a Wild Level No. 17783, Model II. Observations were made on a pair of Committee pattern wooden staves Nos. 0 39 A and 0 39 B.

The system of levelling followed was the same as in previous years, viz., the levelling was carried out both in the fore and back directions by 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 observations 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 same sections were observed under different atmospheric conditions.

The maximum length of the shot permissible was 6 chains and the maximum permissible discordance between the middle wire reading and the mean of the readings on the three wires was

0·003 ft. Two sets were taken at each station by altering the height of the axis of collimation of the instrument, the maximum discrepancy admissible between them being 0·004 ft.

The route followed was along the metalled road from Delhi to Alwar up to Sohna and thence to Rewāri. Portion Sohna to Nūh (about 10 miles) was also along the metalled road, Branch-line Sohna to Nūh, which was re-observed, forms part of the old secondary line 106 B (Palwal to Ballabgarh). A junction was effected at B.M. No. 226/53 D (Type M) at Rewāri with detachment No. 2. The B.M. at Rewāri was connected by levelling to B.M. No. 135/53 D (Type B) at Jhajjar on 23rd December 1951.

Detachment No. 2 consisting of Shri Avinash Chandra (Surveyor), Shri P. N. Sanyal (Surveyor) and 13 *khalāsis* left Dehra Dūn on the 17th September 1951 and proceeded to Lohāru to complete levelling from Bādhara to Dādri of the line Siwāni to Dādri of the previous field season. After the necessary check-levelling, work was commenced from Bādhara and closed on type 'B' bench-mark No. 118/53 D at Dādri.

The detachment then proceeded to Siwāni to connect all newly built type 'B' bench-marks between Siwāni and Bādhara, which were not ready when the secondary levelling was run in the area in 1950–51. This work took about ten days to complete.

The detachment then returned to Dādri and commencing work on 29th October 1951 closed it on type 'M' bench-mark at Rewāri on the 18th December, effecting junction with the other detachment.

The instruments used were Wild Level No. 21201, Model II, and a pair of Committee pattern wooden staves Nos. 0 14 A and 0 14 B.

The route followed was along the camel track from Bādhara to Jeoli, then along unmetalled road up to Mahendragarh via Dādri and then along the metalled road up to Nārnaul. From this place the route was along the railway line up to Rewāri.

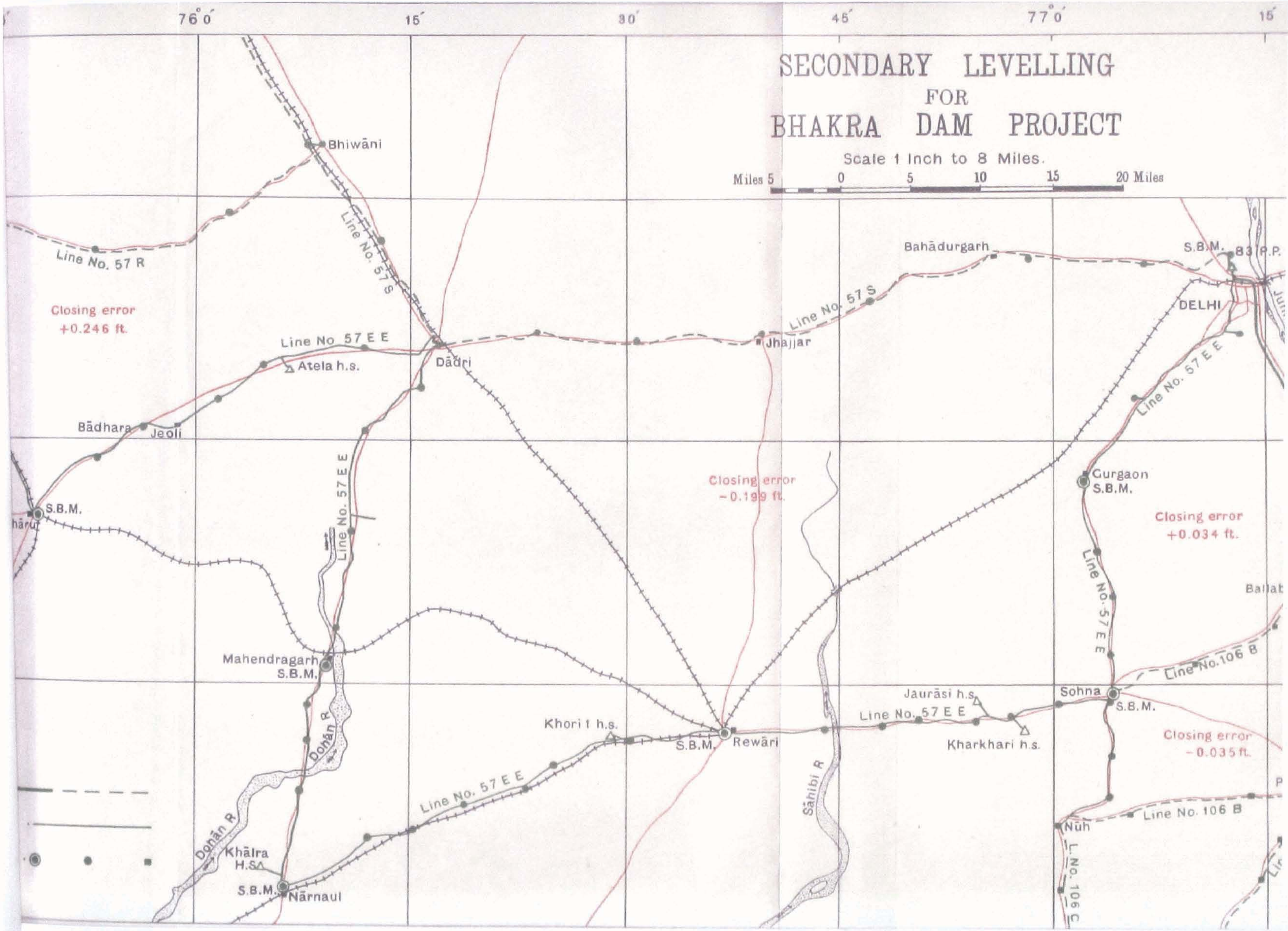
Bullock and camel carts were used for transport by No. 1 detachment, while No. 2 detachment had to rely mostly on camels.

The health of both the detachments was normal.

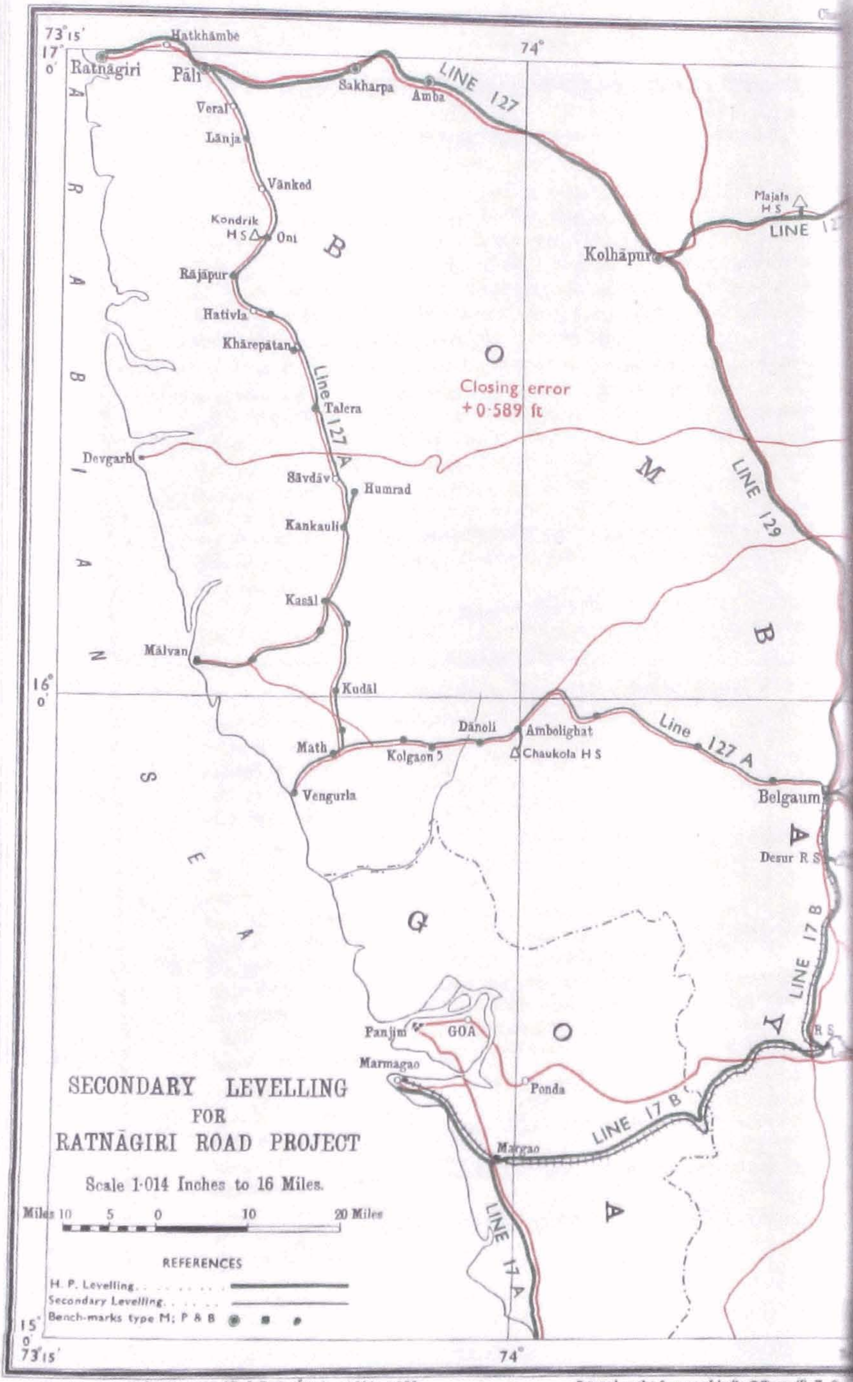
The levelling described above combined with older secondary and high precision levelling forms 4 circuits. The closing errors of these circuits are indicated on Chart VI. These closing errors are satisfactory.

The large circuit Delhi–Jhajjar–Dādri–Nārnaul–Rewāri–Sohna–Gurgaon–Delhi has been sub-divided in two circuits by a tie-line from Rewāri to Jhajjar. This tie-line, however, appears to contain a large error as is clear from the fact that the closing errors of the two circuits on either side of it are of opposite signs. The tie-line has, therefore, been treated as of tertiary accuracy.


LINES O
PRECISE LE
AND
TIDAL ST
Corrected to M
REFERENCES
Levelling of High Precision
Old level net 1858-1909 (Levelling of Precision)
Levelling of Precision 1909 to date
Levelling of Secondary Precision
Tidal Stations on which levelling has been adjusted
Other Tidal Stations not functioning, functioning
Foreign Geodetic Levelling
Kābul
Peshāwar
Srīnagar
Indus R.
Nasratābād
Kandahār
Chaman
Dera Ismail Khān
LAHORE
Quetta
Dehra Dūn
Lhāsa
Brahmaputra R.
Bikaner
Sukkur
Dibrugarh
Darjeeling
Jodhpur
Shillong
Karāchi
Navābandar
Okha Point
Porbandar
Port Albert Victor
Ahmadābād
Jubbulpore
Chittagong
Dublat (Sagar I.)
Shortt I.)
False Point
Akyab
Prince's Dock
BOMBAY
Apollo Bandar
Vizianagram
Vizagapatam
Cocanāda
Godāvarī R.
Hyderābād
Ratnagiri
Bassein
Moulmein
Amherst
Diamond I.
BAY OF BENGAL
ARABIAN SEA
Marmagao
Kārwār
MADRAS
Mangalore
ANDAMAN ISLANDS
Port Blair
Mergui
Koh Hlak
GULF OF SIAM
Calicut
Cochin
Negapatam
Tuticorin
Trincomalee
Nagarkoil
Minicoy
NICOBAR ISLANDS
Irrawaddy R.
Chindwin R.
Salween R.
Mekong R.



SECONDARY LEVELLING
FOR
BHAKRA DAM PROJECT
Scale 1 Inch to 8 Miles.
Miles 5 0 5 10 15 20 Miles
76°0′
15′
30′
45′
77°0′
15′
Bhiwāni
Line No. 57 R
Line No. 57 S
Closing error +0.246 ft.
Line No 57 E E
Atela h.s.
Dādri
Jhajjar
Line No. 57 S
Bahādurgarh
S.B.M.
83 P.P.
DELHI
Line No. 57 E E
Bādhara
Jeoli
S.B.M.
Line No. 57 E E
Closing error -0.199 ft.
Gurgaon S.B.M.
Closing error +0.034 ft.
Line No. 57 E E
Mahendragarh S.B.M.
Line No. 106 B
Sohna
S.B.M.
Jaurāsi h.s.
Line No. 57 E E
Kharkhari h.s.
Khori t h.s.
S.B.M.
Rewāri
Closing error -0.035 ft.
Donān R
Sāhibi R
Line No. 57 E E
Line No. 106 B
Nūh
L. No. 106 C
Khālra H.S.
S.B.M.
Nārnaul



Reg. No. 174 D./N. C. 1952 (G. & T. C. 1·014 = 16 Miles)-300.

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

The portion Nūh to Sohna originally levelled in 1943–44 has been revised. The new difference of height between Nūh and Sohna is −49·512 feet, the old difference being −49·650 feet. The new values have been accepted.

19. Connection of bench-mark of reference at Apollo Bandar and the zero of the tide-gauge.—The Bombay Port Trust authorities had reported a crack in the stone flag of the pavement bearing the inscription of the bench-mark of reference of the Apollo Bandar Tidal Observatory. It was, therefore, decided to check the stability of this bench-mark. Detachment No. 1, on closing work at Jhajjar was asked to carry out this check-levelling.

The detachment arrived at Bombay on the 29th December 1951 and carried out check-levelling to establish the stability of S.B.M. (No. 2PP/47 B). This was then connected to the bench-mark of reference No. 9PP/47 B at Apollo Bandar by fore and back levelling. Six old bench-marks were picked up and connected. No disturbance to the bench-mark of reference could be discerned from the results of check-levelling. The top of the tide-pole was then connected by levelling to the bench-mark of reference. This connection showed that the setting of the zero of the tide-gauge did not require any change.

Some bench-marks were also established along the harbour for the Bombay Port Trust. The detachment then proceeded to Pāli in connection with the Ratnāgiri District Roads Project.

20. Secondary Levelling for Ratnāgiri District Roads Project.—Detachment No. 1 arrived at Pāli on 26th January 1952 and commenced work from type 'M' bench-mark No. 21/47 H after the necessary check-levelling. The work was closed on a new type 'B' bench-mark No. 289/47 H at Kankauli where a junction was effected with levelling Detachment No. 2.

Detachment No. 2 after closing work at Rewāri proceeded to Kolhāpur for checking the levelling from Kolhāpur to Miraj carried out in 1948–49. This was completed from 1st January to 10th January 1952. The detachment then proceeded to Belgaum and commenced work on 14th January 1952 from the standard bench-mark No. 37/48 I after establishing its stability by check-levelling. The work was closed on type 'B' bench-mark at Kankauli effecting junction with No. 1 detachment on 13th April 1952. Two branch-lines, Math to Vengurla about 6 miles long and Kasāl to Mālvan about 20 miles long were also observed.

The route followed by No. 1 detachment was along Bombay–Konkan–Goa metalled road up to Nandgaon and then along the new alignment to Kankauli. The route followed by No. 2 detachment was along the metalled roads between Belgaum and Vengurla, between Math and Kankauli and between Kasāl and Mālvan. The route was undulating, especially between Amboli and Danoli the fall being 2,139 feet in a distance of about 9½ miles, necessitating about 35 stations per mile.

Bullock carts were used as means of transport by both the detachments. The health was normal.

The new secondary levelling described above forms a closed circuit with the high precision levelling from Pāli to Belgaum via Kolhāpur (see Chart VII). The closing error of this circuit is +0·589 ft. in 305 miles which is satisfactory.

21. **Secondary Levelling for Chambal Project.**—Secondary levelling in Kotah district of Rājasthān was taken up at the request of the Chief Development Engineer, Chambal Project, Kotah.

Detachment No. 3 consisting of Shri M. L. Sahdev (Surveyor), Shri K. L. Swani (Trig. Computer) and 12 *khalāsīs* left Dehra Dūn on 28th November 1951 and commenced work from type 'M' bench-mark No. 21PP/45 O at Kotah, after the necessary check-levelling.

The instrument used was Wild Level No. 21194, Model II, with a pair of Committee pattern wooden staves Nos. 0 16 A and 0 16 B.

At the request of the O.C. No. 2 Party (N.C.) a special system of numbering the bench-marks in the field records was adopted. These numbers were painted on stones for easy identification by the levellers of No. 2 Party.

All half-mile bench-marks, viz., milestones and stones embedded opposite fourth furlongs in each circuit were given serial numbers with the circuit letter A, B or C prefixed to them as A-1, B-2 or C-3, etc. For other inscribed bench-marks a smaller letter *a*, *b*, etc., was affixed to the number of the preceding half-mile bench-mark, viz., A-4*a*, B-3*a*, etc.

The whole work formed 3 closed circuits and one branch-line as shown in Chart VIII.

The first circuit started from type 'M' bench-mark No. 21PP/45 O at Kotah and passing through Bhonra, Sultānpur and Rangpur, closed on the same bench-mark.

The route followed was along the metalled Kotah–Bāran road up to Bhonra, thence along the unmetalled Bhonra–Sultānpur road to Sultānpur. From here the line was run along cart-tracks to Rangpur via Jatoli, Nimoda and Ghagtāna and finally to Kotah along the metalled Kotah–Rangpur road.

The second circuit started from bench-mark No. A-38*a* at Bhonra of circuit No. 1 and after passing through Anta, Siswāli and Barod, closed on bench-mark No. A-57*a* at Sultānpur.

The route followed was along the metalled Kotah–Bāran road up to Anta thence along the unmetalled Anta–Siswāli road up to Siswāli and finally along the metalled road to Sultānpur.

The third circuit started from bench-mark No. B-52*a* at Siswāli of circuit No. 2 and passing through Bamori Kalān, Mangrol, Both and Sarkannia closed on bench-mark No. B-22*b*.

The route followed was along cart-tracks up to Bamori Kalān, thence along the unmetalled road up to Māngrol, thence along unmetalled Māngrol–Bāran road up to Both, thence along the cart-tracks up to Sarkannīa and finally along the unmetalled road to Anta.

A branch-line, 32 miles long, starting from bench-mark No. 17/45 O at Kotah and closing on new bench-mark No. 53/45 P at Rāna Pratāp Sāgar Dam site near Rāwatbhāta village was also run to provide a spirit-levelled connection to the type 'B' bench-mark constructed by the Chief Development Engineer, Chambal Project.

The route followed was along the metalled road, a portion of which was still under construction. The route lay through jungle and was mostly undulating from Borābās onwards. There was also a *ghāt* portion of about 5 miles between Borābās and Kolipura.

In addition to the type 'B' bench-marks and half-mile stones fixed by the Project authorities, a number of inscribed bench-marks were also established on rocks, culverts and milestones, etc.

Connections were also effected to Pātan T.S. in sheet 45 O and to Mendi T.S., Badgāon T.S. and Kishanganj T.S. in sheet 54 C. One topo. triangulation station, Both h.s.—fixed by No. 2 Party the same year, was also connected in sheet 54 C.

For transport a truck supplied by the Chief Development Engineer was used whenever possible, otherwise bullock carts had to be employed.

The health of the detachment remained good.

The closing errors of the three circuits A, B and C (see Chart VIII) are −0·078 ft., −0·077 ft. and −0·067 ft. in a distance of 64·46, 54·45 and 58·12 miles respectively. These errors have been disbursed, each B.M. receiving a correction proportionate to its distance from the starting bench-mark.

22. **Secondary Levelling for Son Canal Project.**—To provide height control for the Son Canal Project, one detachment carried out the following three secondary levelling lines :—

(i) Durgauti to Muthāni for the Bhabua area,

(ii) Bārun to Rafiganj for the Aurangābād area, and

(iii) Bārun to Husainābād for the Nabinagar area.

Detachment No. 4 consisting of Shri T. K. Visvanathan (Surveyor), Shri Jagjit Singh Oberoi (Trig. Computer) and 12 *khalāsīs* left Dehra Dūn on the 3rd December 1951 and commenced work from type 'B' bench-mark No. 107/63 O at Durgauti on 8th December after the necessary check-levelling.

The route followed was along cart-tracks via Kharigawan, Rāmgarh and Betri villages up to Bhabua, thence along the metalled road up to Muthāni. The work was closed on 20th January 1952 on inscribed bench-mark No. 115/63 O at Muthāni, since the type 'B' bench-mark No. 116/63 O at Muthāni was found destroyed and the next nearest permanent bench-mark, viz., No. 122PP/63 O (Type A) at Kudra Post Office was also missing.

The instrument used was Watts Microptic Level No. 58510 for the first three weeks, and as the bubble reading device was found defective, further levelling was carried out using Watts Microptic Level No. 58585. Committee pattern staves Nos. 0 18 A and 0 18 B were used.

Inscribed bench-marks on the line were made in advance by No. 3 Party in order not to delay the tertiary levelling and these were connected later on by the secondary levelling detachment. New type 'B' bench-marks were constructed at Chainpur, Rāmgarh and Bhabua, but since these were not ready when the secondary levelling was being carried out, three inscribed bench-marks were left at each of these places by the secondary levelling detachment and the type 'B' bench-marks were connected later on to these by double tertiary levelling.

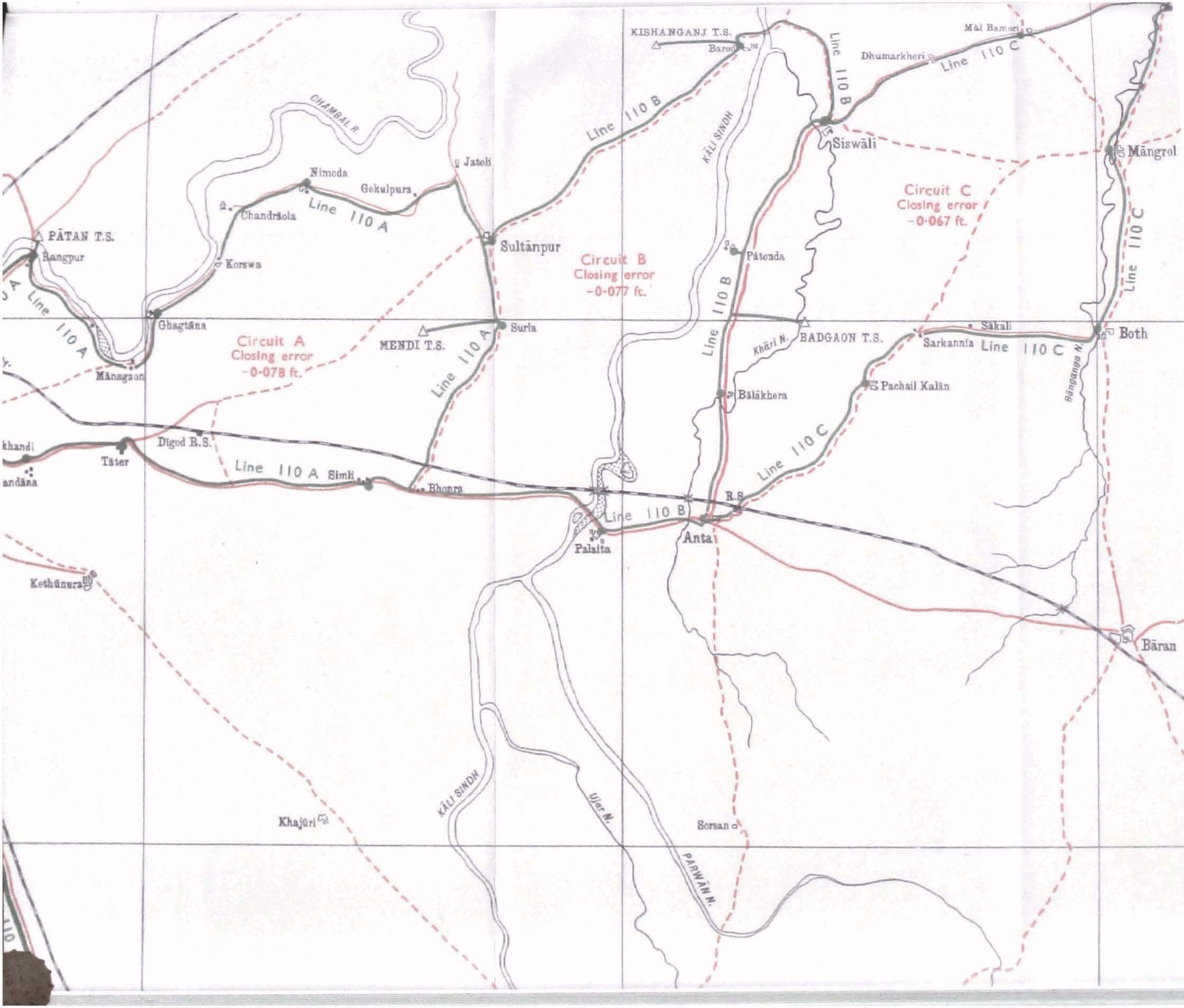
The area is malarious but regular prophylactic doses of quinine kept the detachment free from infection. No difficulty was experienced in the matter of rations. Bullock carts were employed for transport.

Line Durgauti to Muthāni.—Check-levelling at Durgauti establishes that the nearby inscribed bench-marks have all sunk. As the type 'B' bench-mark at Durgauti could not be connected to any other permanent bench-mark no definite evidence as to the possibility of its having risen is available. The published height of the type 'B' at Durgauti has, therefore, been retained. The closed circuit Durgauti–Bhabua–Durgauti yields a closing error of —0·090 ft. in a distance of 47 miles and this has been adjusted proportionately to the distance of each bench-mark from the starting datum and the portion from bench-mark No. 415/63 O at Mohania to bench-mark No. 115/63 O at Muthāni treated as pendant. The probable error calculated from the usual formula is 0·00360 ft. per mile.

Line Bārun to Rafiganj.—After closing work at Muthāni on 20th January 1952 the detachment proceeded to Bārun and commenced work on 27th January 1952 from type 'A' bench-mark at Bārun after the necessary check-levelling.

The route followed was along the metalled road up to Son E. Bank R.S., thence along the railway line up to Palmerganj R.S. and thence along the metalled road up to Obra. From Obra the route followed cart-track via Barāhi up to Goh, thence along the unmetalled road to Rafiganj R.S. where work was closed on B.M. No. 182/72 D on 11th March 1952, after necessary check-levelling.

A new type 'B' bench-mark was established at Obra and another at Goh was later on connected by double tertiary levelling since the bench-mark was not ready when the secondary levelling was being carried out. One station of topographical triangulation, viz., Pachar h.s. was connected by levelling.



KISHANGANJ T.S.
Baroda
Mal Bamori
Dhumarkheri
Line 110 C
Line 110 B
CHAMBAL R.
KALI SINDH
Siswāli
Māngrol
Jatoli
Nimoda
Gokulpura
Chandrāola
Line 110 A
PĀTAN T.S.
Rangpur
Korswa
Sultānpur
Circuit C
Closing error
-0·067 ft.
Circuit B
Closing error
-0·077 ft.
Pātonda
Ghagtāna
Surla
MENDI T.S.
Circuit A
Closing error
-0·078 ft.
Mānsgaon
Khāri N.
BADGAON T.S.
Sakali
Sarkannia
Both
Bānganga N.
Pachail Kalān
Bālākhera
Digod R.S.
Tāter
Simli
Bhonra
R.S.
Anta
Palaita
Bāran
Kethūnura
Khajūri
Sorsan
Ujar N.
PARWĀN N.

