SURVEY OF INDIA

TECHNICAL REPORT
1947

PART III—GEODETIC WORK

PUBLISHED BY ORDER OF
THE SURVEYOR GENERAL OF INDIA

COMPILED AT THE SURVEY RESEARCH INSTITUTE
AND
PRINTED AT THE OFFICE OF THE GEODETIC BRANCH,
SURVEY OF INDIA, DEHRA DŪN, INDIA 1948.

Price Four Rupees, or Six Shillings

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INTRODUCTION

1. Up till 1943 the geodetic work of the Survey of India was the responsibility of the Director, Geodetic Branch, who looked after this work in addition to his other duties such as the administration and direction of Topographical Surveys, Cantonment Surveys, Drawing and Forest Map Offices, Printing and Photo-Zinco Sections and the Survey Stores Organization. The geodetic activities had been greatly curtailed since 1931 due to financial stringency and remained almost in abeyance during the World War II.

With the entry of Japan into the War, geodetic problems connected with the promotion of the War effort greatly increased and in 1943 the Government of India sanctioned the creation of a War Survey Research Institute to deal with these problems. The continuance of this Survey Research Institute on a permanent basis was sanctioned with effect from 2nd December 1946.

2. An account of the geodetic work of the Survey of India has been published in the annual Geodetic Reports, issued from 1925 to 1940. The 1940 report was brought out during the war conditions when considerations of paper economy restricted its size and no time was available to interpret the results due to preoccupation with more urgent war work. It was therefore necessarily a very brief one and was only designed to place on record the more important items of geodetic work to safeguard against the risk of their being forgotten altogether. The present report includes all information of geodetic interest which accumulated during the period 1st October 1939 to 30th September 1947 and which is not reported in the 1940 Report. The following is a very brief review of the contents of this Report.

3. *Triangulation in the neighbouring countries of India.*—(Chapter I). Important gaps between the triangulation of India and its neighbouring countries have been filled during World War II and a continuous chain of triangulation now exists from Syria to Malaya. Its extension to Australia in the East and to European triangulation in the West is a problem of considerable interest to the geodesists and the work executed during the late war has brought it appreciably nearer fulfilment.

Apart from errors of observations, the actual discrepancies at the junctions of the various countries are due to differences of spheroids and datums. They will be a source of confusion to the topographers and the military operating in these areas as the maps of the neighbouring countries and the grids on them will be out of tune. The adoption of a universal spheroid and the reduction to one common datum with a view to getting all surveys in the same terms is the obvious solution but the amount of effort and resources required make it prohibitive.

4. *Levelling.*—(Chapter II). Work on the levelling of High Precision remained in abeyance from 1941 to 1945. In 1946–47, one detachment worked from Bombay to Ratnāgiri and added 338 miles of single levelling to the new High Precision level net commenced in 1913–14. This net when completed is expected to comprise of 15800 miles of levelling of which about 5,000 miles (10,000 miles of single levelling) still remain to be done.

An important achievement has been the connection of the Indo-Burma levelling to that of Siamese levelling by No. 2 Indian Field Survey Company. A direct connection of Amherst Tidal observatory, the datum of levelling in Burma, to Koh Hlak, the Siamese datum, appears desirable.

5. *Gravity.*—(Chapter III). The old method of observations with the pendulums involving a cumbersome procedure has now given place to differential instruments called the gravimeters, which yield much more precise results. A Frost gravimeter has been acquired and the intention is to establish a 10-mile grid of gravity stations as against the existing 70-mile grid. This might enable us to distinguish curiosities within the first ten miles of the earth's crust for intensive study and might guide us to the selection of regions for intensive detailed work. These gravimeter stations will also serve as reference bench-marks for detailed local geophysical prospecting. The instrument is being used on a systematic programme of gravity observations in Raniganj Coalfields area of Bengal and in an area north of Nagpur. These areas have been recommended by the Mineral Adviser to the Government of India as suitable for exploratory work connected with prospecting for minerals by geophysical methods. The observations are being combined with work with Magnetic variometers, which is expected to yield much valuable confirmatory evidence of the existence of buried deposits. Details of observations and results will be published in the next Technical Report.

A gravity survey of the neighbouring seas of India is most desirable to elucidate the complex nature of the geoid in India and it will incidentally help in several other important problems.

6. *Deviation of the Vertical.*—(Chapter IV). The results of the observations made in 1940–41 in north-western parts of India (already reported in Geodetic Report 1940) are discussed and the charts of the Geoid and Compensated Geoid in India have been redrawn. A chart showing the circuit errors of the geoidal sections has been included. It is intended to strengthen some of the weaker sections in the near future.

In Chapter I are discussed the triangulation systems between India and Australia and the gaps there in. It is also most desirable that there should be a geoidal section available for this stretch. The Indian section of the geoid at present extends from the Persian

Frontier through Bengal to Victoria Point (the extreme south of Burma) and its extension some day to Australia is indicated. Our observations from Mandalay to Victoria Point in 1937–38 point to an extraordinarily large rise of the geoid towards the south. The islands between Java and Australia are regions where presumably active phenomena are going on in the earth's subcrust and geoidal rise is likely to be considerable there too. With the junction of Siamese triangulation with Malaya, it is of great interest that the Siamese should do a geoidal section from Victoria Point to the northern edge of Malaya and the Malayans should extend it in the north-west to south-easterly direction in their country.

7. *Computing Office.*—(Chapter V). The main activities of the Computing Office have been the preparation of tables for and the conversion of data on different spheroids and projections to military grid systems and its publication to meet the needs of British and Indian forces in Paiforce and South East Asia Commands. The adjustment and publication of triangulation and traverse data all over India in a new series of complete data pamphlets is being contemplated but is held up for want of adequate personnel.

8. *Head-quarters Routine.*—(Chapters VI & VII). The tidal predictions, and the magnetic, seismographical and meteorological observations at Dehra Dūn have been carried on as usual.

The magnetic observatory has been out of commission since August 1943 when serious flooding of the underground chambers necessitated the removal of the instruments. The present site has now become unsuitable due to the construction of new buildings all around it and the construction of a new observatory at a site about 15 miles away from Dehra Dūn has been approved by the Government.

9. *Future programme.*—The emphasis on geodetio work has now shifted to a certain extent from the fundamental to the economic objective. There is at present an acute shortage of trained personnel and some of the instruments need modernization. Despite these handicaps a beginning has already been made with the programme, which has been in abeyance since some years now. The execution of intensive work on the determination of values of gravity at a network of stations all over India at spacing of about 10 miles, the restarting of the magnetic observatory at Dehra Dūn and the continuance of magnetic observations at Repeat Stations, the redetermination of the tidal constants to improve predictions at ports, the completion of the programme of High Precision Levelling for the new level net, and the provision of more lines of secondary levellings to meet the requirements of Central and Provincial Governments for engineering and irrigation projects are some of the items on which a start has been made.

DEHRA DŪN, *July, 1948.*

B. L. GULATEE, M.A. (CANTAB.),
President, Survey Research Institute.

Chapter I

TRIANGULATION IN THE NEIGHBOURING COUNTRIES OF INDIA

B. L. Gulatee, M. A. (Cantab.)

Section I.—Triangulation from India to Australia and Philippines (Refer to Chart I)

1. **General.**—At the triennial Conference of the International Union of Geodesy and Geophysics at Stockholm in 1930, a resolution was passed that Siam and neighbouring countries should collaborate with each other in effecting junctions between their systems of triangulation with the object of continuing, if possible the chain of triangulation to the Australian continent and the Philippines. Enquiries were addressed in 1931 to the various Governments in pursuance of this resolution and the meagre information then collected was published by the author in Survey of India Geodetic Report, Vol. VIII, Chapter VII, Section II, pages 84 to 86, and Chart XXII. More information has since become available and some new triangulation connections, notably that between the triangulations of Malaya and Siam, have been effected during World War II. As a result the earlier discussion and chart have become obsolete. A revised chart has now been incorporated in this Report as Chart I. The triangulations and their junctions with each other are described below in some detail and it is hoped that it will be possible to assess from this information how much work remains to be done to continue the triangulation chain from India to Australia and Philippines, and to complete the geodetic block Irâq, Persia, India, Burma, Siam, F.I.C., and Malaya.

2. **Siamese Triangulation.**—The Siamese compute their triangulation on Everest spheroid, but the orientation of this spheroid is not identical with that adopted by the Survey of India for the computation of the Primary triangulation of India and Burma. The datum for co-ordinates of the Siamese triangulation is the station Khao Luang of the Survey of India Bangkok secondary series, 1878–81, its co-ordinates accepted being latitude 13° 43′ 30″·34, longitude 99° 32′ 22″·94. These are unadjusted values and a correction of −1″·65 in latitude and −1″·42 in longitude was applied to them when the triangulation in Burma was adjusted in 1916, but the Siamese have retained the older unadjusted values given above.

As regards scale and azimuth the Siamese Survey rightly adopted their own fundamental values independent of the Survey of India since the latter could not be expected to be free from serious error not only on account of its great distance from the origin but also because it was based on a spheroid which does not fit the geoid very well. Scale is derived from eight measured bases, details of which are given in Table I. Of these, the bases at Sen-Seb, Puket and Nagorn Srīdharmrāj were measured prior to 1911. Their lengths depended on 2-metre standard bars and were considered to be of a low degree of accuracy. The Sen-Seb and Puket bases were not used for the control of the primary triangulation and although Nagorn Srīdharmrāj base was included, its length was regarded as doubtful and it was eventually remeasured in 1929, and was found to be 1/40,000 shorter in length than the earlier value. Its new value, however, has not yet been used by the Siamese to recompute the co-ordinates of the triangulation stations situated between Rājburi base and Nagorn Srīdharmrāj base. The other bases used for the control of primary triangulation are Rājburi, Nagorn Sawarn, Chāndhāburī and Lampang. They are measured with 25-metre invar wires which were standardized by the International Bureau of Weights and Measures at Sévres. The base at Khulu, Changwat Ubonrathani, was measured in 1937 with the object of adopting it as starting side for the Geodetic triangulation chain of Ubon-Udon. The measurement was made with two of the 25-metre invar wires, which had been used previously for the measurement of all bases from 1927 onwards. These wires were suspected to have changed their reputed lengths due to frequent use and aging with time and consequently the length of the base was regarded as provisional only till these wires were restandardized. Enquiries are being made from the Siamese Survey Department whether a restandardization has since been made and the length of the base finalized.

The fundamental azimuth adopted by the Siamese Survey is an astronomical value observed in 1910 at Khao Ngem of Khao Ngu, viz., 179° 44′ 34″·308 $\pm$0″·168. This value is the mean of 24 observations to Polaris and circum-polar stars observed at elongations and appears to be well determined. The Siamese were right in preferring an astronomical azimuth to an Indian geodetic azimuth at a station of Bangkok secondary series, which was the only junction available at the time, as this series was of a very low quality and its azimuths were not reliable and were not controlled by any Laplace station. The introduction of two Laplace stations at Rājburi Base South-End (at a distance of 22 miles from the origin of Siamese Survey in latitude 13½°) and the other at Doi Khun Kong in latitude 18½° in 1933 and 1938 respectively has enabled the Siamese datum to be definitely related to the Indian datum. The corrections required to the Siamese values of geodetic azimuths at the two places to satisfy the Laplace equation are +0″·6 and +3″·7 and these amounts can well be generated in the Siamese triangulation. The prime vertical deflection derived from longitudes at Rājburi is −12″·4 and that at

Doi Khun Kong is $-14''\cdot1$. Bearing in mind the fact that the Everest spheroid on *account of its axes being too small* would produce a deflection of 14″ E. with respect to a more reasonable spheroid like the International or Clarke 1880, we see that roughly the Siamese orientation on the Everest spheroid as regards azimuth is practically the same as the Indian one. The details of the two Laplace stations are given in Table 4.

3. **Discrepancies at Indo–Siamese Junctions.**—Table I of Survey of India Geodetic Report, Vol. VII, Chapter I gives discrepancies in co-ordinates, height, log side and azimuth at three connections, one each in latitude 20° N., 14° N. and 10° N., between the Indian and *Siamese triangulations*. The *information* about the Siamese data was collected from their annual reports available with the Survey of India at the time of the publication of Geodetic Report, Vol. VII in 1931 and was incomplete in several respects. Complete lists of final co-ordinates of the Primary triangulation of Siam and records of angles of some portions have now become available. The new lists of co-ordinates show that the Siamese co-ordinates published prior to 1931 *have undergone slight* changes and that there are a number of other stations common to the Siamese and Indian triangulations in latitude 20° N., 14° N., and 10° N. in addition to the three published in Geodetic Report, Vol. VII. The Indian values also at lat. 10° N. and 20° N. have received corrections due to introduction of remeasured value of Mergui base and the readjustment of Mong Hsat series (1929–31) brought about by a measured base at Keng Tung. The discrepancies at all the common stations are now given in Tables 2 and 3.

The discrepancies in latitude and longitude at 14° N. junction, i.e., at the origin of the Siamese Survey are solely due to the adjustment of the Burma triangulation; those at 20° N. and 10° N. are due both to the adjustment of Burma triangulation and the difference of scale and azimuths between the Siamese and Indian triangulations (see para 2 above) and are not unreasonable. These discrepancies in position are plottable on the 1 inch = 1 mile scale and it has to be borne in mind that a discrepancy of about 200 feet will occur at the junction between Siamese and Indian mapping.

The discrepancies in height in Lat. 20° N. junction are not serious. The discrepancies at the other two junctions are due to the Survey of India heights being far removed from spirit-levelling.

Since Siamese triangulation is based on consistent Laplace equations, the Siamese and the Indian azimuths should agree with each other at the junctions. Actually we find a discrepancy of about 19″, 29″ and 18″ in latitudes 20°, 14° and 10° respectively. This is mainly due to the fact that the published Indian geodetic azimuths are not corrected for Laplace. The Laplace stations at Keng Tung, Taungpila and Toungoo at about latitude 20° N. and Mergui at 12° N. show that the Indian values of azimuth at these stations require a correction of about $-12''$ and $-9''$ respectively (see Table 5).

In latitude 18½° N. the Siamese Laplace station Doi Khun Kong shows that Siamese azimuth there requires a correction of +3″·7. If these corrections are applied, the large discrepancies of 19″ and 18″ are reduced to small amounts, which is satisfactory.

In latitude 14° N., however, the discrepancy in azimuth is 29″. The Siamese Laplace station at Rājburi Base S. indicates that the Siamese value of the azimuth does not require any appreciable correction, while the Indian Laplace Station at Moulmein shows that Indian value of the azimuth is likely to require a correction of about −10″ (see Table 5). Thus there is an unexplained residual of 19″, which can only be attributed to the weakness of the Bangkok secondary series of the Survey of India observed in 1879–81, which has an average triangular error of 5″ (worst 13″) and mean closing error in log sides of five quadrilaterals 0·0000145 (worst 0·0000451). This portion of the work executed by Mr. McCarthy was never meant to be used for geodetic purposes.

As has already been mentioned the scale of the Siamese triangulation is in terms of their own measured bases. The lengths of these bases have been reduced to sea-level by means of their geoidal heights while the Indian bases have been reduced to sea-level by means of their heights on Everest spheroid, which is about 300 feet below the geoid in this area. The Siamese values thus require a correction of about −0·0000061 to bring the values of the log sides of the two countries into the same terms.

Again the Indian sides are expressed in terms of Indian feet whereas the Siamese sides are in terms of British feet and consequently the Siamese values require a further correction of +0·0000019 to reduce them to Indian terms.

The above two corrections reduce the discrepancies at the three junctions (see Table 3) to −0·0000072, −0·0000482 and −0·0000110. These appear to be systematic, but the discrepancy at the latitude 20° N. junction, viz., −0·0000072 is reasonably small and needs no further consideration.

The large discrepancy of −0·0000482 in latitude 14° N. can be attributed to the weakness of the Indian triangulation. The portion of the Burma Coast series between latitudes 14½° and 16° is very weak, the side closures of four successive figures being 139, 55, 254 and 114 in the 7th decimal of the log. This is followed by the Bangkok secondary series, which is known to be weak, with a probable error in log side of about 0·0000200.

The discrepancy of −0·0000110 at 10° N. is satisfactory. The major portion of this discrepancy, however, appears to arise from the Siamese triangulation. The Indian value of the junction side is in terms of the Mergui Base which is only 140 miles away and is derived from good quality triangulation (average triangular error 0″·4, mean side closure from five figures 0·0000025, worst 0·0000059). The Siamese value of the junction side Khao Jamaya–Khao Natathern is in terms of the 1929 value of the Nagorn Sīdharmrāj Base and is a definite improvement on the discrepancy with this side in terms of the 1909 value of this base. The Siamese, however, report that the acceptance of the 1929 value of Nagorn Srīdharmrāj base worsens the misclosures in log side of the triangulation on the Rājburi base from 141 to 248 in 7th decimal of the log. An effort was made to locate where the weakness lies by obtaining the values of observed angles of the triangulation south of latitude 10° N. from the Siamese Survey Department during the late war. A closed loop of triangulation from 10° N. junction via Puket and Nagorn Srīdharmrāj Base and back to this junction was computed in the Dehra Dūn Computing Office using only a simple chain of well conditioned triangles. The average triangular error of the triangulation forming this circuit is about 1″ and the closing error of this 400-mile circuit is 113 in 7th decimal of the log and 0″·8 in azimuth. This portion of the Siamese triangulation appears to be good and the source of the bad misclosure on Rājburi base probably lies in the weakness of the Siamese triangulation between 10° N. junction and Rājburi base. This is confirmed by the fact that the average triangular error of this portion is about 3″ and average closing error in log side from nine figures is 99 in the 7th decimal of the log (worst 280). There is a clear necessity for inserting a new base between the Rājburi and Srīdharmrāj bases and the Siamese are contemplating to put in one.

TABLE 1.—*Siamese Bases*

No.	Name of base	Apparatus employed	Standard	Date	Length (metres)	p.e.
						mm.
1	Sen-Seb ..	100-metre Invar tapes Nos. 1 & 2	2-metre Invar bars Nos. 4, 5 & 6	Jan. 1907	7741·11008	±4·083
2	Puket ..	100-metre Invar tapes Nos. 1 & 2	2-metre Invar bars Nos. 4, 5 & 6	March 1907	1183·88619	±0·83
3	Nagorn Srī-dharmrāj	(1) 100-metre Invar tapes Nos. 1 & 2 (2) 25-metre Invar wires 753, 756, 757 & 758	(1) 2-metre Invar bars Nos. 4, 5 & 6 (2) 25-metre Invar wires 753, 756, 757 & 758	(1) Aug. 1909 (2) Aug. 1929	(1) 9401·41577 (2) 9401·18519	(1)±3·11 (2)±0·72
4	Rājburi ..	100-metre Invar tapes Nos. 1 & 2	25-metre Invar wires Nos. 309 & 310	Feb.-March 1911	7919·186121	±4·835
5	Nagorn Sawarn ..	100-metre Invar tapes Nos. 1 & 2	25-metre Invar wires Nos. 309 & 310	March 1914	6501·889467	±2·370
6	Chāndhāburi	25-metre Invar wires Nos. 753, 756, 757 & 758	25-metre Invar wires Nos. 753, 756, 757 & 758	April 1927	5850·135665	±2·156
7	Lampang ..	25-metre Invar wires Nos. 753, 756, 757 & 758	25-metre Invar wires Nos. 753, 756, 757 & 758	April 1928	11045·56097	±0·91
8	Amphoe Khulu ..	25-metre Invar wires Nos. 753 & 758	25-metre Invar wire No. 756 8-metre Invar wire No. 707 and 4-metre Invar tape No. 910.C_1	April 1937	12188·315*	..

* Value not final.

TABLE 2.—*Discrepancies in co-ordinates and heights between Indian and Siamese triangulation*

Station	Indian triangulation values	Siamese triangulation values	Discrepancy Indian *minus* Siamese	REMARKS
At 20° N.	° ′ ″	° ′ ″	″	
Doi Pakulin (Loi Pakulin H.S.)	Lat. 20 20 37·079 Long. 99 00 25·939 Ht. 5173 feet	20 20 39·342 99 00 25·808 5175 feet	− 2·263 + 0·131 − 2 feet	Siamese 1928 Indian 1930–31
Doi Thum (Loi Tum H.S.)	Lat. 20 23 37·515 Long. 99 27 07·568 Ht. 6248 feet	20 23 39·928 99 27 07·474 6255 feet	− 2·413 + 0·094 − 7 feet	Siamese 1928 Indian 1930–31
Doi Khi Hlek (Loi Kyi-Lek h.s.)	Lat. 20 02 24·83 Long. 98 49 29·96 Ht. 6494 feet	20 02 26·930 98 49 29·922 6495 feet	− 2·100 + 0·038 − 1 feet	Siamese 1928 Indian 1909–11
Doi Pha Hempog (Loi Pahompok H.S.)	Lat. 20 04 09·926 Long. 99 08 42·466 Ht. 7533 feet	20 04 12·214 99 08 42·446 7539 feet	− 2·288 + 0·020 − 6 feet	Siamese 1928 Indian 1928–29
At 14° N.	° ′ ″	° ′ ″	″	
Khão Ang Hin H.S.	Lat. 13 54 34·88 Long. 99 19 33·37 Ht. 881 feet	13 54 36·510 99 19 34·606 867 feet	− 1·63 − 1·24 + 14 feet	Siamese 1910 Indian 1879
Khão Pakhong H.S.	Lat. 13 54 16·36 Long. 99 30 05·23 Ht. 890 feet	13 54 18·074 99 30 06·554 875 feet	− 1·71 − 1·32 + 15 feet	Siamese 1910 Indian 1879
Khão Hip Nam H.S.	Lat. 13 52 04·80 Long. 99 40 36·07 Ht. 837 feet	13 52 06·635 99 40 37·469 822 feet	− 1·84 − 1·40 + 15 feet	Siamese 1910 Indian 1880–81
Khão Luang H.S.	Lat. 13 43 28·69 Long. 99 32 21·52 Ht. 1393 feet	13 43 30·340 99 32 22·940 1382 feet	− 1·65 − 1·42 + 11 feet	Siamese 1911 Indian 1879–80
Khão Khio H.S.	Lat. 13 43 25·65 Long. 99 42 47·04 Ht. 1070 feet	13 43 27·388 99 42 48·556 1057 feet	− 1·74 − 1·52 + 13 feet	Siamese 1911 Indian 1880
Khão Ngu H.S.	Lat. 13 34 31·22 Long. 99 46 17·00 Ht. 795 feet	13 34 32·923 99 46 18·602 784 feet	− 1·70 − 1·60 + 11 feet	Siamese 1911 Indian 1880
At 10° N.	° ′ ″	° ′ ″	″	
Khão Jamaya (Chamaya) H.S.	Lat. 10 40 16·502 Long. 99 01 10·499 Ht. 1828 feet	10 40 17·290 99 01 12·192 1817 feet	− 0·788 − 1·693 + 11 feet	Siamese 1914 Indian 1931
Khão Natathern H.S.	Lat. 10 23 59·738 Long. 98 58 13·890 Ht. 2100 feet	10 24 00·444 98 58 15·658 2087 feet	− 0·706 − 1·768 + 13 feet	Siamese 1915 Indian 1931

TABLE 3.—*Discrepancies in azimuths and log sides between Indian and Siamese triangulation*

At 20° N.

Station A to Station B	Indian triangulation values		Siamese triangulation values		Difference Indian *minus* Siamese	
	Azimuth at A	Log side feet	Azimuth at A	Log side feet	Azimuth	Log side
	° ′ ″		° ′ ″		″	10^{-7} ×
Loi Tum H.S. to Loi Pakulin H.S.	83 15 52·6	5·1859699	83 15 32·9	5·1859831	+19·7	−132
Loi Pakulin H.S. to Loi Pahompok H.S.	334 34 38·3	5·0423510	334 34 18·8	5·0423600	+19·5	−90
Loi Tum H.S. to Loi Pahompok H.S.	41 49 40·8	5·1985074	41 49 22·4	5·1985195	+18·4	−121
				Mean ..	+19·2	−114

At 14° N.

Station A to Station B	Indian triangulation values		Siamese triangulation values		Difference Indian *minus* Siamese	
	Azimuth at A	Log side feet	Azimuth at A	Log side feet	Azimuth	Log side
	° ′ ″		° ′ ″		″	10^{-7} ×
Khão Ang Hin H.S. to Khão Luang H.S.	311 33 52	5·0051230	311 33 23·3	5·0051707	+29	−477
Khão Ang Hin H.S. to Khão Pakhong H.S.	271 41 54	4·7041868	271 41 22·7	4·7042338	+31	−470
Khão Pakhong H.S. to Khão Khio H.S.	311 07 52	4·9986310	311 07 23·5	4·9986889	+29	−579
Khão Pakhong H.S. to Khão Luang H.S.	348 22 36	4·8238975	348 22 07·7	4·8239525	+28	−550
Khão Luang H.S. to Khão Khio H.S.	270 15 50	4·7899528	270 15 21·4	4·7900105	+29	−577
Khão Luang H.S. to Khão Ngu H.S.	303 18 41	4·9038592	303 18 12·0	4·9039116	+29	−524
Khão Khio H.S. to Khão Ngu H.S.	338 58 41	4·7613291	338 58 14·6	4·7613783	+26	−492
				Mean ..	+29	−524

TABLE 3.—*Discrepancies in azimuths and log sides between Indian and Siamese triangulation.—(Concld.)*

At 10° N.

Station A to Station B	Indian triangulation values		Siamese triangulation values		Difference Indian *minus* Siamese	
	Azimuth at A	Log side feet	Azimuth at A	Log side feet	Azimuth	Log side
	° ′ ″		° ′ ″		″	10^{-7} ×
Khāo Jamaya (Chamya) H.S. to Khāo Natathern	10 08 52·7	5·0000847*	10 08 34·5	5·0000999†	+18·2	−152

* Indian value in term of Mergui Base.
† Siamese value in terms of 1929 value of Srīdharmrāj Base.

TABLE 4.—*Siamese Laplace Stations*

Laplace stations	Rājburi South Base $\phi = 13° 33'$	Doi Khun Kong $\phi = 18° 27'$
	° ′ ″	° ′ ″
Siamese geodetic longitude ..	99 50 22·17	99 30 16·46
Correction for Indian terms ..	− 1·42	− 0·42
∴ Geodetic long. in Indian terms (G) ..	99 50 20·75	99 30 16·04
Astronomical longitude (A) ..	99 50 04·83	99 20 57·09
	″	″
∴ $\xi = (A-G+3''\cdot 16)\cos\phi$ ..	− 12·4	14·1
Siamese geodetic azimuth (G) ..	177 09 13·90	334 17 06·70
Astronomical azimuth (A) ..	177 09 11·55	334 17 05·72
	″	″
$\delta G = A - G - (A - G + 3\cdot 16)\sin\phi =$ Correction to geodetic azimuth	+ 0·6	+ 3·7

TABLE 5.—*Indian Laplace Stations*

Laplace stations	Mergui W. End Base $\phi=12° 22'$	Taungzun (Moulmein) $\phi=26° 16'$	Toungoo $\phi=18° 56'$	Taungpila $\phi=20° 42'$	Keng Tung S. End Base $\phi=21° 18'$
	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
Astronomical longitude (A) ..	98 43 44·5	97 37 23·4	96 25 36·8	95 53 18·0	99 36 10
Geodetic longitude (G)	98 43 59·7	97 37 40·0	96 25 55·2	95 53 29·1	99 36 33
$\xi = (A-G+3''\cdot16)\times \cos\phi$ ..	− 11″·8	− 12″·0	− 14″·4	− 7″·4	− 10″
Astronomical azimuth (A) ..	252 20 14	31 16 19	30 46 37	240 23 15	130 27 21
Geodetic azimuth (G)	252 29 26	31 16 33	30 46 53	240 23 26	130 27 37
$\delta G = A-G-(A-G+3''\cdot16)\sin\phi$ = correction to published geodetic azimuth	− 9″	− 10″	− 11″	− 8″	− 12″

4. **French Indo–China Triangulation.**—The primary triangulation of French Indo-China is computed on the Clarke's 1880 spheroid and consists of two main meridional and several chains of parallel (see Chart I). The origin of this triangulation is Hanoi Belvedere where latitude and azimuth were observed astronomically in 1902. The longitude was obtained roughly by connecting this origin by a series of rapid triangulation in 1886–87 to Haiphong, the longitude of which was ascertained in 1874 by time obtained by telegraph from Cape St. Jacques whose longitude in turn had been obtained telegraphically from that of Singapore.