Bullock carts were employed for transport. The area is notorious for dacoity and organized thefts and it was found necessary to recruit an additional *khalāsi* locally to keep guard at night. The health of the detachment was normal.

The new levelling along with older secondary levelling forms a closed circuit, Palmerganj–Goh–Rafiganj–Palmerganj, yielding an error of +0·038 feet in 58 miles which is satisfactory.

The line has been adjusted between bench-mark No. 162/72 D at Palmerganj R.S. and No. 182/72 D at Rafiganj R.S. disbursing an error of −0·095 ft. in 40 miles, proportionately to distance, the portion between bench-marks No. 156/72 D at Son E. Bank R.S. and No. 162/72 D being adjusted between stable bench-marks.

The probable error calculated from the usual formula is 0·00303 ft. per mile.

Line Bārun–Husainābād.—After closing work at Rafiganj on 11th March 1952 the detachment proceeded to Bārun and commenced work on 14th March 1952 from the type 'A' bench-mark at Bārun, the stability of which had already been established, and working along the railway line closed work on 29th March 1952 on the newly constructed type 'B' bench-mark at Husainābād, which was also the terminal point of the double tertiary line from bench-mark No. 94/72 D at Amba, run by No. 3 Party.

The detachment then returned to Dehra Dūn.

Bullock carts were the means of transport. The health of the detachment was normal.

The new secondary levelling together with the double tertiary line from Amba to Husainābād and old H.P. levelling forms a closed circuit, viz., Bārun–Aurangābād–Amba–Husainābād–Bārun, yielding a closing error of +0·006 ft. in 75 miles.

As the secondary levelling line does not close on any old bench-mark, no correction has been applied to bench-marks of this line. The double tertiary line has been adjusted between B.M. No. 94/72 D at Amba and type 'B' bench-mark at Husainābād.

The probable error calculated from the usual formula is 0·00411 ft. per mile.

23. **Permanent Bench-marks.**—During the course of levelling operations the following new permanent bench-marks were built and connected :—

2 Type 'C' and 24 Type 'B' in Bombay State.
5 Type 'M' and 32 Type 'B' in Punjāb (India).
37 Type 'B' in Rājasthān.
6 Type 'B' in Bihar.
2 Type 'B' in Delhi.

TABLE 1.—*Tabular statement of out-turn of work, season 1951–52*

Detachments and lines levelled	Dates	Distance levelled: Main-line (Mls.)	Distance levelled: Extras and branch-lines* (Mls.)	Distance levelled: Total (Mls.)	Total: Rises (feet)	Total: Falls (feet)	Number of stations at which the instruments were set up	Number of bench-marks connected: Protected Primary: Rock-cut	Number of bench-marks connected: Protected Primary: Others	Number of bench-marks connected: Others
No. 1 Secondary Levelling Detachment.										
Line Delhi to Sohna	21-9-51 to 19-10-51 and 23-10-51 to 26-10-51	40	6	46	796	701	672	..	8	69
Line Sohna to Nūh	19-10-51 to 22-10-51 and 26-10-51 to 1-11-51	..	19	19	89	138	178	..	4	14
Line Sohna to Rewāri	2-11-51 to 23-11-51	26	4	30	620	458	400	2	7	58
Line Rewāri to Jhajjar	24-11-51 to 23-12-51	..	48	48	123	218	428	..	1	47
Bombay Harbour Levelling	3-1-52 to 17-1-52	10	2	12	98	104	230	..	1	46
Pāli to Belgaum (Portion Pāli to Kankauli)	27-1-52 to 9-4-52	67	26	93	4,871	5,312	1,872	3	8	172
No. 2 Secondary Levelling Detachment.										
Line Siwāni to Dādri (Portion Bādhara to Dādri)	22-9-51 to 28-10-51	28	20	48	1,209	837	708	..	14	31
Line Sohna to Dādri (Portion Rewāri to Dādri)	29-10-51 to 17-12-51	79	17	96	764	2,084	1,324	1	17	97
Line No. 127 (Ratnāgiri to Hyderābād Deccan) portion Kolhāpur to Miraj (Revision)	1-1-52 to 11-1-52	34	..	34	844	843	702	1	1	62

* This column includes check-levelling and relevelments also. *(Continued)*

TABLE 1.—*Tabular statement of out-turn of work, season 1951–52*—(concld.)

Detachments and lines levelled	Dates	Distance levelled: Main-line	Distance levelled: Extras and branch-lines*	Distance levelled: Total	Total: Rises	Total: Falls	Number of stations at which the instruments were set up	Number of bench-marks connected: Protected Primary: Rock-cut	Number of bench-marks connected: Protected Primary: Others	Number of bench-marks connected: Others
		Mls.	*Mls.*	*Mls.*	*feet*	*feet*				
No. 2 Secondary Levelling Detachment.										
Line Pāli to Belgaum (Portion Kankauli to Belgaum)	13–1–52 to 13–4–52	100	43	143	7,894	5,690	3,128	..	18	191
No. 3 Secondary Levelling Detachment.										
Line Kotah to Kotah via Bhonra, Sultānpur	1–12–51 to 12–1–52 and 7–2–52 to 9–2–52	65	13	78	955	946	1,063	..	7	157
Line Bhonra to Sultānpur via Anta and Siswāli	13–1–52 to 6–2–52 and 10–2–52 to 14–2–52	45	11	56	977	989	798	..	7	121
Line Siswāli to Anta via Māngrol	15–2–52 to 13–3–52	42	8	50	740	641	667	..	5	99
Line Kotah to Rāwatbhāta	14–3–52 to 4–4–52	32	4	36	1,370	1,100	602	..	14	45
No. 4 Secondary Levelling Detachment.										
Durgauti to Muthāni	8–12–51 to 20–1–52	45	26	71	410	374	633	..	1	125
Bārun to Rafiganj	27–1–52 to 11–3–52	56	6	62	877	513	794	1	2	115
Bārun to Husainābād	14–3–52 to 29–3–52	30	..	30	333	205	388	..	2	43

* This column includes check-levelling and relevelments also.

TABLE 2.—*Check-levelling*

Discrepancies between the old and new heights of bench-marks.

Bench-marks of the original levelling that were connected for check-levelling			Distance from starting bench-mark	Observed height above (+) or below (−) starting bench-mark as determined by			Difference (check − original). The sign + denotes that the height was greater and the sign −, less in 1951-52 than when originally levelled.
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1951–52	
			miles		*feet*	*feet*	*feet*
				At Delhi			
86	53 H	Step ..	0·00	1931–32	0·000	0·000	0·000
87	,,	Step ..	0·03	,,	− 0·722	− 0·716	+0·006
85	,,	Step ..	0·25	,,	− 1·506	− 1·511	−0·005
84PP	,,	Floor ..	0·51	,,	− 4·951	− 4·953	−0·002
83PP	,,	Standard B.M. ..	1·46	,,	− 34·948	− 34·938	+0·010
333	,,	Parapet ..	1·48	,,	− 31·895	− 31·856	+0·039
332	,,	Rock ..	1·81	,,	− 83·221	− 83·188	+0·033
				At Bombay			
2PP	47 B	Standard B.M. ..	0·00	1946–48	0·000	0·000	0·000
1	,,	Step ..	0·34	,,	+ 0·034	+ 0·035	+0·001
43 (81)*	,,	Step ..	0·35	,,	+ 0·135	+ 0·136	+0·001
44 (88)*	,,	Step ..	0·67	,,	− 0·680	− 0·683	−0·003
10	,,	Step ..	0·72	,,	− 0·625	− 0·628	−0·003
35	,,	Step ..	0·87	,,	+ 2·590	+ 2·587	−0·003
36 (139)*	,,	Newel of steps ..	1·07	,,	− 2·952	− 2·948	+0·004
9PP	,,	Apollo Bundar ..	1·12	,,	− 6·010†	− 6·009	+0·001
3	,,	Step ..	0·06	,,	− 2·171	− 2·170	+0·001
4	,,	Step ..	0·08	,,	− 2·132	− 2·132	0·000
5	,,	Step ..	0·29	,,	− 3·519	− 3·518	+0·001
6	,,	Step ..	0·29	,,	− 3·437	− 3·436	+0·001
45 (105)*	,,	Seat ..	0·63	,,	+ 2·833	+ 2·844	+0·011
46 (79)*	,,	Step ..	0·90	,,	− 3·804	− 3·793	+0·011
				At Belgaum			
37	48 I	Standard B.M. ..	0·00	1948–51	0·000	0·000	0·000
228	,,	Stone ..	0·06	,,	+ 0·039	+ 0·040	+0·001
227	,,	Plinth ..	0·08	,,	− 29·104	− 29·104	0·000
221	,,	Plinth ..	1·40	,,	+ 11·454	+ 11·443	−0·011
222	,,	Stone ..	1·58	,,	+ 12·595	+ 12·600	−0·005
223	,,	Step ..	1·74	,,	+ 9·433	+ 9·429	−0·004
225	,,	Flooring ..	2·30	,,	− 45·594	− 45·592	+0·002
226 (40)	,,	Embedded B.M. ..	2·33	,,	− 49·846	− 49·839	+0·007

* Number in Bombay Island Levelling.

† Differential height between 2PP/47B and 9PP/47B taken from levelling of 1914–15.

(Continued)

TABLE 2.—*Check-levelling*.—(contd.)

Discrepancies between the old and new heights of bench-marks.

Bench-marks of the original levelling that were connected for check-levelling			Distance from starting bench-mark	Observed height above (+) or below (−) starting bench-mark as determined by			Difference (check − original). The sign + denotes that the height was greater and the sign −, less in 1951–52 than when originally levelled.
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1951–52	
			miles		*feet*	*feet*	*feet*
			At Pāli on Line No. 127				
29	47 H	Standard B.M. ..	0·00	1946–49	0·000	0·000	0·000
28	,,	Flooring ..	0·01	,,	+ 3·697	+ 3·698	+0·001
27	,,	Bed rock ..	0·14	,,	− 30·981	− 30·981	0·000
26	,,	Stone ..	0·61	,,	+ 45·038	+ 45·038	0·000
25	,,	Abutment ..	2·03	,,	−140·645	−140·648	−0·003
24	,,	Pier ..	3·00	,,	− 49·560	− 49·555	+0·005
171	47 G	Culvert ..	3·66	,,	+139·388	+139·385	−0·003
170	,,	Bed rock ..	4·15	,,	+ 84·654	+ 84·651	−0·003
169	,,	Sheet rock ..	5·06	,,	− 50·169	− 50·158	+0·011
168	,,	Abutment ..	5·71	,,	−235·531	−235·504	+0·027
156	,,	Bed rock ..	6·60	,,	− 9·385	− 9·345	+0·040
157	,,	Bed rook ..	6·94	,,	+ 26·172	+ 26·210	+0·038
158	,,	Rook ..	7·56	,,	+ 5·762	+ 5·816	+0·054
159	,,	Rook ..	8·63	,,	− 77·734	− 77·627	+0·107
1	47 H	Bed rock ..	9·56	,,	−128·967	−128·866	+0·101
2	,,	Bed rook ..	10·70	,,	−266·778	−266·663	+0·115
3	,,	Bed rook ..	11·75	,,	−301·944	−301·819	+0·125
4	,,	Bed rock ..	12·45	,,	−325·499	−325·379	+0·120
5	,,	Stone ..	13·36	,,	−398·143	−398·007	+0·136
6	,,	Bed rook ..	13·81	,,	−432·976	−432·830	+0·146
13	,,	Type 'M' at Ratnāgiri ..	14·40	,,	−414·399	−414·261	+0·138
30	,,	S. Prism ..	0·00	,,	− 0·763	− 0·764	−0·001
31	,,	N. Prism ..	0·00	,,	− 0·744	− 0·744	0·000
32	,,	Iron bolt ..	0·00	,,	− 0·393	− 0·396	−0·003
33	,,	Stone ..	0·35	,,	+ 16·277	+ 16·274	−0·003
34	,,	Stone ..	0·88	,,	+ 40·439	+ 40·439	0·000
35	,,	Rook ..	1·68	,,	− 77·911	− 77·888	+0·023
			Revision levelling. Sohna–Nūh on Line No. 106 B				
766 (660)	53 H	Embedded B.M. ..	0·00	1943-44	0·000	0·000	0·000
767 (659)	,,	Rook ..	0·19	,,	+ 16·928	+ 16·934	+0·006
768 (653)	,,	Rook ..	0·36	,,	+ 13·484	+ 13·492	+0·008
769 (656)	,,	Culvert ..	1·35	,,	− 1·231	− 1·240	−0·009
770 (655)	,,	Step ..	1·90	,,	− 13·568	− 13·582	−0·014
771 (654)	,,	Pillar ..	3·04	,,	− 37·447	− 37·499	−0·052
772 (653)	,,	Culvert ..	4·12	,,	− 39·156	− 39·166	−0·010
775 (652)	,,	Embedded B.M. ..	5·23	,,	− 46·235	− 46·191	+0·044

(Continued)

TABLE 2.—*Check-levelling.*—(contd.)

Discrepancies between the old and new heights of bench-marks.

Bench-marks of the original levelling that were connected for check-levelling			Distance from starting bench-mark	Observed height above (+) or below (–) starting bench-mark as determined by			Difference (check – original). The sign + denotes that the height was greater and the sign –, *less in 1951–52 than* when originally levelled.
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1951–52	
			miles		*feet*	*feet*	*feet*
				Revision levelling. Sohna–Nūh on line No. 106 B			
776 (*651*)	53 H	Culvert ..	5·98	1943–44	– 42·462	– 42·404	+0·058
777 (*650*)	,,	Milestone ..	6·73	,,	– 41·136	– 40·896	+0·240
779 (*649*)	,,	Culvert ..	8·08	,,	– 43·699	– 43·632	+0·067
781 (*647*)	,,	Pillar ..	10·25	,,	– 42·452	– 42·338	+0·114
783 (*645*)	,,	Pillar ..	12·25	,,	– 45·355	– 45·215	+0·140
784 (*646*)	,,	Type B ..	12·27	,,	– 49·650	– 49·512	+0·138
				At Dādri on line No. 57 S			
118	53 D	Type B ..	0·00	1931–32	0·000	0·000	0·000
117	,,	Well ..	0·13	,,	+ 6·103	+ 6·094	–0·009
116	,,	Step ..	0·26	,,	+ 5·249	+ 5·237	–0·012
115	,,	Flooring ..	0·42	,,	+ 7·669	+ 7·665	–0·004
114	,,	Bridge ..	0·75	,,	+ 3·670	+ 3·649	–0·021
113	,,	Bridge ..	2·04	,,	+ 0·713	+ 0·703	–0·010
119	,,	Bridge ..	0·19	,,	+ 3·637	+ 3·655	+0·018
				At Kotah on line No. 110			
21PP	45 O	Type 'M' Kotah ..	0·00	1928–30	0·000	0·000	0·000
20	,,	○ Supplementary mark ..	0·00	,,	– 0·717	– 0·716	+0·001
19	,,	+ Supplementary mark ..	0·00	,,	– 0·739	– 0·738	+0·001
22	,,	Step ..	0·07	,,	+ 9·710	+ 9·712	+0·002
23	,,	Marble Flooring ..	0·11	,,	+ 15·360	+ 15·365	+0·005
24	,,	Plinth ..	0·20	,,	+ 15·162	+ 15·161	–0·001
25	,,	Stone ..	0·54	,,	– 7·066	– 7·061	+0·005
17	,,	Step ..	0·75	,,	+ 27·786	+ 27·794	+0·008
16	,,	Stone ..	0·84	,,	+ 28·292	+ 28·311	+0·019
15	,,	Step ..	1·08	,,	+ 27·725	+ 27·649	–0·076
13	,,	Rock in situ ..	2·05	,,	+ 52·380	+ 52·390	+0·010

(*Continued*)

TABLE 2.—*Check-levelling.*—(concld.)

Discrepancies between the old and new heights of bench-marks.

Bench-marks of the original levelling that were connected for check-levelling			Distance from starting bench-mark	Observed height above (+) or below (−) starting bench-mark as determined by			Difference (check − original). The sign + denotes that the height was greater and the sign −, less in 1951-52 than when originally levelled.
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1951–52	
			miles		*feet*	*feet*	*feet*
			At Bārun on line No. 70 A				
19	72 D	Type 'A' ..	0·00	1914–15	0·000	0·000	0·000
20	,,	On stone coping of sluice ..	0·41	,,	− 1·579	− 1·573	+0·006
21	,,	On stone block ..	1·38	,,	− 12·341	− 12·328	+0·013
			At Son E. Bank R.S. on line No. 70L				
156	72 D	On stone block ..	0·00	1925–26	0·000	0·000	0·000
157	,,	On stone block ..	1·30	,,	+ 3·584	+ 3·586	+0·002
158	,,	On railway bridge ..	2·35	,,	− 17·943	−17 ·949	−0·006
160	,,	On railway bridge ..	4·33	,,	− 27·402	− 27·411	−0·009
161	,,	On stone block ..	5·45	,,	− 26·335	− 27·712	−1·377
162	,,	On stone block ..	6·65	,,	− 28·591	− 28·627	−0·036
163	,,	On stone block ..	7·21	,,	− 30·547	− 30·578	−0·031
164	,,	On railway bridge ..	7·53	,,	− 30·790	− 30·821	−0·031
			At Rafiganj on line No. 70L				
182	72 D	On stone block ..	0·00	1925–26	0·000	0·000	0·000
181	,,	On stone block ..	0·94	,,	− 6·140	− 6·116	+0·024
178	,,	On stone block ..	4·18	,,	+ 1·110	+ 1·122	+0·012
176	,,	On stone block ..	6·30	,,	− 23·749	− 23·659	+0·090
175	,,	On stone block ..	6·06	,,	− 23·859	− 23·839	+0·020
			At Mohania on line No. 70L				
215	63 O	On stone block on wall of R.S. ..	0·00	1925–26	0·000	0·000	0·000
214	,,	On stone block on wall of R.S. ..	1·40	,,	− 7·598	− 7·564	+0·034
213	,,	On stone block on wall of R.S. ..	2·41	,,	− 10·412	− 10·379	+0·033
212	,,	On stone block on wall of R.S. ..	3·63	,,	− 6·555	− 6·513	+0·042
			At Durgauti on line No. 70A				
107	63 O	Type 'B' at Durgauti	0·00	1914–15	0·000	0·000	0·000
109	,,	On kerb of well ..	3·09	,,	+ 7·937	+ 7·812	−0·125
110	,,	On parapet of bridge	4·06	,,	+ 6·320	+ 6·218	−0·102
111	,,	On milestone ..	6·19	,,	+ 14·367	+ 14·354	−0·013
112	,,	On veranda of P.O. Mohania ..	7·00	,,	+ 14·822	+ 14·722	−0·100
113	,,	On milestone ..	9·47	,,	+ 18·681	+ 20·085	+1·404
114	,,	On parapet of bridge	10·26	,,	+ 23·519	+ 23·385	−0·134
115	,,	On parapet of bridge	11·85	,,	+ 25·446	+ 25·300	−0·146
106	,,	On parapet of bridge	0·68	,,	+ 10·389	+ 10·292	−0·097

TABLE 3.—*List of triangulation stations connected by spirit-levelling, season 1951–52*

Degree Sheet No.	Name of station	Height above mean sea-level		Difference (Lev.—Trian.)	REMARKS
		Spirit-levelling	Triangulation		
		feet	*feet*	*feet*	
45 O	Pātan T.S. Lat. 25° 17′ 20″·60 Long. 75 56 42·08	839	831	+ 8	⊙ mark on floor of vault connected.
54 C	Mendi T.S. Lat. 25° 14′ 35″·19 Long. 76 09 00·81	831	829	+ 2	,,
54 C	Kishanganj T.S. Lat. 25° 23′ 5″·21 Long. 76 16 15·64	769	763	+ 6	,,
54 C	Badgāon T.S. Lat. 25° 14′ 53″·43 Long. 76 21 00·22	804	799	+ 5	,,
54 C	Both h.s. Lat. 25° 14′ 38″·88 Long. 76 30 12·98	828	826	+ 2	⊙ uppermost mark connected.
53 H	Pirghaib T.S. Lat. 28° 40′ 35″·09 Long. 77 12 52·03	787	794	− 7	G.T.S. on ⊙ ground B.M. floor mark-stone connected.
53 D	Kharkhari h.s. Lat. 28° 12′ 02″·8 Long. 76 57 58·9	1030	1020	+10	◎ on rock in situ.
53 D	Jaurasi h.s. Lat. 28° 14′ 05″·1 Long. 76 54 42·5	955	946	+ 9	◎ on rock in situ.
53 D	Khālra H.S. Lat. 28° 03′ 38″·70 Long. 76 04 34·27	1452	1446	+ 6	⊙ lower mark on stone connected.
53 D	Khori No. 1 h.s. Lat. 28° 11′ 39″·0 Long. 76 28 50·9	1386	1380	+ 6	⊙ on rock in situ.

(*Continued*)

SECONDARY LEVELLING

FOR

SON CANAL PROJECT

Scale 1 Inch to 8 Miles

Chart IX

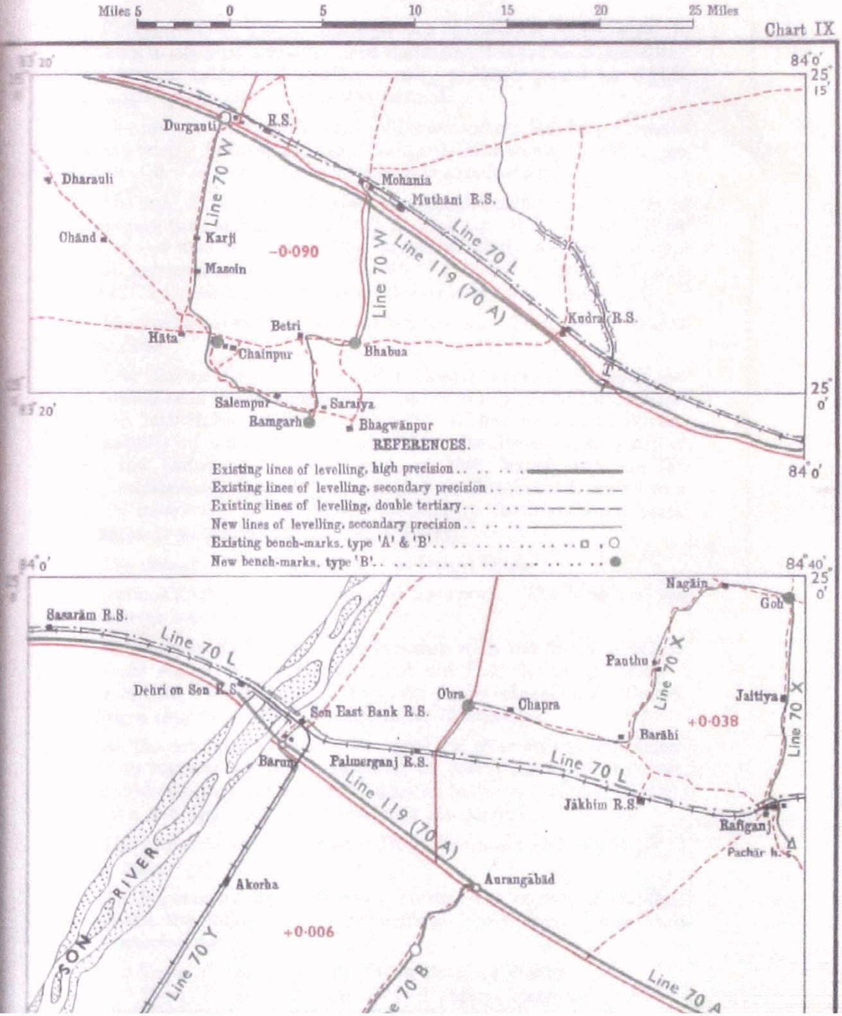


TABLE 3.—*List of triangulation stations connected by spirit-levelling, season 1951–52*—(concld.)

Degree Sheet No.	Name of station	Height above mean sea-level		Difference (Lev.—Trian.)	REMARKS
		Spirit-levelling	Trian-gulation		
		feet	*feet*	*feet*	
53 D	Atela h.s. Lat. 28° 34′ 25″·57 Long. 76 06 28·62	1336	1332	+ 4	⊙ on rock in situ.
53 D	Selan (Seiling) h.s. Lat. 28° 25′ 07″·74 Long. 76 12 23·01	995	990	+ 5	⊙ on rock in situ.
47 H	Kondivli h.s. Lat. 16° 42′ 53″·00 Long. 73 34 11·50	729	734	− 5	..
48 E	Chaukola H.S. Lat. 16° 55′ 31″·44 Long. 73 59 21·13	2795	2794	+ 1	⊙ on upper mark-stone.
72 D	Pachar h.s. Lat. 24° 47′ 08″·59 Long. 84 39 26·35	708	704	+ 4	⊙ on rock in situ.
87 A	Chutham S.* Lat. 11° 41′ 13″·04 Long. 92 43 30·16	83	84	− 1	B ⊕ M on hill top.
87 A	Ross S.* Lat. 11° 40′ 33″·93 Long. 92 45 43·30	16	16	0	B ⊕ M on stone slab.
87 A	F.G. Base North S.* Lat. 11° 43′ 03″·37 Long. 92 30 21·69	133	133	0	⊙ upper mark-stone.

* Connected by spirit-levelling in 1950–51.

Chapter IV

TIDES

BY A. N. RAMANATHAN, M.A., A.R.I.C.S.

24. **Tidal Observations.**—(*a*) *By port authorities.*—Automatic tide-gauge observations were continued, as usual, at Aden, Kandla, Bombay (Apollo Bandar) and Calcutta (Garden Reach) with the Survey of India gauges, and at Vizagapatam, Saugor, Gangra, Balari and Diamond Harbour with the ports' own instruments. The observations at Gangra and Balari were, however, discontinued from 1st February and 1st March 1952 respectively, sufficient data having been obtained at both these ports for purposes of analysis. The half-hourly observations on tide-pole at Kandla port (Passenger Jetty) were continued up to 15th January 1952, while the daylight observations of high and low waters at Bhāvnagar and Rangoon were continued for the whole year.

An automatic tide-gauge of the Newman's pattern was installed at Port Blair in Phœnix Bay on 27th March 1952 and has since been in operation. A brief history of the old tidal observatory which was in existence at Ross Island during 1880–1925, as well as the reason for changing the site to the mainland (S. Andamans), have been given in the last year's Technical Report. A short description of the new observatory is given towards the end of this Chapter (page 37).

There have been no serious breaks in the registrations of these various gauges except at Vizagapatam where the instrument had become too old and worn-out to function satisfactorily. The following are details of the breaks that occurred :—

Port	Dates of breaks	Remarks
Aden ..	17th–18th September 1951	Due to stoppage of gauge-clock.
Bombay ..	18th–19th May 1951	Due to overhauling of gauge-clock.
Vizagapatam ..	23rd–24th July 1951 27th August–27th Sept. 1951 7th–31st October 1951 16th–28th November 1951 22nd–24th December 1951 1st–3rd March 1952	Due to repairs and overhauling of the gauge. (Daylight observations on tide-pole were carried out during these intervals).

At Kandla, owing to the limited range of the present pencil screw (of one-inch pitch) in the instrument, the registrations of certain extreme tides were again missed during the year. It has unfortunately not been possible yet to procure and fit in a new pencil screw (of half-inch pitch) to meet the problem.

The Bombay Observatory was inspected by the Surveyor of Port Trust in May 1951. No inspections were carried out in respect of the other observatories.

(*b*) *By touring tidal detachment of the Survey of India.*—A programme of 31 days' systematic observations on tide-pole at each of the Secondary ports Dāhānu, Thāna, Alībāg and Janjīra on the Bombay coast had been contemplated, but did not materialize during the year due to financial stringency. Existing tidal information at these places is not very reliable. It is proposed to take up this programme during the coming season if possible.

Chart X shows the Primary and Secondary tidal stations at which tidal data have so far been obtained along the Indian coast.

25. Analysis of Observations.—Work on harmonic analysis and reduction of observations continued to be heavy during the year. The following are details of the different analyses that were carried out :—

(*a*) *15-day analysis.*—The observations that had been carried out by the Marine Survey of India early in 1951 at Duncan Passage (Sisters Islands) and Aberdeen Jetty (Port Blair) were analysed by the Admiralty method. The results are given in Table 1.

In the case of Port Blair the corresponding old constants, hitherto in use for standard predictions (for Ross Island), are also included in the Table for comparison. No significant change in the constants has been noticeable except in the case of Z_0 (height of mean sea-level above datum), the latter change being probably due either to some abnormal meteorological conditions that might have been prevalent during the fortnight's observations, or to a subsidence of the old bench-mark (s) of reference at Ross Island.

(*b*) *29-day analysis.*—The field observations that had been carried out by the touring tidal detachment of the Department at Port Albert Victor (Standard Port), Navabandar and Bhāvnagar concrete jetty during 1950–51 were analysed by the Liverpool Institute's method, yielding 28 components. The constants derived are given in Table 2(*a*).

In the case of Port Albert Victor the old constants have also been included in the Table for comparison with the new values. Considering that the site of the new observations is about 3 miles further up the creek from the old site, the disagreement in Z_0 can be regarded as reasonable. There has been no significant change in the other tidal constants.

The field observations of 1947–48 that had been carried out at Cochin, Beypore and Bassein, and had previously been analysed by the Admiralty method

(vide Technical Report 1948–49, Part III), were re-analysed during the year under report by the more elaborate Liverpool Institute's method for a comparative study. The revised values of the harmonic constants, which can now be accepted in preference to those previously published are given in Table 2(*b*).

Analysis of 29 days' observations was also carried out for Car Nicobar Island (Andaman-Nicobar group), Khori Creek (Gulf of Kutch) and Tekra Lighthouse (Gulf of Kutch). Observations at the first station had been carried out by the Marine Survey of India early last year, while the observations at the latter two stations had been carried out by the Kandla port authorities during early 1950. The results of the analyses are given in Table 2(*c*).

(c) *One-year analysis.*—The intensive analysis of one year's data, which was in progress last year, for Kandla port (with central day 1st March 1950) was completed during the current year. The results of the analysis, however, showed considerable divergence from those obtained previously from two series of 29 days' observations. It was, therefore, decided to carry out the intensive analysis of another year's data (with central day 25th January 1951). The constants obtained from the two separate annual analyses being in reasonable agreement, the mean of the two sets was accepted for further work. These mean constants are given in Table 3. The discrepancies between the 29-day and one-year values of the constants appear to have been due to possible inaccuracies in the tide-pole readings, particularly during the 29-day periods.

Partial analysis of one year's tide-pole observations at two stations (Batighar Creek and Paradip Lock) on the Mahānadi River was carried out at the request of the Navigation Officer, Hirakud Dam Project, for obtaining a suitable datum for hydrographic surveys of the river. The results of the analysis are at Table 4.

(*d*) *Harmonic shallow water analysis.*—The analyses (first approximation) of shallow water components for the ports of Elephant Point, Rangoon, Amherst and Moulmein were carried out from one year's data in each case, on lines similar to those adopted for the Hooghly River ports (vide Technical Reports 1950 and 1951, Part III). The analyses for Rangoon and Moulmein were based on the primary predictions for Elephant Point and Amherst respectively, with suitable block corrections applied to them. The primary predictions were obtained by the normal method of open sea predictions using all the available components of the old Indian tide-predicting machine. The primary constants that were used for the basic predictions as well as the table of corrections applied and the harmonic shallow water constants obtained, are shown in Tables 5(*a*) to 6(*d*).

The second approximation analyses for Saugor and Diamond Harbour, which had been taken up last year, could not be completed due to other priority commitments. It is proposed to take this up, as well as the second approximation analyses for the remaining riverain ports, during the ensuing year.

Harmonic shallow water analysis was also taken up for Kandla port, based on the primary predictions obtained from the constants of Table 3. The need for this analysis became obvious when the primary predictions that had been prepared and supplied to the port authorities for the year 1952 were compared with the corresponding "actuals" observed during the first few weeks of the year. The comparison revealed large discrepancies due to shallow water effects, amounting to as much as 2 feet in height and 40 minutes in time. This analysis work has been assigned a high priority, to enable revised predictions for the port for 1952 to be supplied as soon as possible, carrying a higher order of accuracy than before. The results of the analysis will be given in the next Technical Report.

26. **Tidal Predictions.**—During the period under report, the preparation of the annual tide-tables for the Indian Ocean ports for 1952 was completed, and that for the years 1953 and 1954 was continued. Preliminary computations for the machine settings for 1955 were also taken in hand.

The "Tide-Tables of the Indian Ocean 1952" and the separate pamphlet for Bombay port for the year 1952 were published during April 1951. The separate tidal pamphlets for the Hooghly River (3 ports) and the Rangoon River (2 ports) were published in the month of August.

The tide-tables relating to the year 1953 are now at press in various stages of printing. Proofs of predictions for 51 ports (out of a total of 67 required to be included in the Tide-Tables) have already been examined and passed for printing.

Advance tidal predictions for 18 ports for the year 1953 were despatched, in accordance with the standing International arrangements for exchange of official predictions, to the Hydrographic Departments of Britain, the United States and Portugal during September–October 1951. Advance predictions for 3 ports each for 1953 were also supplied to the Liverpool Tidal Institute and to the Indian Navy during this period.

In accordance with the same exchange arrangements, advance predictions for 28 foreign ports for the year 1953 were received from the Admiralty, U.S. Coast and Geodetic Survey, the French Hydrographic Department and the Liverpool Tidal Institute for inclusion in the Tide-Tables of the Indian Ocean.

At the request of the Kandla port authorities, tidal predictions for Kandla port for the year 1952 were prepared and supplied in manuscript form. The predictions were asked for in connection with the port's development project.

27. **Corrections to Predictions.**—Empirical corrections, based on the observations of recent years, were, as usual, applied to the predictions for Navlakhi, Bhāvnagar, Bombay (Apollo Bandar), Vizagapatam and Chāndbāli for the year 1954. Except for Bhāvnagar and Vizagapatam, the corrections were the same as those applied to the 1953 predictions (see Technical Report 1949–50 and 1951, Part III). The revised corrections in the case of Bhāvnagar and Vizagapatam are given in Tables 7 and 8.

For Aden, empirical corrections were introduced for the first time from 1954, based on the observations of the last 5 years. The (predicted—actual) differences for the port appeared to be rather erratic in time, but uniform and consistently in one direction in height. Only height corrections have, therefore, been applied. These are shown in Table 9.

In the case of Rangoon, as the method of Harmonic Shallow Water Corrections has been applied to the predictions for 1954, no empirical corrections were required.

28. **Accuracy of Predictions.**—Tables 10 to 17 give details of the discrepancies between the predicted and observed tides, during 1951, at the places where "actuals" were observed, and Table 18 gives the greatest errors in the predicted heights of low water at these places during the same year. The general quality of the predictions for the year 1951 remained practically the same as before.

A table showing the comparative accuracy of the old method of riverain predictions and the new method of harmonic shallow water corrections as tried out in the cases of three Hooghly River ports, was published in the last year's Technical Report. A similar statement in the case of the remaining riverain ports, for which it is proposed to adopt the new method from 1954, is given in Table 19 of this report. The new method appears to be a distinct improvement over the old one.

29. **New Tide-predicting Machine.**—The new tide-predicting machine with 42 components, which was on order from the United Kingdom, has been completed and shipped to India by Messrs. Légé and Co., London. It is expected to be installed in Dehra Dūn and put into operation during the middle of 1952.

The general appearance of the machine is shown by the photograph at Plate XI. The 42 components provided are :—

Top row : Sa, Ssa, Mm, Msf, Mf, M_4, MS_4, MN_4, S_4, MK_4, SN_4.

2nd row : M_{12}, M_{10}, M_8, M_6, $2MS_6$, $2MN_6$, $2MK_6$, $2SM_6$, MSN_6, MSK_6, $2SN_6$.

3rd row : M_2, S_2, N_2, K_2, ν_2, μ_2, L_2, T_2, $2N_2$, $2SM_2$.

Bottom row : K_1, O_1, P_1, Q_1, M_1, J_1, OO_1, S_1, MK_3, MO_3.

Apart from the additional shallow water components as compared with the existing Indian machine of 24 components, the new machine is an improvement on the older model in that (i) it affords a direct reading of the machine indications on suitable dials that have been provided and (ii) it affords greater convenience in operation and adjustment, the angle dials having been fitted in the front instead of at the back, and the components themselves having been arranged in order of species instead of in an erratic order. The machine gives a range of 48 feet at the scale of one centimetre per foot.

30. **New Tidal Observatories.**—The six new tide-gauges, of the vertical Légé type, that were on order from the United Kingdom have already been shipped to India and are expected to arrive shortly. It is proposed to instal them, as soon as they arrive and are tested, at some of the following stations :—Vizagapatam, Madras, Mangalore, Cochin, Bhāvnagar, Verāval, Ratnāgiri and Dhāmra Point.

Port Blair Tidal Observatory.—Mention has already been made about a new tidal observatory having been established at Port Blair on 27th March 1952. The observatory house, of size 12 feet × 12 feet × 15 feet, is situated near the S.E. end of Phœnix Bay and stands on a small jetty, the floor of which is supported on 9 wooden pillars driven deep into the sea-bed. The float-cylinder, 15 feet in length and 2 feet in diameter, is suspended with its bottom about 1·5 feet above sea-bed and with its flanges resting on the observatory floor, and is kept vertical by chains tied to surrounding piles. Six holes of 1-inch diameter, drilled at the bottom, control the flow of sea-water that moves the float. The bottom of the cylinder remains about 1·5 feet below the lowest low water ever recorded.

The zero of the tide-gauge has been set at 18·492 feet below the reference bench-mark marked $\overset{\text{G.T.S.}}{\underset{\text{B.M.}}{\bigcirc}}$, situated behind the Transport Office of the Marine Department. The height of the bed plate above the zero of the gauge is 15·230 feet. A reference tide-staff has also been installed (fixed to one of the jetty piles) close to the observatory, with its zero set to agree with the zero of the tide-gauge. Accepting the height of the above reference bench-mark above sea-level to be 13·787 feet, as fixed by levelling across from Ross Island, the height of the datum of soundings above the zero of the tide-gauge works out to be 1·105 feet.

31. **Miscellaneous.**—The re-computation of the non-harmonic tide levels, appearing in Table III (*b*) of the Indian Ocean Tide-Tables, for the Indian ports has been taken in hand. The new computations are based on the "actuals" or predictions, as available, of the recent years and conform to the latest Admiralty procedure.

The compilation of a Table giving the highest high water and the lowest low water ever recorded at each of the Standard Indian Ports up-to-date has been carried out during the year. The compilation is at present in hand of two pamphlets, one giving detailed descriptions and heights of all available tidal and Marine Survey bench-marks along the Indian coast and the other giving the various relationships between the datum, bench-mark (s), mean sea-level, tide-gauge zero, etc., at each of the Standard tidal stations.

TABLE 1.—*Harmonic Tidal constants derived from 15-day analysis (Admiralty Method of analysis).*

Serial No.	Place and position with description of Tide-pole	Period of observations and Central day	Level of Zero of Tide-pole: Below Chart datum	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 datum)	Description of B.M. of reference
			feet	*feet*	*Burma Standard Time (06h 30m fast on G.M.T.)*										*feet*	
1	SISTERS ISLANDS (Duncan Passage) Lat. 11° 08′ N.; Long. 92° 44′ E. (Tide-pole erected in the bay adjoining the sandy strip which runs along the Northern side of East Sister Island)	15 days 2-3-51	2·30	22·81	H ft. $g°$	1·93 277	0·92 316	0·46 250	0·25 316	0·35 333	0·19 302	0·12 333	0·06 106	0·03 190	3·49†	Bench Mark situated on a rock on northern side of West Sister Island. There is a cement platform about one foot high built on the rock. The platform has an iron rod protruding 0·34 feet above the cement base. The datum is 20·85 feet below this rod.
2	PORT BLAIR* Lat. 11° 40′ N.; Long. 92° 46′ E. Old (Tide-gauge at Ross Island)	41 years ..	1·16	13·27	Old 1880–1921 H ft. $g°$	2·00 283	0·96 324	0·40 274	0·26 319	0·40 332	0·16 300	0·13 329	0·01 128	0·01 229	3·60	G.T.S. □ B.M. 1898 (Type B) at Ross Island in the compound of the Settlement Club.
	New (Tide-pole erected at Aberdeen jetty at Port Blair)	15 days 3-3-51	1·65	33·80	New 1951 H ft. $g°$	1·96 283	1·01 320	0·52 262	0·27 320	0·45 335	0·12 317	0·15 335	0·01 314	0·01 182	3·67†	G.T.S. ○ B.M. (Type C upper-mark) No. 1 in situ on rock about 15 feet high, above the *bund* that runs along the coast from Marine to Aberdeen Jetty. B.M. is north of Cellular Jail about 34 feet from edge of the *bund*.

* Standard Port. † Corrected for seasonal variations.

TABLE 2(*a*).—*Harmonic Tidal Constants derived from 29-day analysis* (Liverpool Institute's method of analysis).

	1				2		3	
Place and position with description of Tide-pole	PORT ALBERT VICTOR* Lat. 20° 58′ N. Long. 71° 33′ E.				NAVABANDAR Lat. 20° 45′ N. Long. 71° 05′ E.		BHĀVNAGAR (CONCRETE JETTY) Lat. 21° 45′ N. Long. 72° 15′ E.	
	Tide-gauge station at the mouth of the creek.		Tide-pole erected at the port jetty, about 3 miles up the creek from the old tide-gauge station.		Tide-pole fixed on the north side of the extreme east end of the pier and 10 ft. west of the reference B.M.		Tide-pole erected at east end of the jetty	
Period of observations and Central day of analysis	4 years ..		29 days 3-12-50		29 days 9-1-51		29 days 18-2-51	
Time Meridian	*Indian Standard Time (05h 30m fast on G.M.T.)*							
Level of zero of Tide-pole: Below chart datum	4·00 ft.		3·30 ft		..		..	
Level of zero of Tide-pole: Below B.M. of reference	16·74 ft.		18·39 ft.		11·82 ft.		42·76 ft.	
Harmonic Constants	Old (1900–03)†		Now (1950)		..		..	
	H. ft.	g°	H. ft.	g°	H. ft.	g°	H. ft.	g°
M_m	..	..	0·08	021	0·45	028	0·10	004
M_{sf}	0·07	250	0·27	206	0·19	122	0·23	014
Q_1	0·16	072	0·18	075	0·16	040	0·17	070
O_1	0·73	072	0·70	073	0·64	067	1·09	072
P_1	0·46	073	0·54	074	0·48	067	0·85	085
K_1	1·62	077	1·64	074	1·44	067	2·57	086
J_1	0·11	104	0·18	130	0·13	085	0·14	191
$2N_2$	0·13	358	0·12	029	0·06	335	0·25	071
μ_2	0·32	347	0·29	357	0·24	333	0·28	243
N_2	0·78	048	0·75	053	0·46	006	2·22	110
ν_2	0·11	121	0·15	056	0·09	008	0·43	113
M_2	2·87	075	2·83	074	1·65	019	10·34	136
L_2	0·10	185	0·04	122	0·07	222	0·45	160
T_2	0·10	106	0·00	108	0·04	059	0·10	174
S_2	1·12	105	1·05	100	0·77	061	3·22	176
K_2	0·27	100	0·28	112	0·21	064	0·88	179
$2SM_2$	0·03	088	0·00	341	0·07	047	0·18	353
MO_3	0·04	170	0·06	210	0·01	122	0·16	011
M_3	0·02	176	0·05	007	0·02	001	0·08	316
MK_3	0·05	183	0·07	197	0·05	168	0·26	130
MN_4	0·00	145	0·12	190	0·08	172	0·28	129
M_4	0·21	208	0·27	220	0·18	207	0·66	137
MS_4	0·16	250	0·17	273	0·14	244	0·47	182
MK_4	..	..	0·05	276	0·04	247	0·13	165
$2MN_6$	..	..	0·11	167	0·01	294	0·12	115
M_6	0·11	175	0·15	191	0·03	235	0·24	180
$2MS_6$	..	..	0·12	256	0·08	255	0·23	168
$2SM_6$	..	..	0·05	291	0·01	297	0·07	198
Height of local M.S.L.: above chart datum = Z_0	6·78 ft.		6·56 ft.‡		..		..	
Height of local M.S.L.: above T.P. zero = S_0	..		9·92 ft.‡		6·10 ft.‡		21·52 ft.‡	
Description of B.M. of reference.	Bench-mark on the plinth of the Light House (Tidal observatory) immediately below the door way.		G.T.S. □ B.M. embedded in a 3 feet cube of masonary about 4 inches below ground level, 39 feet 9 inches N. of NW. corner of E. store shed and 46 feet 6 inches NW. of NE. corner of same. An upright stone slab with letters G.T.S. cut on its W. face is fixed in masonary 1 foot E. of the bench-mark.		□ B.†M. inscribed on the stone of the 3rd stair from top which is north of the extreme E. end of the pier.		O B.M. cut at the NE. corner of the east godown of the port.	

* Standard port. † Standard constants (B.A. method). ‡ Corrected for seasonal variations.

TABLE 2(*b*).—*Harmonic Tidal Constants derived from 29-day analysis* (Liverpool Institute's method of analysis).

		1		2		3	
Place and position with description of Tide-pole		COCHIN* Lat. 9° 58′ N. Long. 76° 15′ E.		BEYPORE* Lat. 11° 10′ N. Long. 75° 48′ E.		BASSEIN Lat. 19° 18′ N. Long. 72° 48′ E.	
		See Technical Report 1948–49, Part III					
Central day of analysis		30–12–47		4–2–48		16–3–48	
Time Meridian		*Indian Standard Time (05h 30m fast on G.M.T.)*					
Level of zero of Tide-pole	Below chart datum	0·83 ft.		– 0·29 ft.		– 0·84 ft.	
	Below B.M. of reference	9·31 ft.		17·00 ft.		17·40 ft.	
Harmonic Constants		H. ft.	g°	H. ft.	g°	H. ft.	g°
Mm	.. ..	0·07	300	0·12	001	0·24	094
Msf	.. ..	0·16	192	0·04	214	0·10	357
Q_1	.. ..	0·06	068	0·10	061	0·16	017
O_1	.. ..	0·20	070	0·36	054	0·70	050
P_1	.. ..	0·19	063	0·27	054	0·52	059
K_1	.. ..	0·56	062	0·82	054	1·58	060
J_1	.. ..	0·02	018	0·07	071	0·09	054
$2N_2$	.. ..	0·02	285	0·04	262	0·12	304
μ_2	.. ..	0·03	130	0·02	288	0·16	324
N_2	.. ..	0·15	306	0·32	294	0·85	345
ν_2	.. ..	0·03	312	0·06	299	0·16	289
M_2	.. ..	0·68	344	0·98	331	3·94	006
L_2	.. ..	0·01	006	0·07	090	0·06	141
T_2	.. ..	0·02	066	0·02	024	0·08	043
S_2	.. ..	0·30	054	0·37	026	1·44	045
K_2	.. ..	0·08	091	0·10	030	0·89	049
$2SM_2$	.. ..	0·02	067	0·00	298	0·02	228
MO_3	.. ..	0·03	094	0·00	021	0·04	106
M_3	.. ..	0·02	100	0·00	132	0·05	057
MK_3	.. ..	0·04	155	0·03	106	0·02	293
MN_4	.. ..	0·01	001	0·03	336	0·09	283
M_4	.. ..	0·02	092	0·04	030	0·28	306
MS_4	.. ..	0·02	194	0·04	115	0·20	017
MK_4	.. ..	0·01	171	0·01	119	0·05	020
$2MN_6$	.. ..	0·01	086	0·02	076	0·02	039
M_6	.. ..	0·01	123	0·01	215	0·02	103
$2MS_6$	.. ..	0·01	059	0·01	218	0·02	058
$2SM_6$	.. ..	0·00	129	0·00	268	0·01	096
Height of local M.S.L.	Above chart datum = Z_o	2·20 ft.†		2·86 ft.†		7·5 ft.‡	
	Above T.P. zero = S_o	..		..		..	
Description of B.M. of reference.		*See Technical Report 1948–49, Part III.*					

* Standard port.
† Corrected for seasonal variations.
‡ Provisional value.

TABLE 2(*c*).—*Harmonic Tidal Constants derived from 29-day analysis* (Liverpool Institute's method of analysis).

		1		2		3	
Place and position with description of Tide-pole		CAR NICOBAR Lat. 0° 10′ N. Long. 92° 15′ E.		KHORI CREEK Lat. 22° 58′ N. Long. 70° 14′ E.		TEKRA LIGHT HOUSE Lat. 22° 57′ N. Long. 70° 07′ E.	
		Tide-pole erected at the outer end of Malacca Jetty at Car Nicobar Island		The Tide-pole was fixed near the west bank of Kandla creek, about 4½ miles S. of Kandla near the junction of Kandla and Khori creeks		The Tide-pole was fixed near the west bank of Nakti creek, N. of the junction of Nakti and Kara creeks about 1¾ miles down the creek from Tuna Bandar	
Central day of analysis		30–3–51		27–3–50		29–3–50	
Time Meridian		*B.S.T.* (*06h 30m fast on G.M.T.*)		*I.S.T.* (*05h 30m fast on G.M.T.*)			
Level of zero of Tide-pole	Below chart datum	. .		. .		. .	
	Below B.M. of reference	11·92 ft.		25·17* ft.		10·54 ft.	
Harmonic Constants		H. ft.	g°	H. ft.	g°	H. ft.	g°
Mm		0·17	003	0·19	074	0·57	111
MSf		0·03	008	0·12	042	0·32	306
Q_1		0·01	190	0·17	076	0·30	079
O_1		0·10	280	0·74	069	0·59	077
P_1		0·07	335	0·64	087	0·60	086
K_1		0·22	330	1·02	089	1·82	087
J_1		0·01	285	0·09	079	0·34	084
$2N_2$		0·04	270	0·24	041	0·27	027
μ_2		0·01	278	0·75	189	0·88	188
N_2		0·32	265	1·67	042	1·89	035
ν_2		0·06	266	0·32	044	0·37	039
M_2		1·70	273	7·50	060	7·53	061
L_2		0·03	123	0·75	042	1·08	051
T_2		0·05	314	0·12	100	0·13	007
S_2		0·69	316	2·07	101	2·20	099
K_2		0·24	320	0·56	105	0·60	102
$2SM_2$		0·04	218	0·08	344	0·19	348
MO_3		0·02	345	0·10	249	0·08	192
M_3		0·02	209	0·08	200	0·24	282
MK_3		0·07	320	0·09	008	0·11	117
MN_4		0·02	106	0·26	336	0·23	350
M_4		0·04	146	0·50	353	0·57	009
MS_4		0·04	206	0·26	041	0·29	064
MK_4		0·01	209	. .	. .	0·06	067
$2MN_6$		0·03	033	0·16	267	0·12	302
M_6		0·03	046	0·19	288	0·23	297
$2MS_6$		0·01	101	0·18	317	0·16	346
$2SM_6$		0·00	144	. .	. .	0·04	023
Height of local M.S.L.	above chart datum = Z_0	. .		. .		. .	
	above T.P. zero = S_0	3·39† ft.		12·40† ft.		9·88† ft.	
Description of B.M. of reference.		Old Malacca Jetty B.M. situated in the centre of the jetty about 30 feet from the shore. It is 280 feet from the sea-end of the demolished jetty and about 170 feet from the south end of Akhoojee Boat-shed.		Top of an iron-pipe fixed in concrete in mud, N. of fishermen's huts on the W. bank of Kandla creek, about 4½ miles S. of Kandla near the point where the creek meets the gulf.		Top of the iron-pipe fixed in the centre of the concrete platform 8 feet square and ½ foot high in mud on W. bank of Nakti creek and on E. bank of Kara creek about 1¾ miles down the creek from Tuna Bandar. The mark is about ½ furlong from the water-front of Nakti creek and 3 furlongs from the water-front of Kara creek.	

* Provisional value.

† Corrected for seasonal variations.

TABLE 3.—*Harmonic Tidal Constants derived from 2 years' analysis* (Liverpool Institute's method of analysis).

Place : KANDLA

Latitude	Longitude	Standard time	Observational data	
			Length	Central days
23° 02′	70° 14′	I.S.T.	Two years	1-3-50 and 25-1-51

Position of tide-pole : Tide-pole situated at Kandla Timber Jetty.
Description of B.M. of reference :—

B.M. ⊡ + 26·99 cut on S. parapet of cargo-jetty. The mark is 13 yards E. of the point where jetty meets the ground of the bank.

Level of zero of Tide-pole { above chart datum (or zero of prediction) ·013 ft. ; below B.M. of reference 26·977 ft.

	H. ft.	g°		H. ft.	g°		H. ft.	g°		H. ft.	g°
Z_0*	12·497		$2Q_1$	0·028	266	OQ_2	0·062	344	MO_3†	0·146	266
Sa†	0·130	082	σ_1	0·058	129	MNS_2	0·216	170	M_3	0·078	209
Ssa†	0·074	149	Q_1†	0·170	077	$2N_2$†	0·336	321	SO_3	0·134	172
Mm	0·096	000	ρ_1	0·044	088	μ_2†	0·508	190	MK_3†	0·087	343
MSf	0·100	048	O_1†	0·726	079	N_2†	1·532	043	SK_3	0·098	071
Mf	0·100	012	MP_1	0·154	147	ν_2†	0·522	045			
			M_1	0·067	135	OP_2	0·117	192	MN_4†	0·240	342
			χ_1	0·034	078	M_2†	7·744	065	M_4†	0·508	004
			π_1	0·058	077	MKS_2	0·066	279	SN_4	0·064	046
			P_1†	0·424	080	λ_2	0·280	077	MS_4†	0·270	050
			S_1†	0·074	111	L_2†	0·532	074	MK_4	0·082	047
			K_1†	1·686	090	T_2†	0·082	067	S_4	0·050	088
			ψ_1	0·027	218	S_2†	2·146	111	SK_4	0·028	184
			ϕ_1	0·042	210	R_2	0·048	145			
			θ_1	0·016	089	K_2†	0·582	108	$2MN_6$	0·166	273
			J_1†	0·073	141	MSN_2	0·144	300	M_6†	0·230	261
			SO_1	0·094	252	KJ_2	0·026	118	MSN_6	0·056	330
			OO_1	0·072	161	$2SM_2$†	0·108	325	$2MS_6$	0·228	338
									$2MK_6$	0·070	330
									$2SM_6$	0·044	025
									MSK_6	0·022	124

* Local M.S.L. above chart datum.
† Components of the Indian Tide-machine.

TABLE 4.—*Harmonic Tidal Constants derived from 1-year analysis* (Liverpool Institute's method of analysis).