The following values have been adopted :—

Hanoi Belvedere, Latitude $23^{G}\cdot369881$ = $21° 01' 58''\cdot414$

Longitude $114\cdot997568$ = $105\ \ 50\ \ 06\ \cdot120$

Azimuth at Hanoi Belvedere of Nuikhe = $269^{G}\cdot739920$

= $242° 45' 57''\cdot341$

In 1930 the longitude of Phu-lien observatory (near Haiphong) was observed using wireless time signals. An astronomical determination of latitude was also made. The observations were repeated in 1933 in connection with the International longitude programme. The observatory pillar was connected to the origin (Hanoi Belvedere) by proper triangulation in Hanoi–Haiphong chain, and it was discovered that the longitude adopted for Hanoi Belvedere in 1902 was in error by 34·72 seconds (centesimal) = $11''\cdot25$. All triangulation in Indo-China is, however, based on the 1902-value of the longitude of the datum; consequently all map meridians have to be shifted to the west by 11″·25. Similarly the old 1902 astronomical latitude determination at Thanh Hoa base was found to be in error by 41 seconds (centesimal) when astro. latitude was again determined in 1924.

For scale, the French Indo-China triangulation system rests on the length of the Thanh Hoa base measured in 1902 with 24-metre tape. In addition to this, six other bases have been measured which are tabulated below along with misclosures of triangulated sides on to these bases.

No.	Name of the Base	Apparatus employed	Date of measurement	Measured Length	Triangulated Length	Discrepancy (measured *minus* triangulated)
			year	*metres*	*metres*	
1	Sontay Base	Information not available	1899 1925	4363·796 4364·0498	4363·740 4363·740	+1/78,000 +1/14,100
2	Haiphong Base	Information not available	1902	6308·449	6308·417	+1/197,000
3	Savannakhet Base	24-metre Invar Tape Nos. 339-340	1913	7513·847	7515·010	+1/6,500
4	Tourane Base	24-metre Invar Tape Nos. 339-340	1913	51303·131	51310·766	+1/6,700
5	Baria Base	24-metre *Jaderine* Nos. A, B58	1905	7981·843	via Tamane 7981·496 via Savannakhet 7982·320	+1/54,000 −1/12,000
6	Sisophone Base	24-metre Invar Tapes Nos. 236, 237, 339 & 340	1928	49344·77	North Path 49344·51 South Path 49345·30	+1/190,000 −1/93,000

The discrepancies in the last column show that some of the work is of a very low quality.

There are three Laplace stations, details of which are given in the table below :—

Name of station	Co-ordinates			Deflection		δG = Accumulated error in triangulated azimuth
	Latitude	Longitude	Azimuth	Meridian	P.V.	
	° ′ ″	° ′ ″	° ′ ″	″	″	″
1. Baria S. End Base A	10 27 34·320	107 15 16·520	170 39 58·002			
G	10 27 30·749	107 15 06·273	170 40 10·330			
A − G	+ 3·571	+10·247	−12·328	+ 3·57	+10·08	+14·2
2. Konwa A	13 37 54·631	102 56 55·845	74 18 13·935			
From N. Chain G	13 37 50·453	102 56 53·167	74 18 22·866			
A − G	+ 4·178	+ 2·678	− 8·931	+ 4·18	+ 2·60	+ 9·6
From S. Chain G	13 37 50·827	102 56 53·070	74 18 12·214			
A − G	+ 3·804	+ 2·775	+ 1·721	+ 3·80	+ 2·70	− 1·1
3. Tourane A	16 00 21·820	108 15 37·155	11 33 10·331			
G	16 00 15·900	108 15 26·700	11 33 19·549			
A − G	+ 5·920	+10·455	− 9·218	+ 5·92	+10·05	+12·1

The triangulation network has not been adjusted on to these bases and Laplace stations on the plea that some parts of it are of too low a quality and do not justify adjustment. The primary triangulation of Indo-China is thus good enough for mapping on 1/100,000 scale but not for scientific study of deflections or of the geoid. Discrepancies of as much as 1/6,000 in scale and 30″ in azimuth exist at the junctions of various chains.

Discrepancies at junctions with Indian and Siamese triangulations.—As shown in Chart I, the triangulation of French Indo-China is connected directly to the geodetic triangulation of India and Burma in latitude 20° N. and to the Siamese triangulation in latitudes 16° N., 14½° N. and 12½° N.

The first junction is with very weak series of exploratory triangulation carried out by McCarthy in about 1880. McCarthy's work was based on Pahompok, H.S., a station of the Survey of India primary triangulation series (Mong Hsat). The discrepancies at common stations between French Indo-China and the values of McCarthy's triangulation (reduced to terms of 1916-

adjustment of Burma triangulation) are given below :—

Serial No.	Common station	McCarthy's values		French Indo-China values	Discrepancies McCarthy *minus* F.I.C.
			° ′ ″	° ′ ″	
1	Sam Sunn ..	Lat.	19 07 44	19 07 43	+ 1 second
		Long.	103 48 31	103 48 02	+ 20 seconds
		Ht.	8710 ft.	8595 ft.	+115 feet
2	Pou Ba ..	Lat.	18 58 53	18 58 51	+ 2 seconds
		Long.	103 09 18	103 08 49	+ 29 „
		Ht.	9355 ft.	9248 ft.	+107 feet
3	Pou Sunn ..	Lat.	19 40 33	19 40 34	− 1 second
		Long.	103 21 41	103 21 11	+ 30 seconds
		Ht.	7345 ft.	7260 ft.	+ 85 feet
4	Pou Ke ..	Lat.	19 18 51	19 18 50	+ 1 second
		Long.	103 16 54	103 16 24	+ 30 seconds
		Ht.	7072 ft.	6971 ft.	+101 feet
5	Pou Sao ..	Lat.	19 09 21	19 09 20	+ 1 second
		Long.	103 28 13	103 27 44	+ 29 seconds
		Ht.	8614 ft.	8497 ft.	+117 feet
6	Hawchawi Pou Nougpi ..	Lat.	10 38 41	19 38 40	+ 1 second
		Long.	102 49 51	102 40 19	+ 32 seconds
		Ht.	6208 ft.	6143 ft.	+ 65 feet
				Mean Lat.	+ 1 second
				Long.	+ 30 seconds
				Ht.	+ 98 feet

In the same latitude a series of minor triangulation of F.I.C. is also connected to McCarthy's triangulation, the discrepancies at the common stations being as follows :—

Serial No.	Common station	McCarthy's values		French Indo-China values	Discrepancies McCarthy *minus* F.I.C.
			° ′ ″	° ′ ″	
1	Phu Sangnam ..	Lat.	20 04 40	20 04 48	+ 1 second
		Long.	101 43 15	101 42 36	+ 39 seconds
		Ht.	5920 ft.	5810 ft.	+110 feet
2	Phu Siou Chimosi ..	Lat.	19 53 24	10 53 25	− 1 second
		Long.	102 08 33	102 07 56	+ 37 seconds
		Ht.	1288 ft.	1180 ft.	+108 feet
3	Sang Nhoyou Changemo	Lat.	19 46 16	19 46 14	+ 2 seconds
		Long.	102 05 29	102 04 51	+ 38 „
		Ht.	5223 ft.	5126 ft.	+ 97 feet
4	Mokloi ..	Lat.	20 08 56	20 08 56	0 seconds
		Long.	101 56 36	101 55 58	+ 38 „
		Ht.	4033 ft.	3937 ft.	+ 96 feet
				Mean Lat.	+ 1 second
				Long.	+ 38 seconds
				Ht.	+103 feet

It appears from the above tables that there is a relative discrepancy of 8″ in longitudes of the stations common to McCarthy's triangulations in lat. 19° and lat. 20°. This can be attributed partly to the weakness of McCarthy's triangulation and partly to the lack of adjustment of F.I.C. minor triangulation to the primary triangulation.

At latitude 16° the discrepancies between Siamese and French Indo-China systems are as follows :—

Serial No.	Common station	Siamese values in terms of Precise Traverse	F.I.C. values	Discrepancies Siam *minus* F.I.C.	REMARKS
		° ′ ″	° ′ ″		
1	Phu Kham	Lat. 15 51 29·287 Long. 105 06 46·931 Ht. 1161 ft.	15 51 30·203 105 06 16·226 1194 ft.	− 0·916 sec. +30·705 „ −33 feet	1906–08
2	Phu Chamosi	Lat. 16 26 41·636 Long. 104 45 14·321 Ht. 1423 ft.	16 26 42·308 104 44 44·424 1453 ft.	− 0·762 sec. +29·897 „ −30 feet	1906–08
3	Phu Paln	Lat. 16 04 58·505 Long. 105 01 26·008 Ht. 743 ft.	16 04 59·442 105 00 56·478 782 ft.	− 0·937 sec. +30·430 „ −30 feet	1906–08
4	Phu Nang Manu (Menang)	Lat. 16 30 10·156 Long. 104 22 53·818 Ht. 2026 ft.	16 30 10·022 104 22 24·718 2062 ft.	− 0·766 sec. +29·100 „ −36 feet	1906–08
5	Phu Phnau	Lat. 16 53 12·512 Long. 104 24 47·922 Ht. 1976 ft.	16 53 13·057 104 24 18·763 2022 ft.	− 0·545 sec. +29·150 „ −46 feet	1906–08
			Mean ..	Lat. −0·79 Long. +29·86 Ht. −37 ft.	sec. „ feet

The French Indo-China chain concerned is the second meridional chain executed between 1906 and 1909 while the Siamese triangulation is a recent one (1932–35), connected to the main triangulation by means of a primary traverse run in 1929–32. The co-ordinates of this triangulation, which connects the Siamese traverse to the F.I.C. triangulation as given in the Siamese lists are in terms of an independent astronomical origin at West monument of Don Thapa Chang Base. The Siamese values of co-ordinates given in the above table for the common stations have been brought into terms of the traverse by applying the difference between traverse and astronomical co-ordinates of the West monument of Don Thapa Chang Base.

The junction at latitude 14½° N. is based on two stations of F.I.C. Cambodia chain, viz., Anlong Swai and Mae Kai.

Of these the position of Anlong Swai is definitely identical, but the position of Mae Kai (P. Serouy) was not recovered in 1925, and the Siamese and the F.I.C. stations may not be quite identical. The discrepancies at these two stations are given below :—

Serial No.	Common station	Siamese values (1925)	F.I.C. values (1911)	Discrepancies Siamese *minus* F.I.C.
		° ′ ″	° ′ ″	
1	Khao Phnom Anlong Swai	Lat. 14 22 34·911 Long. 103 44 38·171 Ht. 1485 ft.	14 12 37·913 103 44 07·327 1500 ft.	− 3·0 seconds +30·8 ,, −15 feet
2	Khao Phnom Mae Kai (P. Serouy)	Lat. 14 17 53·992 Long. 103 06 23·050 Ht. 1749 ft.	14 17 57·356 103 05 52·383 1763 ft.	− 3·4 seconds +30·7 ,, −14 feet

The junction at latitude 12½° initially involved poor quality triangulation (McCarthy and Montguere) in this area but it has now been superseded by Siamese modern primary triangulation. On the French side, the connection is with 1911 North Cambodia series and the 1932 Cardamomes chain. Due to the fact that the various chains of the F.I.C. triangulation have not been adjusted on to one another, the values of co-ordinates of the stations common to these series are slightly different. According to the F.I.C. reports the stations Khao Phra Bat and Khao Sra Bap are badly connected to the F.I.C. triangulation, and the relative discrepancy at these two stations and Koh-i-Chang may well be due to this fact. The discrepancies are tabulated below :—

Common station	Siamese values	F.I.C. values	Discrepancies Siamese *minus* F.I.C.	REMARKS
	° ′ ″	° ′ ″	″	
1. Khao Phra Bat	Lat. 12 50 14·808 Long. 102 10 21·976 Lat. .. Long. ..	12 50 18·349 102 09 51·590 12 50 17·374 102 09 52·076	− 3·5 +30·4 − 2·6 +29·9	N. Cambodia 1911 Cardamomes chain 1932
2. Khao Sra Bap	Lat. 12 32 58·180 Long. 102 12 33·805 Lat. .. Long. ..	12 33 01·677 102 12 03·331 12 33 01·893 102 12 03·911	− 3·5 +30·5 − 3·7 +29·9	N. Cambodia 1911 Cardamomes chain 1932
3. Koh-i-Chang	Lat. 12 05 38·00 Long. 102 19 48·00 Ht. 2091 ft.	12 05 42·034 102 19 17·270 2079 ft.	− 4·0 +30·7 +12 ft.	

The discrepancies at the three junctions in latitudes 12½°, 14½° and 16° can be reduced to terms of the Indian primary triangulation by applying the discrepancies between India and Siam in Table 2. The discrepancies in latitudes at all the junctions are small and need no special consideration. The discrepancies in height may be attributed almost entirely to the lack of uniformity in the adopted datums for heights for the various F.I.C. chains and the poor quality of their work. The discrepancies in longitude at various junctions are systematic and unduly large. The major contributory causes for this are :—

(*a*) The Indian and Siamese triangulation, are computed on Everest spheroid with Kaliānpur (Lat. 24° 07′ 11″·26, Long. 77° 39′ 17″·57) as origin. The F.I.C. triangulation on the other hand is based on an independent origin Hanoi Belvedere (Lat. 21° 01′ 58″·414, Long. 105° 50′ 06·120″) and is computed on Clarke's 1880 spheroid. At such a large distance from the origin, the Siamese longitudes on Everest spheroid are greater by about 14′ than the values that would have been obtained had the Indian and Siamese triangulations been computed on Clarke's 1880 spheroid.

(*b*) As mentioned before, the F.I.C. values are in terms of a rough value of longitude at Hanoi Belvedere which needs increasing by 11″.

The residual discrepancy after allowing for the above two factors is satisfactorily small and is due to independent datum of the two countries and the errors of observation. The fact, however, remains that the primary triangulation of French Indo-China needs toning up in any case and *inter se* adjustment of its various series is desirable to achieve consistency in what exists. A firm connection of the geodetic net of French Indo-China with the primary triangulation of Burma in the north and with the primary triangulation of Siam in the south has yet to be achieved. The north junction would need a short chain of about 30 to 40 miles closing in Burma near the Keng Tung Base. The connection in the south can be effected by either of the two chains Sisophone–Chāndhāburi–Rājburi–Mergui or Sisophone–Nagorn Sawarn–Amherst.

5. **Primary Triangulation in Malaya.**—There are three different systems of primary triangulation in Malaya executed at different times and based on different datums. The earliest one known as the " Perak System " was commenced in 1885 with the object of providing points in Perak for the control of traverses run for revenue surveys. The fundamentals of this system are a base measured with a 50-foot steel chain at Larut, an astronomical latitude and azimuth observed at Scott's Hill, Taiping and the longitude of Fort Cornwallis Flagstaff, Penang. The longitude was determined by Commander (later Admiral) Mostyn Field in H.M.S. Egeria in 1893 by the exchange of telegraphic signals with Mr. Angus Sutherland

at Singapore, Old Transit Circle. The longitude, 103° 51′ 15″·75 E., accepted for Singapore in order to arrive at this determination of Fort Cornwallis Flagstaff was based upon that of an observation spot, 103° 51′ 15″·00 E., fixed in 1881 by Lieutenant Commander Green, United States Navy, with reference to the transit circle of Madras Observatory, the corresponding longitude of the latter being taken as 80° 14′ 51″·51 E.

In 1899 it was decided to extend the triangulation over the whole area of the Federated Malaya States and a new triangulation called the "Bukit Asa System" was started. This system is based on the astronomical latitude and azimuth observed at Bukit Asa. The fundamental longitude of both the Perak and Bukit Asa systems is the same, viz., longitude of Fort Cornwallis Flagstaff, Penang, the value adopted being 100° 20′ 44″·4 E.

The Perak and Bukit Asa systems have 36 points in common. The mean discrepancies in latitude and longitude between the two systems (Bukit Asa–Perak) derived from these points are —0″·22 and —0″·12 respectively. The unadjusted data of both these systems of triangulation are published in F.M.S. publication "Trigonometrical data for Primary and Secondary points in the Federated Malaya States and adjacent territories", 1917.

These triangulations were not considered good enough as they revealed considerable discrepancies from the results of primary traverses which had to be run in some areas of dense tropical growth, and as there were possibilities of connecting the triangulation of Malaya with that of its neighbouring countries to the north and south, it was decided to observe a new geodetic chain of first order by reobserving at selected stations of the old triangulation. The new chain is known as the "Repsold System". The datum for this triangulation is Kertau where astronomical latitude and azimuth were determined. The longitude is taken to be the same as the geodetic longitude of Kertau in the Bukit Asa system. The scale is provided by a measured base at Serting, controlled by two other bases measured at Kedah and Kelantan. The triangulation extends from Singapore 1° 20′ N. to the Siamese frontier 6° 30′ N., a distance of about 400 miles. In addition, a spur runs out north-eastwards to Kelantan Base near Kota Bharu about 6° N. The discrepancy between the triangulated values in terms of Serting base and the measured bases at Kedah and Kelantan is 1/52,000 in a distance of 280 miles, and 1/66,000 in a distance of about 400 miles respectively. The measured values of the bases have been accepted and the triangulated sides adjusted. The longest side of the triangulation is 72 miles, angles being observed with two Repsold 22-cm. broken transit theodolites. The average triangular error is under half a second of arc.

The Repsold system was completed in about 1918, and its details and data are published in the F.M.S. publication "An Account of the Primary Triangulation of Malaya, 1931". There are about 40 points common to the Repsold and Bukit Asa systems. The mean discrepancies in latitude between the two systems is about 3″ and in longitude less than 0″·3. The triangulation is computed on Everest spheroid.

6. **Malaya–Siamese Connection.**—A connection of the primary triangulation of Malaya to that of the Siamese Survey has long been a desideratum. There was one station Goh Beng in Siam which can be computed in terms of F.M.S. triangulation (1931) through a triangulation by H.M.S. Stork. The discrepancies between Siamese and F.M.S. values at Goh Beng are :—

(1) Siamese values		(2) Malayan values		(3) Discrepancies (1) – (2)	
Lat.	Long.	Lat.	Long.	Lat.	Long.
° ′ ″	° ′ ″	° ′ ″	° ′ ″	″	″
7 04 22·81	99 23 50·88	7 04 34·1	99 23 42·47	–11·3	+8·41

On the advice of the Survey Research Institute, Survey of India, Dehra Dūn, a firm connection between the triangulations of the two countries was effected at the end of the war by Captain F. N. Fort, R.E. of the Survey Directorate, Rear Head Quarters Allied Land Forces, S.E. Asia by observing a small triangulation series starting from three Malayan stations and closing on three Siamese stations. The work was commenced on 16th February 1946 and completed on 23rd March 1946. All the six stations were found in perfect condition, the new measurements of the angles between them agree with those previously observed within a few seconds (see table below) and there is no possible doubt about their identity. The previous observations at the Malayan stations were on Repsold system (see para 5 above).

Siamese Stations

(1) Name of station	(2) Siamese value	(3) Capt. Fort's value	(4) Difference (2)–(3)
	° ′ ″	° ′ ″	″
Khao Hleng ..	65 11 29·62	05 11 30·33	–0·71
Khao Nam Khang	66 31 13·90	66 31 09·42	+4·48
Khao China ..	48 17 23·15	48 17 23·04	+0·11

Malayan Stations

(1) Name of station	(2) Malaya value	(3) Capt. Fort's value	(4) Difference (2)–(3)
	° ′ ″	° ′ ″	″
Bt. Perangin ..	17 45 57·10	17 45 57·08	+0·02
G. Keriang ..	22 20 33·36	22 20 34·04	–0·68
Bt. Tunjang ..	139 53 30·22	130 53 28·87	+1·35

Observations were made with a Tavistock theodolite. Horizontal angles were usually observed to opaque beacons, but helios had to be used for vertical angles as the heat haze made the beacons invisible at mid-day. Observations were made on six zeros, with two measures on each zero, one F.R. and one F.L. Weather was bad throughout and time available for observations on each day was small. Consequently at no station was it possible to observe all stations in one round and observing in pairs or threes as the stations were visible had to be resorted to.

13 triangles were observed, the average triangular error being 1″·4. There are three figures, a centred triangle, a braced quadrilateral and a centred quadrilateral with closing errors of log side of 0·0000350, 0·0000088 and 0·0000164 respectively. These closing errors have been adjusted by a semi-rigorous method. Everest spheroid has been used for the computation as for the Primary Triangulation of Malaya in terms of which this triangulation has been computed. The discrepancies in latitude, longitude, height, log side and azimuth between the primary triangulations of Malaya and Siam at the three Siamese stations connected are given below:—

A. Co-ordinates and Heights

Name of station		(1) Siamese values	(2) Malayan values in terms of Repsold system	(3) Discrepancies (1) − (2)
		° ′ ″	° ′ ″	
Khao Nam Khang ..	Lat.	6 32 54·59	6 33 05·66	−11·07
	Long.	100 35 50·96	100 35 42·71	+ 8·25
	Ht.	2305 ft.	2296 ft.	+ 9
Khao Hleng ..	Lat.	6 54 48·77	6 54 59·87	−11·10
	Long.	100 36 25·57	100 36 17·32	+ 8·25
	Ht.	1590 ft.	1579 ft.	+11
Khao China ..	Lat.	6 44 09·25	6 44 20·34	−11·09
	Long.	100 11 41·55	100 11 33·29	+ 8·26
	Ht.	2427 ft.	2418 ft.	+ 9

B. Scale and Azimuth

Side	(1) Siamese values		(2) Malayan values		(3) Discrepancies (1) − (2)	
	Log side	Azimuth	Log side	Azimuth	Log side (7th figure of decimal)	Azimuth
		° ′ ″		° ′ ″		″
Khao Nam Khang-Khao China ..	5·2070705	114 50 15·2	5·2070837	114 50 10·9	−42	−4·7
Kao China-Khao Hleng	5·2115933	246 30 04·1	5·2115945	246 30 08·3	−12	−4·2
Khao Hleng-Khao Nam Khang ..	5·1221691	1 30 31·0	5·1221735	1 30 32·2	−44	−1·2

It will be seen that discrepancies in latitude and longitude agree very satisfactorily with that determined earlier at Goh Beng. The longitude discrepancy however, deserves a special mention as the longitude determination of F.M.S. datum is in doubt. It is obtained by telegraphic signals from Singapore the longitude of which in turn was fixed in 1881 by Green of the United States Navy from Madras Observatory. The longitude of Madras Observatory has been undergoing several changes. The 1881 value on which F.M.S. datum is based was found to be too great by about 4 seconds when another determination was made in 1894–96 via Potsdam–Tehrān–Bushire. This is the value accepted by the Survey of India now but according to Albrecht this needs a further change of 1·635 seconds due to revised value of the component Greenwich–Potsdam in 1903.

The Admiralty charts of Malaya Coast are inconsistent with F.M.S. geographic positions, as they use a value of longitude for this datum which is less than that adopted by F.M.S. by about 5 seconds. Their datum appears to agree with the 1894–96 determination of Madras Observatory. The evidence of the difference between astronomical and geodetic values available at five stations does give a slight indication that the Admiralty value is nearer the truth than the F.M.S. The mean difference is $\phi_A - \phi_G = -2''\cdot 6$ and $L_A - L_G = -16''\cdot 5$. If Admiralty values of "L_G" are taken, $L_A - L_G$ becomes $-11''$, which is much more satisfactory and can be taken as indicative of the fact that even the Admiralty value is on the high side. A further evidence of this is afforded by the junction of Malaya with Riouw triangulation which will be discussed in the next paragraph. It is possible that Green's determination of the difference of longitude between Madras and Singapore is not quite correct. A fresh determination of the longitude of F.M.S. datum is very desirable.

In the above table of discrepancies, (Table A) it might be pointed out that the Siamese values are not quite in Indian terms and need the following corrections :—

	Latitude	Longitude	
For reduction to terms of published Indian triangulation (1880-Adjustment) ..	″ −0·7	″ −1·8	(See Table 2)
For 1937 re-adjustment of Indian triangulation ..	+0·4	+2·2	(Survey of India Professional Paper No. 28)
For error in all published longitudes of Indian triangulation ..	..	−3·2	
Total ..	−0·3	−2·8	

The difference between the Siamese values corrected as above and Malayan values (Siam–Malaya) are, $-11''\cdot 4$ in latitude and $+5''\cdot 5$ in longitude. These can be reckoned as being due to the relative deflections of the datums of the two countries as well as errors of observations. If the Malayan longitudes are decreased as the above evidence seems to show, the discrepancy in longitude between Siam and Malaya will be increased correspondingly but not to that extent as to make it improbable. In fact, the Siamese geodetic longitudes are in terms of Kaliānpur and in the neighbourhood of Kertau, the longitudes computed on Everest spheroid all the way from Kaliānpur are greater than that on a better figure of the earth by about 16″, so that the expected discrepancy between Malaya and Siam longitudes can well be of this order.

7. **Bangka and Riouw Triangulations and the connection to Primary Triangulation of Federal Malaya States.**— (i) *Bangka Triangulation.*—The Bangka primary triangulation executed by the N.E.I. Triangulation Brigade is based on an independent base-line measured at Bakem. This base-line was measured in 1926 with Jaderine apparatus, consisting of three 24-metre Invar wires Nos. 285, 286 and 287. The measured length was 5221·763 metres with relative mean error of $0 \cdot 25 \times 10^{-6}$ in measurement. The co-ordinates are in terms of the astronomical values of latitude, longitude and azimuth, observed in 1926 at B. Rimpah. The latitude was derived from circum-meridian observations with a mean error of 0″·10, azimuth from Transits with a mean error of 0″·19 and longitude by radio time-signals from Batavia, with a mean error of 0″·18. The triangulation is computed on Bessel spheroid.

(ii) *The Riouw Triangulation.*—This triangulation is a continuation of the Bangka, and was observed by the N.E.I. triangulation Brigade from 1935–1938. It consists of 15 primary triangles.