		1		2	
Place and position with description of Tide-pole		PARADIP LOCK Lat. 20° 20′ N. Long. 86° 37′ E.		BATIGHAR CREEK Lat. 20° 19′ N. Long. 86° 44 E.	
		Tide-pole at Paradip Lock		Tide-pole at Batighar Creek	
Central day of analysis		28–9–50		14–10–50	
Time Meridian		*Indian Standard Time (05h 30m fast on G.M.T.)*			
Level of zero of Tide-pole	Below chart datum	..		..	
	Below B.M. of reference	18·11 ft.		20·34 ft.	
Harmonic Constants		H. ft.	g°	H. ft.	g°
M_2		1·706	290	1·751	267
S_2		0·666	336	0·749	306
K_1		0·331	002	0·368	349
O_1		0·175	342	0·158	334
Height of local M.W.L. above T.P. zero = S_0 (For dry months only)		3·803 ft.		5·493 ft.	
Indian Spring Low Water Mark above T.P. zero		0·924 ft.		2·467 ft.	
Description of B.M. of reference.		G.T.S. B.M. 370 (44) outside S.E. wall surrounding False-point Light House 3 feet E. of eastern gate.			

TABLE 5(*a*).—*Harmonic Tidal Constants derived from 5 years' annual analysis* (B.A. method of analysis).

Place: ELEPHANT POINT (Pilakāt creek)

Latitude	Longitude	Standard time	Observational data	
			Length	Years
16° 30′ N.	96° 18′ E.	B.S.T.	5 years	1884 to 1888

Notes :—

(1) Description of the tide-gauge site :
On the right bank of Pilakāt creek, about 340 yards from its junction with the Rangoon river.

(2) B.M. of reference :
A flat concrete pillar (1947) in a fenced enclosure at the NE. end of Elephant Point village, close to the fore-shore.

(3) Height of chart datum { (*a*) below B.M. of reference 26·02 ft. ; (*b*) above zero of tide-gauge 0·00 ft. }

	H. ft.	g°		H. ft.	g°		H. ft.	g°		H. ft.	g°
S_0*	12·01		$2Q_1$			OQ_2			MO_3	0·064	343
Z_0†	12·01		σ_1			MNS_2			M_3		
			Q_1	0·026	342	$2N_2$	0·178	048	SO_3		
Sa	0·842	140	ρ_1			μ_2	0·358	281	MK_3	0·092	024
Ssa	0·129	150	O_1	0·323	000	N_2	1·111	030	SK_3		
Mm			MP_1			ν_2	0·269	038			
MSf			M_1			OP_2			MN_4	0·191	054
Mf			χ_1			M_2	5·902	099	M_4	0·281	080
			π_1			MKS_2			SN_4		
			P_1	0·193	031	λ_2			MS_4	0·291	125
			S_1	0·006	115	L_2	0·395	·126	MK_4		
			K_1	0·746	020	T_2	0·230	141	S_4		
			ψ_1			S_2	2·381	142	SK_4		
			ϕ_1			R_2					
			θ_1			K_2	0·752	140	$2MN_6$		
			J_1	0·030	092	MSN_2			M_6		
			SO_1			KJ_2			MSN_6		
			OO_1			$2SM_2$	0·136	047	$2MS_6$		
									$2MK_6$		
									$2SM_6$		
									MSK_6		

* S_0 = Height of mean-sea-level above zero of tide-gauge.
† Z_0 = " " " chart datum.

TABLE 5(*b*).—*Harmonic Shallow Water Correction Constants* (1st approximation).

Place: ELEPHANT POINT. *Based on*: Elephant Point basic machine* predictions.

Central day of analysis: 1st July 1930. *Derived from*: (A — P)s of 1930.

Constituent	H.W. heights		H.W. times		L.W. heights		L.W. times	
	R	χ	R	χ	R	χ	R	χ
	ft.	°	*min.*	°	*ft.*	°	*min.*	°
C (00)	+0·895	..	−17·00	..	−0·892	..	+7·43	..
(01)	0·121	153	5·08	216	0·051	319	7·15	240
(02)	0·035	292	1·74	267	0·103	041	0·71	243
(11)	0·165	195	7·84	145	0·189	010	3·68	116
(13)	0·236	005	2·22	130	0·049	107	4·44	352
(25)	0·595	025	2·16	002	0·397	207	16·97	029
(27)	0·133	012	6·87	247	0·262	345	7·14	356
(36)	0·047	120	4·00	332	0·016	072	1·04	334
(38)	0·112	190	0·87	349	0·312	012	1·72	308
(50)	0·013	251	2·28	118	0·131	035	0·99	058
(52)	0·041	212	2·69	146	0·204	066	2·28	189
C′ (00)	−0·007	..	+ 0·38	..	+0·003	..	−1·18	..
(11)	0·178	046	1·79	233	0·136	110	3·94	086
(12)	0·022	343	1·60	340	0·009	080	1·66	286
(13)	0·159	110	1·92	355	0·177	144	3·51	330
(27)	0·070	221	0·23	028	0·015	087	1·92	255
(36)	0·024	230	0·05	003	0·053	126	1·86	316
(38)	0·087	009	0·76	315	0·202	311	2·21	340
(40)	0·068	290	1·23	264	0·076	226	0·98	274

* Indian Tide-machine.

TABLE 5(*c*).—*Corrections to be applied to Elephant Point basic predictions to obtain primary predictions for Rangoon.*

	Date	RANGOON H.W.	RANGOON L.W.	Date	RANGOON H.W.	RANGOON L.W.
		ft.	*ft.*		*ft.*	*ft.*
Height corrections.	Jan. 1st to 5th	– 2·6	– 2·2	July 1st to 5th	– 1·9	– 1·4
	6th to 10th	– 2·5	– 2·1	6th to 10th	– 1·8	– 1·2
	11th to 15th	– 2·4	– 2·1	11th to 15th	– 1·7	– 1·1
	16th to 20th	– 2·4	– 2·0	16th to 20th	– 1·7	– 1·0
	21st to 25th	– 2·3	– 1·9	21st to 25th	– 1·7	– 0·9
	26th to 31st	– 2·3	– 1·8	26th to 31st	– 1·6	– 0·8
	Feb. 1st to 5th	– 2·3	– 1·8	Aug. 1st to 5th	– 1·7	– 0·7
	6th to 10th	– 2·3	– 1·7	6th to 10th	– 1·7	– 0·7
	11th to 15th	– 2·3	– 1·7	11th to 15th	– 1·7	– 0·6
	16th to 20th	– 2·3	– 1·6	16th to 20th	– 1·8	– 0·6
	21st to 25th	– 2·4	– 1·6	21st to 25th	– 1·8	– 0·6
	26th to 29th	– 2·4	– 1·6	26th to 31st	– 1·9	– 0·6
	March 1st to 5th	– 2·4	– 1·6	Sept. 1st to 5th	– 1·9	– 0·7
	6th to 10th	– 2·4	– 1·6	6th to 10th	– 2·0	– 0·7
	11th to 15th	– 2·5	– 1·5	11th to 15th	– 2·0	– 0·8
	16th to 20th	– 2·5	– 1·5	16th to 20th	– 2·1	– 0·8
	21st to 25th	– 2·5	– 1·5	21st to 25th	– 2·1	– 0·9
	26th to 31st	– 2·6	– 1·5	26th to 30th	– 2·2	– 1·0
	April 1st to 5th	– 2·6	– 1·5	Oct. 1st to 5th	– 2·2	– 1·1
	6th to 10th	– 2·6	– 1·6	6th to 10th	– 2·2	– 1·2
	11th to 15th	– 2·6	– 1·6	11th to 15th	– 2·3	– 1·3
	16th to 20th	– 2·6	– 1·7	16th to 20th	– 2·3	– 1·4
	21st to 25th	– 2·6	– 1·7	21st to 25th	– 2·4	– 1·5
	26th to 30th	– 2·6	– 1·8	26th to 31st	– 2·4	– 1·6
	May 1st to 5th	– 2·6	– 1·9	Nov. 1st to 5th	– 2·4	– 1·7
	6th to 10th	– 2·5	– 1·9	6th to 10th	– 2·4	– 1·8
	11th to 15th	– 2·5	– 1·9	11th to 15th	– 2·5	– 1·9
	16th to 20th	– 2·4	– 2·0	16th to 20th	– 2·5	– 2·0
	21st to 25th	– 2·4	– 2·0	21st to 25th	– 2·5	– 2·1
	26th to 31st	– 2·4	– 2·0	26th to 30th	– 2·5	– 2·2
	June 1st to 5th	– 2·3	– 1·9	Dec. 1st to 5th	– 2·5	– 2·3
	6th to 10th	– 2·2	– 1·9	6th to 10th	– 2·6	– 2·4
	11th to 15th	– 2·2	– 1·8	11th to 15th	– 2·6	– 2·5
	16th to 20th	– 2·1	– 1·7	16th to 20th	– 2·6	– 2·5
	21st to 25th	– 2·0	– 1·6	21st to 25th	– 2·7	– 2·7
	26th to 30th	– 2·0	– 1·5	26th to 31st	– 2·7	– 2·8
Time corrections	All times	H.W. Add 1 hr. 10 min.		. .	L.W. Add 1 hr. 30 min.	

TABLE 5(*d*).—*Harmonic Shallow Water Correction Constants* (1st approximation).

Place: RANGOON. *Based on*: Elephant Point basic machine* predictions.

Central day of analysis: 1st July 1930. *Derived from*: (A — P)s of 1930.

Constituent	H.W. heights		H.W. times		L.W. heights		L.W. times	
	R	χ	R	χ	R	χ	R	χ
	ft.	°	*min.*	°	*ft.*	°	*min.*	°
C (00)	+0·811	..	−17·43	..	−0·935	..	+6·26	..
(01)	0·094	155	10·00	335	0·149	283	3·98	323
(02)	0·036	359	1·96	052	0·174	014	4·71	350
(11)	0·160	196	6·56	154	0·150	008	2·90	129
(13)	0·134	352	1·33	020	0·347	021	6·80	350
(25)	0·223	005	7·28	038	0·795	047	23·65	038
(27)	0·064	310	5·62	234	0·584	018	6·58	011
(36)	0·053	136	4·12	335	0·022	069	0·86	048
(38)	0·174	211	0·06	195	0·443	031	0·97	176
(50)	0·029	276	2·12	175	0·063	341	2·17	261
(52)	0·046	218	1·47	216	0·095	060	3·60	230
C′ (00)	−0·007	..	+ 0·44	..	−0·003	..	−0·74	..
(11)	0·144	037	0·24	180	0·244	105	3·73	097
(12)	0·018	342	2·14	014	0·017	104	2·79	270
(13)	0·200	107	0·84	086	0·156	265	7·50	295
(27)	0·042	223	0·33	202	0·024	001	1·74	275
(36)	0·040	265	0·48	176	0·017	130	2·39	295
(38)	0·074	019	1·53	351	0·221	314	1·93	034
(40)	0·050	291	0·41	325	0·061	241	1·36	320

* Indian Tide-machine.

TABLE 6(*a*).—*Harmonic Tidal Constants derived from 6 years' annual analysis* (B.A. method of analysis).

Place: AMHERST

Latitude	Longitude	Standard time	Observational data	
			Length	Years
16° 05′ N.	97° 34′ E.	B.S.T.	6 years	1880 to 1886

Notes :—

(1) Description of the tide-gauge site.

At the mouth of Moulmein River about 20 feet north of the Water Pagoda.

(2) B.M. of reference : G.T.S. B.M. A.D. 1912 (height 24·645 feet above Amherst M.S.L.) at the P.W.D. Inspection Bungalow.

(3) Height of chart datum { (*a*) below B.M. of reference 34·71 ft. ; (*b*) above zero of tide-gauge 3·59 ft. }

	H. ft.	g°		H. ft.	g°		H. ft.	g°		H. ft.	g°
S_o*	13·654		$2Q_1$			OQ_2			MO_3	0·051	301
Z_o†	10·06		σ_1			MNS_2			M_3		
			Q_1	0·039	332	$2N_2$	0·245	020	SO_3		
Sa	0·758	130	ρ_1			μ_2	0·285	285	MK_3	0·091	328
Ssa	0·149	112	O_1	0·323	336	N_2	1·281	042	SK_3		
Mm			MP_1			ν_2	0·339	040			
MSf			M_1			OP_2			MN_4	0·214	193
Mf			χ_1			M_2	6·320	060	M_4	0·321	030
			π_1			MKS_2			SN_4		
			P_1	0·191	352	λ_2			MS_4	0·318	068
			S_1	0·176	133	L_2	0·321	004	MK_4		
			K_1	0·709	004	T_2	0·422	169	S_4		
			ψ_1			S_2	2·708	102	SK_4		
			ϕ_1			R_2					
			θ_1			K_2	0·987	006	$2MN_6$		
			J_1	0·053	045	MSN_2			M_6		
			SO_1			KJ_2			MSN_6		
			OO_1			$2SM_2$	0·164	010	$2MS_6$		
									$2MK_6$		
									$2SM_6$		
									MSK_6		

* S_o = Height of mean-sea-level above zero of tide-gauge.

† Z_o = „ „ „ chart datum.

TABLE 6(*b*).—*Harmonic Shallow Water Correction Constants* (1st approximation).

Place: AMHERST. *Based on*: Amherst basic machine* predictions.
Central day of analysis: 2nd July 1883. *Derived from*: (A — P)s of 1883.

Constituent	H.W. heights		H.W. times		L.W. heights		L.W. times	
	R	χ	R	χ	R	χ	R	χ
	ft.	°	*min.*	°	*ft.*	°	*min.*	°
C (00)	+0·440	..	+ 7·56	..	−0·280	..	+11·40	..
(01)	0·039	173	4·07	264	0·283	241	4·80	335
(02)	0·088	245	2·19	002	0·085	183	2·60	002
(11)	0·195	241	2·05	005	0·292	049	2·04	205
(13)	0·330	094	7·06	193	0·448	085	9·95	018
(25)	0·063	217	4·92	062	0·267	205	7·27	074
(27)	0·180	242	3·29	094	0·208	358	3·00	013
(36)	0·067	041	2·32	332	0·081	286	2·24	052
(38)	0·217	106	6·54	229	0·212	082	0·70	181
(50)	0·099	333	2·93	269	0·120	003	4·62	058
(52)	0·073	278	3·89	207	0·165	076	3·01	303
C′ (00)	−0·005	..	− 0·54	..	+0·019	..	−0·65	..
(11)	0·116	067	1·56	197	0·121	107	1·74	128
(12)	0·051	145	0·67	129	0·066	030	1·16	157
(13)	0·036	204	2·32	330	0·044	116	3·08	073
(27)	0·055	147	0·17	079	0·033	011	1·18	041
(36)	0·071	245	0·90	120	0·034	073	0·88	069
(38)	0·024	316	0·36	302	0·146	279	1·37	002
(40)	0·029	272	0·88	257	0·016	319	0·52	129

* Indian Tide-machine.

TABLE 6(*c*).—*Corrections to be applied to Amherst basic predictions to obtain primary predictions for Moulmein.*

	Date	MOULMEIN				
		H.W.	L.W.	Date	H.W.	L.W.
		ft.	*ft.*		*ft.*	*ft.*
Height corrections.	Jan. 1st to 5th	− 6·5	− 2·6	July 1st to 5th	− 5·6	− 0·5
	6th to 10th	− 6·6	− 2·6	6th to 10th	− 5·6	− 0·2
	11th to 15th	− 6·6	− 2·6	11th to 15th	− 5·5	+ 0·1
	16th to 20th	− 6·7	− 2·6	16th to 20th	− 5·4	+ 0·4
	21st to 25th	− 6·7	− 2·6	21st to 25th	− 5·4	+ 0·8
	26th to 31st	− 6·8	− 2·6	26th to 31st	− 5·3	+ 1·1
	Feb. 1st to 5th	− 6·8	− 2·6	Aug. 1st to 5th	− 5·3	+ 1·5
	6th to 10th	− 6·8	− 2·6	6th to 10th	− 5·2	+ 2·0
	11th to 15th	− 6·9	− 2·5	11th to 15th	− 5·2	+ 2·4
	16th to 20th	− 6·9	− 2·5	16th to 20th	− 5·2	+ 2·5
	21st to 25th	− 6·9	− 2·5	21st to 25th	− 5·2	+ 2·6
	26th to 29th	− 6·9	− 2·4	26th to 31st	− 5·2	+ 2·6
	March 1st to 5th	− 7·0	− 2·3	Sept. 1st to 5th	− 5·3	+ 2·5
	6th to 10th	− 7·0	− 2·3	6th to 10th	− 5·3	+ 2·3
	11th to 15th	− 7·0	− 2·2	11th to 15th	− 5·4	+ 2·2
	16th to 20th	− 7·0	− 2·2	16th to 20th	− 5·4	+ 2·0
	21st to 25th	− 7·0	− 2·2	21st to 25th	− 5·5	+ 1·7
	26th to 31st	− 6·9	− 2·2	26th to 30th	− 5·6	+ 1·2
	April 1st to 5th	− 6·9	− 2·3	Oct. 1st to 5th	− 5·7	+ 0·8
	6th to 10th	− 6·9	− 2·4	6th to 10th	− 5·8	0·0
	11th to 15th	− 6·8	− 2·4	11th to 15th	− 5·9	− 0·5
	16th to 20th	− 6·8	− 2·5	16th to 20th	− 6·0	− 1·0
	21st to 25th	− 6·7	− 2·5	21st to 25th	− 6·0	− 1·2
	26th to 30th	− 6·7	− 2·5	26th to 31st	− 6·1	− 1·5
	May 1st to 5th	− 6·6	− 2·4	Nov. 1st to 5th	− 6·2	− 1·7
	6th to 10th	− 6·6	− 2·4	6th to 10th	− 6·3	− 1·8
	11th to 15th	− 6·5	− 2·3	11th to 15th	− 6·3	− 1·9
	16th to 20th	− 6·4	− 2·2	16th to 20th	− 6·4	− 2·0
	21st to 25th	− 6·3	− 2·1	21st to 25th	− 6·4	− 2·2
	26th to 31st	− 6·2	− 2·0	26th to 30th	− 6·5	− 2·3
	June 1st to 5th	− 6·1	− 1·9	Dec. 1st to 5th	− 6·5	− 2·4
	6th to 10th	− 6·0	− 1·7	6th to 10th	− 6·6	− 2·5
	11th to 15th	− 6·0	− 1·5	11th to 15th	− 6·6	− 2·6
	16th to 20th	− 5·9	− 1·4	16th to 20th	− 6·7	− 2·7
	21st to 25th	− 5·8	− 1·1	21st to 25th	− 6·7	− 2·7
	26th to 30th	− 5·7	− 0·8	26th to 31st	− 6·7	− 2·8
Time corrections	All times	H.W. Add 1 hr. 10 min.		..	L.W. Add 3 hrs. 00 min.	

TABLE 6(*d*).—*Harmonic Shallow Water Correction Constants* (1st approximation).

Place: MOULMEIN. *Based on*: Amherst basic machine* predictions.
Central day of analysis: 1st July 1883. *Derived from*: (A—P)s of 1883.

Constituent	H.W. heights		H.W. times		L.W. heights		L.W. times	
	R	χ	R	χ	R	χ	R	χ
	ft.	°	*min.*	°	*ft.*	°	*min.*	°
C (00)	+0·360	..	+5·35	..	−0·016	..	+10·68	..
(01)	0·107	197	10·38	329	0·405	180	2·61	333
(02)	0·078	270	6·30	101	0·288	278	4·92	350
(11)	0·269	238	4·60	042	0·072	240	7·37	196
(13)	0·353	108	6·32	203	1·135	032	12·75	018
(25)	0·158	173	7·93	023	2·848	043	16·04	051
(27)	0·232	240	2·85	081	0·932	021	5·92	025
(36)	0·037	090	1·34	237	0·138	028	2·95	086
(38)	0·217	108	3·53	227	0·515	062	1·16	036
(50)	0·159	301	1·31	244	0·396	271	2·70	295
(52)	0·164	288	2·11	310	0·114	200	6·05	264
C′ (00)	−0·009	..	−0·79	..	−0·001	..	−0·53	..
(11)	0·005	043	2·45	179	0·287	103	1·13	172
(12)	0·051	165	2·10	102	0·159	019	1·41	035
(13)	0·086	092	1·92	338	0·540	292	4·94	291
(27)	0·045	103	1·01	042	0·060	325	0·34	037
(36)	0·052	271	0·92	087	0·046	324	1·17	354
(38)	0·028	220	1·42	293	0·081	234	1·70	118
(40)	0·035	275	0·48	268	0·034	133	0·30	227

* Indian Tide-machine.

TABLE 7.—*Corrections applied to the predicted times and heights at Bhāvnagar for 1954.*

Month		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
H.W.	Time min.	−10											
	Height ft.	+0·4	+0·4	+0·6	+0·6	+0·4	+0·4	+0·4	+1·0	+0·8	+0·6	+0·4	+0·2
L.W.	Time min.	+50										+40	
	Height ft.	See Table below											

Predicted height in feet	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
	Corrections to predicted heights of Low Water ft.									
0	5·9	5·8	5·8	5·7	5·6	5·6	5·5	5·4	5·4	5·3
1	5·2	5·1	5·0	5·0	4·9	4·8	4·7	4·6	4·5	4·5
2	4·4	4·3	4·2	4·1	4·1	4·0	3·9	3·8	3·8	3·7
3	3·6	3·5	3·5	3·4	3·3	3·3	3·2	3·1	3·0	3·0
4	2·9	2·8	2·7	2·6	2·6	2·5	2·4	2·4	2·3	2·2
5	2·2	2·1	2·0	2·0	1·9	1·9	1·8	1·7	1·7	1·6
6	1·5	1·5	1·4	1·4	1·3	1·3	1·2	1·2	1·1	1·1
7	1·0	1·0	0·9	0·9	0·9	0·8	0·8	0·8	0·7	0·7
8	0·7	0·6	0·6	0·5	0·5	0·5	0·5	0·4	0·4	0·4
9	0·3	0·3	0·3	0·3	0·3	0·2	0·2	0·2	0·2	0·1
10	0·1	0·1	0·1	0·1	0·1	0·1	0·0	0·0	0·0	0·0
11	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
12	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	−0·1	−0·1
13	−0·1	−0·1	−0·1	−0·1	−0·1	−0·1	−0·1	−0·1	−0·1	−0·1
14	−0·1	−0·1	−0·1	−0·1	−0·1	−0·1	0·0	0·0	0·0	0·0
15 and above	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0

The corrections have been based on (P — A) differences of the years 1946–50.

TABLE 8.—*Corrections applied to the predicted times and heights at Vizagapatam for 1954.*

Month	H.W. Time min.	H.W. Height ft.	L.W. Time min.	L.W. Height ft.
January ..	—20	+0·2	—20	0·0
February ..		+0·4		+0·2
March ..		+0·3		+0·2
April ..		+0·2		0·0
May ..		+0·2		—0·2
June ..		+0·2		—0·1
July ..		+0·1		—0·2
August ..		0·0		—0·2
September ..		0·0		—0·2
October ..		+0·2		—0·1
November ..		+0·2		0·0
December ..		0·0		0·0

The corrections have been based on (P—A) differences of the years 1946–50.

TABLE 9.—*Corrections applied to the predicted times and heights at Aden for 1954.*

Month	H.W. Time min.	H.W. Height ft.	L.W. Time min.	L.W. Height ft.
January .. to December ..	Nil	+ 0·2	Nil	+ 0·2

The corrections have been based on (P—A) differences of the years 1947–51.

TABLE 10.—*Mean errors E_1* and E_2* for 1951.*

ADEN

PERIOD 1051	MEAN ERRORS (Predicted – Actual)												Number of errors exceeding			
	E₁								E₂				30 *minutes* in time		0·5† *feet* in height	
	H.W. Time		H.W. Height		L.W. Time		L.W. Height		H.W. Time	H.W. Ht.	L.W. Time	L.W. Ht.	H.W.	L.W.	H.W.	L.W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	–	+	–	+	–	+	–								
Jan. 1–15	3·0			0·1		0·0		0·2	8·0	0·3	6·0	0·2	0	0	0	0
16–31		9·0		0·2		0·0		0·2	13·0	0·2	12·0	0·2	0	0	0	0
Feb. 1–15		7·0		0·0		0·0		0·1	12·0	0·2	11·0	0·2	0	0	1	0
16–28		0·0		0·1	3·0			0·0	12·0	0·1	10·0	0·1	1	0	0	0
Mar. 1–15	7·0			0·1	11·0			0·2	12·0	0·2	15·0	0·2	1	4	0	1
16–31		0·0		0·2	4·0			0·1	11·0	0·3	12·0	0·2	0	0	1	1
April 1–15	3·0			0·3	3·0			0·2	10·0	0·3	16·0	0·3	0	3	0	0
16–30	4·0			0·2	7·0			0·1	12·0	0·2	12·0	0·2	3	1	0	0
May 1–15	14·0			0·2	6·0			0·1	19·0	0·2	14·0	0·2	6	2	0	0
16–31	3·0			0·3	8·0			0·2	14·0	0·3	12·0	0·2	0	2	0	0
June 1–15	11·0			0·2	6·0			0·1	16·0	0·3	14·0	0·2	4	2	0	0
16–30	5·0			0·3	7·0			0·3	15·0	0·3	12·0	0·3	3	0	0	0
July 1–15	1·0			0·3	0·0			0·3	16·0	0·3	13·0	0·3	2	0	0	0
16–31		6·0		0·1	0·0			0·1	19·0	0·3	18·0	0·2	6	4	1	0
Aug. 1–15		12·0	0·0			4·0		0·0	14·0	0·1	11·0	0·1	0	3	0	0
16–31		5·0		0·4	4·0			0·4	27·0	0·4	20·0	0·5	14	4	3	5
Sept. 1–15		4·0		0·3	7·0			0·3	14·0	0·3	15·0	0·3	3	3	0	0
16–30		1·0		0·3	0·0			0·3	15·0	0·3	20·0	0·3	4	5	0	0
Oct. 1–15	1·0			0·2	2·0			0·1	10·0	0·3	13·0	0·2	1	2	0	0
16–31	4·0			0·1		0·0		0·2	14·0	0·2	11·0	0·2	3	1	0	0
Nov. 1–15		1·0		0·3	3·0			0·2	12·0	0·3	13·0	0·2	2	2	0	0
16–30	13·0			0·3		2·0		0·3	18·0	0·3	15·0	0·3	5	3	0	0
Dec. 1–15	14·0			0·2		3·0		0·2	17·0	0·2	12·0	0·2	6	3	0	0
16–31	16·0			0·1	2·0			0·2	21·0	0·2	10·0	0·2	5	0	0	0
TOTALS ..	99·0	45·0	0·0	4·8	73·0	9·0	–	4·4	351·0	6·1	317·0	5·5	69	44	6	7
MEANS ..	+	2·0	–	0·2	+	3·0	–	0·2	15·0	0·3	13·0	0·2				

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

TABLE 11.—*Mean errors E_1* and E_2* for 1951.*

BHĀVNAGAR

PERIOD 1951	MEAN ERRORS (Predicted – Actual†) E₁ H.W. Time minutes +	E₁ H.W. Time minutes –	E₁ H.W. Height feet +	E₁ H.W. Height feet –	E₁ L.W. Time minutes +	E₁ L.W. Time minutes –	E₁ L.W. Height feet +	E₁ L.W. Height feet –	E₂ H.W. Time minutes	E₂ H.W. Ht. feet	E₂ L.W. Time minutes	E₂ L.W. Ht. feet	Number of errors exceeding 30 minutes in time H.W.	30 minutes in time L.W.	1·0‡ feet in height H.W.	1·0‡ feet in height L.W.
Jan. 1–15		2·0	0·2			2·0		0·5	3·0	0·5	3·0	0·9	0	0	3	6
16–31		0·0	0·6			1·0		0·0	4·0	0·7	3·0	0·6	0	0	3	4
Feb. 1–15		1·0	0·3		0·0			0·2	4·0	0·3	2·0	0·9	0	0	1	7
16–28		2·0	0·2			2·0		0·1	4·0	0·2	3·0	0·5	0	0	0	1
Mar. 1–15	1·0			0·1	3·0		0·1	0·3	4·0	0·2	6·0	0·3	0	1	0	0
16–31		4·0		0·3	2·0			0·3	4·0	0·4	4·0	0·4	0	0	0	0
April 1–15		0·0	0·4		3·0				4·0	0·6	4·0	0·4	0	0	1	0
16–30		6·0		0·0		16·0	0·6		8·0	0·3	20·0	0·7	0	5	0	2
May 1–15		0·0	0·3			3·0	1·0		6·0	0·4	21·0	1·2	0	2	0	8
16–31		2·0	0·1			6·0	0·9		8·0	0·4	9·0	0·9	0	0	0	7
June 1–15		2·0	0·0			2·0		0·3	3·0	0·1	3·0	0·3	0	0	0	1
16–30		3·0	0·0			2·0		0·3	3·0	0·3	3·0	0·3	0	0	0	0
July 1–15		1·0	0·0			1·0		0·1	2·0	0·0	3·0	0·1	0	0	0	0
16–31		1·0	0·1			1·0		0·5	3·0	0·1	3·0	0·5	0	0	0	1
Aug. 1–15	1·0		0·5			5·0		0·2	2·0	0·5	7·0	0·4	0	0	1	1
16–31		0·0	0·6			3·0		0·3	1·0	0·6	8·0	0·3	0	1	2	1
Sept. 1–15	1·0		0·4			17·0	0·1		3·0	0·4	18·0	0·2	0	4	0	0
16–30	0·0		0·8		10·0		0·5		5·0	0·3	21·0	0·7	0	5	3	4
Oct. 1–15	4·0		0·5		1·0		0·7		10·0	0·5	10·0	0·8	0	0	1	6
16–31		1·0	0·8		12·0		0·6		6·0	1·0	15·0	0·6	0	1	5	2
Nov. 1–15	0·0			0·1		5·0	0·0		7·0	0·4	11·0	0·1	0	0	2	0
16–30		2·0	0·4			22·0	0·0		5·0	0·4	23·0	0·2	0	7	1	0
Dec. 1–15	1·0		0·1			10·0	0·0		8·0	0·4	16·0	0·1	0	5	1	0
16–31	2·0		0·3		2·0		0·0		5·0	0·3	19·0	0·2	0	5	1	0
TOTALS ..	10·0	27·0	6·6	0·5	33·0	98·0	4·5	3·1	111·0	9·8	235·0	11·6	0	36	25	51
MEANS ..	–	1·0	+	0·3	–	3·0	+	0·1	5·0	0·4	10·0	0·5				

* E_1 is with regard to sign : E_2 is without regard to sign.
† Actual values are tide-pole readings during daylight only.
‡ One-tenth of the mean range of the spring-tides is 3·1 feet.

TABLE 12.—*Mean errors E_1* and E_2* for 1951.*

BOMBAY (APOLLO BANDAR)

PERIOD 1951	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		15·0		0·1		15·0		0·1	20·0	0·2	17·0	0·3	6	4	0	0
16–31		10·0	0·1			13·0	0·3		17·0	0·3	16·0	0·3	1	2	0	0
Feb. 1–15		2·0		0·0	1·0		0·2		7·0	0·2	13·0	0·3	0	3	0	0
16–28		6·0		0·2		3·0	0·1		9·0	0·2	10·0	0·3	0	1	0	0
Mar. 1–15		0·0		0·3	6·0			0·1	6·0	0·4	11·0	0·3	0	1	0	0
16–31		2·0		0·4		1·0		0·2	8·0	0·5	11·0	0·3	1	1	0	0
April 1–15		8·0		0·3		6·0	0·1		13·0	0·4	13·0	0·4	1	2	0	0
16–30		9·0		0·2	3·0			0·2	13·0	0·5	9·0	0·4	1	0	0	0
May 1–15		11·0		0·1		1·0	0·2		13·0	0·2	12·0	0·3	0	1	0	0
16–31		4·0		0·0		5·0		0·1	11·0	0·2	12·0	0·3	0	2	0	0
June 1–15		7·0	0·1			7·0	0·1		10·0	0·3	10·0	0·2	0	1	0	0
16–30		1·0	0·2			2·0		0·1	9·0	0·3	10·0	0·2	0	0	2	0
July 1–15	1·0		0·0		7·0		0·2		13·0	0·3	12·0	0·2	0	2	0	0
16–31		13·0	0·0			7·0		0·2	16·0	0·4	13·0	0·3	4	1	0	0
Aug. 1–15		6·0	0·1			2·0	0·0		11·0	0·5	11·0	0·2	0	0	0	0
16–31		14·0	0·3			0·0	0·2		17·0	0·3	12·0	0·3	5	4	0	0
Sept. 1–15		5·0	0·1			1·0	0·1		10·0	0·2	7·0	0·3	0	0	0	0
16–30		10·0	0·2			4·0	0·2		13·0	0·2	15·0	0·4	0	4	0	0
Oct. 1–15		1·0	0·2		2·0		0·2		7·0	0·3	9·0	0·3	0	0	0	0
16–31		8·0	0·1			4·0	0·1		9·0	0·3	11·0	0·3	0	2	0	0
Nov. 1–15		4·0	0·1			3·0	0·0		7·0	0·4	8·0	0·3	0	0	0	0
16–30		8·0	0·0			6·0	0·0		10·0	0·2	9·0	0·3	0	1	0	0
Dec. 1–15		10·0	0·3			8·0	0·2		11·0	0·4	9·0	0·3	0	1	0	0
16–31		18·0	0·0			24·0	0·1		18·0	0·3	24·0	0·2	3	9	0	0
TOTALS ..	1·0	172·0	1·8	1·6	19·0	121·0	2·3	1·0	278·0	7·5	284·0	7·0	22	42	2	—
MEANS ..	– 7·0		+ 0·0		– 4·0		+ 0·1		12·0	0·3	12·0	0·3				

* E_1 is with regard to sign : E_2 is without regard to sign.
† One-tenth of the mean range of the spring-tides is 1·2 feet.

TABLE 13.—*Mean errors E_1* and E_2* for 1951.*

VIZAGAPATAM

PERIOD 1951	MEAN ERRORS (Predicted – Actual)												Number of errors exceeding			
	E_1								E_2				30 minutes in time		0·5† feet in height	
	H.W. Time (minutes)		H.W. Height (feet)		L.W. Time (minutes)		L.W. Height (feet)		H.W. Time (minutes)	H.W. Ht. (feet)	L.W. Time (minutes)	L.W. Ht. (feet)	H.W.	L.W.	H.W.	L.W.
	+	−	+	−	+	−	+	−								
Jan. 1–15		1·0	0·0		6·0		0·1		5·0	0·2	8·0	0·1	0	0	0	0
16–31	2·0		0·1		2·0			0·1	2·0	0·2	3·0	0·1	0	0	0	0
Feb. 1–15	0·0		0·1		2·0			0·0	2·0	0·1	3·0	0·1	0	0	0	0
16–28	1·0			0·0	0·0			0·1	1·0	0·1	0·0	0·1	0	0	0	0
Mar. 1–15	3·0			0·3	4·0			0·2	5·0	0·3	4·0	0·2	0	0	0	0
16–31	1·0			0·1	1·0			0·0	9·0	0·1	6·0	0·1	2	1	0	0
April 1–15		1·0	0·1		2·0		0·1		5·0	0·2	2·0	0·1	0	1	0	0
16–30		3·0	0·3		1·0		0·3		4·0	0·3	3·0	0·3	1	1	5	5
May 1–15	3·0		0·0		5·0		0·1		6·0	0·3	6·0	0·2	0	0	0	0
16–31	2·0		0·1		0·0		0·2		8·0	0·1	9·0	0·2	1	1	0	1
June 1–15	2·0			0·5	0·0			0·4	6·0	0·5	4·0	0·4	1	1	13	6
16–30	4·0			0·2	7·0			0·1	7·0	0·2	11·0	0·2	1	1	0	0
July 1–15	3·0		0·0		2·0		0·1		5·0	0·1	5·0	0·2	0	2	0	0
16–31	4·0			0·3	1·0			0·3	6·0	0·4	6·0	0·4	0	2	8	8
Aug. 1–15	1·0			0·1		1·0		0·1	5·0	0·2	5·0	0·1	0	0	0	0
16–31		3·0	0·2			4·0	0·1		7·0	0·2	6·0	0·2	2	0	2	0
Sept. 1–15	0·0		0·0			0·0		0·0	0·0	0·2	0·0	0·2	0	0	0	0
16–30	2·0		0·5			2·0	0·5		2·0	0·5	2·0	0·6	0	0	9	9
Oct. 1–15	7·0		0·2		5·0		0·2		7·0	0·3	6·0	0·4	0	1	3	5
16–31	0·0		0·4		0·0		0·2		0·0	0·4	0·0	0·3	0	0	7	0
Nov. 1–15	1·0		0·1		2·0		0·3		6·0	0·2	7·0	0·3	0	1	0	8
16–30		1·0	0·4			2·0	0·4		1·0	0·4	4·0	0·4	0	0	3	4
Dec. 1–15		1·0		0·4	5·0			0·1	3·0	0·8	5·0	0·6	1	2	19	18
16–31	2·0			0·1		1·0	0·1		3·0	0·1	5·0	0·2	0	1	0	0
TOTALS ..	38·0	10·0	2·5	2·0	45·0	10·0	2·7	1·4	105·0	6·4	110·0	6·0	9	15	69	64
MEANS ..	+ 1·0		+ 0·0		+ 1·0		+ 0·1		4·0	0·3	5·0	0·2				

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

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

TABLE 14.—*Mean errors E_1* and E_2* for 1951.*

SAUGOR (DUBLAT)

PERIOD 1951	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		3·0	0·0			5·0		0·4	6·0	0·2	8·0	0·5	0	0	0	2
16–31		6·0		0·2		5·0		0·1	8·0	0·3	9·0	0·4	1	1	2	0
Feb. 1–15	5·0			0·3	2·0			0·2	13·0	0·4	14·0	0·4	2	4	1	0
16–28		2·0		0·8		5·0		0·0	12·0	0·8	8·0	0·4	3	1	6	1
Mar. 1–15		4·0		0·7		3·0		0·4	6·0	0·7	9·0	0·5	0	0	6	4
16–31		4·0		0·5	2·0			0·2	18·0	0·7	19·0	0·5	7	6	5	1
April 1–15		4·0		0·3		2·0	0·1		12·0	0·3	16·0	0·4	1	5	2	0
16–30		12·0		0·4		12·0		0·3	12·0	0·4	13·0	0·3	1	1	0	0
May 1–15		2·0		0·2		2·0	0·1		7·0	0·3	7·0	0·5	0	1	0	2
16–31		13·0	0·5			16·0	0·1		14·0	0·5	17·0	0·2	1	3	2	0
June 1–15	1·0			0·2	2·0			0·1	8·0	0·4	10·0	0·3	0	0	2	0
16–30		4·0	0·2			6·0		0·3	6·0	0·3	8·0	0·6	0	0	0	3
July 1–15		10·0	0·9			6·0	0·3		13·0	0·5	10·0	0·4	2	1	2	1
16–31		2·0		0·2		4·0		0·9	12·0	0·5	11·0	0·9	2	2	4	11
Aug. 1–15		2·0		0·1	2·0			0·4	6·0	0·2	7·0	0·5	0	0	0	4
16–31		6·0	0·4			7·0	0·1		11·0	0·6	14·0	0·4	2	2	5	0
Sept. 1–15		5·0	0·3			5·0	0·0		9·0	0·4	7·0	0·3	1	0	2	1
16–30		2·0	0·5			4·0	0·6		12·0	0·5	16·0	0·6	4	5	7	6
Oct. 1–15	2·0			0·2	0·0			0·5	7·0	0·4	7·0	0·6	0	0	1	5
16–31	8·0			0·3	4·0			0·1	12·0	0·4	12·0	0·3	3	4	0	0
Nov. 1–15		1·0	0·2			5·0		0·1	6·0	0·4	9·0	0·3	0	0	0	0
16–30	5·0		0·1		1·0		0·3		9·0	0·4	8·0	0·4	0	0	0	3
Dec. 1–15	7·0			0·3	8·0			0·2	11·0	0·9	17·0	0·5	1	6	10	3
16–31	1·0			0·3		2·0		0·2	6·0	0·4	8·0	0·4	0	1	3	2
TOTALS ..	29·0	82·0	2·5	5·0	21·0	89·0	1·6	4·4	236·0	10·9	264·0	10·6	31	43	60	49
MEANS ..	−	2·0	−	0·1	−	3·0	−	0·1	10·0	0·5	11·0	0·4				

* E_1 is with regard to sign : E_2 is without regard to sign.
† One-tenth of the mean range of the spring-tides is 1·4 feet.

TABLE 15.—*Mean errors E_1* and E_2* for 1951.*

DIAMOND HARBOUR

PERIOD 1951	MEAN ERRORS (Predicted – Actual) E₁ H.W. Time (minutes) +	−	E₁ H.W. Height (feet) +	−	E₁ L.W. Time (minutes) +	−	E₁ L.W. Height (feet) +	−	E₂ H.W. Time (minutes)	E₂ H.W. Ht. (feet)	E₂ L.W. Time (minutes)	E₂ L.W. Ht. (feet)	Number of errors exceeding 30 minutes in time H.W.	L.W.	Number of errors exceeding 1·0† feet in height H.W.	L.W.
Jan. 1–15		2·0	0·6			0·0	0·1		11·0	0·6	10·0	0·5	0	0	2	4
16–31		5·0	0·3		13·0		0·3		10·0	0·5	16·0	0·5	1	5	1	5
Feb. 1–15	4·0		0·1		9·0		0·2		15·0	0·4	14·0	0·5	3	4	1	4
16–28		0·0		0·5	12·0		0·3		14·0	0·5	14·0	0·5	1	2	2	4
Mar. 1–15		1·0		0·1	8·0		0·2		10·0	0·3	11·0	0·4	0	2	1	1
16–31	4·0			0·0	9·0		0·2		20·0	0·6	19·0	0·5	6	4	5	2
April 1–15		6·0	0·4		3·0		0·7		12·0	0·6	17·0	0·7	2	7	5	9
16–30		8·0		0·1		2·0	0·0		12·0	0·4	12·0	0·3	3	1	0	1
May 1–15		3·0	0·1		12·0		0·4		15·0	0·5	15·0	0·5	3	3	1	3
16–31		7·0	0·7			5·0	0·4		9·0	0·7	12·0	0·5	0	1	8	4
June 1–15		1·0	0·1		16·0		0·0		11·0	0·5	21·0	0·4	1	8	1	0
16–30	1·0		0·4		3·0		0·0		6·0	0·4	13·0	0·6	0	3	1	4
July 1–15		13·0	0·6			1·0	0·4		15·0	0·6	16·0	0·5	5	4	6	5
16–31		4·0	0·2		12·0			0·3	10·0	0·7	18·0	0·6	0	5	6	3
Aug. 1–15		4·0	0·5		15·0		0·1		8·0	0·5	10·0	0·4	0	5	4	2
16–31	3·0		0·9		10·0		0·4		10·0	1·0	16·0	0·5	1	5	16	2
Sept. 1–15		0·0	0·7		2·0		0·3		12·0	0·9	11·0	0·4	2	1	13	0
16–30		1·0	0·9		11·0		1·1		14·0	0·9	21·0	1·1	2	4	10	13
Oct. 1–15	3·0		0·1		13·0		0·1		11·0	0·5	13·0	0·3	0	1	8	1
16–31	6·0		0·2		21·0		0·4		12·0	0·6	22·0	0·5	3	6	0	2
Nov. 1–15		8·0	0·9		4·0		0·5		11·0	0·9	12·0	0·5	1	0	12	2
16–30	2·0		0·6		12·0		0·6		11·0	0·8	18·0	0·6	1	4	7	7
Dec. 1–15	2·0		0·3		18·0		0·1		14·0	1·0	23·0	0·5	1	10	12	6
16–31		1·0	0·4		12·0		0·3		7·0	0·7	14·0	0·6	0	2	5	4
TOTALS ..	25·0	59·0	9·0	0·7	215·0	8·0	7·1	0·3	280·0	15·1	377·0	12·4	36	87	122	88
MEANS ..	−	1·0	+	0·3	+	9·0	+	0·3	12·0	0·6	16·0	0·5				

* E_1 is with regard to sign : E_2 is without regard to sign.
† One-tenth of the mean range of the spring-tides is 1·6 feet.

TABLE 16.—*Mean errors E_1* and E_2* for 1951.*

CALCUTTA (GARDEN REACH)

PERIOD 1951	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		3·0		0·2		8·0		0·0	10·0	0·2	13·0	0·6	0	0	0	4
16–31		4·0		0·2	6·0			0·2	11·0	0·3	14·0	0·6	0	4	2	1
Feb. 1–15	4·0			0·3	2·0			0·0	17·0	0·3	16·0	0·5	4	5	2	5
16–28	3·0			0·9	11·0			0·1	13·0	0·9	16·0	0·5	1	2	9	2
Mar. 1–15		5·0		0·6		3·0		0·2	8·0	0·6	9·0	0·5	0	0	4	3
16–31	2·0			0·5	7·0			0·1	13·0	0·6	21·0	0·5	4	5	7	5
April 1–15		7·0	0·1			1·0	0·3		14·0	0·5	19·0	0·4	0	8	3	0
16–30		4·0		0·6		7·0		0·2	10·0	0·6	13·0	0·5	1	1	4	2
May 1–15		7·0	0·2		1·0		0·1		11·0	0·4	14·0	0·3	1	1	0	0
16–31		9·0	0·4			18·0	0·4		10·0	0·6	22·0	0·7	2	5	7	7
June 1–15		6·0		0·4	6·0			0·2	13·0	0·6	14·0	0·5	1	1	6	2
16–30		1·0		0·3		10·0	0·2		12·0	0·5	13·0	0·5	0	2	0	4
July 1–15		5·0		0·3		1·0		0·0	12·0	0·4	11·0	0·5	1	2	1	1
16–31	4·0			0·2	9·0		0·6		13·0	0·4	19·0	0·8	1	8	2	11
Aug. 1–15		1·0	1·0		10·0		1·5		12·0	1·0	15·0	1·5	0	3	10	23
16–31		8·0	1·4			1·0	1·9		12·0	1·4	14·0	1·9	3	3	23	30
Sept. 1–15		12·0	1·3			7·0	2·0		15·0	1·3	11·0	2·0	0	1	20	28
16–30		12·0	1·5			1·0	2·4		16·0	1·5	18·0	2·4	4	4	23	29
Oct. 1–15		5·0	0·9			5·0	2·2		10·0	0·9	8·0	2·2	0	0	9	27
16–31		5·0	0·8		4·0		1·7		12·0	0·8	16·0	1·7	1	3	12	28
Nov. 1–15		10·0	1·0			12·0	1·4		13·0	1·0	14·0	1·4	1	4	20	21
16–30		0·0	0·6			2·0	0·9		12·0	0·7	15·0	0·9	0	4	6	9
Dec. 1–15	7·0			0·0	2·0		0·3		17·0	0·8	22·0	0·7	5	8	11	8
16–31	1·0			0·0		4·0	0·2		12·0	0·4	14·0	0·6	0	1	1	4
TOTALS ..	21·0	104·0	9·2	4·5	68·0	80·0	16·1	1·0	298·0	16·7	361·0	22·7	80	70	182	254
MEANS ..	− 3·0		+ 0·2		− 1·0		+ 0·6		12·0	0·7	15·0	0·9				

* E_1 is with regard to sign : E_2 is without regard to sign.
† One-tenth of the mean range of the spring-tides is 1·3 feet.

TABLE 19.—*Accuracy Statement of H.S.W. predictions and old Riverain predictions.*

Serial No.	Name of port and year of comparison		Method of predictions	Times: Correct within (*minutes*) 5	10	15	20	25	30	Heights: Correct within (*feet*) 0·5	1·0
				%	%	%	%	%	%	%	%
1	Elephant Point 1930*	H.W.	Old	2	5	Not computed	15	Not computed	44	65	91
			H.S.W. method	37	66		98		100	89	100
		L.W.	Old	12	18		41		60	55	89
			H.S.W. method	32	69		93		98	76	98
2	Rangoon 1930*	H.W.	Old (with empirical corrections)	35	71		94		98	71	90
			H.S.W. method	43	69		96		98	86	100
		L.W.	Old (with empirical corrections)	17	38		79		100	69	85
			H.S.W. method	32	54		91		98	80	92
3	Amherst 1886†	H.W.	Old	44	70	85	93	97	99	49	78
			H.S.W. method	33	60	80	91	98	100	66	94
		L.W.	Old	34	62	77	88	95	97	46	75
			H.S.W. method	29	56	78	89	95	100	48	84
4	Moulmein 1924‡	H.W.	Old	34	63	81	90	95	96	66	94
			H.S.W. method	17	37	64	87	95	98	27	69
		L.W.	Old	28	44	60	75	83	87	79	99
			H.S.W. method	13	23	45	66	80	92	37	67

* Percentages from the results of verification for a period of 2 months.
† Percentages from the results of verification for a period of 9 months.
‡ Percentages from the results of verification for a period of 3 months.

CHAPTER V

GRAVITY

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

32. **Summary.**—During the period under report, no departmental field programme of gravity observations with the Frost gravimeter was undertaken due to acute shortage of funds. Observations were, however, carried out at Madras and Bombay in collaboration with Mr. W. E. Bonini of the Woodshole Oceanographic Institution, U.S.A., who happened to visit India in connection with the global programme of gravity observations sponsored by the Naval Research Office, Washington. These observations were made with a geodetic Worden gravimeter with a view to establishing accurately fixed gravity stations at these places to serve as sub-standards for regional gravity programme with the Frost gravimeter. Opportunity was also taken to observe a loop of a linear extent of about 220 miles to the north of Madras and another loop of about 160 miles comprising Bombay–Alībāg–Poona. Observations were also taken at Bangalore.

33. **Narrative.**—During the month of August 1951, Mr. W. E. Bonini re-occupied the stations at Palam Airport, Imperial Hotel, New Delhi and Dum Dum Airport which had been observed last year as well with the Worden gravimeter. The results confirmed the values obtained with the Frost gravimeter by the Survey of India.

On 14th September 1951, Mr. Bonini arrived in Madras from Saigon, and Mr. B. L. Gulatee, Director, Geodetic and Training Circle, joined him there on that date. A 10-day programme was chalked out and the following observations were carried out :—

(i) Circuit Madras–Renigunta–Gūdūr–Madras comprising 26 stations. In addition 4 stations in Madras city, one at Tiruchirapalli and one at Arkonam were also observed.

(ii) 6 stations around Bombay, 1 at Alībāg and 17 stations along the Bombay–Poona road at intervals of about 15 miles.

(iii) 4 stations around Bangalore, 2 stations in the Kolār Gold Fields area and 6 stations along the Bangalore–Kolār Gold Fields road.

During the course of the above observations, 10 pendulum stations were also re-occupied.

34. **Gravity Sub-standards.**—The Frost gravimeter has a limited range and to guard against inaccuracies arising from any uncertainty in its calibration constant when it has to cover an area of such a large extent as India it is necessary to have a network of reliable sub-standard stations suitably distributed. With the establishment of Worden gravimeter stations at Bombay, Bangalore, Tiruchirapalli, Madras, Renigunta and Hyderābād during the period under report, and with gravimeter stations established at Delhi, Calcutta, Amritsar, Jammu, Srīnagar, Agra and Dehra Dūn in previous years, there are now a sufficient number of gravity stations to serve as sub-standards for work with the Frost gravimeter without the fear of systematic errors assuming unduly large proportions.

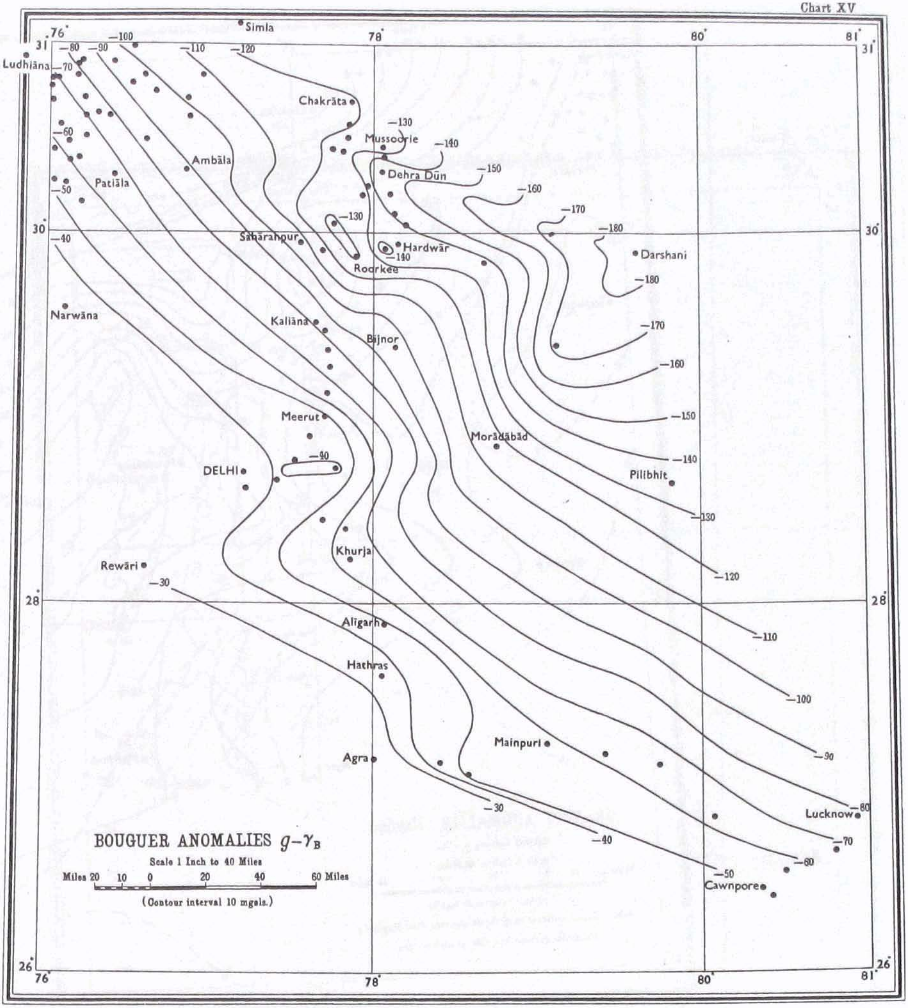
35. **Old Pendulum stations.**—The number of old pendulum stations re-observed with the Frost and Worden gravimeters now totals 36. This includes 10 stations observed during the year under report. The results are given in Table 1.

Three of the stations observed this year, viz., Bangalore, Renigunta and Talegaon show unusually large discrepancies with the pendulum values.

At Edgar Shaft (Surface), Kolār Gold Fields, the observations with the Frost and Worden gravimeters do not appear to have been made at the same site. Gravity difference between Bangalore and Edgar Shaft (Surface) by pendulum observations is 50 mgals., by Frost gravimeter 44·6 mgals. (see Technical Report 1948–49, Part III, Chapter III, Table 5) and by Worden gravimeter 47·6 mgals.