This triangulation connects the Bangka triangulation to the primary triangulation of Malaya at 5 stations. The discrepancies (Malaya–N.E.I.) at the common points of the two systems are tabulated below :—

No.	Common station	F.M.S. values (Bukit Asa terms)	Dutch values (Bangka terms)	Discrepancy FMS – NEI Lat.	Long.
		° ′ ″	° ′ ″	″	″
1	Belungkor ..	Lat. 1 27 29·90 Long. 104 04 31·57	1 27 32·21 104 04 18·35	−2·31	+13·22
2	Mandai ..	Lat. 1 24 14·70 Long. 103 46 17·14	1 24 10·94 103 46 04·08	−2·24	+13·06
3	Pulai ..	Lat. 1 36 05·83 Long. 103 32 50·96	1 36 08·03 103 32 37·80	−2·20	+13·16
4	Batu Puteh (T. 588)	Lat. 1 19 48·46 Long. 104 24 26·76	1 19 50·86 104 24 13·49	−2·40	+13·27
5	Pulau Pisang .. (T. 575)	Lat. 1 28 09·27 Long. 103 15 27·05	1 28 11·39 103 15 13·97	−2·12	+13·08
			Mean ..	−2·25	+13·16

The discrepancies are due to difference of terms of the two systems, and the sign and magnitude of the longitude difference confirms the suspicion mentioned in the preceding paragraph that the assumed longitude of the F.M.S. datum at Penang is too large.

8. Triangulation in Sumatra, Java and Lesser Soenda Islands.—A history of the geodetic survey in the Netherlands East Indies, and details about triangulation, base measurement and astronomical observations are given in the reports published in Tome 7 (1930), Tome 11 (1934), Tome 13 (1938) and Tome 15 (1939) of "Travaux de *L'* Association Internationale de Geodesie".

The triangulations of Sumatra, Java and Lesser Soenda Islands although originally based on independent datums have been adjusted in 1930–33 and now form a continuous chain. The geodetic datum of the whole system is the astronomical values of latitude, longitude and azimuth at G. Genock in North Central Java. The longitude is determined by radio time-signals relative to the meridian of the former time-signal station at Batavia, the longitude of which in turn was derived from the 1926 World Longitude Observations. The entire triangulation of N.E.I. is computed on Bessel spheroid.

The Sumatra Triangulation System.—It contains 155 primary, 225 secondary and 3303 tertiary stations. The main chain of primary triangulation was carried out between 1883 and 1916 and consists of well-conditioned triangles. It is controlled by two base-lines (Sampeon and Padang) measured in 1910 and 1927 respectively with Jaderine apparatus. The triangulation in the most northerly part of Sumatra in the residency of Acheen, which is based for scale on a base-line measured near Lam Keubene, was started in 1931 and was in progress till 1939.

The Primary Triangulation in Java.—This triangulation was started in 1866 and completed in 1880. Three bases (Simplak in W. Java, Logantoeng in N. Central Java and Tangsil in E. Java) were measured in 1872, 1875 and 1877 respectively, all with the Repsold apparatus.

The whole system has 114 points situated on highest mountains. The primary angles were measured with 10-inch micrometer theodolites from Pistu and Martins and a 12-inch theodolite from Repsold, the targets being heliotropes. All observations have been made on stone pillars.

The primary triangulation net in Lesser Soenda Islands consists of 11 points only, and was executed in 1912–18. It covers Bali and Lombok Islands and terminates on Sumbawa Island. The accuracy of its angles is about the same as in the principal chain of Sumatra.

9. Possibility of Connection with Australia.—As can be seen from Chart I, the first gap to be filled in is that between the Federated Malaya States triangulation and the N.E.I. system on the main land of Sumatra or Java. The gap is too wide to be dealt with by ordinary triangulation methods, as the whole of Eastern Sumatra is swampy. It should be possible, however, to get over this either by a suitable radar technique or by the parachute flare method used for connecting the triangulations of Denmark and Norway. This link if completed will take the chain continuously upto Bali and Lombok Islands.

The second gap is that between longitude 117° E. and Australia. There is no triangulation in the islands between Australia and the Soenda Archipelago, and in Australia itself, there is no geodetic triangulation in these parts. Australia, however, is planning to map great expanses of its territory by adaptation of radar to survey and it may then be possible to effect the above connection across the intervening islands partly by triangulation and partly by radar, either by the Commonwealth itself or through international scientific agencies.

In addition to the above gaps there are the following weak links in the connecting triangulations :—

(i) The triangulation connection of India and Burma series needs strengthening.

(ii) The Siamese triangulation between junction with India at 10° N. and Rājburi base needs improving.

10. **Possibility of Connection to Triangulation of Philippines.**— There is a remote possibility of continuing the triangulation chain India–Siam–Malaya–N.E.I. to Philippines through Celebes, when the Sumatra–Java–Soenda Archipelago triangulation is extended to Flores Islands. The triangulation in Sarawak, Brunei, and Borneo may also get linked up to the triangulations of Celebes and Philippines at some distant future date. A brief account of triangulations in these countries is therefore placed on record below.

11. **Triangulation in Celebes.**—The Celebes primary triangulation system consists of 72 stations. The observations were commenced in 1911. The angles were measured with 27-cm. micrometer theodolites from Pistu and Martins, Wegner and Wanschaff. Three bases (Djeneponto 1911, Tondano 1915, Korodolo 1920) were measured with Jaderine apparatus.

The triangulation is based on an astronomical latitude and azimuth determination at M. Lowe P.I. and a telegraphic longitude determination at Makassar in 1891. The triangulation chain has been adjusted on 3 bases and 5 astro. azimuths. The differences between geodetic and astro. azimuths found were of the order + 27" and − 21", which are said to be due to the plumb-line deflections caused by the big mountain masses and the sea. The Celebes triangulation system is not connected either with the Borneo or with the Philippines triangulation systems.

12. **Triangulation in the Philippine Islands.**—An account of the triangulation in the Philippines is given in the publication of the Bureau of Coast and Geodetic Survey, Manila "The Triangulation of the Philippine Islands, Vols. I and II". The main triangulation work in the Philippines was done by the U.S. Coast and Geodetic

Survey from 1901 to 1926. It was done in bits of second and third order triangulation scattered throughout the Islands, each bit being based on its own geodetic datum. Eventually these separate pieces were connected by second order triangulation, which was connected with the Luzon datum.

The principal triangulation of the Philippine Islands is therefore of the second order, i.e. accuracy ± 1/10,000, and average triangular error about 3″. It forms the frame-work on which all other triangulation in the archipelago is based. It is well controlled by 98 measured bases, 52 observed azimuth and 49 latitude and telegraphic longitude stations.

All the positions and azimuths have been computed on Clarke's spheroid of 1866.

The fundamentals of the geodetic datum at Luzon are as follows :—

Lat.	13°	13′	41″	·000 N.
Long.	121	52	03	·000 E.
Azimuth to Baltassar	9	12	37	·00

13. **Triangulation in Brunei** —The details of the triangulation in Brunei are published in a book "The triangulation of Brunei by W.F.N. Bridges, D.S.O., Surveyor General F.M.S. and S.S." from which the following brief information has been abstracted :—

The triangulation of Brunei was carried out in 1935. The observations were made with a 10–inch Repsold theodolite at the primary stations and with a 3–inch Zeiss theodolite at the secondary stations. The p.e. of an observed angle, is ± 0″·055 for primary work and ± 0″·77 for secondary work. The average triangular error for primary work is 1″·12 and for secondary work, 1″·51.

The scale of the triangulation is derived from Marudi Base-line, measured in August 1935, with Invar tapes, the final length accepted being 19703·2536 feet with a p.e. of ± 0·0197 feet.

The initial azimuth of the triangulation is the azimuth at Timbalai of Pisang. The value adopted is 206° 31′ 42″·04 ± 0″·21. This is derived from 33 sets of time observations to Polaris made in 1936 with a 10-inch Repsold theodolite. Observations to Polaris were also made by the Sarawak Survey department in 1936 at Miri. The resulting azimuth Miri–Lambir was 180° 16′ 02″·20 ± 0″·23 and this agreed almost exactly with the azimuth of this line derived from triangulation.

The fundamental latitude and longitude accepted are those of Timbalai. The values adopted are 5° 17′ 02″·55 N. and 115° 10′ 57″·58 E. The latitude is derived from 48 observations of 19 pairs of stars by Talcott method, and has p.e. of ± 0″·11. The values agree closely with the Admiralty value, viz. 5° 17′ 02″·89 derived from observations at the nearby Flagstaff, Labuan to which a connection was made. The longitude is also similarly derived.

The datum for heights is the mean sea-level at Muara determined by tide-pole observations for a lunar month.

The spheroid used in computations is Everest with $a = 20{,}929{,}31 \cdot 8$ feet, $1/\epsilon = 300 \cdot 8$.

14. **Sarawak East and West Triangulation**.—Sarawak East triangulation is a continuation of Brunei triangulation based on Timbalai as datum. Sarawak West triangulation is based on astronomical co-ordinates of Golf Links Lat. 1° 32′ 49″ ·94 N., Long. 110° 20′ 27″ ·00 E.

The following information has been abstracted from Empire Survey Review No. 42, pages 206 to 214.

The primary triangulation in Sarawak has been computed in two sections :—

(*a*) the portion falling within the Western Meridional District of the State, and

(*b*) the portion falling within the Eastern Meridional District of the State.

Each portion is regarded as a separate entity and no adjustment for closure has been made to either of them.

The western system is in terms of the Matang Base (p.e. ± 1/1300,000), the latitude and longitude observed at Kuching (Golf Links Trig), and the azimuth observed at Serapi.

The eastern system is in terms of the Marudi Base (p.e. ± 1/1,000,000), the latitude and longitude observed at Labuan, and the azimuth observed at Timbalai (Labuan). An azimuth observed at Miri agrees with that derived from triangulation within 0″ ·04.

There are 10 stations which are common to both series. The mean discrepancy (West series — East series) at these stations is + 2″ ·10 in latitude and —2″ ·27 in longitude. The discrepancy in the values of the side Pantak–Spali in terms of the two is 1 in 207,000. The closure in azimuth between Serapi and Timbalai or Serapi and Miri is 2″.1.

Heights of the eastern series are closely in terms of M.S.L., those of the western series are based on a mean tide level at Kuching and are likely to be higher than the M.S.L. at the mouth of the Sarawak river.

15. **Triangulation in Borneo.**—(*a*) *North Borneo.* Complete details about the triangulation and its datum in North Borneo are not available. There is said to be a primary chain from Marudu Bay at the extreme north of the island, along the north–west coast to Labuan and the Sarawak border where it joins the triangulation of Sarawak. The portion between Jasselton and the Sarawak border was not finished until 1940.

The scale of this triangulation is derived from a base measured near Jesselton and the datum for the co-ordinates is the astronomical values of the latitude and longitude of Jesselton determined in 1938 by H.M.S. Herald.

The triangulation when completed will be connected to the triangulation of Brunei and the co-ordinates will then possibly be put in terms of its datum.

(*b*) *Triangulation in South Eastern Residency of Borneo.* The triangulation of this residency may be taken to have started in 1933, and was still in progress in 1939. Till April 1939, seventeen primary, 8 secondary and 15 tertiary stations had been observed. The computed co-ordinates were till 1939 based on the small primitive base-line near Balik Papen and Samarinda of the Royal Dutch Oil Company Survey. An accurate base-line was however observed in 1937 with three Invar wires Nos. 285, 286 and 1096 and Jaderine apparatus, near Djoewari (about 60 km. N.E. of Amoentai). Its length was 61100·95080 metres (reduced to M.S.L.) with probable mean total error of 1/5 M ; details of measurement, etc., are given in N.E.I. report to the International Union of Geodesy and Geophysics, 1939. It is not known if any use of this base-line has been made as yet or not.

The datum for co-ordinates is the astronomical latitude and longitude and azimuth observed at G. Segara (P5) accepted values being latitude 0° 32′ 12″·83 S ± 0″·163, longitude 117° 08′ 48″·47 E. of Greenwich ± 0″·12 and azimuth at P5 to P2 is 180° 52′ 07″·437 ± 0″·216. The longitude is determined by observing fundamental stars east and west for time and rythmic time signals from Malabar and Saigon for time comparison with Bosscha Astronomical Observatory at Lembang.

SECTION II.—TRIANGULATION LINKING INDIA, PERSIA, IRAQ AND SYRIA, EXECUTED DURING WORLD WAR II. (Refer to Chart II)

16. **The Primary Triangulation of Irāq.**—The primary triangulation of Irāq is only of secondary precision and was executed between 1930–35. It is divided into two series : the North Series and the South Series. Both the series start with the measured base at Nahrwān (E. of Baghdād). The North Series closes on a measured base at Kirkuk and the South Series on that at Batha. The measured values of the bases have been accepted and discrepancies between the triangulated and measured values have been adjusted. The details are given below :—

No.	Name of base	Apparatus employed	Date of Measurement	Length	Probable Error	Discrepancy (Measured – triangulated value)
				metres	mm.	
1	Nahrwān	30-Metre Invar Tapes Nos. 76, 77, 78 (Tape No. 76 was used as a standard)	1930	4441·91448	±3·00	Starting Base
2	Kirkuk	do.	1930	2009·30950	±3·34	1/20,000
3	Batha	do.	1930	2012·17679	±2·46	1/15,000

The initial latitude and longitude are the astronomical values of Nahrwān S. End Base :

Latitude 33° 19′ 10″·87 ± 0″·20 (for N & S. stars)
Longitude 44° 43′ 25″·54 ± 0″·69 (from wireless time-signals),

and the initial azimuth is that at 1 M of 2 M based on Polaris observations. The value adopted is 10° 55′ 51″·8 ± 1″·6.

Astronomical observations were also made for latitude, longitude and azimuth at Kirkuk and Batha, the differences *A–G* at these two stations being as follows :—

		Geodetic	Astronomical	*A – G*
		° ′ ″	° ′ ″	″
1. At Kirkuk S. end ..	Lat.	35 24 10·99	35 24 08·16	−2·83
	Long.	44 20 23·30	44 20 18·76	−4·54
Az. S. end of N. end ..		187 50 55·11	187 50 53·00	−2·11
2. At Batha N.W. end of base	Lat.	31 04 39·71	31 04 44·40	+4·69
	Long.	45 50 36·11	45 50 37·95	+1·84
Azimuth		..	unreliable	..

All observations have been made with an 8-inch theodolite on six zeroes on both faces, two measures on each face. The average triangular error of the North Series is 1″·48 (max. 5″·31) and that of the South series 1″·61 (max. 5″·39).

The reference spheroid is the Clarke's spheroid of 1880.

17. **The Paiforce Triangulation in Persia.**—Chart XIX shows the general lay-out of the net work of triangulation in Persia. This triangulation was wholly executed during the years 1941–43 by Indian Field Survey Companies forming part of the British and Indian forces in the area in World War II and supersedes the low quality work executed during World War I by the Mesopotamian Expeditionary Force.

The present work comprises 35 series forming 13 closed circuits, and 12 pendant series. The average triangular error of the whole triangulation which was executed with the universal Wild and Tavistock theodolites is about 7″. The lay-out consists generally of elongated quadrilaterals, due to necessity of speed, and nature of the country. The ratio of length to breadth of these quadrilaterals is mostly 2 to 1.

The starting data of the triangulation (base, azimuth and co-ordinates) are derived from stations Khanaqin (sheet NI-38I) and Qara Tapeh (sheet NI-38I) of Irāq Primary Triangulation. The triangulation is computed on Clarke's 1880 spheroid. To check the scale of the triangulation short bases were measured at frequent intervals. A number of azimuths from Sun or Polaris were also observed, but have not been used. The average discrepancy between triangulated and measured value of a base was 1/6,000. The discrepancies between triangulated and astro. bearings were irregular and varied from − 49″ to + 42″. In addition to these, three geodetic bases and Laplace stations were observed at Hamadān, Tehrān and Isfahān, results of which are as follows :—

Details of Bases

No.	Name of base	Apparatus used	Length of base reduced to sea level	Internal accuracy	Discrepancy with triangulated value	REMARKS
			metres			
1	Hamadān	100-foot Invar Tapes Nos. 1, 3 & 6	5142·7670	1/225,000	1/8,500	No. 1 Standard tape used for comparison
2	Isfahān	100-foot Invar Tapes Nos. 3 & 6	0376·4613	1/200,000	1/50,000	No. 7 do.
3	Tehrān	20-foot Tape No. 2 and 100-foot Invar tapes Nos. 3 & 6	5609·9645	1/3,000,000	1/2,400	No. 4 do.

Results of Astronomical Observations at Laplace Stations

Name of Laplace station	(1) Astronomical value		p.e.	(2) Geodetic value	(3) Diff. (1)−(2)	(4) −δG*
		° ′ ″	″	° ′ ″	″	
Hamadān	Latitude	34 55 30·0	±1·3	34 55 47·1	− 8·1	
	Longitude	48 33 24·0	±1·5	48 33 30·3	− 6·3	
	Azimuth from Polaris	176 37 59·5	±1·4	176 38 09·2	− 9·7	+ 6·1
Isfahān	Latitude	32 53 36·4	±0·3	32 53 34·4	+ 2·0	
	Longitude	51 26 04·5	±3·0	51 25 52·3	+12·2	
	Azimuth from Polaris	298 20 12·2	±0·42	298 20 57·1	−44·9	+51·5
Tehrān	Latitude	35 42 15·7	±0·3	35 42 20·0	− 4·3	
	Longitude	51 29 21·0	±1·5	51 29 07·4	+13·6	
	Azimuth from Polaris	114 39 52	±0·3	114 40 37	−45	+53

* Accumulated error of geodetic azimuth $= -\delta G = -(A_A - A_G) + (L_A - L_G)\sin\phi$.

The Laplace equation at Tehrān was not used to correct the geodetic azimuth as the value of astronomical longitude at this station is rather weak due to the rate of the chronometer not being properly determined.

The measured short bases, and the three geodetic bases referred to above have been made use of in the adjustment of the triangulation. Circuits closing on the Irāq primary or secondary points have been adjusted, so as to bring the whole network of Paiforce triangulation in Irāq terms.

This triangulation should not, however, be considered as anything of geodetic accuracy. It is a war time rapid work in which accuracy of the order 1/15,000 can be said to have been attained. The portion Isfahān to Nain, in particular, is very weak.

18. The Trans-Persian Triangulation connecting the Indian Primary and Irāq Primary systems.—The Irāq-Indian triangulation gap between Nain and Zahidān has been linked in 1944 by an Indian Army Survey Detachment under Capt. P. A. Thomas, R.I.E. A narrative of this work with a detailed account of the whole operation is published in the "Survey of India, War Research Series, Pamphlet No. 9". The work is mainly of good quality triangulation, one unavoidable gap, a quadrilateral in which all the angles could not be observed being made good by a 4-chain subtense traverse. The triangulation has an overall accuracy of 1/20,000, which can be stepped upto say 1/50,000 by a small amount of additional work to tone up the scale and to reinforce the Laplace control. Glass arc theodolites were used and average triangular error of the whole series was 2″. Computation of co-ordinates has been carried out working from the Indian end in terms of the Indian origin at Kaliānpur. The published values of the co-ordinates were in terms of Everest spheroid, but have been converted to those of the International spheroid, and computations thence have been carried westward in terms of the International spheroid.

The derived values of co-ordinates at Nain in International terms relative to Kaliānpur are :

Latitude 32° 54′ 30″·6
Longitude 53° 05′ 41″·4

The co-ordinates of the same point relative to Nahrwān, the Irāq origin in International terms are :

Latitude 32° 54′ 23″·5
Longitude 53° 05′ 36″·8

The discrepancies between these (Indian-Irāq) are :

+ 7″·1 in latitude, and
+ 4″·6 in longitude,

which are attributable to (1) relative deviations of the vertical at the datums of Indian and Irāq triangulations and (2) errors generated in the triangulation between the two origins, probable errors for which have been roughly estimated to be

± 2″·5 in latitude, and
± 3″·0 in longitude.

If the results of the Persian work are expressed in terms of Clarke 1880 spheroid in keeping with the Mid-East triangulation and are based on triangulation in Irāq origin terms, the co-ordinates of stations close to the 60° E. meridian differ from their values in terms of the published Indian triangulation pamphlets by + 12″·1 in latitude and — 4″·4 in longitude. This represents the discrepancy that would exist between the maps of India and Persia at their junctions.

19. **Primary Triangulation in Syria.**—Chart II shows the primary triangulation in Syria and the Levant. It consists of 8 series of varying but good accuracy. The main series (Alleppo Meridian & Coastal series) forms the back-bone of the triangulation. The mean square error of a direction (Ferrero's formula) is, for the meridian chain ± 0″·78 and for the coastal series ± 0″·87. The origin of the triangulation for azimuth and latitude is the southern terminal of the Bekaa Base.

The fundamental longitude was measured at the geodetic pillar at Ksara and is 35° 53′ 25″·26 E. of Greenwich. The scale of the triangulation is governed by 3 bases at Bekaa, Bab, and Hassetche. The triangulation is stated to have been adjusted on to these bases, but the closing errors of one base on another cannot be ascertained from the information available.

Check latitudes, longitudes and azimuths were also measured at Bab and Hassetche. Details are not available but we have the results which disclose the following differences from the geodetic values carried through the chain from Bekaa.

Station	Astronomical values	Geodetic values	A − G
	° ′ ″	° ′ ″	″
Bab ..	Lat. Long. } Not available Az.	Not available	− 6·318 +10·789 +21·125
Hassetche S. end of base .. Az. at S. end to N. end ..	Lat. 36 30 23·100 Long. 40 46 20·550 105 37 11·183	36 30 27·056 40 46 10·042 105 36 50·243	− 3·956 +10·508 +20·940

The two sets of observations show a satisfactory agreement between them. The Laplace equation at them, however, indicates an error of 15″ in the geodetic azimuth. The triangulation is unlikely to have developed this error and consequently there appears to be some error in the initial azimuth at the origin at Bekaa.

The co-ordinates of all the primary points published in Trig. lists issued by G.H.Q. M.E.F., are on Bekaa system. The bases at Bab and Hassetche have been used for adjustment but astronomical observations were ignored. Clarke's 1880 spheroid has been used for computation.

20. The Irāq-Syria Triangulation Connection.— The Irāq-Syria triangulation connection was carried out by Lt.-Col. G. H. Osmaston and Major R. H. Sams, R.E., of the Survey Directorate, Paiforce in December 1941, and was confirmed by further triangulation done by Capt. P. G. Mott, R.E., of the same Directorate in March 1942.

Col. Osmaston's series made a connection between the Irāq secondary stations Tel Kharnuf, Qabr Hajr and Tel Huwaish in the Irāq-Syrian frontier in sheet NJ-37X, and the Syrian primary stations Tel Hanta (Tel Abu Jerade) and Tel Safra in the same sheet.

Closures on Syrian values were as follows :—

Station	Irāq values (Grid metres)	Syrian values (Grid metres)	Differences Irāq-Syria	REMARKS
Tel Safra	E. 1828 072·5 N. 367 591·0 H. 1147·2 feet	1828 009·0 367 867·1 1147·3 feet	+63·5 metres −276·1 „ −0·1 feet	Value in Grid C (Origin 39° 30″ 45° 00″) Clarke's 1880 spheroid
Tel Hanta	E. 1809 207·3 N. 352 843·0 H. 1290·7 feet	1809 140·8 353 118·8 1292·7 feet	+66·5 metres −275·8 „ −2·0 feet	
Side (Tel Safra to Tel Hanta)	23945·8 metres	23948·3 metres	−2·5 metres or−1/10,000	
Azimuth at Tel Safra of Tel Hanta	231° 59′ 00″	231° 59′ 14″	−14″	

The connection was made firmer when Capt. Mott carried forward the triangulation from Tel Hanta–Tel Safra starting with the Irāq values and closing on Syrian primary stations Kapes Darh and Mabsbat near the Turko–Syrian border. The differences here (Irāq-Syria) were as follows :—

Station	Value in Irāq terms (Grid metres)	Syrian values (Grid metres)	Differences Irāq-Syria	REMARKS
Kapes Darh	E. 1758 818·8 N. 406 749·1 H. 1722·7 feet	1758 750·6 407·032·3 1726·4 feet	+68·2 metres −283·2 ,, −3·7 feet	
Mabsbat	E. 1778 828·1 N. 396 454·4 H. 1405·9 feet	1778 761·3 396 735·3 1404·2 feet	+66·8 metres −280·9 ,, +1·7 feet	
Side Kapes Darh to Mabsbat	22502·3 metres	22504·6 metres	−2·3 metres or−1/10,000	
Azimuth at Kapes Darh of Mabsbat	297° 13′ 31″	297° 13′ 46″	−15″	

Thus the Irāq and Syrian primary systems have an average discrepancy of about + 65 metres in E., − 280 metres in N. (or − 9″·1 in latitude & + 2″·6 in longitude), − 1/10,000 in scale, 15″ in azimuth and negligible in heights.

21. **Indo-European Connection.**—The connection of Indian and European triangulations has long been considered as of great scientific interest. It is, however, obviously beset with considerable political, topographical and financial difficulties. In 1913, a connection was made after arduous field work between the triangulations of India and Russia in the Pamirs, details of which are given in the Records of the Survey of India, Vol. VI, 1913. The work was done under the impression that it would lead to the connection between Indian and European systems of triangulation. However, from the scanty information gleaned from various sources later, it appeared that Russian geodetic triangulation did not extend upto the Indian border and that it was not connected to European triangulation. It is possible that in their vigorous pre-war programme the Russians have managed to throw in a chain of geodetic triangulation in Turkistān and have also effected a connection with Europe but nothing is known of these details. In any case, the lay-out of connecting Indian triangulation and the precision with which angular measurements were made could not be effected upto geodetic standards on account of the difficulties of the terrain and this work can not be revised without considerable efforts.

The work of the Indian Survey Military units is, therefore, of great interest as a contribution to the achievement of the Indo-European connection. The Indian triangulation has been extended to Persia and Irāq (some portions are of course very weak, see paras 17 and 18), and a junction has been effected between the Irāq primary triangulation and the French Syrian triangulation. A connection of the Syrian primary triangulation to the European triangulation via Palestine or via Turkey is a definite possibility.

22. **Discrepancies at Junctions of Various Countries.**—The triangulation series of the countries discussed in this chapter, having all been connected, it should be possible to reduce all these triangulations to the Indian datum at Kaliānpur. The question of the spheroid to be chosen however demands further consideration. The triangulation of India and Burma is computed on Everest spheroid which does not fit the geoid at all well and its axes are about 3,000 feet smaller than those of the more modern spheroids adopted to represent the figure of the earth. If this spheroid is used consistently in all neighbouring countries such as Persia, Burma, Siam, Indo-China, etc., (which is by no means the case at present), the map sheets at the junctions will no doubt fit and the topographers will not be worried, but still certain complications will be introduced. In the first place, all these countries will occupy on the map more than their proper share of the earth's surface and secondly in the out-lying areas there will be a large systematic difference between triangulated and astronomical positions. Thus in Siam the use of Everest spheroid extended so far east from Kaliānpur datum produces a systematic tendency for astronomical longitudes to be about 17″ too small. There is also a systematic tendency for astronomical latitudes to be about 8″ too large in Siam south of latitude 16° N. These large deflections of the plumb-line will not in any way be due to anomalous masses in the earth's crust but only to an unsuitable spheroid. On a good spheroid, the astronomical values are only liable to random departures from the triangulated values. The availability of accurate triangulation in the countries bordering India has brought to the fore the question of adoption of a suitable spheroid like the International in India and the determination of its orientation at the datum. But this will, involve besides republishing of all our trig. data, a shift of the details of all maps with respect to their graticule—a colossal undertaking. In the long intervening period, the country will be saddled with two sets of maps and the scheme requires such ample resources and finance that inspite of its indubitable advantages, there is no hope of embarking upon it at an early stage and it can only be regarded as a long range objective. There is thus no alternative but to put up with the present state of affairs in which each country's maps are gridded with respect to its own sphericals on its own independent origin and at the boundaries when one crosses from one datum to another, the spherical graticules of a series may be out of sympathy with that on any adjacent map series of another country and the graticules may be out of sympathy with the grid. As an example, at the meridian of 60° E. which is the junction line of the Indian and Persian grids, the discrepancy (India-Persian

terms) is + 14″·6 in latitude and — 2″·6 in longitude. The two sets of maps on either side of 60° E. will obviously differ by the above amounts and there may appear a no man's land in between, not covered by any map, which will be a source of worry to the topographers, especially when working on larger scales. The remedy is, to have a certain area of overlap (say amounting to one sheet depth) on either side of the junction line and have maps on both these systems in this area. The two sets of maps should also indicate the discrepancies by suitable marginal notes.