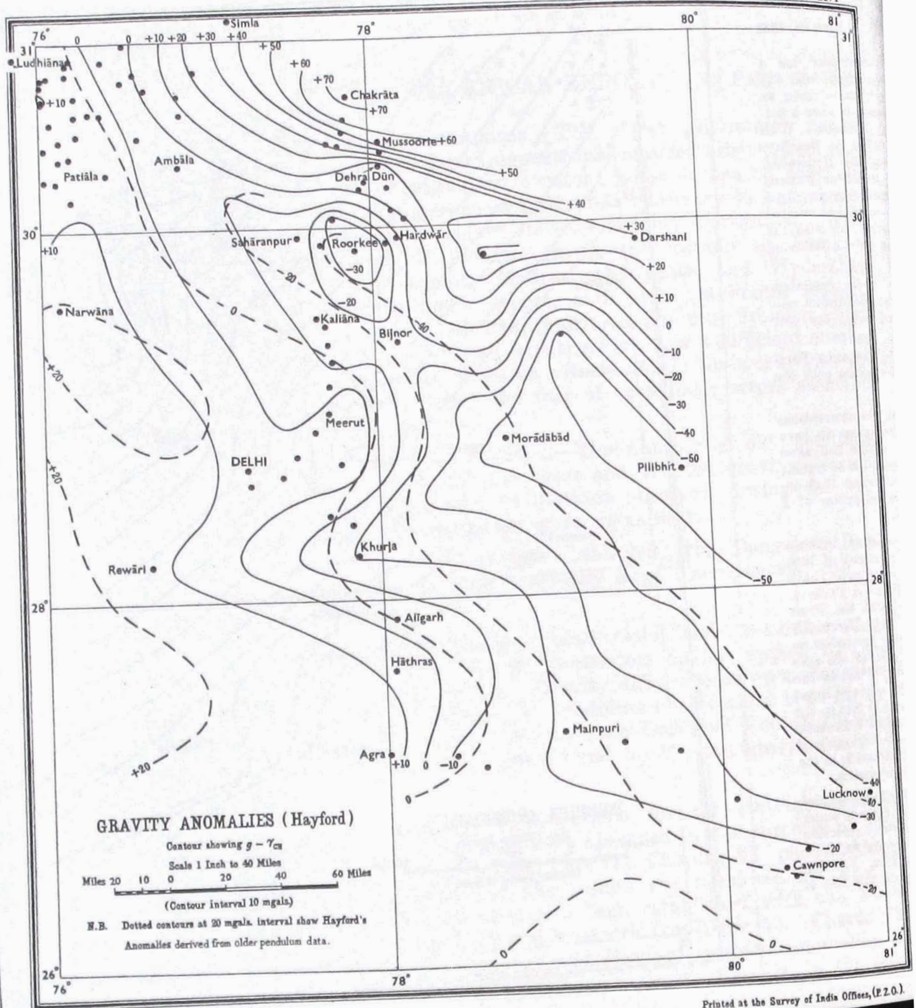
36. **Results.**—Gravity reductions for all stations between Cawnpore and Delhi which were observed in the summer of 1950 (*vide* Technical Report 1951, Part III, Chapter VI, para 54) have now been completed and the results are tabulated in Table 2. A number of stations have also been established with the Frost gravimeter between Delhi and Mussoorie (see Table 5). Charts XV and XVI show the Bouguer and Hayford isostatic anomalies on Helmert spheroid with contour intervals of 10 mgals. in the area N.W. of Cawnpore extending up to Patiāla. The dotted line on the latter chart represents the older generalized anomaly contours based on pendulum data. The easterly part of this region is just to the north of the Vindhyans and is associated with negative isostatic anomalies. The Delhi series near Delhi marks the beginning of positive gravity anomalies and the extension of the Arāvallis in the north-westerly direction is also a region of positive anomalies.

The gravity results throw an interesting light on the current belief amongst the geologists that the Arāvalli range extends under the Indo-gangetic alluvium from Delhi in a north-easterly direction till it meets the Himālayas. This is not borne out by the negative isostatic anomalies from Meerut to near Dehra Dūn. Gravity evidence indicates that the shape of the trough along this line is



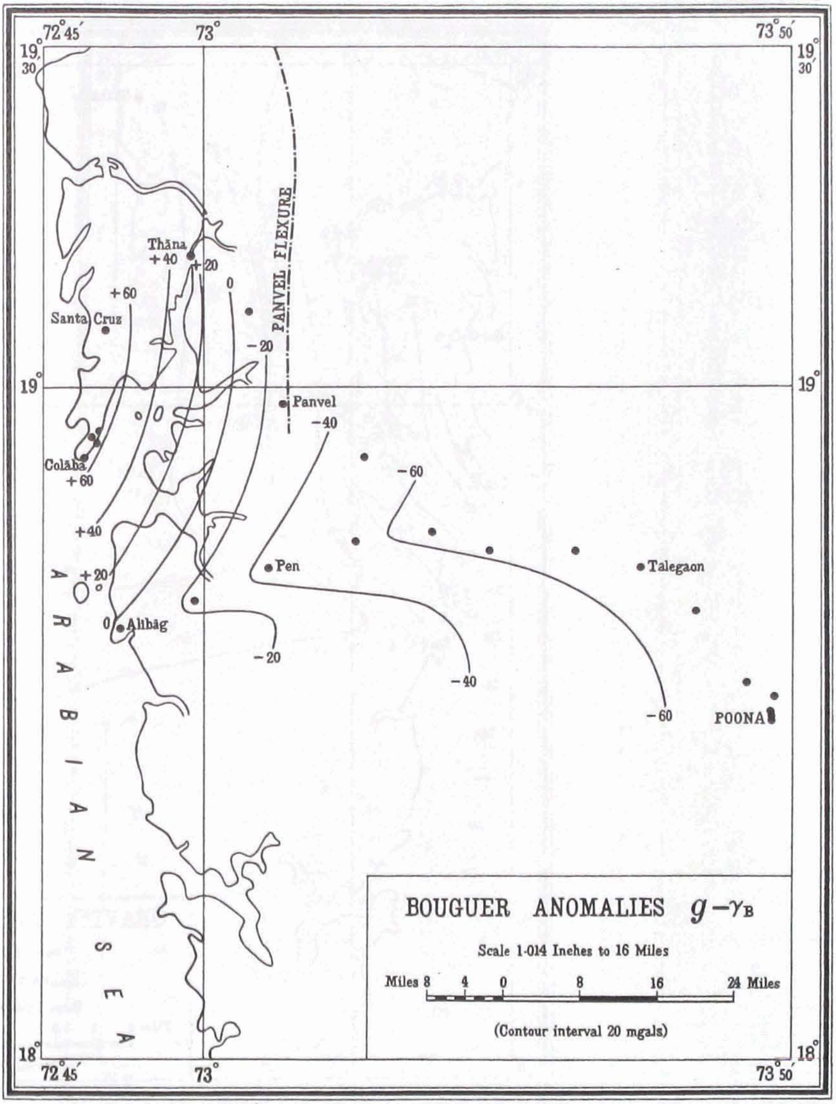
Reg. No. 165 D/N.C. '52 (G. & T.C. 1"=40 Miles)-300.

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

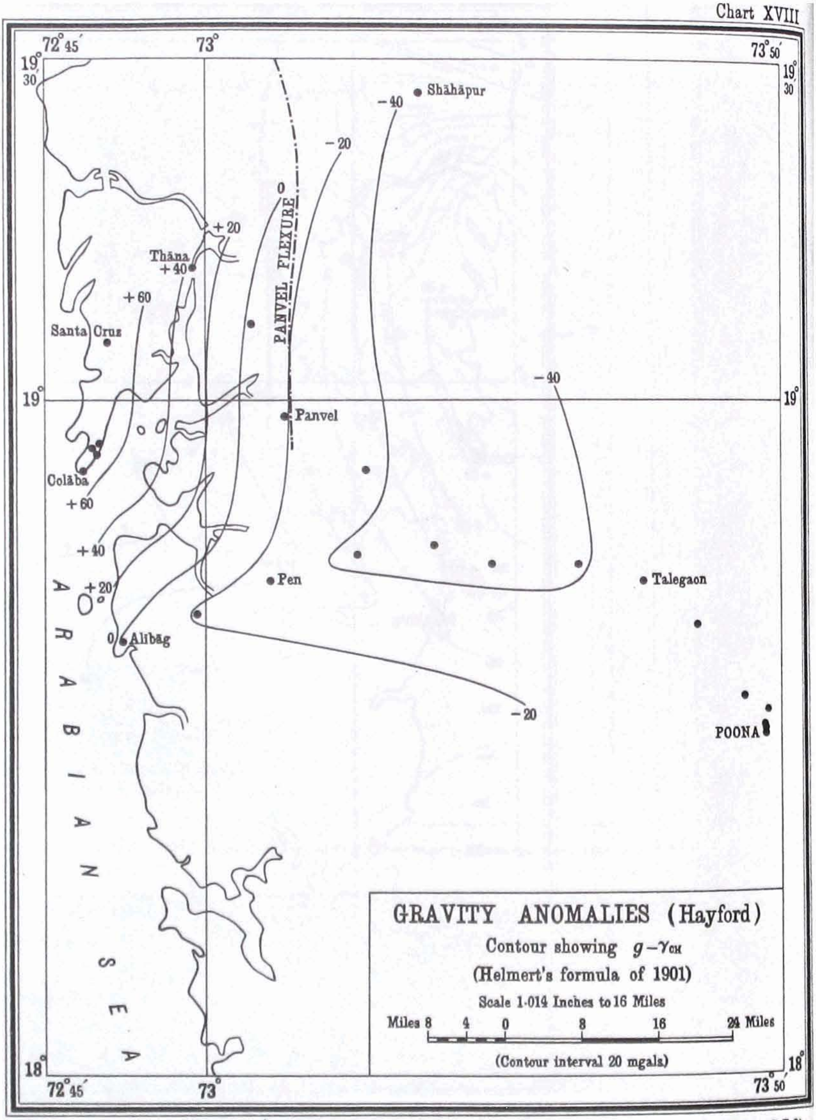


Printed at the Survey of India Offices, (P.Z.O.)

Reg. No. 187 D/N.C.' 52 (G. & T.C. 1"=40 Miles)—300.

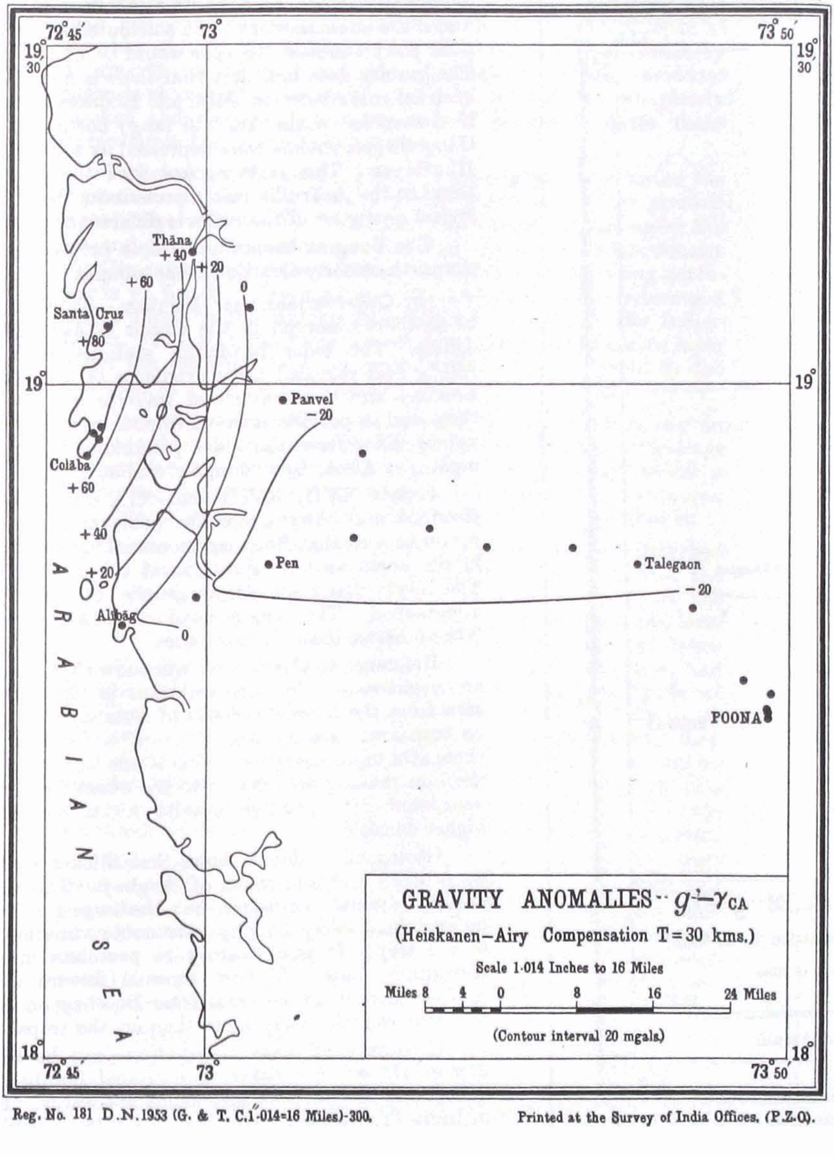


Reg. No.179 D. N.1953(G. & T. C.1·014=16 Miles)-300. Printed at the Survey of India Offices, (P.Z.O).



Reg. No. 180 D.N. 1953 (G. & T. C,1″·014=16 Miles)-300.

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



GRAVITY ANOMALIES $g_0''-\gamma_{CA}$

(Heiskanen–Airy Compensation T = 30 kms.)

Scale 1·014 Inches to 16 Miles

Miles 8 4 0 8 16 24 Miles

(Contour interval 20 mgals)

Reg. No. 181 D.N.1953 (G. & T. C.1″·014=16 Miles)-300. Printed at the Survey of India Offices. (P.Z.O).

asymmetrical there being greater downwarping near its northern edge and if the anomalies are to be attributed solely to lighter sediments, their thickness near Roorkee would be of the order of 10,000 feet. The gravity data indicates that there is no shallow concealed ridge of dense rocks between Delhi and Roorkee and it rather appears as if the rocks of the Arāvalli range north-east of Delhi under the Gangetic geosyncline were depressed as a downwarp in front of the Himālayas. This is in accord with the fact that in spite of the trend of the Arāvallis being present in the Himālayas, the lithological character of the rocks is different from the true Arāvallis.

The Bouguer anomalies become progressively more negative in the north-easterly direction as the mountainous areas are approached.

37. **Observations near Bombay.**—Table 3 gives the results at 24 stations observed in the circuit Colāba–Thāna–Panvel–Poona–Alībāg. The older pendulum stations at Colāba, Panvel and Alībāg had revealed large gradients of gravity east and south of Bombay and this gravimeter traverse was undertaken to confirm these and to provide some additional information. The gravimeter values differ from the older pendulum values at Bombay by 3·1 mgals., at Alībāg by 2·0 mgals. and at Panvel by 0 mgal.

Charts XVII, XVIII and XIX show respectively Bouguer, Hayford and Airy anomalies (thickness of crust 30 kms.). It would be seen that Bouguer anomalies increase steadily from Panvel in the north-westerly direction at the rate of 6 mgals./per mile. The Hayford and the Airy anomalies also increase as sea-board is approached. The area is no doubt disturbed and Airy anomalies fare no better than Hayford ones.

Reference to Chart XIII will show that the gravity anomalies are negative on the pre-cambrians in the peninsula. It will be seen from the anomaly charts of Bombay that the anomalies even on trap areas are no less. Correction for local geology will make them still more negative. This is apt to puzzle many authors who keep on making statements to the effect that such formations are associated with positive gravity anomalies on account of their higher densities.

Geological evidence shows that thickness of trap decreases as we proceed east and south of Bombay. This is borne out by the gravity anomaly contours, but the large gravity gradients cannot be explained solely by any reasonable variations in the thickness of the trap. It is obligatory to postulate in addition a hidden disturbing cause. A most unusual feature which the contours disclose is that as we cross from Bombay on to the sea, gravity becomes conspicuously more than on the traps.

A variety of mass distributions can be brought forward to explain the gravity disturbance around Bombay. The plumb-line deflections in this area also point sea-wards. Burrard in Survey of India Professional Paper No. 17 (1918) postulated the existence of a zone of subterranean deficiency and of crustal tension between Bombay and the Western ghāts. This is extremely unlikely.

The geologists attribute the extraordinary straightness of the western coast of India to faulting in early Tertiary period. This fault may have thrown down the traps of Bombay to a depth of the order of 2,000 feet which by itself will produce a slight deficiency of gravity to the sea-ward side of Bombay. Gravity evidence suggests that this fault is a minor feature and its effect is completely masked and reversed by an upwarp of unusually dense rocks immediately below the faulted mass.

In broad general terms, gravity data suggests that under the crystallines and the trap area of the peninsula, the lighter granitic layer is unusually thick. This layer is practically absent under the sea and there is in addition a structural feature of excess density with its extremity between Colāba and Alībāg and extending northwards to Kutch. This may well be analogous to the submerged ridges found by the Murray Expedition of 1933–34 in the Indian Ocean. It might also be that even the intermediate basaltic layer under the sea from Bombay northwards has been thinned by the upwelling of the ultra basic magma from below.

The continental shelf to the west of Bombay is obviously an area in which a comprehensive programme of seismic soundings and gravimetric observations is indicated. These should enable a full portrayal of the dense feature suggested by the gravity anomalies. Any further speculation at this stage would be hardly profitable.

In the meantime, it is of interest to point out that the disturbed gravity anomalies are to a certain extent in harmony with the geological history of the region. The lavas of Bombay are the youngest traps of the Deccan area. Even after the traps had been laid down the area was subjected to disturbances. Several dykes of post-trappean age are evidences of this. In particular, the Panvel–Kalyān axis of flexure is well defined (Auden—Trans. of the National Institute of Sciences of India, Volume III, No. 3, pp. 134). To its east, the lavas are flat-lying, but to its west they dip towards the sea at an average angle of about 10°. As will be seen from Chart XVIII the gravity anomalies to the east of this flexure are practically constant, while they increase at a rapid rate westwards achieving high positive values on the waters of the ocean.

The isogams of all the anomalies have a general NE.–SW. trend right up to the coast, supporting the suggestion that the traps do not end abruptly near the coast. It is conceivable that when the faulting occurred and the land occupied by the Arabian sea was submerged under the ocean, more ultra basic material welled through the fissures and this may be responsible for the steep gravity gradients on the sea.

38. **Gravity Observations in the vicinity of Madras.**—It was considered desirable to establish a Worden station at Madras where observations were carried out with the pendulums in 1904. A closed loop of linear extent of about 220 miles was also run along a coastal strip to the north of Madras (about 30 miles in width)

GRAVITY ANOMALIES (Hayford)

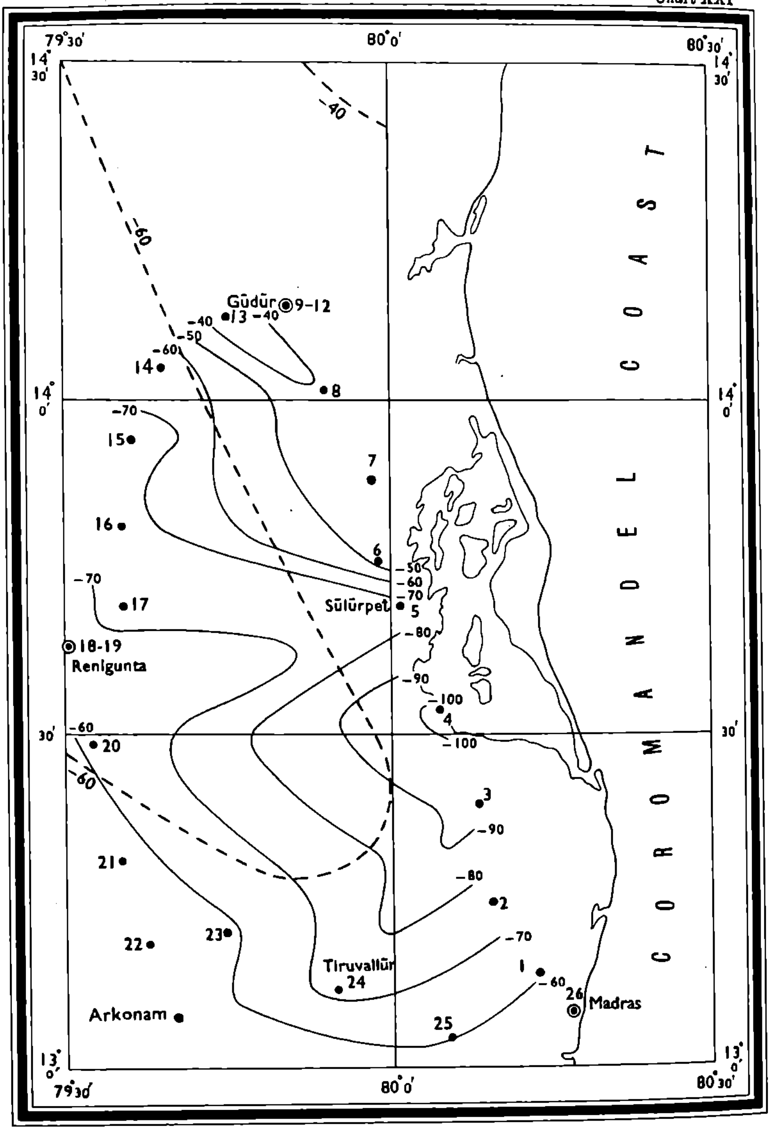
Contour showing $g - \gamma_{CH}$

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

Miles 10 5 0 10 20 30 40 Miles

(Contour interval 10 mgals.)

Chart XXI



REFERENCES

Hayford Anomalies derived from older pendulum data . . . . -40

Old pendulum stations . . . . 26 ◉

New gravimeter stations . . . . 8 •

Reg. No. 162 D/N.C.' 52 (G.&T.C. 1·014=16 Miles)-300.

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

GRAVITY ANOMALIES $g-\gamma_{CA}$

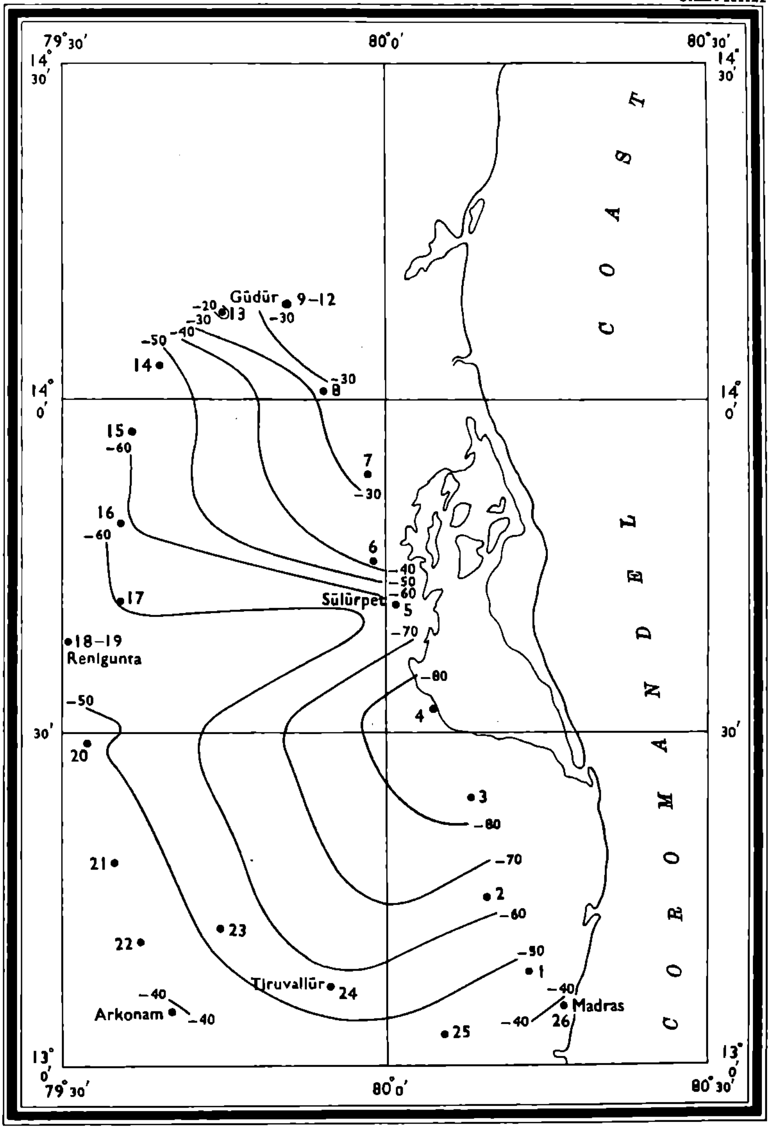
(Heiskanen-Airy Compensation T = 30 kms.)

Scale $\frac{1}{1,000,000}$ or 1·104 Inches to 16 Miles.

Miles 10 5 0 10 20 30 40 Miles

(Contour Interval 10 mgals.)

Chart XXII



Note:— Normal gravity is computed on Helmert's gravity formula:-

$$\gamma_0 = 978\cdot030\ (1 + 5302\cdot10^{-6}\sin^2\lambda - 7\cdot10^{-6}\sin^2 2\lambda)$$

Reg. No. 161 D/N. C.'52 (G. & T.C. 1·014 = 16 Miles)-300. Printed at the Survey of India Offices, (P.Z.O.).

with stations about 10 miles apart (see Chart XX). 30 stations in all were observed, three of them being older pendulum stations. In addition to the usual Free Air, Bouguer and Hayford isostatic anomalies, the Airy anomalies (T = 30 kms.) and the modified Bouguer anomalies were computed. These latter take count of the effect of topography up to zone O (103·6 miles) and of topography and its compensation for the numbered zones 18 to 1. The results are given in Table 4.

Table 1 shows the discrepancies between the pendulum and the gravimeter values.