CHAPTER II

LEVELLING

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

23. **General.**—No levelling of high precision was carried out during the war years 1941 to 1945 due to the non-availability of trained personnel. One detachment under Mr. B. P. Rundev (U.S.S.) was, however, formed in 1946 to run a new levelling line from Bombay to Ratnāgiri, which is not covered by the old precision level net. The Bombay Government had been pressing for it for a long time and the bench-marks along this line had already been built by Bombay Public Works Department in 1938.

Before leaving for Bombay, the detachment also connected West End of the Dehra Dūn base-line. This base is seven miles long and was measured in 1835. Its east end was connected to spirit-levelling in 1862, but the west end had not so far been connected. Of late, some need has been felt for a reliable geodetic base, with the height of both of its ends fixed by spirit-levelling, in order to test new methods of precision traverses and also to provide control data for training purposes. The height of the west end of the base determined by vertical angles from three stations was 1770 feet; the spirit-levelled height as now determined is 1774 feet.

The ending of the war and the presence of an Indian Field Survey Company composed of mobilized Survey of India personnel in Siam afforded the long sought for opportunity for closing the small gap existing between the levelling systems of Burma and Siam.

A line of secondary precision, 52 miles in length, for providing control for the Kosi Dam Project was also carried out by a small detachment under Mr. M. N. Kutty.

24. **Summary of out-turn.**—The total out-turn of work carried out by detachments of the Survey Research Institute during the period under report is as follows :—

(*a*)	H.P. Levelling in both directions ..	6 miles.
	H.P. Levelling in one direction ..	338 miles (344 gross)
(*b*)	Secondary levelling	52 miles.

The details are given in Table 1.

25. **Narpatganj to Barahakshetra.**—The levelling was done with the object of providing height control for the Kosi Dam Project. The detachment under Mr. M. N. Kutty (Class II Probationer) as 1st leveller, and Mr. A. C. Chawla (Class II Probationer) as 2nd leveller started work on 19th February 1946, on the system of

simultaneous double levelling using Zeiss levels Models III and II respectively and Invar staves. The work started from an inscribed bench-mark No. 82/72 N. about 80 yards S. of the junction of roads to Forbesganj and Kamālpur and closed on a new rock-cut bench-mark No. 132/72 N. at Barahakshetra (Nepal). The maximum shot used was 2 to 3 chains and the maximum discrepancy allowed between the two levellers was 0·007 feet. The route followed was partly along unmetalled road and partly along cart-track via Phulka, Ghurna, Basmatia, Bakro, Hardia and Chatra. From Bakro the slope of the ground began to increase and after Chatra the line had to follow a footpath scoped out on the steep slopes of hills and the levelling was carried upto Barahakshetra with much difficulty. The work forms secondary levelling line 151 BB and is pendant. The bench-marks connected enroute were inscribed and rock-cut.

The total length of the line excluding check levelling is 52 miles and contains 35 bench-marks generally spaced about a mile apart except for a distance of 17 miles from Bakro to Hardia, where there is no bench-mark.

The detachment completed field work on the 14th April, 1946.

26. Connection to West End G. T. Base Dehra Dūn.—The observations in the fore and back directions from bench-mark 278/53 F on Dehra Dūn-Chakrāta road of branch line 61 D (Dehra Dūn to Mussoorie via Kālsi and Bhadrāj) were undertaken by Mr. B. P. Rundev (U.S.S.) to connect West End G. T. Base Dehra Dūn in September 1946. Later the line was done in the fore direction only by Mr. Jagan Nath (U.S.S.) from 27th February to 3rd March 1947. The discrepancy between the two levellers was 0·004 feet in a distance of 4·4 miles, which is satisfactory.

The spirit-levelled height of the West End of Dehra Dūn base-line determined by the above levelling is 1774·052 feet.

27. Bombay to Kolhāpur via Ratnāgiri.—A detachment consisting of Mr. B. P. Rundev (U.S.S.) in charge, one Topo Assistant (under training) and 14 *khalāsīs* commenced work on 8th December 1946 from Standard Bench-Mark, in the compound of the P.W.D. Secretariat building, Bombay. For transport the detachment was provided with one 15-cwt. Weapon Carrier, with one driver and a cleaner. The truck remained in good working order throughout the field season and greatly contributed towards the success of the field programme since the detachment remained free from difficulties of procuring local labour and cartage which would have been considerable.

After some check levelling near Bombay the work was continued to Kolhāpur via Ratnāgiri in the fore direction. The line forms part of main lines Nos. 122 and 123 of the new level net. Old bench-marks on the main line No. 29 (Nira-Hubli) at and near about Kolhāpur were found destroyed and the work had to be closed on a new rock-cut bench-mark at Kolhāpur.

The route followed was Bombay to Thāna along Agra road, Thāna to Panvel along Poona road, Panvel to Ratnāgiri via Pen, Nagothana, Mahad, Kashedi Ghāt, Khed, Chiplūn and Sangameshvar along the main motor road and thence to Kolhāpur via Pali, Sakrpa, Amba Ghāt and Malkāpur. The first 50 miles of the line lay on fairly flat ground, but the remaining part was along hilly country which was very steep at places particularly at the Western Ghāts which had to be crossed at two places. The out-turn in the hilly country fell considerably low as about 30 stations on an average had to be occupied in a mile (as against 8 to 10 in the plains). The whole line covered nearly 30,000 feet in rise and fall.

Inspite of all possible help rendered to the detachment by the local officials, the times were abnormal and the procurement of suitable food presented some difficulty. Consequently the health of the detachment remained unsatisfactory. On an average three men suffered from malaria throughout the season and almost the entire personnel from minor ailments from time to time. Towards the end of the season Mr. B. P. Rundev fell sick for three weeks due to sore eyes. He was temporarily relieved on 2nd April by Mr. Jagan Nath (U.S.S.) who carried forward the observations from Wandri, P.W.D. Stores to Ratnāgiri, and also observed the branch-line to Mirya H.S. He also did part of the section Ratnāgiri-Kolhāpur. The total distance observed by him was about 36½ miles. Mr. Rundev was fit enough to resume observations on 20th April and completed the remaining portion of the Ratnāgiri-Kolhāpur section, finally closing work on 29th May 1947.

28. **Indo-Siamese connection.**—Levelling in Burma has been carried to an inscribed bench-mark at Mehsai Bridge about two miles inside Siamese territory in sheet 93 P, and the Siamese in turn had brought their levels to a point Phayao north of Lampang as shown in Chart III. The termination of hostilities and the presence of No. 2 Indian Field Survey Company in the area afforded a unique opportunity for filling this gap. A detachment under Capt. I. K. Ponappa as first leveller and Subedar Z. A. Qureshi as second leveller started work on 8th December 1945 on the system of simultaneous double levelling of secondary precision using Zeiss pattern Model No. 3 levels Nos. 5741 and 38870 respectively and Invar staves. The work started from the Siamese bench-mark CCXCIX at Phayao Police Station and closed on the Standard Bench-Mark 29/93 P at Hawang-Luk. The difference between the first and second leveller was 0·046 feet in a distance of 100·9 miles. The height of B.M. 29/93 P as published in the levelling pamphlets for Burma was found to be 1·567 feet higher than that now obtained in terms of the Siamese levelling.

The levelling in Burma is with respect to the Amherst datum, which was connected to Indian levelling in 1932–33 at Chittagong. This levelling showed that the mean water level at Amherst was 1·364 feet lower than the Indian M.S.L., which is based on nine selected tidal observatories. If this is taken into account and the Burma heights are reduced to Indian M.S.L. datum, the discrepancy between India-Burma and Siamese levelling is reduced to − 0·2 feet.

The Siamese datum for levelling is the tidal observatory at Koh-Hlak where continuous observations were taken for the period 1910–15. While it is of interest to know that mean water levels at Amherst and Koh-Hlak are nearly the same, it may be pointed out that over long distances, it is an inherent weakness of levelling that it cannot give any conclusive results in this respect. The levelling errors assume the same proportions (if not greater) as the discrepancies between the mean water levels at different open sea tidal stations. All that one can say about this figure of 0·2 feet is that it is not unexpected. A direct connection between the Amherst tidal observatory and the Siamese datum, viz., Koh-Hlak tidal station should yield valuable check and it is desirable that this should be carried out at an early date.

29. **The New Level Net.**—The first precision levelling net of India was completed and simultaneously adjusted by the method of least squares in 1909. At the International Geodetic Conference in 1912 it was decided that to satisfy modern scientific requirements there should in future be a new category of levelling to be called "Levelling of high precision", which should satisfy certain standards of accuracy. Work on a new level net, observed on the system of H.P. levelling, was, therefore, commenced in 1913–14 in keeping with the decision of the International Geodetic Conference.

The old precision net was observed on the system of simultaneous double levelling, in which each line was observed by two levellers working independently, one following the other under practically identical conditions. In the system of high precision-levelling each line of levels is levelled independently in both the forward and backward directions on dates separated by about a year.

When the new level net was planned, it was estimated that it would be completed in 1938, but financial stringency which prevailed after 1931 entailed a curtailment of the detachments. Urgent demands for secondary and precision levelling to test the change of levels after the earthquakes and to meet the needs of priority railway and irrigation projects also impeded the progress of H.P. levelling. Work on this class of levelling was almost entirely suspended during the two world wars, with the results that even today about 5,000 miles of H.P. levelling still remain to be executed to complete the new level net.

The levelling under report has added 338 miles to the total mileage of the new level net in one direction only. The net when completed will comprise of about 15,800 miles.

30. **Primary Protected Bench-Marks.**—A complete list of Primary protected bench-marks including standard bench-marks and G.T. stations connected by levelling is being prepared in the Computing Office. These bench-marks are indicated by suitable symbols on Chart V.

TABLE 1.—*Tabular statement of out-turn of work, season 1946–47.*

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: Other	Number of bench-marks connected: Others
H. P. Levelling Detachment.										
Sub-branch-line of Branch-line 61D (Dehra Dūn–Mussoorie via Kālsi & Bhadrāj) from B.M. 278/53F to Dehra Dūn Base-line, W. End S. (Fore)	9-11-46 to 11-11-46	4	..	4	78	104	66	..	1	2
Do. (Back)	12-11-46 to 15-11-46	4	..	4	99	74	58	..	1	2
Do. (Fore)	27-2-47 to 3-3-47	4	..	4	93	119	68	..	1	2
Line No. 122 (Surat to Ratnāgiri) portion Bombay to Ratnāgiri (Fore)	Dec. 46 to April 47	239	12	251	0,849	9,307	4,568	3	4	389
Line No. 123 (Ratnāgiri to Hyderabad Deccan) portion Ratnāgiri to Kolhāpur (Fore)	April 47 to May 47	86	1	87	6,195	4,543	2,054	1	4	158
Secondary Levelling Detachment.										
Line 151BB Narpatganj to Barahakshetra	Feb. 46 to April 46	50	1	51	889	1,184	1,170	..	..	37

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 1946–47 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1946–47	
			miles		*feet*	*feet*	*feet*
			At Dehra Dūn on line 61 D				
278	53 F	Culvert ..	0·00	1928-29	0·000	0·000	0·000
276	,,	Bridge ..	2·15	,,	+ 89·336	+ 89·345	+0·010
275	,,	Pillar ..	2·35	,,	+ 90·768	+ 90·778	+0·010
278	,,	Culvert ..	0·00	,,	0·000	0·000	0·000
279	,,	Culvert ..	1·15	,,	− 40·159	− 40·207	−0·048
			At Bombay on line 32				
2	47 B	S.B.M., Bombay ..	0·00	1877-78, 1906-07	0·000	0·000	0·000
1	,,	Step ..	0·38	1910-11	+ 0·013	+ 0·030	+0·017
81*	,,	Step ..	0·40	1914-15	+ 0·113	+ 0·130	+0·017
82*	,,	Step ..	0·74	,,	− 0·703	− 0·685	+0·018
10	,,	Step ..	0·79	1877-78, 1906-07, 1910-11	− 0·651	− 0·630	+0·021
84*	,,	Step ..	0·96	1914-15	+ 2·584	+ 2·588	+0·004
2	,,	S.B.M., Bombay ..	0·00	1877-78, 1906-07, 1910-11	0·000	0·000	0·000
34	,,	Plinth ..	0·23	1930-31, 1934-35	− 4·711	− 4·697	+0·014
29	,,	Step ..	1·39	,,	− 4·488	− 4·500	−0·012
30	,,	Type 'B' ..	1·44	,,	− 5·497	− 5·510	−0·013
2	,,	S.B.M., Bombay ..	0·00	1877-78, 1906-07, 1910-11	0·000	0·000	0·000
3	,,	Step ..	0·04	,,	− 2·173	− 2·173	0·000
4	,,	Step ..	0·05	,,	− 2·139	− 2·135	+0·004
5	,,	Step ..	0·29	,,	− 3·540	− 3·519	+0·021
6	,,	Step ..	0·29	,,	− 3·458	− 3·437	+0·021
7	,,	Step ..	1·18	,,	− 7·252	− 7·248	+0·004
38	,,	Step ..	1·84	1914-15, 1930-31, 1934-35	− 3·352	− 3·324	+0·028
39	,,	Step ..	2·25	,,	− 0·008	+ 0·008	+0·016
23	,,	Type 'C' ..	2·95	1877-78, 1906-07, 1910-11	+ 13·816	+ 13·852	+0·036

(*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 1946–47 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1946–47	
			miles		*feet*	*feet*	*feet*
				At Bombay on line 32			
41	47 B	Type 'B' ..	2·98	1930-31, 1934-35	+ 12·205	+ 12·238	+0·033
42	,,	G.T. Mark (Observatory) ..	3·01	,,	+ 14·149	+ 14·181	+0·032
2	,,	S.B.M., Bombay ..	0·00	1877-78, 1906-07, 1910-11	0·000	0·000	0·000
105*	,,	Seat ..	0·66	1914-15	+ 2·805	+ 2·831	+0·026
79*	,,	Step ..	0·99	,,	− 3·818	− 3·804	+0·014
76*	,,	Plinth ..	2·35	,,	− 4·788	− 4·863	−0·075
74*	,,	Pillar ..	2·89	,,	− 4·567	− 4·542	+0·025
73*	,,	Sill ..	3·15	,,	+ 0·384	+ 0·406	+0·022
71*	,,	Step ..	3·78	,,	− 3·914	− 3·885	+0·029
				At Kolhāpur on line No. 29			
23	47 L	E.B.M., Kolhāpur ..	0·00	1877-78	0·000	0·000	0·000
22†	,,	Step ..	0·83	,,	− 1·617	− 2·219	−0·602

* B.M's. from "Supplement to the levelling pamphlet 47, Island of Bombay corrected to 1937".

† Disturbed.

TABLE 3.—*List of triangulation stations connected by spirit-levelling, season 1946–47.*

Name of station	Height above mean sea-level		Difference (Lev.—Trian.)	REMARKS
	Spirit-levelling	Triangulation		
	feet	*feet*	*feet*	
Mirya H.S.	471*	473	– 2	

* The S.L. height refers to a ○ cut on brick at top centre of the referring pillar which was 2 feet 5 inches above the platform level. The height of the platform above the mark on rock could not be ascertained.

CHAPTER III

GRAVITY

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

31. **General.**—The year 1939–40 marked the close of an epoch of pendulum observations for gravity in India which were started in the beginning of this century. 564 stations distributed more or less uniformly over India and Burma (an area of over one and a half million square miles) had been completed. This period happened to coincide with the outbreak of war, when the normal geodetic activities of the department had to make way for work which had only a direct bearing on war effort. As it happened, it had been felt for some time that the pendulums had served their purpose by providing a broad frame-work and that the next stage was to put in further stations for detailed studies for which the pendulum apparatus was unsuited on account of the laborious observations and computations that it involved. It had been known since long that the various premier oil companies in the world especially in Amèrica had in their possession precise and quick instruments called gravimeters for differential measurement of gravity, but the secrets of these were jealously guarded. At the end of the war, enquiries revealed that the Frost Gravimeter Co., of Tulsa, Oklahoma were putting on the market a precise gravimeter. This was immediately indented for and one instrument was received early in 1947.

32. **Description of the instrument.**—The Frost Gravimeter is an astatised spring balance for the static measurement of small variations in gravity and has a natural period of 16·5 seconds. The mechanical system consists of a horizontal beam, suspended at one end and loaded with a gold mass at the other end. This end is supported by a main spring making an angle of approximately 45° with the beam. This spring is of the zero length variety and has actually a negative length. Pictorially this sensitive seismograph may be represented as in Chart VII, Fig. 1. A is the pivot and B the end which goes up or down as gravity changes, producing corresponding changes in tension of the main spring M. This deflection of the beam up and down is, however, not read directly but the beam is restored to its undeflected position by another spring W, called the weighing spring which is attached to a micrometer. The tension of the main spring is kept constant at all stations and the difference in weight of the suspended system due to changing gravity is balanced by the weighing spring and read on a micrometer dial. The beam is thus read at the same equilibrium position which is carefully determined as one of minimum level sensitivity. The

capacity of the dial (i.e., the amount of gravity anomaly it can measure) depends on the stiffness of the spring W. With the present spring, one dial division = 0·0809 mgals. The micrometer has 50 scale divisions and is capable of 30 revolutions, so that the instrument has a total capacity of 120 mgals. This range can be increased by insertion of a stiffer weighing spring. The beam is enclosed in a damping box and damping is adjusted to critical value. It carries a hollow cylinder on one end to compensate for variations in the barometric pressure.

The instrument consists of two cylinders which are packed with kapok for insulation and contains two heating coils having a capacity of 25 watts operated by a 6-volt battery. Two thermostats controlled by two sensitive relays maintain the two chambers at a constant temperature. The thermostat which operates the inside heat casting is set 10° above the outside temperature and about 2° higher than that which operates the outside heater, The instrument has to be maintained in thermal equilibrium by keeping it always hooked to a well charged battery and if at any time the battery fails, the instrument must be heated up again for about 12 hours before it can be used otherwise the readings will be most erratic.

During the course of field operations, the gravimeter has to be brought to the base station every few hours to ascertain the drift which is then linearly applied to the intervening stations.

The instrument has a working range of 120 mgals. in one setting and has a sensitivity of 0·1 mgals. per dial division, reading being possible to 0·01 mgals. Its weight is 37 lb.

33. **Tests and trial circuits.**—Soon after the instrument's arrival and assemblage in Dehra Dūn towards the end of March 1947, certain trial observations were taken to test its working. It was received with a very incomplete set of instructions and was found to be very much out of adjustment, particularly as regards the damping box, cross hairs, thermostats and the bubbles. This necessitated its dismantling several times before it could be set right satisfactorily. Frequent tests for drift, backlash, bubble and nul-point were carried out and several preliminary trial runs were made in the Survey of India (G.B.O.) Compound before the instrument could be certified as fit for regular work.

It was often noticed that the bubbles and consequently the cross-hair of the instrument had a tendency for abnormal (and sometimes erratic) drifts, when working out-doors under a survey umbrella or even under shade, this being due to the high sensitivity of the bubbles in relation to small changes of temperature. This difficulty was to a great extent overcome by providing a cloth pad to keep the bubbles covered.

It was not possible to calibrate the instrument between two known gravity stations as is usually done, since all the known stations in India are pendulum stations which are of a far less precision than that attainable with the gravimeter. The makers' cali-

Chart VII

Plan of Gravimeter

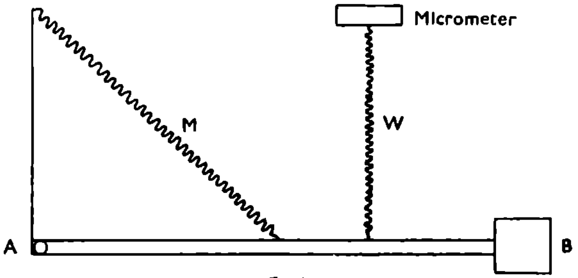


Fig. 1.

Test runs with the Gravimeter.

Scale of Diagram 1 inch = 16 miles.

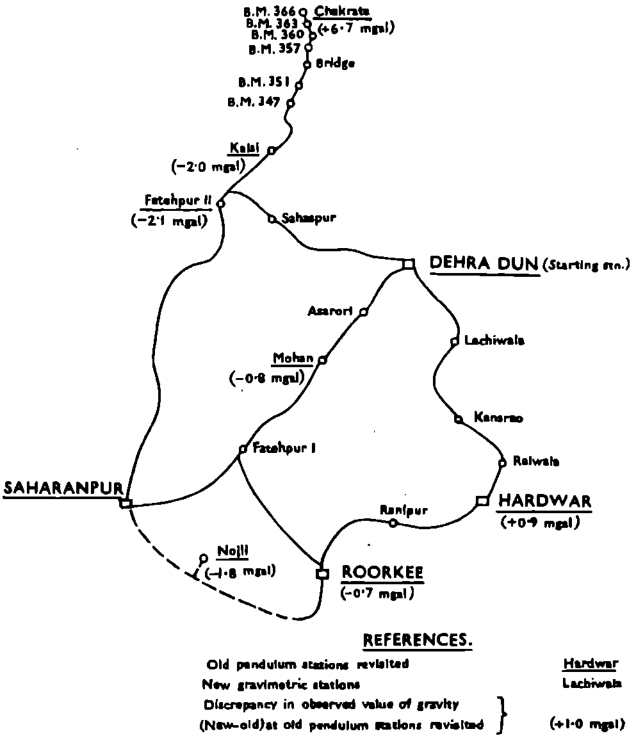


Fig. 2.

bration value, viz., 0·0809 mgals. per dial division (which is said to be correct to 1%) has accordingly been accepted pending an independent determination.

To test the instrument's working under field conditions, a trial closed circuit of about 100 linear miles was first run near about Dehra Dūn during the third week of April by Mr. A. N. Ramanathan, M.A. The traverse started from Dehra Dūn and proceeded along the motorable road to Roorkee via Fatehpur I, thence to Hardwar and thence back to Dehra Dūn via Raiwala, Kansrao and Lachiwala. A 15–cwt. truck was used for transport, the instrument being kept fastened in its cushion box to stand all jolts and jerks during transport. The last 20 miles of the circuit was along a very bad road and the instrument was subject to very severe jolts. The circuit took 3 days to complete and included five old pendulum stations. The maximum discrepancy between the old values of gravity and those now obtained was 1·3 mgals, a very satisfactory result considering that the old values are correct only to 1 or 2 mgals. The closure error of the 100 miles circuit was only 0·6 mgals.

Taking off from station Fatehpur I of the above circuit another old pendulum station at Nojli was connected, the discrepancy there being 1·2 mgals.

To test the behaviour of the instrument in hilly country, where "re-setting" of the instrument is often required, a line was also run in May from Dehra Dūn to Chakrata (a hill station) along the motorable road via Fatehpur II and Kālsi. The traverse was about 60 miles long and included three pendulum stations.

Chart VII, Fig. 2 shows the various traverses run, with the stations observed at and Table 1 shows the results of the observations (adjusted for closure errors of circuit), including the discrepancies with the old values at the known stations connected. The results are on the whole very satisfactory. The procedure that was adopted in establishing the stations say A B C D, etc., in the above traverse was to run A B A, B C B, etc., or A B C B A, C D E D C, etc. depending on the distance between stations, the only condition being that each bit of the traverse so run had to close back on the base stations within 3–4 hours to control the instrument's drift within a reasonable limit. The average drift under normal field conditions was found to be only of the order of 2 dial divisions (i.e., about 0·15 mgals.) per hour. This is more than what is usually claimed for the instrument when it is housed in a vehicle with a specially constructed body. Much larger drifts were encountered on certain occasions when the instrument was taken through a large range of height in a short time.

TABLE 1.—*Results of trial observations with Frost Gravimeter in the vicinity of Dehra Dūn.*

Serial No.	Station (with brief description)	Date of observation	Deduced value of g from observations	Mis-closures	g after adjustment of mis-closures	g from old pendulum stations	Discrepancies with old values (mgals.)
			cm/sec²	cm/sec²	cm/sec²	cm/sec²	
1	P. S. R. I's. Office Room (G.B. compound) ..		979·0630 (assumed)	..	979·0630	979·063	(Assumed as starting value)
2	B.M. No. 10/53J in G.B. compound (on basement) ..	13-16 April	·0629	..	·0629		
3	B.M. No. 6/53J in G.B. compound (on basement) ..	13 April	·0632	..	·0632		
4	B.M. No. 35/53F at Asarori (near Police outpost) ..	14-15 & 17 April	·0666	..	·0666		
5	Aux. mark near B.M. No. 17/53F at Mohan (at NE. corner of square parapet of small brick culvert on E. side of road, about 50 yds. S. of B.M. No. 17/53F) ..	17 April	·1158	+·0001	·1159		
6	Mohan F.R.H. gravity room, (old pendulum station) Mark inside the room about 5 ft. from the door ..	18 April	·1081	+·0001	·1081	·100	− 0·8
7	Fatehpur I D.B. (over B.O.M. in front of N. door)	,,	·1338	+·0001	·1339		
8	Roorkee P.W.D. I.B. (old gravity station—Room No. 1). Mark about 8 ft. E. of the W. door of room ..	19 April	·1281	+·0002	·1283	·129	− 0·7
9	Rānipur R.H. B.M. No. 5/53K on canal milestone No. 5. (Mark on basement just 4 ft. below B.M. level)	,,	·1154	+·0003	·1157		

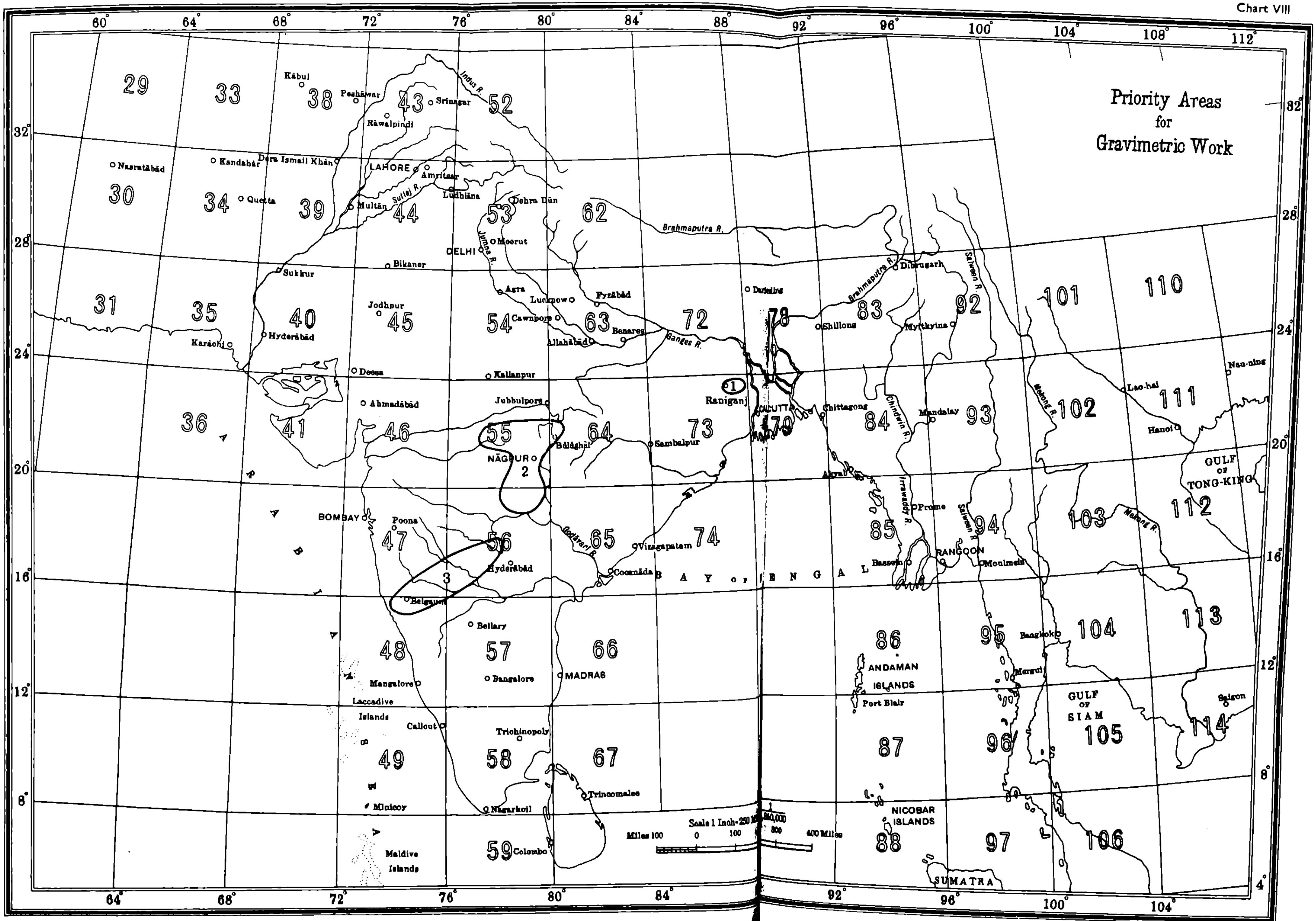
(Continued)

TABLE 1.—*Results of trial observations with Frost Gravimeter in the vicinity of Dehra Dūn.*—(contd.)

Serial No.	Station (with brief description)	Date of observation	Deduced value of g from observations	Mis-closures	g after adjustment of mis-closures	g from old pendulum stations	Discrepancies with old values (mgals.)
			cm/sec²	*cm/sec²*	*cm/sec²*	*cm/sec²*	
10	Māyāpur (Hardwār) canal I.B. (old pendulum station) Mark on N. veranda about 3 ft. in front of E. door of bungalow ..	20 April	979·1226	+ ·0003	979·1229	979·122	+ 0·9
11	Raiwala F.R.H. (on N. veranda of the southern R.H. bungalow, near about the middle of the veranda) ..	,,	979·1065	+ ·0004	979·1069		
12	Kansrao F.R.H. (on E. veranda, about 5 ft. in front of central door) ..	,,	·1055	+ ·0004	·1059		
13	Lachiwala F. R. H. (on N. veranda about 5 ft. in front of central window)	22 April	·0866	+ ·0004	·0870		
14	B.M. No. 10/53J in G.B. compound (on close of circuit)	,,	·0624	+ ·0005	979·0629		
15	Sahāranpur G.T.S. B.M. (B.M. No. 41/53G in the compound of the Church of England). Mark on basement ..	5 May	·1575				
16	Nojli pendulum station (over B.O.M. on floor of Tower Station) ..	13 May	·1412	..	..	979·143	− 1·8
17	B.M. No. 285/53F at Sahaspur I.B. ..	15 May	·1270				
18	Fatehpur II I.B. (pendulum station) Northernmost of 3 large rooms ..	,,	·1449	..	..	·147	− 2·1
19	Fatehpur II I.B. gravimeter pillar G/1 (in front of central entrance to I.B.) ..	,,	·1450				

(*Continued*)

Chart VIII



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Reg. No. 92 M.G.B '48-400

TABLE 1.—*Results of trial observations with Frost Gravimeter in the vicinity of Dehra Dūn.*—(concld.)

Serial No.	Station (with brief description)	Date of observation	Deduced value of g from observations	Mis-closures	g after adjustment of mis-closures	g from old pendulum stations	Discrepancies with old values (mgals.)
			cm/sec²	cm/sec²	cm/sec²	cm/sec²	
20	Kālsi I.B. pendulum room (M.E.S. Barrack, 100 yds. E. of M.E.S. I.B.) ..	16 May	·1290	..	..	979·131	− 2·0
21	B.M. No. 341/53F (Top of culvert) ..	,,	·1258				
22	Culvert, W. of Chakrāta road, between furlong stones 54/5 & 54/6 ..	,,	979·0790				
23	B.M. No. 347/53F (Mark 2 in. lower than B.M.)	17 May	979·0582				
24	B.M. No. 351/53F (Mark close to B.M. on road) ..	,,	·0318				
25	Bridge at mile 64/4 on Chakrāta road (Mark on ground 2 in. below parapet level) ..	20 May	978·9989				
26	B.M. 357/53F (Mark 1 ft. 10 in. below B.M. level) ..	,,	·9701				
27	B.M. 360/53F (Mark 5 ft. below B.M. level)	,,	·9344				
28	B.M. 363/53F (Mark 3 in. below B.M. level) ..	,,	·8054				
29	B.M. 366/53F (Mark 1 ft. 9 in. below B.M. level) ..	,,	·8421				
30	Chakrāta M.E.S. I.B. (Centre of W. veranda which is at the same level as the Pend. Room at NE. corner) ..	21 May	·8257	..	..	978·819	+ 6·7
31	Furlong-stone 76/4 (Just close to Chakrāta gate)—Mark just 7 in. below basement of furlong stone ..	,,	·8375				
32	B.M. 377/53F (upper mark) at Victoria Barracks Block No. 17 ..	,,	978·8088				

34. **Future Policy.**—The observations with pendulums are of a cumbersome nature and a density of one station per degree sheet as was achieved by the end of 1939 was about the limit of economy to which they could be put. When they were initiated the main idea for their execution was the determination of the general figure of the earth. As ideas matured, it was realized that a much closer mesh was needed for the solution of several important problems. One of these is the determination of local humps of geoid over a reference spheroid. This is a matter for international co-operation and requires a knowledge of gravity all over the globe and the desideratum for this is gravity observations over oceans and in southern hemisphere rather than in peninsular India. Denser net in India of course contributes towards this end.

A second geodetic purpose for making dense gravity net specially round the origin of a survey is to find absolute deflections at the datum. Present deflections are determined by what is called astronomic levelling (which is triangulation combined with astronomical determinations of latitude, longitude and azimuth) and as triangulation connections between various countries are beset with several difficulties the deflections determined in various countries are generally not directly comparable with each other. Gravity anomalies provide absolute measure of deflection and a great advance will be made when a sufficient number of them are available uniformly distributed all over the globe.

The broad net of pendulum observations in India has also been put to considerable use by geodesists for testing the various theories of compensation of the earth's major features. In 1938, it was made use of by Burma Oil Company who put more than 6000 gravimeter stations in E. Bengal and Burma, in between the Survey of India pendulum stations.

It is now on the programme of the Survey of India as a long term policy to establish roughly a 10-mile network of gravimeter stations throughout the extent of India and it is hoped that this would provide a much better basis for discussions of the gravity distribution of India than we have at present. These would also serve as reference bench-marks for detailed exploration of limited areas. The Mineral Adviser to the Government of India in consultation with the Geological Survey of India has suggested some priority areas (shown in Chart VIII), which are believed to be economically productive and on which work has already been started. Details of this will be recorded in the next Technical Report.

35. **Base station at Dehra Dūn.**—The initial pendulum observations in India were started by Basevi in 1870–71 and he made as his base station the transit room in the Walker Observatory, Dehra Dūn. Its co-ordinates are Lat. 30° 19′ 29″, Long. 78° 3′ 15″ and its height above mean sea-level is 2238 ft. His observations were ultimately rejected and in 1904, when a start was made with Von Sterneck's pendulums in India, the value of g at this base station

was determined with respect to Kew and was adopted as 979·063 cm./sec^2.

Since 1913, the base station has been changed to Burrard Observatory in the Geodetic Branch compound and pendulum observations were taken in this room before and after the field season. No comparative observations for gravity were however made between these two stations and the value 979·063 cm./sec^2 was adopted for the new station as well. Its co-ordinates and height above mean sea-level are Lat. 30° 19′ 26″, Long. 78° 3′ 21″, Ht. 2229 ft.

The difference of gravity between the two stations has now been measured with the Frost Gravimeter and is 0·4 mgals. which is beyond the limit of precision of the pendulums. Strictly speaking then, the value of gravity at the present Base stations for pendulums in India should be 979·0634 mgals. but in view of the fact that there is a doubt of several milligals in the value of adopted gravity at Dehra Dūn, there is no point in taking count of this small difference at this stage.

36. **Interpretation of results.**—The observed gravity values at all the pendulum stations have been reduced in previous years according to Hayford's hypothesis of compensation and the Hayford anomalies have been used to test the extent of compensation in India. These anomalies are computed on the assumption that the crustal rocks have a density of 2·67, and can only be regarded as preliminary due to the fact that vast areas in India are covered by light alluvium and by dense traps where the above density value does not hold. Just before World War II, the Burma Oil Company established 6000 gravity stations with gravimeters in Eastern Bengal, Shan Plateau and Burma and considerable attention was given to the method to be adopted for their reduction. It was considered desirable to make adequate allowance for the geological structure round each station, and to avoid laborious computations special templates were devised by the Survey of India, under whose direction the reductions were carried out for some stations. It was found that at some places, the anomalies were modified considerably by the application of geological correction. The finalizing of all the Indian anomalies in this light will take some time, as reliable data of rock densities down to considerable depths has yet to be collected for many areas.

In the past Geodetic Reports, besides charts of Hayford gravity anomalies, charts of the so called normal warp anomalies used to be published which were utilized to derive the crustal structure lines in India. Such anomalies were based on empirical considerations. Amongst other things their derivation involved Hayford compensation being taken as usual in outer zones and being neglected in inner zones upto 120,000 feet. Such mixed anomalies are useful when small areas are involved, and when it is desired to obtain correlation by trial and error between the anomalies and the geology, but are less defensible for the study of compensation of India as a whole. Attention is now being focussed to get the anomalies in

India on the regional hypothesis of compensation, for the derivation of which useful tables have been produced by various authorities lately. Good progress has been made with the computations of these anomalies and it is proposed to publish them in a separate pamphlet.

37. **Gravity Observations in neighbouring oceans.**—While the Frost Gravimeter will play a significant part in the intensive study of gravity inside India, it is worth pointing out that observations in the oceans round India are in a way more important. Apart from contributing towards the solution of several fundamental problems such as the ellipticity of the equator, the structure of the ocean floor and the mapping of submarine features, they are sorely needed for the confirmation of the important feature of the geoid as evidenced from a study of the plumb-line deflections.

As an example, deflection data point to a considerable differential rise of the geoid between India and Burma. A preliminary attempt was made to test if the available gravity anomalies confirm it. A point A with lat. 17° 50′, long. 78° 50′ was selected in Central India so that gravity data was available upto a radius of 10° round it. Another suitable point B with lat. 20° 10′, long. 96° 10′ was selected in Burma, but here the data was available only upto an extent of 4° round the station. Stoke's formula gave geoidal rise at A to be − 18 ·3 metres and at B − 0 ·7 metres. The differential geoidal rise is accordingly − 17 ·6 metres which happens to agree almost exactly with that deduced from deflections, but this can only be regarded as fortuitous as the unknown effect of the distant zones has yet to be taken count of. Definite quantitative confirmation will only be possible when more data becomes available in the Bay of Bengal and to the north and east of Burma.

Similarly, deflection results have also indicated a rise of geoid of about 100 ft. in a distance of about 750 miles between Mandalay and Victoria point, but this cannot be corroborated by the gravity method as further observations are needed in the Bay of Bengal, South China Sea, Malaya, Indo-China and Siam. It can be surmised that the values of gravity anomalies in these regions will be predominantly positive.

Chapter IV

DEVIATION OF THE VERTICAL

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

38. **Summary.**—Observations for the deviation of the vertical had been in abeyance since 1940 due to the war. In 1946 Laplace control was required by the Kulu Survey Detachment for its triangulation in that area which had been based on astronomical azimuths ; deflections (both components) at 4 stations were observed for the purpose.

In 1947 observations with a large astrolabe were made at 2 different sites in Lahore.

In addition, the preliminary results of Mr. P. S. Shinghal's astrolabe observations in the years 1939–40 in the Punjāb, Baluchistān and N.W.F.P. have been revised and republished after applying the B. H. corrections which have since become available.

Geoidal Charts VII and VIII of Geodetic Report 1936 showing the Geoid and the Compensated Geoid with respect to the International spheroid have also been brought up-to-date.

Some foreign deflection stations of countries adjacent to India have also been recorded in this chapter for future use in determination of the shape of the geoid in these countries.

39. **Deflections in Kulu.**—(i) *General.*—Both components of the deviation of the vertical were measured by Mr. J. B. Mathur at 4 stations in the Kulu Valley, District Kangra, Punjāb Province. The object of this programme was to provide Laplace stations for the control of triangulation carried out by the Kulu Survey Detachment in 1944 in sheets 52 and 53.

(ii) *Details of observations.*—One night's work with the astrolabe and one night's work with Polaris observations for azimuth with Geodetic Wild No. 130 was normally done at each station. Greenwich time was obtained from the Rugby 09·55 and 17·55 G.M.T. signals Wireless receptions at night were good but the day ones were feeble specially on a cloudy day.

(iii) *Narrative of season's work.*—The detachment consisting of Mr. J. B. Mathur (U. S. S.), Mr. S. D. Bhatt (Topographical Assistant) and 3 *khalāsis* after completing observations for 2 nights at Dehra Dūn for the determination of personal equation left for Kulu on 25th May by train. With the help of ten more *khalāsis* provided by O. C. Kulu Survey Detachment, this astro-detachment started work on 31st May and completed it by the first week of

July 1946 and the detachment returned to Dehra Dūn in the second week of July.

Health was good throughout but weather was inclement. The clouds and rain made the progress slow. Instruments throughout the work remained in good condition.

(iv) *Personal equation.*—The figures obtained for personal equation determined at Dehra Dūn before and after field work were as follows :—

Date	Personal equation
	s.
21–5–46	—0·13
22–5–46	—0·11
24–9–46	—0·14
27–9–46	—0·19
	s.
Mean	—0·14

This mean value of personal equation was accepted and it has been applied to the longitude computations of this astro-detachment.

(v) *Probable errors.*—The average p.e. of a determination of latitude was $\pm$ 0″·64 and of local time $\pm 0^s$·033.

(vi) *Laplace Stations.*—Astronomical observations for latitude, longitude and azimuth were made at four stations, viz., Kulu h.s., Bijli h.s., Banjar h.s. and Soja R.H. s.

The initial azimuth (at Bijli h.s. of Kokhan h.s.) used for computation of the triangulation of the Kulu Survey Detachment was derived from the astronomically observed azimuth by applying the Laplace correction, details of which are given below. The astronomical azimuths observed at the other three stations, similarly corrected for Laplace, provided a satisfactory check on the azimuths derived by triangulation.

Details of the Laplace correction at Bijli h.s.

Geodetic latitude	λ_g = 31° 55′ 27″
Geodetic longitude	L_g = 77 09 06
Astronomical longitude	L_a = 77 08 20
Laplace correction to astro. azimuth $[(L_a - L_g) + 3''\cdot 2] \times \text{Sin}\lambda_g$ =	+23″
Astronomical azimuth at Bijli h.s. of Kokhan h.s.	= 26° 21′ 10″
Geodetic azimuth at Bijli h.s. of Kokhan h.s.	= 26° 21′ 33″

40. **Observations at Lahore.**—Observations with the large astrolabe were made by Mr. J. B. Mathur in January 1947 at Lahore at two different sites.

(*a*) The first determination was made at the Punjab University observatory to obtain its astronomical co-ordinates. Geodetic co-ordinates of this location are not known and the University authorities were only interested in the astronomical values.

(*b*) The second site was at the triangulation station on the south-eastern tower of Lahore railway station. The objective here was to determine the deflections of the plumb-line.

It was not possible to observe for personal equation before this programme because of bad weather, and after the programme due to sudden break-down of the wireless set on return to Dehra Dūn. The personal equation of this observer has, however, been well determined on other occasions and a value of $-0^{s}\cdot14$ has been accepted for correcting the astronomical longitude of the observation stations at Lahore.

Thus derived the astronomical co-ordinates of University observatory transit pillar are λ_a 31° 33′ 46″ ·0
L_a 74 18 28 ·8

and the astronomical and geodetic co-ordinates of the triangulation station on the south-eastern tower of Lahore railway station are as follows:

λ_a 31° 34′ 43″ ·5 L_a 74° 20′ 22 ·8
λ_g 31 34 37 ·5 L_g 74 20 15 ·5

The resultant deflections on the International spheroid are + 11″ ·9 in meridian and + 7″ ·2 in P.V.

41. **Revision of results of 1939–40 observations.**—Geodetic Report 1940, Chapter II, Table 1 gives the results of Mr. P. S. Shinghal's observations with the astrolabe in 1939–40 in the Punjāb, Baluchistān and N.W.F.P. These published results were provisional since B. H. corrections were not then available and Admiralty corrections for wireless time signals were applied. The B. H. corrections have since been received and the values of astronomical longitudes and P.V. deflections have therefore been revised. The revised values are printed in Table 1 of this chapter.

42. **Geoidal Charts.**—Charts XIII and XIV show the Geoid and the Compensated Geoid with respect to the International spheroid. These charts have been drawn by utilizing 1163 deflection stations, the majority of which are sited at an average distance of about 15 miles on the main lines, one running east to west from Burma to Persian frontier and the other from north to south through Cape Comorin. With the help of these two main lines and some old azimuth and latitude stations it is possible to form circuits and derive their closure errors. These are shown on Chart XV. Closures in NW. only India are based on modern work and are satisfactory. Some of the large circuit errors are due to scanty data and the use of older unreliable azimuths for deriving P.V. deflections. For arriving at the geoidal contours, the closing errors have been provisionally dispersed by giving less weight to the weaker lines. Further work is required to strengthen the weak lines as also to brace up the main framework. Some further stations in Burma, say a line from Mandalay to Dibrugarh or Manipur road would

close a useful circuit and would carry the geoid into unexplored regions.

43. Conclusions.—(i) *The Geoid in NW. India.*—In the NW. of India the 1939–40 observations have changed the picture of the geoid considerably—compare Chart VII, of Geodetic Report 1936. The zero contour which ran from north-east of Amritsar midway between the Beas and the Sutlej rivers now runs north of Amritsar almost along latitude 32° to longitude 72½° and then turns south and follows the course of the river Jhelum to its confluence with the Sutlej and then turns northwards and goes along the main stream of the river Indus. The 20-foot contour maintains its trend upto a point, latitude about 29½° and longitude 68°, and then bends towards the east to longitude 70°, whence it seems to turn northwards. The 40-foot contour also turns eastwards from lat. 30°, long. 68°. It is of considerable interest to watch the further course of the 20-foot and the 40-foot contours, but observations in the tribal territory and Afghānistān would be necessary, prospects of which at the moment are not very bright.

(ii) *The Geoid in Burma and Siam.*—Deflection data for the Siamese stations is given in para 44. These are not enough for a reliable section of the geoid. It will be seen however that the meridional deflections are systematically southwards, in the same way as in Burma. The result is that while the geoid in peninsular India displays humps of the order of 30 feet or so above the International spheroid, its rise in south Burma is 110 feet in a distance of 1000 miles which is phenomenal and without parallel anywhere else in the world. Observations of plumb-line deflections in Siam, Malaya and Dutch East Indies are very desirable to see if the high rise continues in these areas. A reference to the table in para 44 giving meridional deflections in Malaya shows that when they are corrected by + 11″·4 to bring them to Siamese terms (vide Chapter I, para 6, page 20) the deflections here too are systematically southwards indicating that the geoid persists in its rise southwards.

(iii) *Plumb-line deflections and Geoid in Kulu.*—Observation on mountains and in valleys are always an important addition to knowledge, even though the application of topographic and compensation corrections to them are unreliable on account of rugged topography. Such stations are unrepresentative and as a rule values of deflections at them cannot be interpolated from the surrounding stations. Again, the degree of compensation of the Himālayas cannot be assessed with any degree of accuracy on account of dearth of data and such observations give valuable information in this respect.

It is well known that in India, one of the most salient characteristics of the observed deflections of the plumb-line is their independence of the major visible features, indicating that there are equally important hidden features at work. For instance in the Gangetic plains, the deflections are by no means dominated by the mighty Himālayas. Again, Finsterwalder carried out a triangulation in

Nanga Parbat area and found the curious result that some of the deflections were directed away from the Nanga Parbat massif, indicating a zone of large mass defect.

The Kulu valley is roughly at an elevation of 4,000 feet, the neighbouring hills being 16,000 feet high. No gravity or deflection data was available in this region before. To get an idea of the variation of deflection, two stations were selected in the valley and two on high hills (height about 8,500 feet).

The results are tabulated below :—

Name of Station		Latitude		Longitude		Height in feet	International spheroid deflection	
							Meridian	P.V.
		°	′	°	′			
1. Kulu	h.s.	31	57	77	07	3963	−28·0	−25·8
2. Bijli	h.s.	31	55	77	09	8066	−30·8	−36·5
3. Banjar	h.s.	31	39	77	21	4995	−13·4	−41·3
4. Soja R.H.	s.	31	34	77	22	8697	−13·0	−35·2

It will be seen that the deflections are large but not in any way exceptional. They are comparable with what has been obtained previously at other stations at the outer foot-hills of the Himālayas. The deflections at all the four stations are towards north east, which is in conformity with the topography, there being hills rising to 20,000 feet or more in this direction.

The number of stations in this area is by no means sufficient for drawing a reliable section of the geoid, the nearest old station being about 70 miles away. They have been utilized, however, to extend the geoidal contours to the north-west of Dehra Dūn (Chart XIII). These display a tendency to join up with similar contours in Srinagar (Kashmīr) area. The geoid appears to rise from south to north. Although the available Himālayan geoidal sections are few, evidence is accumulating that geoid in the main goes with topography and that the opinion expressed in Geodetic Report VIII, page 55, that geoid would be found to be depressed under the Himālayas, since these are folded sedimentary ranges, is incorrect.

44. **Foreign Deflection Stations.**—During the war, deflection data for certain foreign stations has become available. This is put down below for permanent record.

(i) *Siam.*—Table 3 on page 75 of Geodetic Report 1934 is reproduced here (see page opposite) with a few alterations and additions since the publication of that report.

Siamese Latitude Stations

Name (1)	Longitude (2)	Astronomical Latitude (3)	Geodetic latitude (Siamese terms) (4)	Geodetio latidute (Indian terms Everest) (5)	Geodetic latitude (International) (6)	Geodetic latitude (International corrected for Laplace adjustment) (7)	A − G (3) − (7)
	° ′	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	″
Koh Yāo-Yai	98 36	7 58 32·1	7 58 21·6	7 58 21·4	7 58 24·9	7 58 25·2	+6·9
Base N. Nagorn Sridharmrāj ..	99 58	8 28 47·6	8 28 37·5	8 28 37·3	8 28 40·7	8 28 41·2	+6·4
Khao Pākglōhng Bāngphakbie ..	98 16	9 00 16·0	9 00 07·4	9 00 07·1	9 00 10·2	9 00 10·5	+5·5
Khao Gūang	99 56	12 27 38·2	12 27 30·0	12 27 28·7	12 27 30·9	12 27 31·5	+6·7
Khao Srabāp	102 13	12 33 06·1	12 32 58·2	12 32 56·8	12 32 59·0	12 33 00·0	+6·1
Base S. Rājburi	99 50	13 33 18·5	13 33 11·5	13 33 09·8	13 33 11·6	13 33 12·3	+6·2
Khao Bhrik	101 33	14 54 05·9	14 53 58·2	14 53 56·4	14 53 57·9	14 53 58·8	+7·1
Base E. Nagorn Sawarn ..	100 11	15 23 10·9	15 23 06·0	15 23 04·2	15 23 05·4	15 23 06·3	+4·6
Khao Kungkang	99 04	15 28 26·1	15 28 23·7	15 28 21·9	15 28 23·1	15 28 23·8	+2·3
Doi Khun Kong	99 30	18 27 27·8	18 27 28·7	18 27 26·6	18 27 26·9	18 27 27·8	0·0

At Rājburi Base S. End and Doi Khun Kong observations have also been made for astronomical longitude and azimuth. Details of these are given in chapter I, Table 4. The following are the P.V. deflections at these two stations.

Name of Station	Latitude	Longitude	Deflections in P.V.	
			Everest spheroid	International spheroid
Rājburi Base S. End ..	° ′ 13 33	° ′ 99 50	″ −12·4	″ +1·3
Doi Khun Kong ..	18 27	99 30	−14·1	−0·6

(ii) *Malaya.*—The following table gives the results of astronomical observations in Malaya. The geodetic values are in terms of Repsold system and on Everest spheroid. Details are given in "An account of Primary Triangulation of Malaya, 1931".

Comparison of Latitudes

Name of Station	Astronomical latitude = A	Geodetio latitude = G	Difference A − G
Kertau	° ′ ″ 3 27 53·96	Starting point (Obsd. Lat. adopted)	
Serting Base N. End ..	2 54 00·78	° ′ ″ 2 54 02·28	″ −1·50
Asa	3 40 49·27	3 40 52·50	−3·23
Bedong	4 35 17·79	4 35 17·06	+0·73
Kledang	4 35 38·10	4 35 41·48	−3·38
Kedah Base S. End ..	6 08 26·92	6 08 27·68	−0·76
Faber	1 16 24·61	1 16 28·15	−3·54

Comparison of Azimtuhs

Azimuth Observed	Astronomical azimuth = A	Geodetio azimuth = G	Difference A − G
At Kedah Base S. End to Keriang ..	° ′ ″ 312 03 52·16	° ′ ″ 312 03 49·47	″ +2·69
At Asa to Liang East ..	34 56 33·34	34 56 34·83	−1·49

(iii) *Indo-China.*—Geodetic data in Indo-China is based on the astronomically fixed values of Hanoi and computed on Clarke's 1880 spheroid.