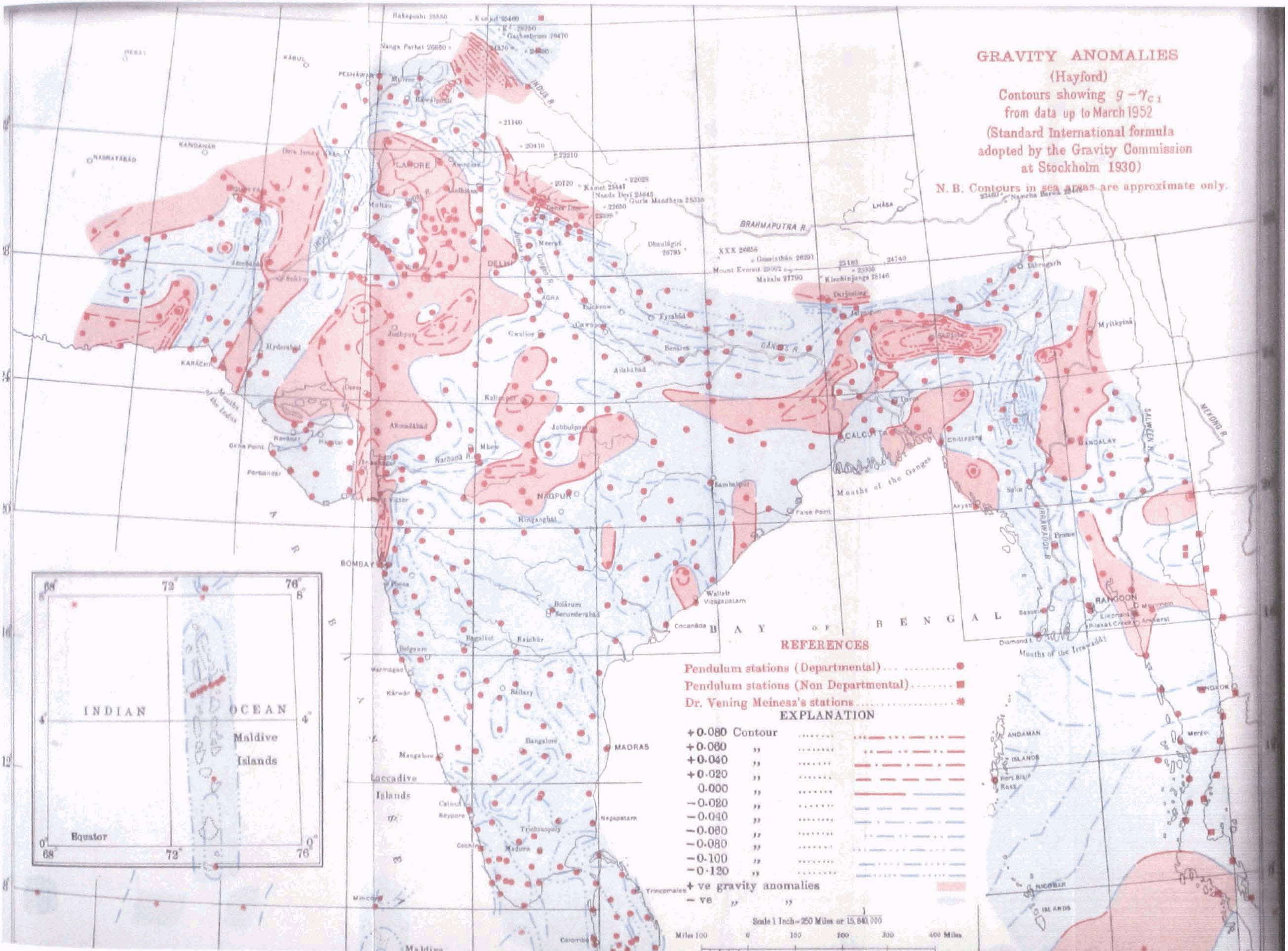
Charts XX, XXI and XXII show the Bouguer anomalies, Hayford isostatic anomalies (T = 113·7 kms.) and Airy anomalies (T = 30 kms.) with contour intervals of 10 mgals.

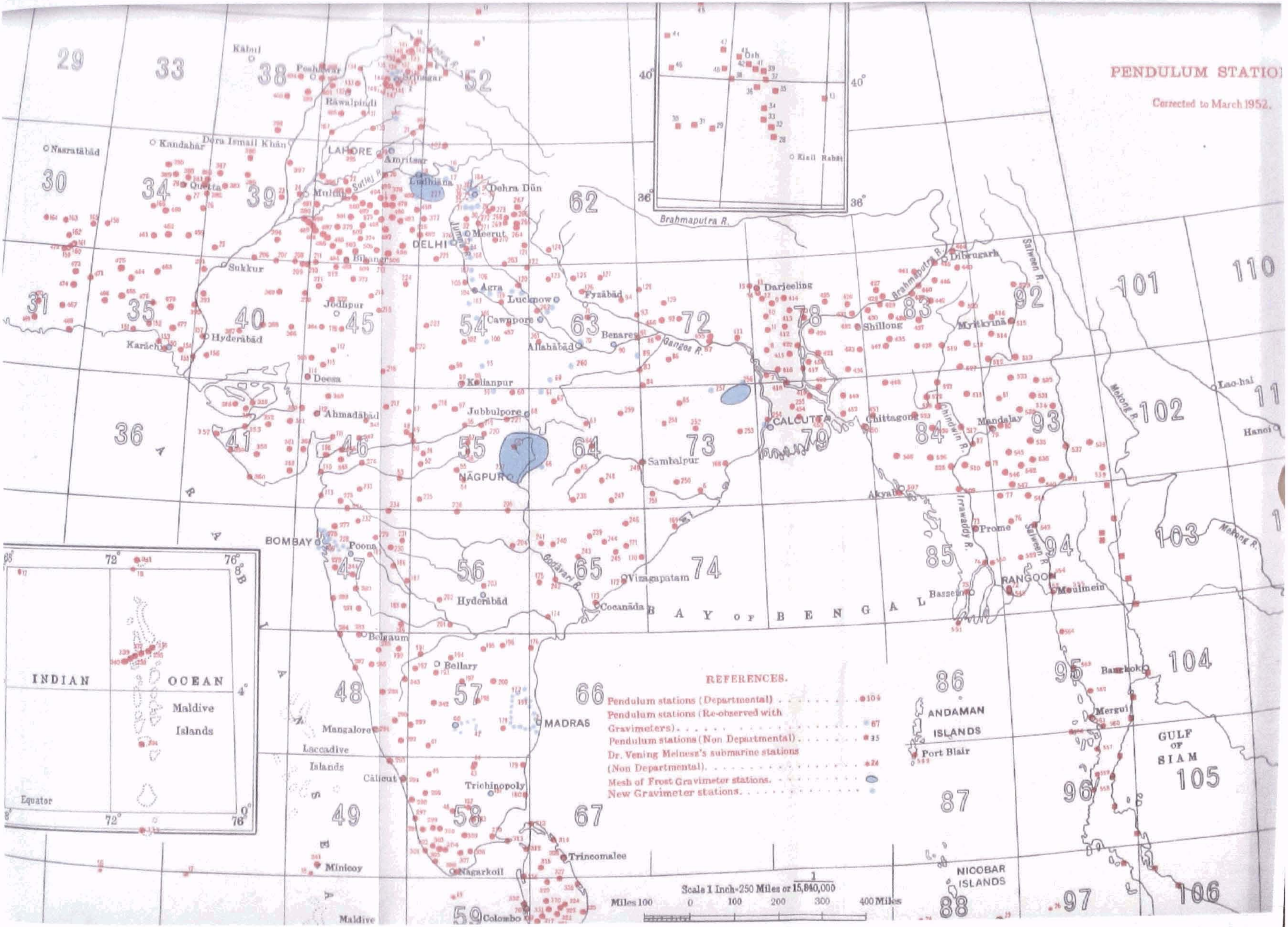
The area in question comprises a variety of geological formations, the major structure being the unclassified crystallines, gneisses and schists of Archæan age. These include highly metamorphosed sedimentary and igneous materials with several basic dykes running through them.

The weathering of the older Archæan gneisses and schists yielded the earliest sediments which formed the oldest sedimentary strata known as the Dhārwār system. These metamorphosed Archæan sediments appear to rest on gneisses and form a series of highly folded and sheared strips having a strike in the NW.–SE. direction. The eastern region (Madras to Gūdūr) comprises of Pleistocene and recent deposits and beyond the western region are the Cuddapah series and traps west of Renigunta are the rhyolites in the Cuddapah trap.

The Hayford and Airy anomalies show practically identical characteristics. The region is one of negative isostatic anomalies, the maximum gravity low being in the vicinity of station No. 4. Although the area is comparatively flat (being only interspersed with minor hills), the Bouguer anomalies are markedly negative.

39. **Hayford Gravity Anomalies.**—Chart XIII shows the Hayford gravity anomalies in India against a geological background. It would be seen that anomalies of same sign persist over large areas—a state of affairs which is not favourable to isostasy. The anomalies are not corrected for local geology but it is only in few cases that they follow the geological trends. The most notable one is the Indo-Gangetic trough which is well delineated by negative anomalies. There are, however, marked contradictions. The Archæan rocks which constitute the main body of the peninsular shield and the extensive plateau basalts of Deccan which are much heavier than normal rocks are characterised by negative anomalies, while the sea to the north of Bombay is apparently associated with heavy positive ones. Throughout the length and breadth of India, there are evidences of important sub-crustal features which appear to mask the effect of local geology.


GRAVITY ANOMALIES
(Hayford)
Contours showing $g - \gamma_{c1}$
from data up to March 1952
(Standard International formula
adopted by the Gravity Commission
at Stockholm 1930)
N. B. Contours in sea areas are approximate only.
REFERENCES
Pendulum stations (Departmental)
Pendulum stations (Non Departmental)
Dr. Vening Meinesz's stations
EXPLANATION
+0.080 Contour
+0.060 ,,
+0.040 ,,
+0.020 ,,
0.000 ,,
−0.020 ,,
−0.040 ,,
−0.060 ,,
−0.080 ,,
−0.100 ,,
−0.120 ,,
+ ve gravity anomalies
− ve ,, ,,
Scale 1 Inch = 250 Miles or 15,840,000
Miles 100 0 100 200 300 400 Miles
BAY OF BENGAL
INDIAN OCEAN
Maldive Islands
Equator
Laccadive Islands
BRAHMAPUTRA R.
GANGES R.
INDUS R.
SALWEEN R.
MEKONG R.
Mouths of the Ganges
Mouths of the Irrawaddy
DELHI
LAHORE
CALCUTTA
BOMBAY
MADRAS
NAGPUR
RANGOON
MANDALAY
KARACHI
PESHAWAR
KANDAHAR
LHASA
ANDAMAN ISLANDS
NICOBAR ISLANDS



PENDULUM STATIO
Corrected to March 1952.
REFERENCES.
Pendulum stations (Departmental) 104
Pendulum stations (Re-observed with Gravimeters) 87
Pendulum stations (Non Departmental) 35
Dr. Vening Meinesz's submarine stations (Non Departmental) 24
Mesh of Frost Gravimeter stations.
New Gravimeter stations.
Scale 1 Inch=250 Miles or 1/15,840,000
Miles 100 0 100 200 300 400 Miles
Kābul
Peshāwar
Srīnagar
Rāwalpindi
Nasratābād
Kandahār
Dera Ismail Khān
LAHORE
Amritsar
Quetta
Multān
Sutlej R.
Ludhiāna
Dehra Dūn
Meerut
DELHI
Jumna R.
Bikaner
Sukkur
Agra
Lucknow
Fyzābād
Jodhpur
Cawnpore
Benares
Allahābād
Ganges R.
Hyderābād
Karāchi
Deesa
Ahmadābād
Katlanpur
Jubbulpore
NĀGPUR
Sambalpur
Darjeeling
Shillong
Dibrugarh
Brahmaputra R.
Myitkyinā
Salween R.
CALCUTTA
Chittagong
Mandalay
Chindwin R.
Irrawaddy R.
Akyab
Prome
RANGOON
Moulmein
Bassein
Mekong R.
Lao-kai
Hanoi
BOMBAY
Poona
Godāvari R.
Vizagapatam
Cocanāda
Hyderābād
Belgaum
Bellary
MADRAS
Mangalore
Laccadive Islands
Calicut
Trichinopoly
Minicoy
Nagarkoil
Colombo
Trincomalee
Maldive
BAY OF BENGAL
ARABIAN SEA
ANDAMAN ISLANDS
Port Blair
NICOBAR ISLANDS
Bangkok
Mergui
GULF OF SIAM
Kizil Rabāt
Brahmaputra R.
INDIAN OCEAN
Maldive Islands
Equator
29 33 38 52 30 34 39 62 31 35 40 45 54 63 72 78 83 92 101 110 36 41 46 55 64 73 79 84 93 102 47 56 65 74 85 94 103 48 57 66 86 95 104 49 58 67 87 96 105 59 88 97 106


GRAVITY ANOMALIES
(Hayford)
AND
GEOLOGY
N.B. The gravity anomalies are based on Helmert's 1901 formula.
REFERENCES
Pleistocene & Recent
Siwalik System, Coastal Tertiary & Pleistocene
Oligocene & Lower Miocene
Eocene
Deccan Trap
Vindhyan
Cuddapah, Delhi, etc
Dharwarian
Granites & Gneisses
+ve contours , −ve contours
Scale 1 Inch = 250 Miles
Miles 100 0 100 200 300 400 Miles
KĀBUL
PESHĀWAR
SRINAGAR
LHĀSA
DELHI
AGRA
Lucknow
Cawnpore
Benares
Allahābād
Hyderābād
KARĀCHI
Mouths of the Indus
NĀGPUR
CALCUTTA
Mouths of the Ganges
Sambalpur
False Point
BOMBAY
Poona
Waltair
Vizagapatam
Cocanāda
B A Y O F B E N G A L
Raichūr
Bellary
Bangalore
MADRAS
Mangalore
Calicut
Cochin
Madura
Trichinopoly
Negapatam
Tuticorin
Cape Comorin
Trincomalee
Colombo
CEYLON
MANDALAY
RANGOON
Moulmein
Prome
IRRAWADDY R.
SALWEEN R.
MEKONG R.
Mouths of the Irrawaddy
ANDAMAN
ISLANDS
Port Blair
NICOBAR
ISLANDS
BANGKOK
Mergui
Dibrugarh
Myitkyina
Dacca
Darjeeling
Jalpaiguri
Mount Everest
Makalu
Kinchinjunga
Dhaulāgiri
Nanda Devi
Kamet
Gurla Mandhata
Namcha Barwa
Multān
Lahore
Amritsar
Meerut
Jodhpur
Sukkur
Mhow
Jubbulpore
Ahmadābād
Porbandar
Hāwār
Harmagao
Nagercoil
Pāmban Pass
Minicoy
Akyab
Chittagong
Diamond Harbour
Kidderpore
Diamond I.
Bassein
Amherst

The Rājputāna was subjected to intense igneous activity in the Puráná era which was responsible for the formation of the Arāvalli range. This is a region of positive gravity anomalies. The anomalies are markedly positive on the Arāvalli range indicating under-compensation, although this range has been subjected to heavy denudation through countless ages.

Very little gravity data exists on the high Himālayas. There appears to be a tendency for the anomalies to be positive on the high hills.

TABLE 1.—*Gravity values—Pendulum and Gravimeter.*

Serial No.	No. of pendulum station	Sheet No.	Name of Station	Height	Latitude	Longitude	Years of observation	Pendulum value	Gravimeter value*	Pendulum *minus* gravimeter	REMARKS
				feet	° ′ ″	° ′ ″		*gals.*	*gals.*	*mgals.*	
27	2	66 C	Madras	20	13 04 08	80 14 54	1904, 1951	978·279	978·2837	— 4·7	Exact position.
							1929, 1951	·282		— 1·7	
28	181	58 J	Trichinopoly (Tiruchirapalli) ..	207	10 47 58	78 40 46	1929, 1951	·162	·1622	— 0·2	Approximate position.
29	40	57 G	Bangalore ..	3118	13 00 41	77 35 01	1908, 1951	·025	·0315	— 6·5	Approximate position.
							1929, 1951	·026		— 5·5	
30	42	57 L	Edgar Shaft (Surface) ..	2945	12 55 47	78 15 41	1908, 1951	·076	·0791	— 3·1	Approximate position.
31	3	47 B	Colāba, Bombay ..	34	18 53 45	72 48 47	1904, 1951	·631	·6341	— 3·1	Exact position.
32	177	57 N	Gūdūr ..	49	14 08 36	79 50 53	1929, 1951	·311	·3099	+ 1·1	,, ,,
33	199	57 O	Renigunta ..	365	13 38 06	79 30 25	1930, 1951	·226	·2328	— 6·8	,, ,,
34	278	47 F	Panvel ..	40	18 58 38	73 07 08	1933, 1951	·545	·5450	0·0	,, ,,
35	109	47 B	Alībāg ..	12	18 38 30	72 52 10	1913, 1951	·551	·5530	— 2·0	,, ,,
36	228	47 F	Talegaon ..	2060	18 44 01	73 40 44	1931, 1951	978·356	978·3695	—13·5	Approximate position.

* By Worden gravimeter. In terms of Washington D.C. (g=980·1190 gals.).

TABLE 2.—*Gravity Anomalies between*

Serial No.	Sheet No.	Stations	Height	Latitude		Longitude		g (meter factor 0·0817)
				(from 1 inch maps)				
			feet	°	'	°	'	*gals.*
1	63 B	Lucknow Rly. Stn. ..	385	26	40·9	80	55·1	978·9790
2	"	" S.B.M. ..	390*		49·0		56·0	·9791
3	"	" Royal Hotel Room No. 34	390		51·0		55·0	·9804
4	"	Bani P.W.D. I.H. ..	385		39·0		47·8	·9806
5	"	Unao P.W.D. I.H. ..	410		32·8		29·7	·9804
6	"	Cawnpore Rly. Stn. ..	405		27·2		21·3	·9755
7	"	" S.B.M. ..	404*		28·6		20·6	·9771
8	"	" Chakeri airfield	405*		24·1		25·0	·9772
9	"	" Circuit House..	405		27·0		21·6	·9791
10	"	" M.E.S. I.H. ..	405		27·2		21·5	·9772
11	"	Bilhaur P.W.D. I.H. ..	465	26	50·6	80	04·4	978·9889
12	54 M	Gursahāiganj P.W.D. I.H.	480	27	07·0	79	44·0	979·0120
13	"	Mainpuri P.W.D. I.H. ..	520		15·0		03·0	·0221
14	"	Nabiganj P.W.D. I.H. ..	500		11·0	79	24·0	·0162
15	54 I	Shikohābād P.W.D. I.H.	530		05·0	78	34·8	·0126
16	"	" canal I.H...	535		05·1		34·8	·0138
17	"	Firozābād P.W.D. I.H. ..	540		08·6		24·2	·0243
18	"	Agra P.W.D. I.H. ..	550		09·0		00·8	·0516
19	"	" S.B.M. ..	525*		10·8		01·4	·0532
20	"	" Pend. Stn. ..	535*		10·3		01·1	·0531
21	"	Hāthras Pend. Stn. ..	587*		36·9		03·4	·0713
22	"	Aligarh Pend. Stn. ..	612*		53·5		00·5	·0745
23	"	" S.B.M. ..	612*		54·4		04·4	·0756
24	"	" P.W.D. I.H. ..	612*	27	54·3	78	04·5	·0760
25	53 H	Khurja Pend. Stn. ..	649*	28	14·3	77	51·9	·0803
26	"	Bhur P.W.D. I.H. ..	669		24·6		50·0	·0954
27	"	Hāpur P.W.D. I.H. ..	694		44·0		46·7	·1410
28	"	Sikandrābād P.W.D. I.H.	672		27·3		42·1	·1094
29	"	Ghaziābād P.W.D. I.H. ..	691*	28	40·2		25·1	·1346
30	53 G	Meerut S.B.M. ..	737*	29	00·0		42·5	·1503
31	53 H	New Delhi Imperial Hotel porch	695*	28	37·5	77	13·1	979·1371
		Mean with regard to sign						
		Mean without regard to sign						
		Range						

* Spirit-levelled heights. Other heights are approximate.
† $g-\gamma_B = g-\gamma_A$ — attraction of topography up to zone O.
‡ Modified $g-\gamma_B = g-\gamma_B$ — effect of T+C for zones 18—1.

Lucknow and New Delhi via Cawnpore, 1950

HELMERT'S FORMULA					INTERNATIONAL FORMULA	
$g - \gamma_A$	$g - \gamma_B$†	Modified $g - \gamma_B$‡	Hayford's compensation 113·7 km.	Heiskanen-Airy compensation T = 30 km.	Hayford's compensation 113·7 km.	Heiskanen-Airy compensation T = 30 km.
mgals.	*mgals.*	*mgals.*	*mgals.*	*mgals.*	*mgals.*	*mgals.*
−66·9	−79·0	−48·3	−39·5	−48·2	−56·5	−65·2
−65·4	−78·3	−47·6	−38·0	−47·5	−55·0	−64·5
−66·5	−79·4	−48·7	−39·1	−48·6	−56·1	−65·6
−52·2	−65·0	−35·6	−26·1	−35·5	−43·1	−52·5
−42·6	−56·1	−29·4	−19·4	−27·2	−36·4	−44·2
−41·2	−54·5	−29·1	−19·1	−26·8	−36·1	−43·8
−41·4	−54·7	−29·3	−19·3	−27·0	−36·3	−44·0
−35·8	−49·1	−23·7	−13·7	−21·4	−30·7	−38·4
−37·4	−50·7	−25·3	−15·3	−23·0	−32·3	−40·0
−39·5	−52·8	−27·4	−17·4	−25·1	−34·4	−42·1
−50·5	−65·2	−38·7	−28·0	−35·9	−45·0	−52·9
−45·8	−61·3	−34·6	−23·2	−31·1	−40·2	−48·1
−41·8	−58·6	−33·5	−21·0	−28·2	−37·9	−45·1
−44·7	−60·9	−33·9	−22·1	−29·9	−38·9	−46·8
−38·1	−55·2	−31·9	−18·7	−25·1	−35·7	−42·1
−36·6	−53·7	−30·4	−17·2	−23·6	−34·2	−40·6
−29·9	−47·3	−24·5	−11·1	−17·5	−28·0	−34·4
− 3·3	−20·9	+ 0·9	+15·6	+10·1	− 1·3	− 6·8
− 5·1	−22·1	− 0·3	+14·4	+ 8·9	− 2·5	− 8·0
− 3·5	−20·7	+ 1·1	+15·8	+10·3	− 1·1	− 6·6
−13·3	−31·9	− 6·0	+ 8·2	+ 1·0	− 8·7	−15·9
−28·4	−48·2	−20·1	− 5·4	−13·0	−22·2	−29·8
−28·4	−48·2	−20·1	− 5·4	−13·0	−22·2	−29·8
−28·9	−48·7	−20·6	− 5·9	−13·5	−22·7	−30·3
−45·0	−65·8	−36·0	−20·5	−27·1	−37·3	−43·9
−40·9	−62·1	−30·1	−14·4	−22·7	−31·2	−39·5
−17·6	−39·2	− 6·7	+10·3	+ 5·1	− 6·4	−11·6
−29·9	−51·1	−21·1	− 5·2	−13·0	−22·0	−29·6
−20·7	−42·2	− 8·7	+ 7·9	− 3·7	− 8·8	−20·4
−24·2	−46·9	− 8·2	+10·2	+ 0·2	− 6·5	−16·5
−13·2	−34·9	− 3·9	+13·1	+ 5·6	− 3·6	−11·1
−34·8	−51·7	−24·2	−11·3	−18·9	−28·2	−35·8
34·8	51·7	24·4	17·4	21·6	28·2	35·8
63·6	58·7	49·8	55·3	58·9	55·4	59·0

TABLE 3.—*Gravity Anomalies of Bombay*

Serial No.	No. of Pendulum Station	Sheet No.	Stations	Height	Latitude (from 1-inch maps)		Longitude (from 1-inch maps)		g (observed value)**
				feet	°	′	°	′	*gals.*
1		47 A	Bombay Santa Cruz Air Port ..	12	19	05·1	72	50·9	978·6571
2		47 B	„ Airlines Hotel	20	18	55·9		49·5	·6382
3		„	„ Apollo Bandar	20		55·2		50·2	·6346
4	3	„	„ Colāba Observatory connecting Walk Pend. Stn.	34*		53·7		48·9	·6341
5		„	„ Colāba G.T.S. B.M. ..	34*		53·7		48·9	·6348
6		„	„ Air India office, Mahatma Gandhi road	20	18	56·2		50·2	·6371
7		47 A	P-1 Thāna T.B. ..	30	19	11·7	72	58·8	·6137
8	278	47 F	P-2 Panvel Pend. Stn.	40*	18	58·6	73	07·1	·5450
9		„	P-3 Pen T.B. ..	31*		44·1	73	05·7	·5135
10		47 B	P-4 Mile-post 10 from Alībāg to Pen ..	20		41·2	72	59·0	·5310
11		„	P-5 Alībāg Mag. Obsy.	20*		38·7	72	52·1	·5530
12		47 F	P-6 Mile-post 29/3 from Alībāg	240		46·4	73	13·8	·4923
13		„	P-7 Khapoli M.S. 60 from Alībāg ..	280		47·1		21·0	·4770
14		„	P-8 Milestone 76, 2 miles N. of Lonāvla ..	2030		45·6		26·5	·3689
15		„	P-9 Mile-post 85/3 ..	2010		45·5		34·5	·3675
16	228	„	P-10 Talegaon Pend. Stn.	2060*		44·0		40·7	·3695
17		„	P-11 Napier Hotel, Poona	1860		31·2		52·9	·3678
18		„	P-12 Poona S.B.M. 53 P.P.	1867*		30·9		53·0	·3691
19		„	P-13 Poona Bund Garden	1805		32·4		53·3	·3746
20		„	P-14 Kirkee S.B.M. 45 P.P.	1855*		33·6		50·8	·3712
21		„	P-15 Poona 55 P.P. ..	1905*		30·4		53·1	·3663
22		„	P-16 Mile-post 100 to Bombay on Bombay–Poona road ..	2025		40·1		46·1	·3686
23		„	P-17 Mile-post 55 to Bombay on Bombay–Poona road ..	170	18	53·9		14·6	·5118
24		47 E	P-18 Mile-post 34 to Bombay on Bombay–Poona road ..	59	19	06·6	73	03·9	978·5666
			Mean with regard to sign ..						..
			Mean without regard to sign						..
			Range						..