Astronomical latitudes check with the geodetic ones as follow :—

Station	Astronomical values	Geodetic values	(A − G)	=(A−G)
	G	G	Seconds (Centesimal)	"
Tong ..	23·4670 94	23·4686 41	− 6·47	−2·1
Thanh Hoea ..	22·0013 67	22·0003 41	+10·26	+3·3
Tournne ..	17·7845 13	17·7826 86	+18·27	+5·9
Baria ..	11·6217 04	11·6206 02	+11·02	+3·6
San Sun ..	21·2537 96	21·2537 59	+ 0·37	+0·1
Pon Chom ..	18·2737 34	18·2726 06	+11·28	+3·7
Sisophone (Konwa)	15·1464 91	N. Path 15·1452 01 S. Path 15·1453 17	+12·90 +11·74	+4·2 +3·8

In addition the following astronomical stations have been observed including the Laplace stations.

Station	Astronomical		Geodetic		Deflections	
	Lat.	Long.	Lat.	Long.	Meridian	P.V.
	° ′ ″	° ′ ″	° ′ ″	° ′ ″	″	″
Haiphong (Phu-Lien Pillar)	20 48 21·70	106 37 44·37	20 48 22·05	106 37 31·65	−0·35	+11·89
E. end of Sisophone Base	13 55 14·81	102 51 07·71	13 55 09·81	102 51 05·70	+5·00	+ 1·95
Tourane Base	16 00 21·82	108 15 37·16	16 00 15·90	108 15 26·70	+5·92	+10·05
Baria Base	10 27 34·32	107 15 16·52	10 27 30·75	107 15 06·27	+3·57	+10·08

(iv) *Netherland East Indies.*—The geodetio triangulation in Java and Sumatra is based on the astronomical latitude and azimuth determinations at Genock in north central Java, and zero meridian is that passing through Batavia. Computations are based on Bessel's spheroid.

The following table gives observed plumb-line deflections in Java and Sumatra with values based on Java system.

No.		Name of Station	Deflection in Meridian	Deflection in P.V. From Longitude	Deflection in P.V. From Azimuth
			″	″	″
S	5	Telokbetoeng	− 6·86		
P	15	Batoehideung	− 7·94		+ 42
P	21	Tindjil	− 38·83		
P	28	Tjiloemloem	− 7·64		
P	30	Anjer	− 3·51	− 8·4	
P	36	Gedē	− 2·17		+ 63
S	38	Biloel	− 3·11		
P	83	Dago	+ 4·21		+ 63
P	88	Soerangga	− 5·08		− 21
S	99	Tjilentab	− 6·18		
S	116	Simplak	+ 9·42		+ 35
S	120	Tjikema	+ 9·61		+ 45
S	122	Buitenzorg	..	− 2·6	
P	126	Batavia	− 0·78		
S	165	Pakis	− 2·50		
P	244	Pogor II	− 28·52		− 8
S	306	Madjelengka	+ 11·03		
S	312	Indramajoe	− 1·81		
S	328	Koeningan	+ 3·20		
P	334	Cheribon	+ 2·42	+ 3·9	+ 6·5
S	351	Patjarloewong	+ 8·77		
S	370	Bliken	− 17·52		
S	372	Selok	− 3·60		
S	391	Endrokilo	− 0·51		
S	403	Boetak (Baglen)	− 7·59		
S	409	Tjirangnja	+ 20·01		
S	413	Midangan	− 7·47		
S	425	Djetiskoelon	− 11·57		
S	429	Djatimalang	− 13·36		
S	433	Soko	+ 8·78		
S	445	Tidar	+ 0·46		
P	447	Tembok	+ 4·50		− 29
S	452	Goeling	− 1·04		
S	456	Ngerandja	+ 7·62		
P	461	Semarang	+ 0·97	+ 3·0	− 12
S	462	Trangkil	+ 5·28		
S	465	Penawangan	+ 2·18		
P	474	Morodemak	− 3·44		
P	475	Nglanggrang	− 4·43		− 5
P	496	Penoenggalan	+ 0·28		+ 16
P	505	Kritjian	+ 11·23		− 7
P	519	Gambiranom	− 16·64		− 19
P	520	Genoek	− 0·20		+ 11
S	605	Madioen	+ 12·01		− 9
P	607	Boetak (Rembanj)	− 2·04		
P	618	Sengoengloeng	− 6·99		
P	691	Nongko	− 8·79		− 38
P	697	Gebang	− 9·49		

(Continued)

No.	Name of Station	Deflection in Meridian	Deflection in P.V. From Longitude	Deflection in P.V. From Azimuth
		″	″	″
P 717	Watoetjeleng	− 3·63		
S 729	Djabong	+ 16·98		
P 740	Banjoelegi	− 4·01		
P 743	Selamat	− 6·10		
P 767	Ronggo	− 3·00		
S 768	Sidoardjo	+ 2·12		− 16
S 773	Soerabaja		+ 1·5	
P 826	Bēsèh	− 2·53		
S 785	Pasoeroean		+ 9·1	
P 844	Rika	− 18·69		
S 847	Besoeki	+ 17·97	+ 3·5	
S 859	Sapikoel	− 2·30		
P 861	Kemirisongo	− 2·75		
P 865	Boeroen			− 32
P 873	Djoerangsapi	+ 8·32		− 40
P 875	Boeroean	− 5·63		
P 897	Gilian	− 7·40		
S 910	Banjoewangi		+ 7·5	
P 912	Ikan	− 3·92		
T 2841	Taloek	+ 4·4	+ 4·0	
T 2875	Kepenoean	+ 0·2	+ 3·0	
T 2876	Tadjong Medang	− 0·8	+ 3·2	
T 2983	Tebing Tinggi	+ 1·8	− 1·1	
T 2985	Merloeng	+ 0·6	+ 0·7	
T 3020	Baserah	− 1·0	− 0·7	
T 3022	Peranap	+ 1·6	+ 0·5	
T 3023	Ajermolek	+ 0·3	− 1·9	
T 3026	P. Djoemahat	0·0	− 0·2	
T 3027	Pengalian Kwantan ..	− 1·2	− 3·0	
T 3028	Kota Baroe	− 1·2	+ 2·6	
T 3029	Pengalian Gangsal ..	− 0·8	− 1·7	
T 3030	Pajaroembai	+ 0·4	+ 1·1	
T 3031	Pengkalan Kasai	+ 8·3	+ 3·6	
T 3006	Mandiangin	0·0	+ 5·2	
T 3025	Renjat	− 0·4	+ 0·6	
T 2821	G. Sahilan	+ 2·3	+ 2·6	
T 2866	Pantei Tjermin	+ 0·4	+ 0·8	
T 2870	D. Bangkoewang	+ 2·2	+ 2·8	
T 2913	S. Roean	− 1·0	− 0·8	
BP.A	Padang	− 6·0	..	
P 62	Tor Batoe na Goelang ..	− 5·5	..	
P 118	Serati	+ 0·9	..	
T 2030	Soeroelangoen (Rawas) ..	+ 4·0	..	
T 1871	Moeara Enim	+ 2·5	..	
T 1006	Boenga Mas	+ 3·6	..	
T 1878	Lahat	+ 6·4	..	
S 136	Batoeradja upon Ogan ..	+ 0·2	..	
T 1828	Batoeradja upon Komering ..	− 5·9	..	
T 1705	Negeri Batin	+ 0·9	..	
T 1635	Kota Boemi	− 2·9	..	
T 1599	Soekadana	+ 0·5	..	
P 71	Dempo	− 6·6	..	

(Concluded)

(v) *Persia.*—The following table gives deflections in Persia, derived from astronomical observations to control Paiforce triangulation in World War II. The geodetic data is in terms of Irāq Primary triangulation with its origin at Nahrwan (Baghdād) S. end of Base, and are computed on Clarke's 1880 spheroid. The determination of astronomical values at Tehrān is very weak.

Station	Date	Geodetic Latitude	Geodetic Longitude	Deflection in meridian	Deflection in P.V.
		° ′ ″	° ′ ″	″	″
Hamadān SW. Base ..	1943	34 55 47	48 33 30	− 8·1	− 5·2
Tehrān SW. Base ..	1943	35 42 20	51 29 07	− 4·3	+11·0
Isfahān SW. Base ..	1943	32 53 34	51 25 52	+ 2·0	+10·2
Bahramabād* ..	1944	30 23 50	55 58 18	+17·9	+ 6·5

* Geodetic values for this station are in terms of Indian triangulation transferred on International spheroid.

DEFLECTION STATIONS

TABLE 1

Serial No.	Sheet No.	Observed at	Height in feet	International Spheroid Deflections Meridian	International Spheroid Deflections P.V.	Calculated Deflections Hayford System Meridian	Calculated Deflections Hayford System P.V.	Calculated Deflections Uncompensated Topography Meridian	Calculated Deflections Uncompensated Topography P.V.
				″	″	″	″	″	″
1071	43 D	Baikal h.s.	1830	+13·4	− 1·5	− 1·8	− 1·0		
1072	D	Dhoktalia ..	1875	+14·4	− 2·5				
1073	H	Ghogiat ..	655	+11·4	+ 0·5	− 4·6	+ 0·3		
1074	H	Gūnia T.S.	700	+ 9·1	− 1·5	− 2·6	− 0·9		
1075	H	Bāla T.S.	677	+11·0	+ 3·5	− 1·8	− 0·9		
1076	44 E	Hūjan T.S.	646	+12·1	+ 3·6	− 1·4	− 0·7		
1077	E	Sāngla Hill ..	650	+ 8·4	+ 1·0	− 1·1	− 0·7		
1078	E	Khurnawala T.S.	623	+ 1·0	+ 0·8	− 0·9	− 0·4		
1079	E	Rirāna T.S.	607	− 2·4	− 6·2	− 0·9	− 0·4		
1080	E	Bārāla T.S.	588	− 4·1	− 6·7	− 0·7	− 0·4		
102	F	Akbar S.	641	+ 0·2	− 6·2	− 0·6	− 0·4		
1081	F	Kadianwala T.S.	561	− 0·5	− 4·2	− 0·7	− 0·3		
1082	F	Pirghani T.S.	557	− 2·6	− 4·0	− 0·5	− 0·4		
1083	F	Akbar-da-Bunga T.S.	538	+ 1·0	− 3·3	− 0·4	− 0·4		
1084	F	Khāi Mosque ..	500	+ 0·2	− 2·8	− 0·4	− 0·4		
1085	C	Chisti Tomb ..	470	+ 2·2	− 3·6	− 0·4	− 0·4		
1086	C	Unnis Chak ..	460	+ 1·7	− 4·0	− 0·3	− 0·1		
1087	C	Tamiwali-Bhindi	450	+ 4·5	− 4·5	− 0·3	− 0·0		
1088	39 O	Bakhidera T.S.	431	+ 3·6	− 6·5	− 0·4	+ 0·0		
1089	O	Godri T.S.	370	+ 2·0	− 6·2	− 0·4	− 0·1		
1090	O	Date Khan S.	397	+ 3·5	− 4·1	− 0·4	+ 0·4		
1091	O	Pirhar T.S.	348	+ 3·4	− 2·8	− 0·6	+ 0·4		
44	K	Paphra T.S.	316	+ 5·4	+ 2·2	− 0·8	+ 0·6		
1092	K	Dhaggu-Sunerī-wāla	300	+ 3·5	+ 8·9	− 1·6	+ 1·8		
1093	K	Gangah T.S.	321	+ 0·9	+14·0	− 1·8	+ 2·3		

COLUMN 4: Except at G.T. and other triangulation stations all heights are approximate and correct to within 10 to 20 feet.

DEFLECTIONS 1939–40

EVEREST'S SPHEROID						
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections: Meridian	Deflections: P.V.	Serial No.
° ′ ″	° ′ ″	° ′ ″		″	″	
A 32 58 38·9	A 72 52 22·1			+ 7·0	+ 1·2	1071
G 32 58 31·9	G 72 52 23·8					
A 32 47 43·6	A 72 58 36·1			+ 8·1	+ 0·2	1072
G 32 47 35·5	G 72 58 39·1					
A 32 32 53·5	A 73 04 05·2			+ 5·2	+ 3·1	1073
G 32 32 48·3	G 73 04 04·7					
A 32 19 17·51	A 73 11 10·94			+ 3·0	+ 1·0	1074
G 32 19 14·56	G 73 11 12·93					
A 32 08 57·03	A 73 27 48·18			+ 4·9	+ 5·8	1075
G 32 08 52·15	G 73 27 44·51					
A 31 52 28·17	A 73 18 06·44			+ 6·2	+ 6·0	1076
G 31 52 22·00	G 73 18 02·56					
A 31 42 44·4	A 73 23 00·9			+ 2·5	+ 3·4	1077
G 31 42 41·9	G 73 23 00·0					
A 31 29 48·65	A 73 16 24·43			− 4·7	+ 3·2	1078
G 31 29 53·31	G 73 16 23·87					
A 31 21 15·00	A 73 13 19·02			− 8·1	− 3·7	1079
G 31 21 23·08	G 73 13 25·50					
A 31 05 44·04	A 73 12 57·67			− 9·7	− 4·2	1080
G 31 05 53·73	G 73 13 05·76					
A 30 53 38·10	A 73 17 05·67			− 5·2	− 3·8	102
G 30 53 43·26	G 73 17 13·28					
A 30 37 59·71	A 73 28 49·10			− 5·8	− 1·9	1081
G 30 38 05·54	G 73 28 54·42					
A 30 22 52·78	A 73 35 06·52			− 7·8	− 1·8	1082
G 30 23 00·57	G 73 35 11·72					
A 30 12 28·28	A 73 28 47·24			− 4·2	− 1·0	1083
G 30 12 32·43	G 73 28 51·60					
A 30 01 45·5	A 73 08 26·3			− 4·9	− 0·2	1084
G 30 01 50·4	G 73 08 29·7					
A 29 47 49·3	A 72 50 36·5			− 2·8	− 0·9	1085
G 29 47 52·1	G 72 50 40·7					
A 29 41 32·7	A 72 30 25·5			− 3·2	− 2·0	1086
G 29 41 35·9	G 72 30 31·0					
A 29 34 15·9	A 72 12 24·5			− 0·3	− 1·4	1087
G 29 34 10·2	G 72 12 29·2					
A 29 26 31·84	A 71 51 43·07			− 1·2	− 3·2	1088
G 29 26 32·99	G 71 51 49·93					
A 29 24 59·23	A 71 40 17·79			− 2·8	− 2·8	1089
G 29 25 02·00	G 71 40 24·13					
A 29 15 26·69	A 71 24 17·10			− 1·2	− 0·5	1090
G 29 15 27·92	G 71 24 20·85					
A 29 10 33·56	A 71 07 39·42			− 1·3	+ 1·0	1091
G 29 10 34·87	G 71 07 41·48					
A 29 05 50·20	A 70 49 49·72			+ 0·8	+ 6·2	44
G 29 05 49·37	G 70 49 45·82					
A 29 01 41·1	A 70 21 14·1			− 1·1	+13·1	1092
G 29 01 42·2	G 70 21 02·3					
A 29 17 01·99	A 70 27 56·78			− 3·0	+18·2	1093
G 29 17 05·89	G 70 27 39·06					

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

(*Continued*)

TABLE 1

Serial No.	Sheet No.	Observed at	Height in feet	International Spheroid Deflections		Calculated Deflections Hayford System		Calculated Deflections Uncompensated Topography	
				Meridian	P.V.	Meridian	P.V.	Meridian	P.V.
				"	"	"	"	"	"
1004	39 K	Kambar Shāh	335	− 3·2	+10·2	− 1·9	+ 2·5		
1095	K	Jhakar T.S.	373	− 0·4	+ 9·0	− 1·6	+ 2·4		
1096	J	Khemwala T.S.	409	+ 1·4	+ 3·3	− 1·1	+ 2·1		
1097	J	Kotaddu ..	425	+ 3·2	+ 2·8	− 0·9	+ 2·4		
42	J	Dera Din Panāh S.	441	+ 3·9	+ 6·9	− 1·1	+ 2·2		
1098	J	Tibbi Pawha ..	470	+ 1·8	+ 6·8	− 0·8	+ 3·0		
1099	I	Shahpur T.S.	504	+ 0·5	+ 4·2	− 0·7	+ 2·9		
40	I	Jharkil T.S.	531	− 1·4	+ 1·7	− 1·1	+ 2·5		
1100	M	Bakar T.S.	580	− 4·1	− 3·9	− 1·1	+ 1·9		
1101	M	Ahmad Sindi ..	625	− 3·9	− 6·7	− 1·6	+ 1·7		
1102	38 P	Katurkot ..	625	+ 5·7	− 3·2	− 2·7	+ 2·3		
1103	P	Alluwali ..	650	+12·7	+ 0·5				
1104	P	Mianwali ..	660	+16·3	+ 2·7				
1105	P	Kalwan Dāk ..	940	+12·0	− 6·4				
1106	P	Changa h.s.	1556	+19·0	− 0·4				
1107	43 D	Jatla H.S.	2074	+17·8	− 0·3				
1108	D	Miani Dhok ..	2225	+15·5	− 1·6				
1109	L	Nagrota ..	1125	−15·2	−13·8	−12·1	− 8·7		
91	L	Ranjitgarh T.S.	879	+ 1·3	− 2·4				
1110	L	Chhanni Gondal	780	+ 1·3	− 1·8				
1111	L	Daulat Nagar..	925	+ 1·6	− 2·5				
1112	H	Taura Masumpur	850	+ 0·7	− 7·1				
1113	G	Dina ..	900	+ 2·0	− 4·9				
1114	G	Khabbal s.	1669	+ 3·8	− 6·1				
1115	G	Riwāt h.s.	1962	− 3·8	−10·4				

COLUMN 4: Except at G.T. and other triangulation stations all heights are approximate and correct to within 10 to 20 feet.

DEFLECTIONS 1939–40—(*contd.*)

EVEREST'S SPHEROID						
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections		Serial No.
				Meridian	P.V.	
° ′ ″	° ′ ″	° ′ ″		″	″	
A 29 31 51·0 G 29 31 59·1	*A* 70 33 38·7 *G* 70 33 25·5			− 8·1	+14·3	1094
A 20 46 34·35 G 29 46 39·68	*A* 70 43 37·64 *G* 70 43 25·82			− 5·3	+13·0	1095
A 30 00 42·03 G 30 09 45·76	*A* 70 56 51·51 *G* 70 56 46·32			− 3·7	+ 7·2	1006
A 30 27 11·4 G 30 27 13·4	*A* 70 58 39·3 *G* 70 58 34·7			− 2·0	+ 6·7	1007
A 30 34 00·60 G 30 34 01·87	*A* 70 56 16·67 *G* 70 56 07·29			− 1·3	+10·8	42
A 30 49 44·5 G 30 49 48·1	*A* 70 56 05·1 *G* 70 55 55·8			− 3·6	+10·7	1008
A 31 05 32·80 G 31 05 37·87	*A* 70 56 44·18 *G* 70 56 37·83			− 5·0	+ 8·1	1090
A 31 21 06·69 G 31 21 13·65	*A* 70 59 48·08 *G* 70 59 44·80			− 7·0	+ 5·5	40
A 31 37 36·9 G 31 37 46·7	*A* 71 03 24·0 *G* 71 03 27·3			− 9·8	− 0·1	1100
A 31 52 22·0 G 31 52 31·7	*A* 71 07 54·3 *G* 71 08 00·8			− 9·7	− 2·9	1101
A 32 09 10·3 G 32 09 10·6	*A* 71 15 01·6 *G* 71 15 04·2			− 0·3	+ 0·5	1102
A 32 22 21·7 G 32 22 15·1	*A* 71 25 45·1 *G* 71 25 43·5			+ 6·6	+ 4·1	1103
A 32 34 52·6 G 32 34 42·5	*A* 71 31 08·1 *G* 71 31 03·8			+10·1	+ 6·2	1104
A 32 40 07·1 G 32 40 01·3	*A* 71 46 39·9 *G* 71 46 46·6			+ 5·8	− 3·0	1105
A 32 43 55·4 G 32 43 42·6	*A* 71 59 56·2 *G* 71 59 56·0			+12·8	+ 2·8	1106
A 32 48 34·76 G 32 48 23·30	*A* 72 22 36·81 *G* 72 22 36·76			+11·5	+ 2·7	1107
A 32 48 13·3 G 32 48 04·1	*A* 72 39 37·9 *G* 72 39 39·7			+ 9·2	+ 1·2	1108
A 32 46 59·1 G 32 47 20·6	*A* 74 53 47·2 *G* 74 54 05·1			−21·5	−12·3	1109
A 32 35 07·09 G 32 35 12·10	*A* 74 37 08·50 *G* 74 37 12·48			− 5·0	− 0·7	01
A 32 34 08·8 G 32 34 13·7	*A* 74 21 15·0 *G* 74 21 18·3			− 4·9	− 0·1	1110
A 32 44 49·0 G 32 44 54·6	*A* 74 04 45·1 *G* 74 04 49·0			− 4·7	− 0·6	1111
A 32 56 21·0 G 32 56 26·7	*A* 73 49 55·1 *G* 73 50 04·1			− 5·7	− 5·0	1112
A 33 01 26·0 G 33 01 30·4	*A* 73 36 15·0 *G* 73 36 21·3			− 4·4	− 2·7	1113
A 33 08 40·2 G 33 08 42·9	*A* 73 23 50·5 *G* 73 23 58·2			− 2·7	− 3·8	1114
A 33 29 46·1 G 33 29 55·5	*A* 73 11 27·7 *G* 73 11 40·3			−10·4	− 7·9	1115

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

(*Continued*)

TABLE 1

Serial No.	Sheet No.	Observed at	Height in feet	International Spheroid Deflections Meridian	International Spheroid Deflections P.V.	Calculated Deflections Hayford System Meridian	Calculated Deflections Hayford System P.V.	Calculated Deflections Uncompensated Topography Meridian	Calculated Deflections Uncompensated Topography P.V.
				"	"	"	"	"	"
1116	43 G	Malpur ..	1800	−13·3	−12·2				
74	G	Jāoli H.S.	1012	+ 2·7	− 5·3				
1117	G	Kalriala s.	1758	+ 7·3	− 5·0				
1118	44 J	Faridkot T.S.	683	+ 3·7	+ 0·9	− 0·9	− 1·0		
1119	J	Mukant Singh-wala T.S.	698	+ 4·0	+ 1·2				
1120	J	Banawala T.S.	624	+ 4·2	− 0·4				
1121	F	Karni Khera ..	590	+ 4·3	− 6·6				
1122	38 P	Isa Khel Bārādari	700	+12·8	+ 5·4				
1123	P	Arsala ..	850	+12·1	+ 3·8				
1124	P	Kathgarh ..	600	− 2·9	− 2·4				
1125	L	Yārik bungalow s.	666	− 1·6	− 0·7				
1126	L	Pezo ..	930	+ 2·1	− 1·7				
1127	L	Tajori s.	817	− 0·7	+14·0				
1128	L	Manzai ..	1550	− 5·1	+21·8				
1129	L	Khairu Khel bungalow s.	1177	+ 5·8	+14·0				
1130	L	Gambila S.	935	+ 6·5	+ 9·0				
1131	L	Bannu Fort s.	1287	− 0·6	+16·1				
1132	K	Kurram Garhi Fort NW. corner	1416	− 2·7	+20·1				
1133	K	Shawa (Post) ..	2000	− 6·1	+22·8				
1134	K	Manduri (Post)	2000	− 5·6	+16·0				
1135	K	Arawali Fort ..	3650	− 3·6	+ 8·9				
1136	K	Amalkot ..	4350	− 3·9	+14·3				
1137	K	Pārachinār (milestone) h.s.	5739	−10·7	+13·1				
1138	39 J	Churatta ..	400	+ 0·2	+17·5				
1139	K	Tombi ..	670	− 4·9	+28·0				

COLUMN 4: Except at G.T. and other triangulation stations all heights are approximate and correct to within 10 to 20 feet.

DEFLECTIONS 1939–40—(*contd.*)

EVEREST'S SPHEROID						
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections		Serial No.
				Meridian	P.V.	
° ′ ″	° ′ ″	° ′ ″		″	″	
A 33 43 23·7 G 33 43 43·7	*A* 73 08 17·9 *G* 73 08 32·6			−20·0	− 9·7	1116
A 33 16 45·02 G 33 16 48·85	*A* 73 10 19·92 *G* 73 10 26·50			− 3·8	− 2·8	74
A 33 08 08·0 G 33 08 07·2	*A* 73 00 45·7 *G* 73 00 51·7			+ 0·8	− 2·4	1117
A 30 40 02·15 G 30 40 03·87	*A* 74 45 21·17 *G* 74 45 21·55			− 1·7	+ 2·4	1118
A 30 28 15·58 G 30 28 16·85	*A* 74 33 02·41 *G* 74 33 02·33			− 1·3	+ 2·8	1119
A 30 22 42·17 G 30 22 43·28	*A* 74 16 11·11 *G* 74 16 12·62			− 1·1	+ 1·4	1120
A 30 21 27·0 G 30 21 28·0	*A* 73 58 22·7 *G* 73 58 31·2			− 1·0	− 4·6	1121
A 32 40 55·8 G 32 40 49·2	*A* 71 16 39·3 *G* 71 16 31·6			+ 6·6	+ 9·1	1122
A 32 36 17·2 G 32 36 11·2	*A* 71 02 18·0 *G* 71 02 12·1			+ 6·0	+ 7·6	1123
A 32 08 21·7 G 32 08 30·6	*A* 71 00 05·6 *G* 71 00 07·1			− 8·9	+ 1·4	1124
A 32 06 10·2 G 32 06 17·8	*A* 70 47 35·4 *G* 70 47 34·7			− 7·6	+ 3·3	1125
A 32 19 18·5 G 32 19 22·4	*A* 70 44 08·7 *G* 70 44 09·1			− 3·9	+ 2·3	1126
A 32 18 32·7 G 32 18 39·4	*A* 70 29 57·6 *G* 70 29 39·2			− 6·7	+18·2	1127
A 32 14 57·3 G 32 15 08·4	*A* 70 15 02·7 *G* 70 14 36·0			−11·1	+26·1	1128
A 32 31 30·4 G 32 31 30·7	*A* 70 36 33·6 *G* 70 36 15·5			− 0·3	+18·0	1129
A 32 41 23·50 G 32 41 23·16	*A* 70 47 03·54 *G* 70 46 51·24			+ 0·3	+13·0	1130
A 32 59 34·2 G 32 59 41·1	*A* 70 36 41·6 *G* 70 36 20·7			− 6·9	+20·2	1131
A 33 01 43·8 G 33 01 52·8	*A* 70 32 19·7 *G* 70 31 54·0			− 9·0	+24·2	1132
A 33 13 32·4 G 33 13 44·9	*A* 70 29 14·6 *G* 70 28 46·4			−12·5	+27·0	1133
A 33 27 36·0 G 33 27 48·1	*A* 70 25 56·7 *G* 70 25 35·6			−12·1	+20·2	1134
A 33 37 52·2 G 33 38 02·4	*A* 70 19 39·8 *G* 70 19 27·2			−10·2	+13·1	1135
A 33 46 53·5 G 33 47 04·1	*A* 70 12 45·4 *G* 70 12 26·2			−10·6	+18·6	1136
A 33 53 50·3 G 33 54 07·7	*A* 70 06 04·3 *G* 70 05 46·4			−17·4	+17·5	1137
A 30 04 04·7 G 30 04 09·5	*A* 70 39 04·4 *G* 70 38 42·6			− 4·8	+21·5	1138
A 29 58 24·4 G 29 58 34·3	*A* 70 24 20·3 *G* 70 23 55·2			− 9·9	+32·2	1139

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

(*Continued*)

TABLE 1

Serial No.	Sheet No.	Observed at	Height in feet	International Spheroid Deflections		Calculated Deflections Hayford System		Calculated Deflections Uncompensated Topography	
				Meridian	P.V.	Meridian	P.V.	Meridian	P.V.
				"	"	"	"	"	"
1140	39 K	Rakhi Mithwan	1325	− 9·8	+36·0				
1141	G	Khar ..	5600	− 4·4	+25·0				
1142	F	Rakni ..	3590	− 3·6	+15·4				
1143	F	Rarkhan village peak	4234	− 0·2	+16·9				
1144	F	Saredhaka ..	4425	+ 0·8	+ 9·6	− 3·2	+ 3·6		
1145	F	Tor ..	4120	− 4·1	+ 4·1				
1146	B	Wahar ..	4040	− 5·5	+ 3·4				
1147	B	Loralai ..	4700	− 7·9	+ 3·1				
1148	B	Kach Ahmaqzai	5760	− 6·2	+ 5·6				
1149	34 N	Chinjan ..	7250	− 5·0	+ 7·1				
1150	N	Speraragha ..	7850	− 7·0	− 4·5				
1151	N	Yusuf Kach ..	7000	− 3·6	− 7·3				
1152	N	Gwal ..	5750	− 2·6	− 7·6				
1153	N	Bostan ..	5150	+ 3·1	− 6·7				
1154	J	Baleli ..	5230	+ 0·6	− 2·6				
1155	J	Sariab ..	5660	+ 2·6	− 1·3				
1156	39 L	Lalgoshi T.S.	315	− 1·3	+12·3				
1157	H	Mandadalari T.S.	273	− 1·1	+12·4				
1158	H	Kasmor T.S.	245	+ 1·3	+ 7·9				

COLUMN 4: Except at G.T. and other triangulation stations all heights are approximate and correct to within 10 to 20 feet.