* Spirit-levelled heights. Other heights are approximate.
** By Worden gravimeter.
† $g-\gamma_B = g-\gamma_A$ — attraction of topography up to zone O.
‡ Modified $g-\gamma_B = g-\gamma_B$ — effect of T + O for zones 18 – 1.

series of gravimeter stations, 1951

Helmert's Formula					International Formula	
$g-\gamma_A$	$g-\gamma_B$†	Modified $g-\gamma_B$‡	Hayford's compensation 113·7 km.	Heiskanen-Airy compensation T = 30 km.	Hayford's compensation 113·7 km.	Heiskanen-Airy compensation T = 30 km.
mgals.	*mgals.*	*mgals.*	*mgals.*	*mgals.*	*mgals.*	*mgals.*
+76·4	+76·0	+69·8	+77·5	+80·3	+59·5	+62·3
+66·8	+66·1	+59·2	+66·6	+69·8	+48·6	+51·8
+63·9	+63·2	+56·3	+63·7	+66·9	+45·7	+48·9
+66·1	+64·9	+58·0	+66·2	+70·2	+48·2	+52·2
+66·8	+65·6	+58·7	+66·9	+70·9	+48·9	+52·9
+65·4	+64·7	+57·8	+65·0	+68·2	+47·0	+50·2
+28·6	+27·6	+22·2	+32·6	+36·2	+14·6	+18·2
−27·0	−28·4	−33·5	−19·6	−14·6	−37·6	−32·6
−46·1	−47·2	−53·0	−38·3	−32·5	−56·3	−50·5
−27·0	−27·7	−34·3	−23·0	−18·2	−41·0	−30·2
− 2·7	− 3·4	−10·6	− 2·4	+ 1·3	−20·4	−16·7
−49·6	−57·9	−62·9	−44·9	−37·4	−62·9	−55·4
−61·9	−69·4	−73·6	−49·9	−39·7	−67·9	−57·7
− 3·9	−73·8	−77·6	−45·7	−37·7	−63·7	−55·7
− 7·1	−76·3	−79·7	−42·1	−32·5	−60·1	−50·5
+ 0·9	−70·1	−73·1	−32·6	−21·5	−50·6	−39·5
− 8·0	−72·1	−75·0	−32·1	−18·4	−50·1	−36·4
− 5·7	−70·0	−73·0	−29·9	−16·2	−47·9	−34·2
− 7·4	−69·6	−72·5	−29·9	−16·3	−47·9	−34·3
− 7·1	−71·0	−73·9	−32·4	−19·4	−50·4	−37·4
− 4·5	−70·2	−73·0	−30·1	−17·3	−48·1	−35·3
−10·3	−69·5	−72·3	−30·7	−19·3	−48·7	−37·3
−43·6	−49·5	−54·2	−34·8	−27·4	−52·8	−45·4
−11·1	−13·1	−18·2	− 6·3	− 2·2	−24·8	−20·2
+ 5·1	−21·3	−26·2	− 3·6	+ 3·9	−21·6	−14·1
31·2	57·0	58·0	40·1	34·8	47·6	42·2
138·3	152·3	149·5	127·4	120·0	127·4	120·0

TABLE 4.—*Gravity Anomalies of Madras*

Serial No.	No. of Pendulum Station	Sheet No.	Stations	Height	Latitude °	Latitude ′	Longitude °	Longitude ′
					(from 1-inch maps)			
				feet	°	′	°	′
1		66 C	M-1 Mile-post 7 on Madras–Calcutta road	23	13	08·5	80	13·3
2		"	M-2 Mile-post 16 on Madras–Calcutta road	48		15·0		09·4
3		"	M-3 Mile-post 20/6 Gummidipundi B.M.	45*		23·8		08·0
4		"	M-4 Mile-post 37	24*		32·1		04·4
5		"	M-5 Mile-post 49 Sūlūrpet G.T.S. B.M. ..	24*		41·5	80	00·9
6		57 O	M-6 Milestone 54	34*		45·2	79	58·9
7		"	M-7 Milestone 64	114*	13	52·9		58·3
8		57 N	M-8 Milestone 74	111*	14	00·8		54·1
9		"	M-9 Gūdūr Sub-Registrar's office ..	40		08·8		50·8
10	177	"	M-10 Gūdūr Pendulum station ..	49*		08·6		50·9
11		"	M-11 Gūdūr Railway station ..	40		08·8		50·8
12		"	M-12 Gūdūr Police station	37*		08·6		50·8
13		"	M-13 Mile-post 34 from Erpedu on road Gūdūr to Venkatagiri	99		07·2		44·9
14		"	M-14 Mile-post 26 from Erpedu on road Gūdūr to Venkatagiri	125	14	02·9		39·1
15		57 O	M-15 Mile-post 19 from Erpedu on road Gūdūr to Venkatagiri	240	13	56·7		36·4
16		"	M-16 Mile-post 8	265		48·5		35·3
17		"	M-17 Erpedu T.B.	295		41·5		35·3
18		"	M-18 Renigunta Railway station ..	369		38·1		30·6
19	199	"	M-19 Renigunta Pendulum station ..	365*		38·1		30·4
20		"	M-20 Mile-post 31 on Arkonam road ..	550		29·0		32·3
21		"	M-21 Nagari Railway station ..	395		18·3		34·9
22		"	M-22 Mile-post 50/3 on shortest road to Madras	240		11·0		37·4
23		"	M-23 Mile-post 42	160		12·2		44·7
24		"	M-24 Mile-post 27/5 at Tiruvallūr R.S.	152		06·9	70	54·9
25		66 C	M-25 Mile-post 14	80		02·8	80	05·3
26		"	M-26 Madras Central Railway station ..	25	13	05·0		16·6
27		66 D	Madras Air Port	40	12	59·7		10·8
28	2	66 C	Madras Pendulum station	20	13	04·1		14·9
29		"	Madras Connemara Hotel	20		03·7	80	15·8
30		57 O	Arkonam Junction, Railway station ..	293	13	04·8	79	40·2
				Mean with regard to sign ..				
				Mean without regard to sign				
				Range				

* Spirit-levelled heights. Other heights are approximate.

** By Worden gravimeter.

† $g-\gamma_B = g-\gamma_A$ — attraction of topography up to zone O.

‡ Modified $g-\gamma_B = g-\gamma_B$ — effect of T+C for zones 18—1.

series of gravimeter Stations, 1951

g (observed value) **	Helmert's Formula					International Formula	
	$g - \gamma_A$	$g - \gamma_B$ †	Modified $g - \gamma_B$ ‡	Hayford's compensation 113·7 km.	Heiskanen-Airy compensation T = 30 km.	Hayford's compensation 113·7 km.	Heiskanen-Airy compensation T = 30 km.
gals.	*mgals.*	*mgals.*	*mgals.*	*mgals.*	*mgals.*	*mgals.*	*mgals.*
978·2791	−15·5	−15·2	−40·0	− 61·3	−47·3	− 79·8	− 65·8
·2627	−33·9	−34·3	−58·6	− 75·5	−61·7	− 94·0	− 80·2
·2476	−55·2	−55·5	−79·2	− 95·4	−81·6	−113·9	−100·1
·2434	−66·9	−66·8	−89·2	−102·1	−89·2	−120·6	−107·7
·2743	−42·5	−42·5	−64·1	− 74·5	−61·6	− 93·0	− 80·1
·3030	−15·4	−15·8	−36·8	− 47·1	−34·5	− 65·6	− 53·0
·3059	−10·4	−13·7	−33·9	− 40·7	−28·2	− 59·2	− 46·7
·3095	−12·7	−15·9	−35·3	− 41·4	−29·4	− 59·8	− 47·8
·3101	−24·4	−25·3	−43·9	− 49·0	−37·6	− 67·4	− 56·0
·3099	−23·6	−24·8	−43·4	− 48·5	−37·1	− 66·9	− 55·5
·3101	−24·4	−25·3	−43·9	− 49·0	−37·6	− 67·4	− 56·0
·3107	−23·9	−24·7	−43·3	− 48·4	−37·0	− 66·8	− 55·4
·3181	− 9·7	−12·7	−31·0	− 31·6	−19·8	− 50·0	− 38·2
·2754	−46·9	−51·0	−69·1	− 65·6	−53·4	− 84·0	− 71·8
·2535	−53·5	−61·6	−79·4	− 72·4	−59·7	− 90·9	− 78·2
·2438	−55·2	−64·1	−81·9	− 73·8	−61·1	− 92·3	− 79·6
·2358	−55·6	−65·6	−83·4	− 74·3	−61·2	− 92·8	− 79·7
·2325	−49·5	−62·1	−80·0	− 67·1	−53·3	− 85·6	− 71·8
·2328	−49·6	−62·0	−79·9	− 67·0	−53·2	− 85·5	− 71·7
·2228	−36·0	−54·7	−73·7	− 61·7	−48·5	− 80·2	− 67·0
·2338	−32·4	−45·9	−66·2	− 57·1	−43·4	− 75·6	− 61·9
·2435	−32·3	−40·4	−62·5	− 56·0	−42·2	− 74·5	− 60·7
·2400	−44·2	−49·4	−71·4	− 69·2	−55·1	− 87·7	− 73·6
·2407	−40·7	−45·5	−69·3	− 73·6	−59·4	− 92·1	− 77·9
·2640	−21·5	−23·2	−47·8	− 60·5	−46·3	− 79·0	− 64·8
·2858	− 6·2	− 6·0	−31·4	− 53·2	−39·5	− 71·7	− 58·0
·2818	− 5·3	− 5·6	−31·0	− 48·5	−34·0	− 67·0	− 52·5
·2837	− 8·3	− 7·9	−33·3	− 55·0	−41·1	− 73·5	− 59·6
·2855	− 6·2	− 5·8	−31·2	− 53·0	−39·3	− 71·5	− 57·8
978·2399	−26·8	−36·6	−57·7	− 52·9	−39·7	− 71·4	− 58·2
..	−31·0	−35·3	−56·4	− 60·8	−47·8	− 79·3	− 66·3
..	31·0	35·3	56·4	60·8	47·8	79·3	66·3
..	61·6	61·2	58·2	70·5	69·4	70·6	69·5

TABLE 5.—*Gravimeter stations between Mussoorie and Delhi*

Serial No.	Sheet No.	Stations	Height	Latitude (from 1-inch maps)		Longitude (from 1-inch maps)		g -(meter factor 0·0817)	Helmert's Formula $g-\gamma_B$	Helmert's Formula Hayford's Compensation 113·7 km.
			feet	°	′	°	′	*gals.*	*mgals.*	*mgals.*
1	53 J	Mussoorie Pend. Stn.	6924	30	27·6	78	04·5	978·7918	−125·2	+53·0
2	,,	Bhatta B.M. 201 ..	5122		26·2		04·8	·9054	−138·5	+32·8
3	,,	Kulukhet B.M. 178/126	4151		25·0		04·9	978·9582	−137·4	+30·8
4	,,	Rajpur Pend. Stn. ..	3321		24·0		05·1	979·0030	−146·8	+28·6
5	,,	Dehra Dūn Pend. Stn.	2239		19·5	78	03·4	·0330	−148·6	+ 2·9
6	53 F	Fatehpur D.B. B.M.	985	30	02·8	77	45·8	·1348	−131·5	−30·8
7	53 G	Saharanpur S.B.M. ..	900	29	57·3		33·5	·1584	−105·9	−19·3
8	,,	Roorkee Pend. Stn. ..	887		52·3		54·0	·1289	−130·7	−38·2
9	,,	Muzaffarnagar P.W.D. I.B. ..	808		27·9		41·8	·1484	− 83·1	−12·6
10	,,	Ghasipur B.M. 133 ..	787		22·2		42·5	·1466	− 78·9	−11·0
11	,,	Khatauli B.M. 154 ..	769		16·5		43·9	·1418	− 77·5	−13·0
12	,,	Daurala B.M. 169 ..	751		07·8		42·9	·1431	− 66·0	− 5·4
13	,,	Meerut S.B.M. ..	737	29	00·0		42·1	·1503	− 49·7	+ 8·1
14	53 H	Mohiuddinpur B.M. 149 ..	716	28	53·5		37·3	·1470	− 46·0	+ 8·9
15	,,	Muradnagar B.M. 165	705		46·2		30·8	·1435	− 40·8	+10·9
16	,,	Delhi Pend. Stn. ..	715		41·4		12·9	·1464	− 31·2	+16·8
17	,,	Ghaziābād P.W.D. I.H.	691		40·2		25·1	·1346	− 42·2	+ 7·9
18	,,	New Delhi Imperial Hotel porch ..	695		37·5		13·1	·1371	− 34·9	+13·1
19	53 H	Delhi Qutab Minar (Ground) ..	805	28	31·5	77	11·2	979·1258	− 33·9	+12·0

CHAPTER VI

COMPUTATIONS AND PUBLICATIONS

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

40. **Adjustment of Topographical Triangulation in India.**— During the period under report, the Computing Office remained busy with the reduction of the results of the field operations. The shortage of trained personnel still continues and it has not yet been possible to employ a sufficient number of computers on the scrutiny of the records of topographical triangulation, its adjustment and compilation of the results into pamphlets for publication. There is a huge mass of data covering the whole of India and the progress made so far in sorting it out has been extremely slow. Only three pamphlets have been printed in a period of about 4 years and material has been collected and scrutinized for the publication of two others. Efforts are being made to increase the number of computers and it is hoped that the out-turn will increase in due course.

41. **Triangulation in Irāq and Irān.**—Triangulation in Irāq and Irān was carried out by Indian military survey units during World Wars I and II, by the Irāq Survey Department and by the Anglo-Irānian Oil Company. Brief details of the triangulation are given in Technical Report 1947, Part III, paras 46 to 49. The data is being published in pamphlets, each pamphlet generally covering an area of one degree of latitude by one degree of longitude. The preface to each pamphlet gives an account and details of the adjustment of the various series included in it. 28 pamphlets have been published so far out of an estimated total of about 80 pamphlets and one is under preparation.

42. **Computations.**— The results of the following field observations were computed :—

(i) Observations of the geodetic triangulation in Andamans, and

(ii) Secondary levelling for Bhakra Dam Project in the Punjab (I) and Delhi States, for the Chambal Irrigation project in Rājasthān, and for the Son Canal Project in Bihār.

A narrative account of the geodetic triangulation is given in Chapter I and that of levelling in Chapter III.

A good deal of work on the estimation of heights at old pendulum stations and new gravimetric stations for the calculation of gravity anomalies on different hypotheses has also been carried out.

43. **Survey Star Almanac.**—During the period immediately following the World War II great difficulty was experienced in procuring the Nautical Almanacs from the United Kingdom and it was decided to bring out a Survey Star Almanac for the use of civil and military survey units. The first issue of this pamphlet for 1945 was published in 1944. Star places for the whole year for all stars down to magnitude 3·5 and selected stars to magnitude 4·0 were included. Declinations were printed to the nearest second of arc and right ascensions to the nearest tenth of time for the middle of each month. Circumpolar stars (and Ursa Minoris) were given separately for every fifth-day. Tables of phases of the Moon and azimuth of Polaris were also included. Two star charts were given at the end. This publication was very handy and was found to fulfil a great need. Its publication was continued till 1951. Since then Her Majesty's Stationery Office, London has brought out "Star Almanac for Land Surveyors" which contains all the information included in the Survey of India Star Almanac. The publication of the Survey Star Almanac has, therefore, been discontinued. Copies of the "Star Almanac for Land Surveyors" can be obtained in India through the Librarian, British Information Services, Mansingh Road, New Delhi.

44. **Technical Papers.**—During the period under report one addition has been made to the series of Technical Papers of the Survey of India. Technical Paper No. 5 "Geodetic and Geophysical Aspects of the Earthquakes in Assam" reviews the geodetic and geophysical work carried out in the area after the great earthquake of 1897 and proposals are made for similar work to be carried out to study the effects of the great earthquake of 1950.

45. **Heights of Himālayan Snow-peaks.**—The mighty expanse of the Himālayas contains a number of peaks much higher than those in any other part of the world. The heights of these peaks have not been determined sufficiently accurately. For example it is not known to what extent the value 29,002 feet adopted for the height of Mount Everest is wrong.

It is on the programme of the Survey of India to re-observe the height of Mount Everest during October and November 1952 from a distance of about 20 to 25 miles with precise instruments.

46. **Computation of Heights observed with Paulin Barometers.**—As mentioned in Technical Report 1948–49, Part III, page 96 observations were made with four Paulin barometers in the Rāniganj and Nāgpur areas of gravimetric survey in 1948–49 for determination of the heights of gravimetric stations. The heights of these stations were also determined by spirit-levelling or tacheometric levelling. The work was of an experimental nature and was undertaken to test the performance of the Paulin barometers under field conditions and to get an idea of the accuracy obtainable with these instruments.

The results of observations at 28 stations in the Rāniganj area are given in Technical Report 1948-49, Part III, Table 1, page 98. Results of observations at 41 stations in the Nāgpur area are given in Table 1 of this Chapter. The discrepancies between the heights by Paulin's and spirit-levelling are unexpectedly large and indicate that these instruments are too delicate to withstand rough usage under field conditions. It is hoped to continue the experiment elsewhere to find out whether it is possible to develop a technique by which it would be possible to obtain better and more reliable results.

47. **Inspection of G.T. Stations.**—During the year under report 22 G.T. stations were visited by units of the Northern Circle, Survey of India, 18 stations each by units of the Eastern and Southern Circles. Four stations were reported upon by levelling detachments of the Geodetic and Training Circle.

48. **Publications Issued.**—A list of all important geodetic publications issued by the Survey of India is given at the end. The following publications were brought out during the period under report :—

1. Technical Report 1951, Part III—Geodetic Work.
2. Technical Paper No. 5 "Geodetic and Geophysical Aspects of Earthquakes in Assam".
3. Levelling Pamphlet for the use of the Commissioners for the Port of Calcutta.
4. Auxiliary Tables Part V with additions.
5. Levelling Pamphlet for 1/M sheet 45.
6. Secondary levelling pamphlets Nos. 56, 57 and 72.
7. Triangulation Pamphlet for sheet 54 A.
8. Handbook of Topography, Chapter IV—Theodolite Traversing.

TABLE 1.—*Heights by Paulin Barometers in Nāgpur Area*

1	2	3	4	5
Serial No.	Gravity Station No.	Spirit-levelled heights	Heights derived by Paulin aneroids	Difference Col. 3−Col. 4
		feet	*feet*	*feet*
	Sheet 55 N			
1	G 1 ..	2077	2048	+29
2	G 2 ..	1859	1853	+06
3	G 3 ..	2084	2061	+23
4	G 4 ..	2004	1995	+09
5	G 5 ..	1899	1885	+14
6	G 6 ..	2027	2015	+12
7	G 7 ..	1594	1577	+17
8	G 8 ..	1500	1499	+01
9	G 9 ..	1737	1731	+06
10	G 10 ..	1567	1578	−11
11	G 11 ..	1545	1558	−13
12	G 12 ..	1586	1565	+21
13	G 14 ..	1761	1756	+05
14	G 15 ..	1739	1729	+10
15	G 16 ..	1151	1163	−12
	Sheet 55 O			
16	G 10 ..	1020	984	+36
17	G 12 ..	1069	1078	−09
18	G 17 ..	955	981	−26
19	G 21 ..	885	901	−16
20	G 22 ..	1089	1098	−09
	Sheet 64 B			
21	G 1 ..	1483	1466	+17
22	G 2 ..	1438	1432	+06
23	G 3 ..	1674	1658	+16
24	G 4 ..	1170	1174	−04
25	G 5 ..	1633	1617	+16
26	G 6 ..	1918	1903	+15
27	G 7 ..	1661	1667	−06
28	G 8 ..	1106	1098	+08
29	G 9 ..	1905	1875	+30
30	G 10 ..	2001	1993	+08
31	G 11 ..	1829	1842	−13
	Sheet 64 C			
32	G 1 ..	1065	1072	−07
33	G 2 ..	1040	1053	−13
34	G 3 ..	1883	1889	−06
35	G 4 ..	2049	2049	00
36	G 5 ..	998	1017	−19
37	G 6 ..	995	1030	−35
38	G 7 ..	1959	1963	−04
39	G 8 ..	1927	1906	+21
40	G 11 ..	951	989	−38
41	G 18 ..	1019	1058	−39

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.*
13.	Geodetic Report Vol. III	1926–27. The International Longitude Project. Computations and Publication of data. Observatories. Tides. Gravity and Deviation of the Vertical. Triangulation. Levelling. Research and Technical Notes regarding Personal Equation Apparatus and the height of Mount Everest. Dehra Dūn, 1929. *Price Rs. 3.*
14.	Geodetic Report Vol. IV	1927–28. Computations and Publication of data. Observatories. Tides. Gravity and Deviation of the Vertical. Triangulation. Levelling. Dehra Dūn, 1929. *Price Rs. 3.*
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.*

No.	*Name of Book*	*Details*
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.*
22.	Geodetic Report 1936	Triangulation. Levelling. Deviation of the Vertical. Gravity. Computing Office and Tidal Section. Observatories. Subsoil Water Levels. Levelling in Bengal and Bihār. Dehra Dūn, 1937. *Price Rs. 3.*
23.	Geodetic Report 1937	Triangulation. Levelling. Gravity. Magnetic Survey in Bihār. Computing Office and Tidal Section. Observatories. Dehra Dūn, 1938. *Price Rs. 3.*
24.	Supplement to Geodetic Report 1937	Isostatic reductions of Indian Gravity Stations. Dehra Dūn, 1939. *Price Rs. 2-8.*
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.*

No.	*Name of Book*	*Details*
28.	Technical Report 1947, Part III, Geodetic Work	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 1948–49, Part III, Geodetic Work	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, 1950, Part III, Geodetic Work	Triangulation and Base Measurement. Levelling. Gravity. Deviation of the Vertical. Tides. Observatories. Computations and Publications. Dehra Dūn, 1951. *Price Rs. 4.*
31.	Technical Report 1951, Part III, Geodetic Work	Triangulation and Base Measurement. Observatories. Levelling. Tides. Deviation of the Vertical. Gravity. Computations, Publications and Training. Dehra Dūn. 1952. *Price Rs. 6.*
32.	Technical Report 1952, Part III, Geodetic Work	Triangulation, Observatories. Levelling. Tides. Gravity. Computations and Publications. Dehra Dūn, 1953. *Price Rs. 6.*
33.	Report on the Geodetic Work for 1924–27	Report on the Geodetic Work of the Survey of India for the period 1924–27—Presented at the Third general meeting of the Section of Geodesy, Prague, Dehra Dūn, 1927. *Price Re. 1.*
34.	Report on the Geodetic Work for 1927–30	Report on the Geodetic Work of the Survey of India for the period 1927–30—Presented at the Fourth general meeting of the Section of Geodesy, Stockholm, Dehra Dūn, 1930 *Price Rs. 1-12.*
35.	Report on the Geodetic Work for 1930–33	Report on the Geodetic Work of the Survey of India for the period 1930–33—Presented at the Fifth general meeting of the Geodetic Association, Lisbon, 1933. *Price As. -/6/-.*
36.	Report on the Geodetic Work for 1933–39	Report on the Geodetic Work of the Survey of India for the period 1933–39—Presented at the Seventh general meeting of the Geodetic Association, Washington, 1939. *Price Re. 1.*

No.	*Name of Book*	*Details*
37.	Report on the Geodetic Work for 1939–48	Report on the Geodetic Work of the Survey of India for the period 1939–48—Presented at the Eighth general meeting of the Geodetic Association, Oslo, 1948. *Price Re. 1.*
38.	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.*
39.	Professional Paper No. 15	**Pendulums.** The Pendulum Operations in India and Burma, 1908–13, by Capt. H. J. Couchman, R.E. Dehra Dūn, 1915. *Price Rs. 2-8.*
40.	Professional Paper No. 16	**Geodesy.** The Earth's Axes and Triangulation, by J. de Graaff Hunter, M.A. Dehra Dūn, 1918. *Price Rs. 4.*
41.	Professional Paper No. 22	**Levelling.** Three Sources of error in Precise Levelling, by Capt. G. Bomford, R.E. Dehra Dūn, 1929. *Price Rs. 1-8.*
42.	Professional Paper No. 27	**Gravity.** Gravity Anomalies and the Structure of the Earth's Crust, by Maj. E. A. Glennie, D.S.O., R.E. Dehra Dūn, 1932. *Price Rs. 1-8.*
43.	Professional Paper No. 28	**Triangulation.** The Readjustment of the Indian Triangulation, by Maj. G. Bomford, R.E. Dehra Dūn, 1938. *Price Rs. 4-8.*
44.	Professional Paper No. 29	**Magnetic.** Magnetic Anomalies, by B. L. Gulatee, M.A. (Cantab.). Dehra Dūn, 1938. *Price Rs. 1-8.*
45.	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.*
46.	War Research Series Pamphlet No. 6	Magnetic Anomalies (India and Burma), 1944. *Price Re. 1.*
47.	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. Gulatee, M.A. (Cantab.), with an Appendix "The Persia–India Connection", by Maj. P. A. Thomas, I.E., Dehra Dūn. *Price Rs. 2.*

No.	*Name of Book*	*Details*
48.	Memoirs of The Survey Research Institute Vol. 1. No. 1	Geophysical Prospecting for Manganese near Rāmtek, C.P., by B. L. Gulatee, M.A. (Cantab.). Dehra Dūn, 1947. *Price Rs. 3.*
49.	Technical Paper No. 2	Value of Gravity at Dehra Dūn, by B. L. Gulatee, M.A. (Cantab.). Dehra Dūn, 1948. *Price Re. 1.*
50.	Technical Paper No. 3	Levelling in India, Past and Future, by B. L. Gulatee, M.A. (Cantab.). Dehra Dūn, 1949. *Price Re. 1.*
51.	Technical Paper No. 4	Mount Everest, its Name and Height, by B. L. Gulatee, M.A. (Cantab.). Dehra Dūn, 1950. *Price Rs. 1-8.*
52.	Technical Paper No. 5	Geodetic and Geophysical aspects of the earthquakes in Assam, by B. L. Gulatee, M.A. (Cantab.), F.R.I.C.S., M.I.S. (IND.). Dehra Dūn, 1951. *Price Rs. 1-8.*
53.	Technical Paper No. 6	The Aravalli Range and its Extensions, by B. L. Gulatee, M.A. (Cantab.), F.R.I.C.S., M.I.S. (IND.), Dehra Dūn, 1952. *Price Rs. 2.*

(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, pp. 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, pp. 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).
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).

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

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

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

No.	Details
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, pp. 182–189).
8.	*Isostasy in India, by Lt.-Colonel E. A. Glennie, D.S.O., R.E. (Gerlands Beiträge Zur Geophysik, Vol. 43, No. 4, 1935).
9.	‡The Figure of the Earth from Gravity Observations and the Precision Obtainable, by J. de Graaff Hunter, C.I.E., SC.D. (Philosophical Transactions, Royal Society, Series A, Vol. 234, 1935).
10.	§On the Subterranean Mass-Anomalies in India, by B. L. Gulatee, M.A. (Cantab.), (Proceedings of the Academy of Sciences, Allahabad, U.P., India, Vol. 5, Sept. 1935).
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).
12.	*The Boundary Problems of Potential Theory & Geodesy, by B. L. Gulatee, M.A. (Cantab.), (Gerlands Beiträge Zur Geophysik, Vol. 46, pp. 91–98, 1936).
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. 453–459).
15.	Standards of Measurement, by B. L. Gulatee, M.A. (Cantab.), (Journal of Scientific and Industrial Research, Vol. V, No. 3, Sept. 1946, pp. 104–105).
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. 311–314).
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. 215–217).
18.	Future of Geophysics in India, by B.L. Gulatee, M.A. (Cantab.), (Journal of Scientific and Industrial Research, Vol. VI, No. 2, Feb. 1947, pp. 53–59 & 71).

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

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

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

§ Obtainable from the Academy of Sciences, U.P., Allahabad.

No.	*Details*
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. 1947, pp. 20–24).
20.	Practical application of the Laplace Longitude—Azimuth relation to control of Geodetic Anomalies, by J. de Graaff Hunter, C.I.E., SC.D., F.R.S. (Empire Survey Review, Vol. IX, No. 65, July 1947, pp. 131–134).
21.	The Level net of India and its datum, by B. L. Gulatee, M.A. (Cantab.), (Journal of the Central Board of Irrigation Vol. 5, No. 1, January 1948, pp. 44–50 & 65).
22.	Geodetic Work in India—War and Post War, by B. L. Gulatee, M.A. (Cantab.), (Empire Survey Review, Vol. X, No. 77, July 1950, pp. 302–306).
23.	Topographic-Isostatic Effect of outer Hayford Zones by B. L. Gulatee, M.A. (Cantab.), (Bulletin Geodesique—Nouvelle Series, Annee 1949, No. 12 fer Juin, 1949, pp. 180–183).
24.	Tidal Activities of the Survey of India, by B. L. Gulatee, M.A. (Cantab.), [Assoc. Oceanog. Phys. Proces—Verbaux No. 4, pp. 108–110 (1949)].
25.	On the Need for More Permanent Tide-Gauge Observatories in India, by B. L. Gulatee, M.A. (Cantab.), (Journal of Scientific and Industrial Research, Vol. VII, No. 12, Dec. 1948, pp. 517–520).
26.	Connection of India, Siam and Malaya Triangulations, by B. L. Gulatee, M.A. (Cantab.), (Empire Survey Review, Vol. X, No. 74, October 1949, pp. 175–181).
27.	Trigonometrical Heights and the Coefficient of Terrestrial Refraction, by B. L. Gulatee, M.A. (Cantab.), F.R.I.C.S., M.I.S. (India), (Empire Survey Review, Vol. XI, No. 83, January 1952, pp. 224–230.
28.	Heights of Himālayan Snow-Peaks, by B. L. Gulatee, M.A. (Cantab.), F.R.I.C.S., M.I.S. (India), (Indian Journal of Meteorology and Geophysics, Vol. 3, No 3, July 1952, pp. 165-172).
29.	Tidal Work in India, by B. L. Gulatee, M.A. (Cantab.), F.R.I.C.S., M.I.S. (India), [Assoc. Oceanog. Phys. Proces-Verbaux No. 5, pp. 178–180 (1952)].

G. & T.C.—P.O.—J.S. 387—8-12-52—250 bks.