DEFLECTIONS 1939-40—(*contd.*)

EVEREST'S SPHEROID						
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections		Serial No.
				Meridian	P.V.	
° ′ ″	° ′ ″	° ′ ″		″	″	
A 29 56 51·8 G 20 57 06·6	*A* 70 13 05·4 *G* 70 12 22·0			−14·8	+40·3	1140
A 29 56 01·1 G 29 56 10·5	*A* 69 59 23·4 *G* 60 58 52·7			− 9·4	+29·4	1141
A 30 02 37·5 G 30 02 46·1	*A* 69 55 50·7 *G* 69 55 30·8			− 8·6	+19·9	1142
A 30 15 47·7 G 30 15 53·0	*A* 69 54 20·1 *G* 69 53 58·4			− 5·3	+21·4	1143
A 30 28 32·1 G 30 28 36·5	*A* 69 31 51·8 *G* 69 31 38·2			− 4·4	+14·4	1144
A 30 27 39·4 G 30 27 48·7	*A* 69 09 29·0 *G* 60 09 21·6			− 9·3	+ 9·1	1145
A 30 24 25·5 G 30 24 36·2	*A* 68 55 29·0 *G* 68 55 23·1			−10·7	+ 8·6	1146
A 30 22 19·3 G 30 22 32·3	*A* 68 35 51·1 *G* 68 35 44·5			−13·0	+ 8·4	1147
A 30 20 55·8 G 30 30 07·2	*A* 68 17 35·6 *G* 68 17 25·8			−11·4	+11·1	1148
A 30 34 05·0 G 30 34 15·2	*A* 67 56 46·7 *G* 67 56 34·9			−10·2	+12·8	1149
A 30 32 22·7 G 30 32 34·9	*A* 67 39 19·5 *G* 67 39 21·1			−12·2	+ 1·4	1150
A 30 37 00·3 G 30 37 09·0	*A* 67 26 15·6 *G* 67 26 20·1			− 8·7	− 1·2	1151
A 30 31 28·6 G 30 31 36·3	*A* 67 12 13·4 *G* 67 12 18·1			− 7·7	− 1·4	1152
A 30 25 59·3 G 30 26 01·2	*A* 67 00 30·9 *G* 67 00 34·5			− 1·9	− 0·4	1153
A 30 16 06·0 G 30 16 10·4	*A* 66 56 07·2 *G* 66 56 05·9			− 4·4	+ 3·8	1154
A 30 06 10·0 G 30 06 12·3	*A* 66 58 55·6 *G* 66 58 52·9			− 2·3	+ 5·1	1155
A 28 52 53·59 G 28 52 59·35	*A* 70 03 10·28 *G* 70 02 54·33			− 5·8	+16·7	1156
A 28 42 06·15 G 28 42 11·62	*A* 69 52 19·27 *G* 69 52 03·20			− 5·5	+16·9	1157
A 28 26 25·69 G 28 26 28·66	*A* 69 34 08·23 *G* 69 33 57·04			− 3·0	+12·6	1158

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

(*Continued*)

TABLE 1

Serial No.	Sheet No.	Observed at	Height in feet	International Spheroid Deflections		Calculated Deflections Hayford System		Calculated Deflections Uncompensated Topography	
				Meridian	P.V.	Meridian	P.V.	Meridian	P.V.
				″	″	″	″	″	″
1159	53 E	Kulu h.s.	3063	− 28·0	− 25·8	− 22·2	− 13·1		
1160	53 E	Bijli h.s.	8066	− 30·8	− 36·5	− 30·0	− 25·1		
1161	53 E	Banjar h.s.	4905	− 13·4	− 41·3	− 6·4	− 30·2		
1162	53 E	Soja R.H. s.	8607	− 13·0	− 35·2	− 8·3	− 27·0		
1163	54 I	Lahore (South-eastern tower of railway station)	..	+ 11·9	+ 7·2				

DEFLECTIONS 1946—(*Concld.*)

EVEREST'S SPHEROID						
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections		Serial No.
				Meridian	P.V.	
° ′ ″ A 31 56 37·71 G 31 57 11·03	° ′ ″ *A* 77 06 07·05 *G* 77 06 40·05	° ′ ″		″ −33·9	″ −25·8	1159
A 31 54 50·72 G 31 56 27·30	*A* 77 08 19·05 *G* 77 09 05·83			−36·7	−36·5	1160
A 31 38 26·49 G 31 38 45·78	*A* 77 20 20·55 *G* 77 21 12·18			−19·3	−41·3	1161
A 31 33 41·27 G 31 34 00·15	*A* 77 21 43·05 *G* 77 22 27·57			−18·9	−35·2	1162
A 31 34 43·5 G 31 34 37·5	*A* 74 20 22·8 *G* 74 20 15·5			+6·0	+ 8·9	1163

Chapter V

COMPUTATIONS AND PUBLICATIONS

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

45. **General.**—The normal activities of the Computing Office (S.R.I.), Dehra Dūn, consist of the following :—

(i) Compilation, scrutiny, adjustment and publication of geodetic and topographical triangulation, traverse and levelling data all over India.

(ii) Preparation and publication of tables for the computation and reduction of the results of geodetic operations and of the field survey parties.

(iii) The provision of map projection tables.

(iv) Drafting of professional forms to facilitate computation and reduction of results.

(v) Editing and proof reading of departmental technical publications such as Professional papers, Departmental papers, Geodetic Handbook and some chapters of the Topo. Handbook.

(vi) Preparation and publication of the annual Geodetic Report.

On the outbreak of War in 1939, these activities were seriously interrupted and the entire strength of the Computing Office was employed on the production of data, tables and charts required by the army. Efforts are in progress to resume the pre-war activities although there are difficulties due to shortage of suitably trained personnel and to general unsettlement. The systematic adjustment of topographical triangulation all over India and its publication in pamphlets has now become an urgent necessity on account of frequent demands for data for the various irrigation and other projects and it is hoped to make a serious start with it in the very near future.

The following paras give a brief account of the work carried out during the war years.

46. **Adjustment of tertiary triangulation of Irāq.**—It became evident from the very start of the war—World War II, that the Allied military forces would have to enter Irāq sometime or the other for the defence not only of that country but also of Persia, Arabia, Afghānistān and India and that the survey service would be mostly provided by military survey units raised from the personnel of the Survey of India.

Reference numbers and Values of "*m*" and "M" for all Geodetic Series of the Indian Triangulation. (*See* Records of the Survey of India Vol. IX, p. 137).

For 42 Series entering the Simultaneous Grinding (shown in italics below) Mean Square M = ± 1·04
For Series up to No. 109 ... ... Mean Square M = ± 1·50

No.	Name of Series	Seasons	± *m*	± M
1	South Pārasnāth Mer. ...	1836-39	3·308	3·26
2	Budhon Meridional ...	1833-43	2·242	2·46
3	*Amūa Meridional* ...	1834-38	1·647	1·88
4	*Ranjīr Meridional* ...	1834-41	1·643	1·79
5	*Calcutta Longitudinal* ...	1864-69	0·369	0·32
6	*Great Arc Meridional, Section 24°-30°* ...	1835-66	0·708	0·71
7	*Bombay Longitudinal* ...	1837-39, 1862-63	0·844	0·74
8	*Great Arc Meridional, Section 18°-24°* ...	1837-41	0·567	0·59
9	*Great Arc Meridional, Section 8°-18°* ...	1866-74	0·390	0·36
10	*Singi Meridional* ...	1842-46, 1860-62	1·187	1·14
11	*South Konkan Coast* ...	1842-44, 1866-67	2·176	1·93
12	*Karāra Meridional* ...	1843-45	1·507	1·81
13	*North Malūncha Mer.* ...	1844-46	1·266	1·42
14	*Chendwār Meridional* ...	1844-46	0·841	1·06
15	*Gora Meridional* ...	1845-47	0·973	1·21
16	*Calcutta Meridional* ...	1845-48	1·173	1·99
17	South Malūncha Mer. ...	1845-53	1·606	1·97
18	*Khānpisura Meridional* ...	1845-48	1·227	1·07
19	*Gurwāni Meridional* ...	1846-47	1·165	1·55
20	*North-East Lon.* ...	1846-61	0·446	0·65
21	*Hurilāong Meridional* ...	1848-52	1·502	1·92
22	*North-West Himālaya* ...	1848-53	0·641	0·55
23	*Gurhāgarh Meridional* ...	1848-50, 1859-62	0·914	1·21
24	*East Coast* ...	1848-63	0·608	0·70
25	*Karāchi Longitudinal* ...	1849-55	0·558	0·60
26	*Abu Meridional* ..	1851-52	0·617	0·68
27	*North Pārasnāth Mer.* ...	1851-52	0·895	1·25
28	*Kāthiāwār Meridional* ...	1852-56	0·990	1·11
29	*Gujarāt Longitudinal* ...	1852-62	0·859	1·12
30	Kāthiāwār Lon. ...	1853	1·481	1·34
31	Sābarmati ...	1853-54	1·348	2·84
32	*Great Indus* ...	1853-61	0·359	0·43
33	*Rahūn Meridional* ...	1853 63	0·327	0·37
34	*Assam Longitudinal* * ...	1854-60	0·579	0·71
35	*Cutch Coast* ...	1855-58	0·986	1·27
36	Kashmir Principal ...	1855-60	0·884	0·86
37	*Jogi-Tila Meridional* ...	1855-62	0·481	0·59
38	Sambalpur Lon. ...	1856-57	0·806	0·87
39	(Cutch) Coast Line ...	1856-60	0·975	1·47
40	Kāthiāwār Meridional No. 1 ...	1858-59	0·930	1·51
41	Kāthiāwār Meridional No. 2 ...	1859-60	1·247	1·75
42	Kāthiāwār Meridional No. 3 ...	1859-60	0·969	1·48
43	*Bidar Longitudinal* ...	1860-72	0·311	0·30
44	*Eastern Frontier or Shillong Meridional* ...	1860-64	0·409	0·49
45	*Sutlej* ...	1861-63	0·846	0·63
46	*Madras Mer. and Coast* ...	1860-68	0·426	0·40
47	Kāthiāwār Meridional No. 4 ...	1863-64	1·154	1·73
48	*East Calcutta Lon.* ...	1863-69	0·379	0·57
49	*Mangalore Meridional* ...	1863-73	0·440	0·45
50	Kumaun and Garhwāl ...	1864-65	1·742	1·50
51	Nāsik ...	1864-65	2·033	3·12
52	Burma Coast (*See* 106) ...	1864-82	0·380	0·39
53	*Jubbulpore Meridional* ...	1864-67	0·340	0·31
54	*Madras Longitudinal* ...	1865-73	0·384	0·37
55	Assam Valley Triangulation † ...	1867-78	1·690	2·65
56	*Brahmaputra Mer.* ...	1868-74	0·564	0·70
57	Coimbatore No. 1 ...	1869-71	1·547	2·07
58	*Bilāspur Meridional* ...	1869-73	0·302	0·33
59	Cuddapah ...	1871-72	0·826	0·96
60	Hyderābād ...	1871-72	1·405	1·56
61	Malabar Coast ...	1872,74,80	1·532	1·82
62	Jodhpur Meridional ...	1873-76	0·291	0·32
63	*South East Coast* ...	1874-80	0·622	0·65
64	Eastern Sind Mer. ...	1876-81	0·244	0·30
65	Siam Branch Triangulation ...	1878-81	3·711	4·34
66	Mandalay Meridional ...	1889-95	0·418	0·35
67	Mong Hsat ‡ ...	1891-93	3·054	3·01
68	Manipur Longitudinal ...	1894-99	0·453	0·38
69	Makrān Longitudinal ...	1895-97	0·285	0·26
70	Mandalay Lon. ...	1899-1900	1·696	1·96
71	Manipur Mer. ...	1899-1902, 1915-1916	0·750	0·81
72	Great Salween (*See* 105)	1900-11	0·404	0·32
73	Kidarkanta ...	1902-03	1·323	1·62
74	Kalāt Longitudinal ...	1904-08	0·366	0·25
75	Baluchistān Triangulation ...	1908-09	1·348	1·08
76	North Baluchistān ...	1908-10	0·221	0·17
77	Gilgit ...	1909-11	0·443	0·37
78	Khāsi Hills ...	1909-13	2·038	3·01
80	Upper Irrawaddy ...	1909-11	0·596	0·49
81	Jaintia Hills ...	1910-11	0·966	1·86
82	Bhir ...	1911-12	0·794	0·84
83	Rānchi ...	1911-12	1·840	2·34
84	Villupuram ..	1911-12	1·184	1·76
85	Sambalpur Meridional ...	1911-14	0·250	0·21
86	Indo-Russian Connection	1912-13	2·790	3·92
87	Khandwa ...	1912-13	0·999	1·27
88	Ashta ...	1913-14	1·048	1·33
89	Buldāna ...	1913-14	0·304	0·43
90	Naldrug ...	1913-14	1·466	1·85
91	Nāga Hills ...	1913-14	0·913	0·96
92	Middle Godāvari ...	1914-15	0·913	1·08
93	Kohima ...	1913-15	1·094	1·39
94	Cāchār ...	1914-15	1·077	1·65
95	Bombay Island ...	1911-14	...	...
96	Madura ...	1916-17	1·148	1·63
97	Bāgalkot ...	1916-17	0·701	0·83
99	Rangoon ...	1926-27	1·246	1·25
100	Kurram ...	1927-28	2·096	2·26
101	Peshāwar ...	1927-28	1·267	0·96
102	North Waziristān ...	1927-28	1·895	2·47
103	Chittagong ...	1928-30	0·453	0·45
104	Mong Hsat ...	1929-31	0·441	0·38
105	Great Salween ...	1929-31	0·682	0·58
106	Burma Coast ...	1930-31	0·205	0·19
107	Dālbandin ...	1931-32	0·472	0·32
108	Assam Longitudinal ...	1934-36	0·426	0·47
109	Mandalay Meridional ...	1936-37	0·422	0·35

Mer. = Meridional   Lon. = Longitudinal.

* Portion between longitudes 90¼° and 91½° reobserved in 1937-38. $m = \pm 0·455$. $M = \pm 0·56$.

† Replaced by 108.   ‡ Replaced by 104.

Early in 1940, therefore, the Survey Department of Irāq was contacted to examine the then existing position as regards maps of Irāq. It was found that there were several series of maps, some based on post-1930 primary, secondary and tertiary triangulation of Irāq, which have Nahrwan (near Baghdād) as their datum and which are computed on Clarke's 1880 spheroid, and others based on the triangulation carried out during World War I, which has Fāo (near Basra) as its datum and which is computed on the Everest spheroid. The various sets of maps were naturally discrepant and to bring them into mutual agreement it was necessary to bring all the framework control data into the same terms. It was consequently decided to send a small Computing party consisting of three computers to Baghdād in June 1940 to compile and adjust all triangulation and traverse data of Irāq then available. The party commenced work on 16th July 1940 and completed its job in March 1941 and returned to India. It compiled about 20,000 points and after scrutiny and recomputation the various systems of triangulation were brought into sympathy with each other by graphical adjustment. For this purpose the primary and secondary triangulation of Irāq carried out between 1930 and 1936, as computed and adjusted by the Irāq Survey Department was assumed to be errorless. The co-ordinates of stations and points common to the primary and secondary triangulation and tertiary trangulation were converted from sphericals to rectangulars on the Lambert Orthomorphic Conical projection, Grids B and C and the discrepancies were plotted and graphically disbursed. The Irāq Survey Department had computed the spherical co-ordinates of the primary and secondary triangulation and some tertiary triangulation on Clarke's 1880 spheroid, and the bit of tertiary triangulation based on Fāo as origin on the Everest spheroid. For conversion to grid terms appropriate tables pertaining to the spheroid used for the computation of spherical co-ordinates were specially constructed. The entire triangulation was later converted to grid terms and published in gestetnered pamphlets. The adjustment of some of this data especially that in western Irāq is based on very scanty information and will be revised in the light of Paiforce H.S.B. traverses, which were run between 1941 and 1943. (See Chart XIX).

47. **Adjustment of M.E.F. triangulation in Persia.**—Prior to 1941, whereas Irāq was covered (except in the west) by a network of triangulation, the only triangulation existing in Persia was that carried out by the units of the Survey Party of the Mesopotamia Expeditionary Force of World War I in south and west Persia. This was of a piecemeal character and was to some extent connected with the Irāq tertiary triangulation of the same period based on Fāo, the position of which was astronomically determined. No attempt had been made before 1940 to put this old war-time triangulation in Persia into terms of the post-1930 primary triangulation of Irāq. On the outbreak of World War II, however, this had to be done as this was the only triangulation in the area. The corrections were derived from a comparison of common points, including Fāo, which

had since been connected by Irāq secondary triangulation. These common points were very small in number and detailed information for a proper adjustment of the data was generally lacking. The co-ordinates were converted from spherical to terms of Lambert Grid and published in provisional pamphlets. The adjustment corrections applied are now being revised in the light of the data of Paiforce triangulation in the area executed from 1941 to 1943 described below.

48. **Paiforce triangulation, 1941–43, and its adjustment.**—In 1941, when British and Indian Forces (British Troops Irāq, later known as 10th Army, and finally Paiforce) moved into Irāq and Persia, a Survey Directorate was formed at Baghdād which contained a strong contingent of survey troops including three Indian Field Survey Companies. At first it was intended to revise the existing maps along motorable roads but later it was considered desirable to carry out extensive triangulation in NW. Persia. This triangulation carried out from 1941 to 1943 starts from Khanaqin and Qara Tapeh stations of the Irāq primary triangulation and is connected to the Irāq secondary triangulation at A.D.S. 8 and A.D.S. 6. It covers an area of 70,000 square miles and comprises 13 closed loops of triangulation involving 35 series, and 12 pendant series (see Chart XIX). The details of the various series are given in Table 1.

The final adjustment of the work was carried out by a semi-rigorous method as follows :—

The junction points of the various series were allotted numbers in order to facilitate the definition of the route by which triangulation proceeds. Each circuit is composed of triangulation by two routes, one of which is shorter than the other. The closing errors in 5th figure of the log side (metres), bearings and co-ordinates of the various circuits are given in Table 2 in the sense shorter minus longer route. In the case of circuits, 1, 3, 6 (see Chart XIX) the Irāq primary and secondary triangulation has been regarded as the shorter route. The closing errors in bearings of each circuit are disbursed by apportioning to each route a share based on distance taking count also of the quality of the triangulation of the route. Next the co-ordinates are computed using the adjusted sides and bearings of one flank of the triangulation in each route.

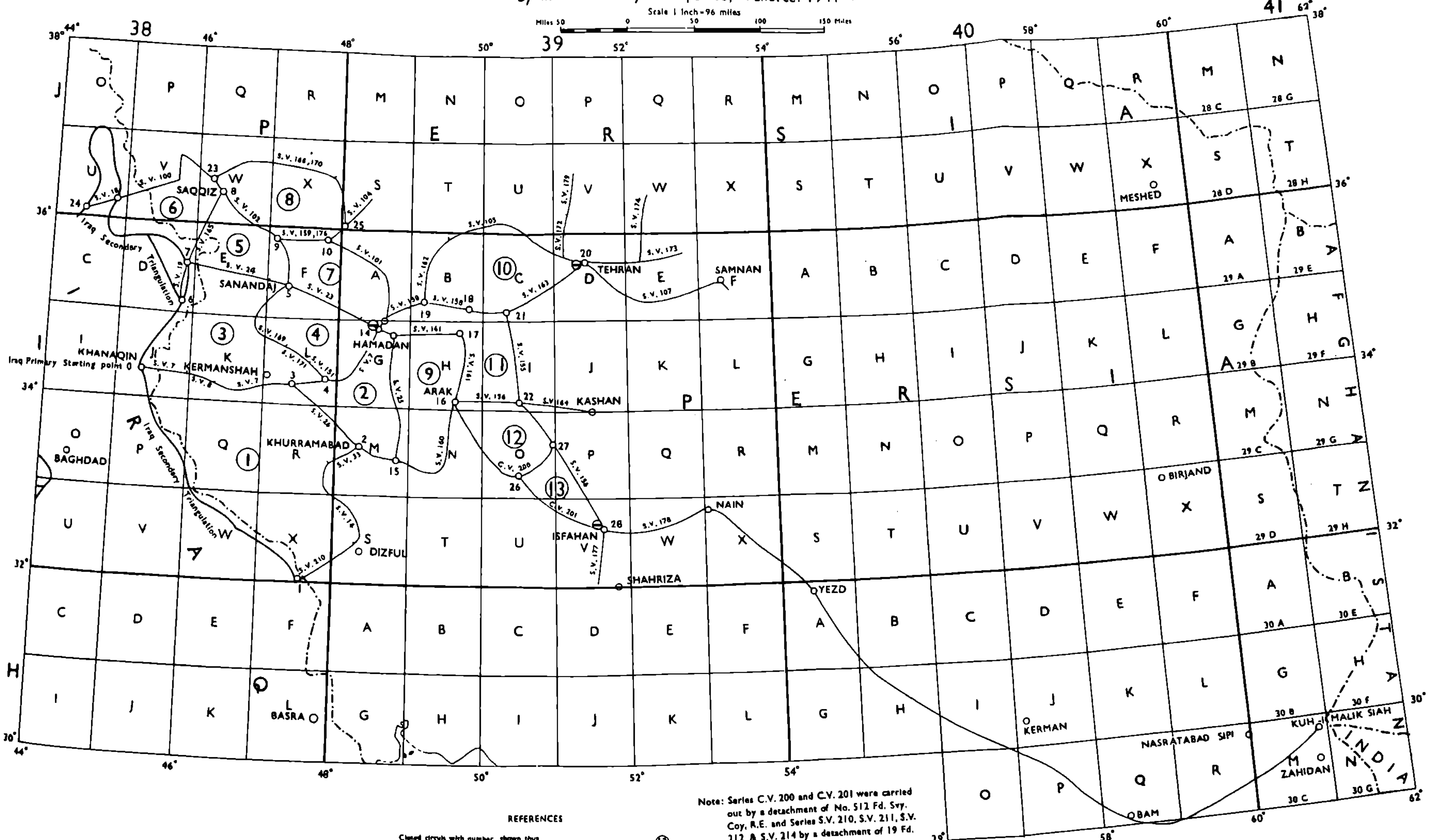
The two routes give slightly different values of the eastings and northings of the junction. The discrepancies are shown in Table 4. The final co-ordinates of the junction points were then fixed in such a way that the adoption of the values improved the closing errors of the adjoining circuits. The corrections to the co-ordinates of the intervening stations of the flanks were obtained by graphical adjustment and the co-ordinates of all other stations were recomputed in terms of the final values of the flank stations from the best conditioned triangles. The intersected points were given the same corrections as the stations from which they were fixed.

In general the triangulation followed motorable communication routes, the stations of observations lying on either side of the

Chart XIX

TRIANGULATION IN PERSIA

By Ind. Fd. Survey Companies, Paiforce. 1941-44



Note: Series C.V. 200 and C.V. 201 were carried out by a detachment of No. 512 Fd. Svy. Coy. R.E. and Series S.V. 210, S.V. 211, S.V. 212 & S.V. 214 by a detachment of 19 Fd. Svy. Coy. R.E.

REFERENCES

Closed circuits with number shown thus .... (12)

Junction Point numbers shown thus o19

Series with number .... S.V. 23

Geodetic Base-line .... ⊖

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Reg. No. 144 M/G.B/'48-400.

U S S R
C H I N A
A F G H Ā N I S T Ā N
I N D I A
OXUS SERIES
ANDKHUI SERIES (1884-86)
BALKH SERIES (1884-86)
DAULATĀBĀD SERIES (1884-86)
Shibarghān
Daulatābād
Tāshkurghān
Khānābād
Jurm
CHAHARSHAMBA SERIES (1884-86)
Chahārshamba Base
Deh Miran
Tukzār
COAL SURVEY PARTY (1940-41)
Shui
BOUNDARY SERIES
Hari Rud
Kohsān Base
HERĀT
Koh-i-Kotal Reg
BAMIĀN SERIES
KĀBUL
KHYBER SERIES (1878-79)
Khyber Base
PESHAWAR
KURAM SERIES
Ghazni
Matun
Talwāra
Sabzawar
Farāh River
Helmand River
Mūsa Qala
SOUTH AFGHANISTAN TRIANGULATION (1878-81)
Barak Khe
Kandahar Base
KANDĀHĀR
Dori River
Kidah
Malik Koti
Khoja Ali Base
Jat Poti
QUETTA
AFGHAN BOUNDARY COMMISSION NO. 1
AFGHAN BOUNDARY COMMISSION NO. 2 (1884-85)
KALĀT LONGITUDINAL SERIES
Murghāb River
Oxus River

Fig. No.147 M/G.B. '48 400.

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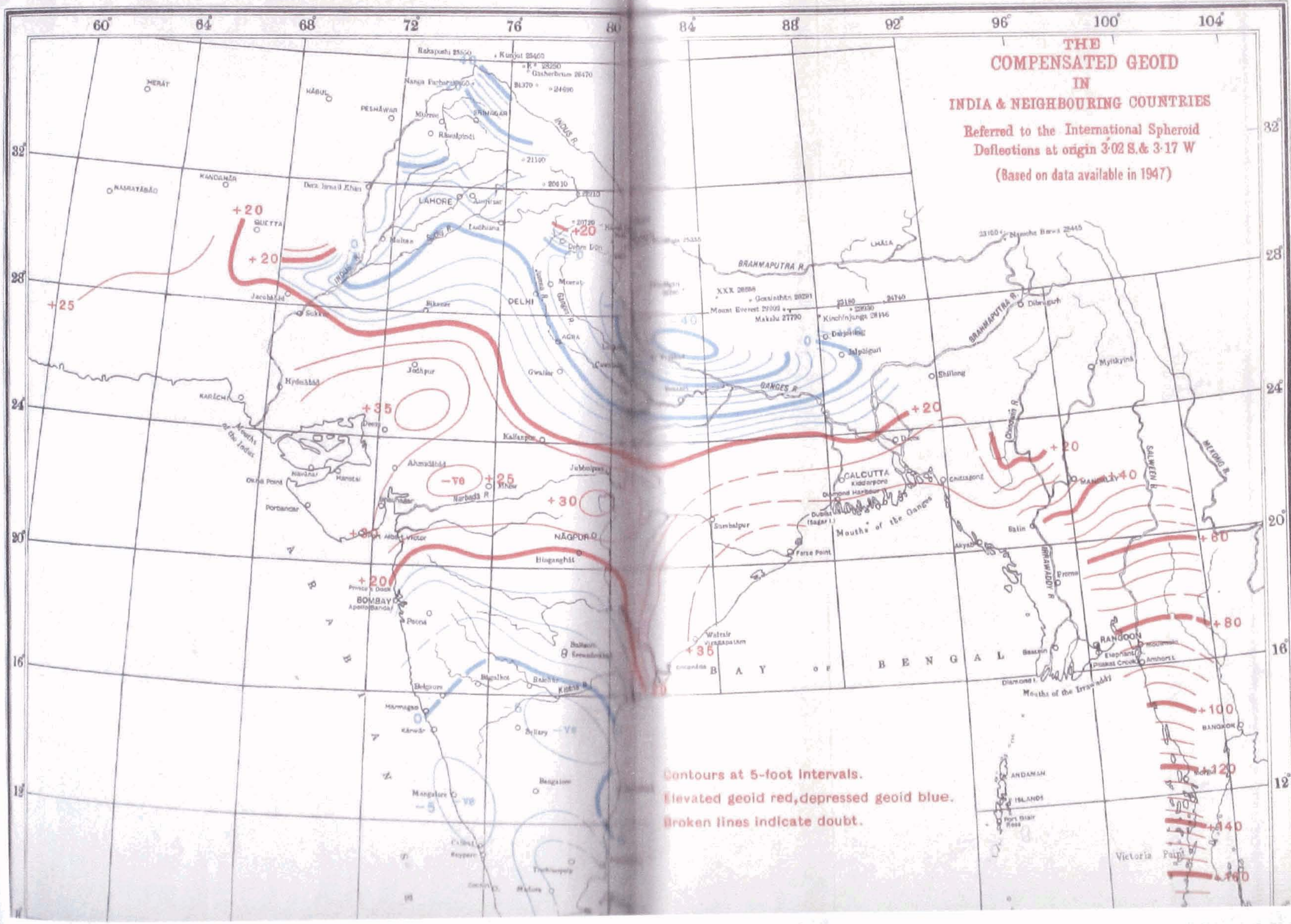
THE
COMPENSATED GEOID
IN
INDIA & NEIGHBOURING COUNTRIES
Referred to the International Spheroid
Deflections at origin 3·02 S.& 3·17 W
(Based on data available in 1947)
Contours at 5-foot intervals.
Elevated geoid red, depressed geoid blue.
Broken lines indicate doubt.
60°
64°
68°
72°
76°
80°
84°
88°
92°
96°
100°
104°
32°
28°
24°
20°
16°
12°
+20
+25
+35
+25
+30
+20
+40
+60
+80
+100
+120
+140
+160
-40
-ve
-5
QUETTA
LAHORE
DELHI
Jodhpur
Ahmadābād
NĀGPUR
BOMBAY
Poona
CALCUTTA
Darjeeling
Shillong
Chittagong
Mandalay
Myitkyina
Prome
RANGOON
BANGKOK
Mangalore
Bellary
Bangalore
Belgaum
Kārwār
Sambalpur
False Point
Waltair
BRAHMAPUTRA R.
GANGES R.
INDUS R.
Narbada R.
IRRAWADDY R.
SALWEEN R.
MEKONG R.
Mouths of the Ganges
Mouths of the Indus
Mouths of the Irrawaddy
BAY OF BENGAL
ARABIAN
ANDAMAN
ISLANDS
Port Blair
Victoria Point
Mount Everest 29002
Makalu 27790
Kinchinjunga 28146

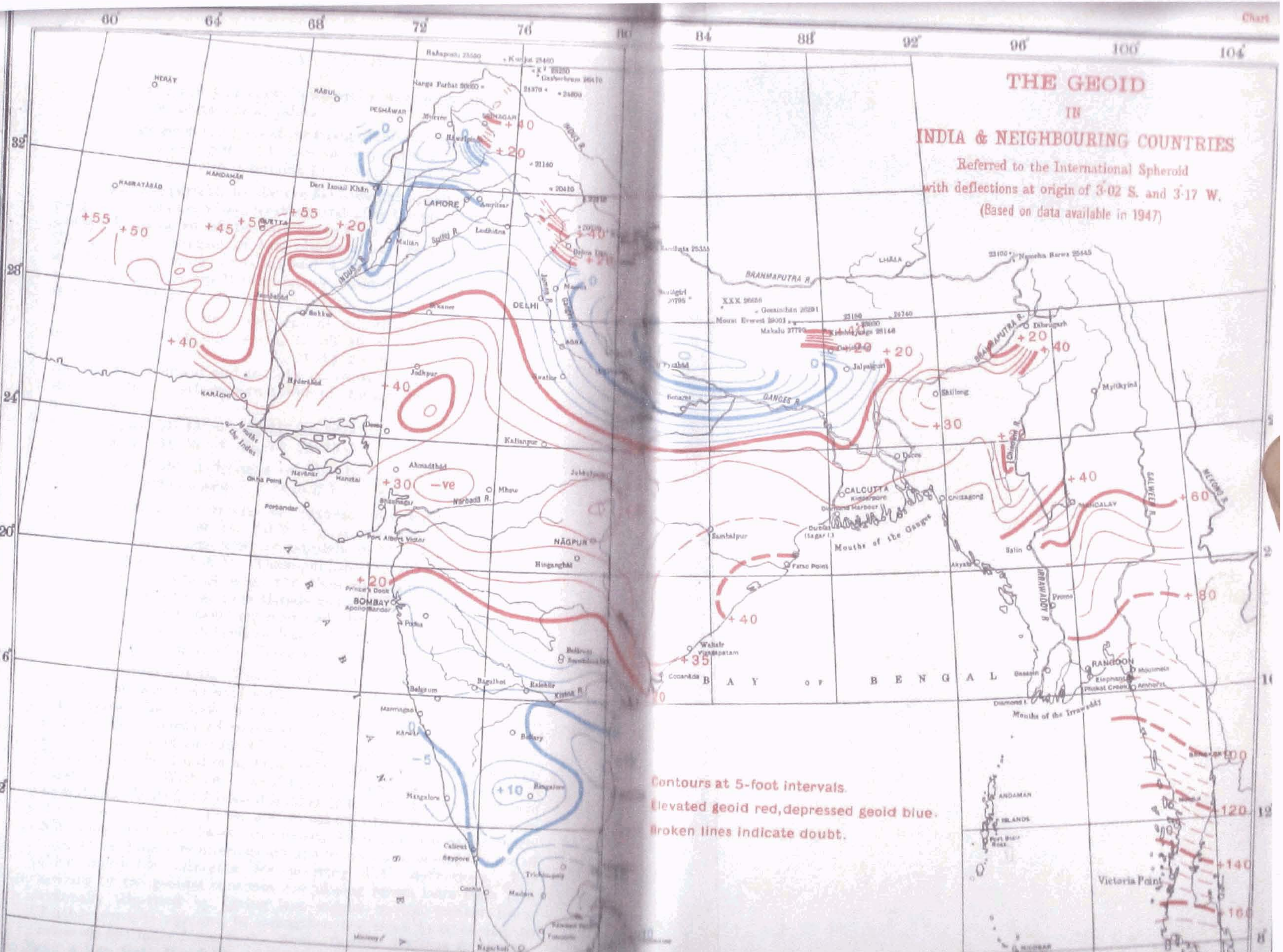
Chart
THE GEOID
IN
INDIA & NEIGHBOURING COUNTRIES
Referred to the International Spheroid
with deflections at origin of 3·02 S. and 3·17 W.
(Based on data available in 1947)
Contours at 5-foot intervals.
Elevated geoid red, depressed geoid blue.
Broken lines indicate doubt.
60
64
68
72
76
80
84
88
92
96
100
104
32
28
24
20
16
12
8
HERAT
KABUL
PESHAWAR
SRINAGAR
LAHORE
Amritsar
Ludhiana
Multan
QUETTA
DELHI
KARACHI
Hyderabad
Jodhpur
Ahmadabad
Mhow
NAGPUR
Hinganghat
BOMBAY
Poona
Belgaum
Bellary
Mangalore
Calicut
Beypore
Cochin
Madura
CALCUTTA
Dacca
Shillong
Jalpaiguri
Chittagong
Akyab
Prome
RANGOON
Moulmein
Amherst
Victoria Point
Myitkyina
Dibrugarh
Sambalpur
Waltair
Cocanada
BRAHMAPUTRA R.
GANGES R.
IRRAWADDY R.
SALWEEN R.
Narbada R.
Kistna R.
Sutlej R.
INDUS R.
B A Y O F B E N G A L
Mouths of the Ganges
Mouths of the Indus
Mouths of the Irrawaddy
ANDAMAN
ISLANDS
+55
+50
+45
+20
+40
+30
−ve
+10
−5
+35
+60
+80
+100
+120
+140
+160

H.
Srinagar
Rāwalpindi
Nasratābād
Kandahār
Dera Ismail Khān
Chaman
LAHORE
Amritsar
Quetta
Multān
Dehra Dūn
Brahmaputra R.
Indus R.
Bahawalpur
Jacobabad
Khanpur
DELHI
Moradabad
Bareilly
Bikaner
Sukkur
Jodhpur
Ajmer
Jaipur
Muttra
Agra
Gwalior
Lucknow
Fyzābād
Gorakhpur
Dibrugarh
Shillong
Myitkyina
Cawnpore
Benares
Allahābād
Karāchi
Tatta
Hyderābād
Barmer
Pali
Deesa
Ganges R.
Aurangabad
Kallianpur
Bhopal
Korwai Kethora
Jubbulpore
Raniganj
Midnapur
Chittagong
Chindwin R.
Mandalay
Sikarpur
Viramgam
Ahmadābād
Navanar
Okha Point
Rajkot
Sehore
Porbandar
Port Albert Victor
Surat
Dhulia
NĀGPUR
Raipur
Sambalpur
Diamond
Dublat
Chāndbāli
Cuttack
False Point
Akyab
Salin
Irrawaddy R.
Prome
Salween R.
Prince's Dock
BOMBAY
Apollo Bandar
Poona
Godāvari R.
Vizianagram
Waltair
Vizagapatam
Bassein
Elephant Point
RANGOON
Moulmein
Amherst
Ratnagiri
Kolhapur
Bāgalkot
Belgaum
Raichūr
Hyderābād
Cocanāda
BAY OF BENGAL
Diamond I.
Kistna R.
Marmagao
Kārwār
Bellary
ARABIAN SEA
ANDAMAN ISLANDS
Port Blair
Mangalore
Bangalore
MADRAS
Mergui
Calicut
Baypore
Trichinopoly
Negapatam
Cochin
Pāmban Pass
Tuticorin
Trincomalee
Minicoy
Nāgarkoil
NICOBAR ISLANDS
Colombo
CEYLON
Galle
Scale 1 Inch=250 Miles
Miles 100 0 100 400 Miles
SUMATRA
George Town
30 31 33 34 35 36 38 39 40 41 43 44 45 46 47 48 49 52 53 54 55 56 57 58 59 62 63 64 65 66 67 68 72 73 74 83 84 85 86 87 88 92 93 94 95 96 97
I II III IV V VI VII VIII IX X XI XII
Line 101 Line 102 Line 103 Line 106 Line 107 Line 109 Line 110 Line 111 Line 113 Line 114 Line 115 Line 116 Line 117 Line 119 Line 120 Line 151
+·026 +1·501 +1·688 +·151 +·205 −·018 −·0·025 +·208 −·171 +·767 −1·605
32° 28° 24° 20° 16° 12° 8°
64° 68° 72° 76° 80° 84° 92° 96° 100°

route within reasonable walking distance. The figures were mostly elongated quadrilaterals (average length being double than that of breadth)—a type well-suited for good maintenance of bearing but less favourable for maintenance of scale. To safeguard the scale frequent short bases were incorporated, and bases of geodetic accuracy were measured at Hamadān, Tehrān and Isfahān. Each section of the triangulation is adjusted between its terminal base-lines. The discrepancies between the triangulated and measured values of the bases are shown in Table 3. Three Laplace stations (i.e. stations at which astronomical observations for latitude, longitude and azimuth are made) were established one each at Hamadān, Tehrān and Isfahān for the control of bearings. Brief details of these Laplace stations are given in Chapter I, para 17.

The adjustment has been completed, but it has not been possible to publish the data due to shortage of personnel. It is hoped to take up this work shortly.

49. **Triangulation linking Irāq to India.**—This link which had been a desideratum for a long time past was effected by a triangulation by Captain P. A. Thomas, R.I.E. in 1944 starting from Nain, the easternmost point of Paiforce triangulation and closing on stations Kūh-i-Malik Siāh H.S. and Kācha Kūh H.S. of the Kalāt Longitudinal Series of the Indian triangulation. Brief details of this triangulation are given in Chapter I, para 18, and a fuller account is published in War Research Series, Pamphlet No. 9. The computations of this triangulation were carried out in the Dehra Dūn Computing Office. With the present link-up of Irāq, Persian and Indian triangulations, it will be possible to print all the data on the appropriate grids in the triangulation pamphlets which will supersede the older ones based on scanty data and scrappy adjustments.

50. **Topographical triangulation in Burma.**—In common with the rest of India, no attempt had been made before World War II at any systematic compilation, scrutiny, and adjustment of the topographical triangulation in Burma. In 1941 when Japan entered the War, this became an urgent necessity and the work was commenced in the Burma Survey Party in Maymyo. The list of co-ordinates with descriptions of stations and points were compiled by degree sheets and data for a rough adjustment were collected and despatched from Maymyo to Dehra Dūn, where adjustment corrections were applied and the co-ordinates converted to Lambert Grid terms in the Computing Office and published in pamphlets. The work was still in progress when the Japanese occupied Burma and the Burma Survey Party left for India. It is regrettable that the original records of all triangulation and traverse were left behind in Burma and are now lost. It has not been possible to save most of the data and whatever was saved is only roughly adjusted and there will now be no opportunity to revise the adjustment until the country has been re-triangulated. The data saved and published in pamphlets is shown on Chart XX. It involved the conversion of about 20,500 points from sphericals to grid terms.

51. **Adjustment of topo triangulation in Assam.**—All available data of topo. triangulation and traverse in Assam was graphically adjusted and converted to grid terms. It involved a conversion of about 10,500 points. The data is published in 14 pamphlets.

52. **Triangulation in the Nicobars.**—Triangulation pamphlet for sheet 88 E published in 1928 gives data of triangulation carried out in 1886–87 in the Nicobars. The co-ordinates of stations and points are given in spherical terms. This triangulation is based on the astronomical co-ordinates and azimuth observed at Camorta observatory, and a base measured near it. The latitude was observed by observations to circum-meridian stars and the longitude by the transport of chronometers from Port Blair, the longitude of which in turn had been determined in terms of the longitude of Madras observatory.

The Admiralty Charts of Nicobar Islands are based on Ray Point flag-staff, which was fixed by Marine Survey in 1921-22. This point was connected to the Survey of India station, Signalling Staff, and the difference in co-ordinates, Admiralty *minus* Survey of India values, was found to be $-1''\cdot 50$ in latitude and $-21''\cdot 72$ in longitude. This difference has been applied as corrections to the Survey of India latitudes and longitudes and the data has been converted to grid terms and published for the use of military units.

A further source of confusion was the fact that the trig. data in terms of Ray Point flag-staff was not in conformity with the graticule on the Admiralty charts, the graticule requiring a shift to the west by $5''\cdot 64$. It is recommended that this defect may be remedied when the charts are redrawn.

53. **Triangulation data in South East Asian countries.**—The trig. records of Malaya and Ceylon were sent to the Computing Office for security reasons and data of the triangulation in French-Indo-China and Siam and some scanty data in China and Japan became available through military channels. Some records of N.E.I. were rescued by an officer of the Indian Military Survey Unit in Batavia.

To meet the requirements of the allied forces trig. data of all these countries was converted to terms of military grid for the area and published in pamphlets. The triangulation of the various countries is computed on different spheroids and appropriate tables had to be improvised for the conversion of data.

54. **Triangulation in Afghānistān.**—Prior to 1940 the only triangulation in Afghānistān was that carried out by observers of the Survey of India in 1878–80 between Kurram and Kābul and in 1884–86 in the west of Afghānistān. The results of this work are published in the Survey of India Synoptical Volumes Nos. 1/A & 1/B. A certain number of points were, of course, also fixed by intersection from stations of various series falling in India.

The positions of all these points were originally computed in spherical co-ordinates on Everest spheroid. In 1936, in order to publish the data in terms of the military grid in rectangular co-ordinates in yards the spherical co-ordinates were given extensive adjustment corrections based on the assumed identity of certain common stations and the altered values were converted to grid terms and published in the Survey of India grid data triangulation pamphlets.

In 1940–42, a detachment of the Survey of India was attached to the *Coal Survey Party of the Geological Survey of India which* carried out exploratory work in Tala, Kahmard, Doāb-i-Rui and Darra-i-Sūf districts of Afghānistān. The Survey of India detachment measured a base at Ishpushta, established origin for the triangulation by astronomical fixing at this place and rapidly extended the triangulation to cover an area of 2,500 square miles in these districts. The 1940–42 triangulation effected connections with the old triangulations of 1878–80 and 1884–86 and it was discovered that the adjustment corrections applied to the co-ordinates of the 1884–86 work in 1936 were erroneous, and that the data published in the Grid Data triangulation pamphlets for the area and the maps based on it would require revision. It has not been possible to revise this data and maps as yet.

The co-ordinates of the 1940–42 triangulation are in terms of its own astronomical origin at Ishpushta and the co-ordinates of the old connected triangulations of 1878–80 and 1884–86 have been brought into the same terms. The co-ordinates are in terms of a military Lambert grid in metres. The entire data is published in a volume entitled "Triangulation in Afghānistān, (Grid Data, Metres), 1947".

55. **Trig. Dossiers.**—On the urgent demands of the military Survey authorities Trig. Dossiers giving a brief history of the triangulation, details regarding its datum and fundamentals and the spheroid used and the degree of the reliability of the triangulation connections with other countries and also the details of projection and the military grid system used for maps were prepared for Burma, Siam, Malaya, French-Indo-China, China, Dutch East Indies and Japan.

The information given in these Trig. Dossiers was collected from various sources including the reports submitted by the various countries to the International Union of Geodesy and Geophysics from time to time.

56. **Azimuthal Maps.**—To meet military requirements calculations were made for the projection and preparation of bearing scales for maps showing the true bearing from a given centre of any point falling in the area of the map concerned. A list of maps produced from time to time is given in Table 5. The projection employed for these maps is a Gnomonic one.

57. **Mercator Projection Tables.**—A number of tables on Mercator projection on Clarke's 1880 spheroid in metres were computed for co-ordinatograph settings on the scale of 1/50,000 and

1/1,000,000 for the projection of sheets of Standard Plotting series required by the army authorities for navigational purposes.

58. **New Geodetic framework.**—Experimental work to test methods for the fixing of positions of survey marks in easily accessible places distributed all over the country at a spacing of about 10 miles, to an accuracy of 1/50,000, was carried out first in the vicinity of Dehra Dūn in 1945 and then during two field seasons of 1946 and 1947 in Erinpura area of Jodhpur state. The computations involving laborious reductions were carried out in the Computing Office. The results indicated that the apparatus and the methods had not attained finality and were not as yet ready for employment on productive work. The work has been suspended for the present to give priority to more urgent work and a detailed report will be published when the experiments are resumed and some successful method is evolved.

59. **Publications.**—In addition to the Grid Tables and data printed for the use of the army the following publications were also seen through the press :—

1. Professional Paper No. 30, "Gravity Anomalies".
2. Geodetic Report 1940.
3. Handbook of Topography, Chapters III & IV (reprinted), V & VII.
4. Levelling Pamphlets for 1/M sheets 39, 46, 47, 63 and 84 and addendums to 54 & 72 and that for 1/M 40 reproduced by photozincography.
5. List of Publications of the Survey of India.
6. Memoirs of the Survey Research Institute, Vol. I, No. 1.
7. Survey Service Pocket Book.
8. Supplement to Topo. Chapters VIII & XII of the Survey of India Handbook of Topography, 1st Edition, 1944.
9. Auxiliary Tables, reprinted.
   - Part I. Graticules of Maps, Seventh Edition, 1943.
   - Part II. Mathematical Tables, Sixth Edition, 1944.
   - Part III. Topographical Survey Tables, Seventh Edition 1944.
   - Part V. Lambert Grid Tables, Sixth Edition, 1941. (reprinted with some additions 1942, 1944).

60. **Miscellaneous.**—All the triangulation and traverse records of the Eastern Circle and most of the records of the Frontier and Southern Circles and some of the foreign countries in S.E.A. Command were transferred to the Computing Office, Dehra Dūn for safe custody during the war and consequently this office had to act as the one central agency for the supply of trig. and traverse data to all civil and military survey units. Calls were sometimes made at an

extremely short notice and demands were varied in nature and extremely heavy. The members of the Computing Office had to work under considerable pressure to meet such requisitions. The data was always required in grid terms involving conversion from spherical and Cassini rectangular co-ordinates, and sometimes computation on different spheroids and different projections. Apart from the data published in various grid data triangulation pamphlets, the co-ordinates of about 100,000 points were supplied to the various units in manuscript after converting the data to grid terms.

A large number of computers were trained both for employment in civil and military units and Headquarters Offices. In some cases their training was combined with productive work.

Numerous professional forms were devised and printed in large quantities.

TABEL 1.—*List of Series of Paiforce Triangulation in Persia*

Series	Observer	Date	Instrument used	Average Triangular Error	± m	± M
S. V. 7	M. N. A. Hashmic	1941–42	Wild	6″	5·0	7·1
S. V. 8	M. A. Farouquie	1941	Tav.	11	0·9	13·3
S. V. 26	R. A. Gardiner	1942	Wild & Tav.	5	3·8	4·7
S. V. 33	M. A. Farouquie	1942	Tav.	6	3·0	4·3
S. V. 14	M. A. Farouquie	1942	,,	7	4·8	6·1
S. V. 210	19th Fd. Survey Coy.	1942–43	,,	4	3·5	4·1
S. V. 25	H. M. Rimmer	1942	,,	8	5·5	7·1
S. V. 151	U. D. Mamgain	1942	Wild	3	2·5	5·7
S. V. 171	L. R. Howard	1942	,,	9	6·4	9·0
S. V. 109	L. R. Howard	1942	Tav.	10	6·0	7·2
S. V. 154	L. R. Howard	1942	Wild	12	7·1	10·8
S. V. 24	U. D. Mamgain	1942	,,	7	6·0	8·1
S. V. 19	U. D. Mamgain	1942	,,	4	2·0	5·5
S. V. 23	U. D. Mamgain	1942	Wild & Tav.	6	5·2	6·3
S. V. 102	U. D. Mamgain	1942	Wild	6	5·0	7·4
S. V. 105	U. D. Mamgain	1942	,,	2	1·1	1·3
S. V. 100	N. N. Dhawan	1942	,,	10	6·0	8·6
S. V. 18	R. A. Gardiner	1942	Tav.	4	2·9	3·7
S. V. 101	A. D. Verma and M. A. Farouquie	1942	,,	6	4·6	6·7
S. V. 159	H. M. Rimmer and N. N. Dhawan	1942	,,	7	4·5	6·5
S. V. 176	D. Dunn	1942	,,	4	2·8	4·0
S. V. 104	M. A. Farouquie	1942	,,	5	3·1	3·3
S.V. 166 & 170	L. R. Howard	1942	,,	7	5·4	7·4
S. V. 160	M. A. Farouquie	1942	,,	4	3·1	3·2
S. V. 161	L. R. Howard	1942	,,	11	7·1	9·0
S. V. 175	J. Cowley	1942	,,	18	15·6	17·3
S. V. 158	L. R. Howard, N. C. Sen, S. D. Gupta	1942	Wild	7	4·7	5·1
S. V. 163	A. D. Verma	1942	Tav.	9	6·3	6·4
S. V. 172	U. D. Mamgain	1942	Wild	6	4·5	5·4
S. V. 106	M. A. Farouquie	1942–43	Tav.	5	3·6	5·1
S. V. 162	U. D. Mamgain	1942	Wild	5	3·1	3·7
S. V. 156	J. C. Ross and A. D. Verma	1942	Tav.	7	5·3	5·8
S. V. 155	S. D. Gupta	1942	Wild	10	7·0	9·0
C. V. 200	No. 1 Section, Mobile Echelon 512 Fd. Survey Coy. R.E.	1942	Tav. & Zeiss	6	5·0	6·3
C. V. 201	No. 1 Section, Mobile Echelon 512 Fd. Survey Coy. R.E.	1942	Tav. & Zeiss	7	4·2	5·0
S. V. 17	P. S. Shinghal	1942	Wild	8	5·3	15·2
S. V. 212	19th Fd. Survey Coy.	1943	Tav.	12	9·0	10·5
S. V. 214	19th Fd. Survey Coy.	1943	,,	5	3·5	6·3
S. V. 15	N. N. Dhawan	1942	Wild	7	4·5	6·8
S. V. 179	I. M. Saklani	1942	,,	8	5·5	10·3
S. V. 174	H. M. Rimmer	1942	Tav.	4	2·8	3·9
S. V. 173	S. D. Gupta	1942	Wild	4	3·1	3·3
S. V. 107	U. D. Mamgain	1942	,,	6	3·9	4·7
S. V. 180	N. C. Sen	1943	Tav.	7	4·8	8·8
S. V. 178	H. H. Phillips	1942	Wild	8	6·1	6·6
S. V. 177	H. H. Phillips	1942	,,	5	3·0	3·0
S. V. 164	S. D. Gupta	1942	,,	8	5·5	5·6

TABLE. 2.—*Closing errors of circuits before adjustment of sides and bearings*

Circuit No.	Series entering into the circuit	Shorter Route	Longer Route	Discrepancies Shorter — Longer			
				ΔE Metres	ΔN Metres	ΔA	ΔS in 5th fig. of log
1	Irāq Primary, S. V. 7, S. V. 8, S. V. 26, S. V. 33, S. V. 14 and S. V. 210.	Irāq Primary & Secondary	0–3–2–1	−24·4	−40·5	− 1	+20
2	S. V. 7, S. V. 26 and S. V. 25.	3–4–14	3–2–15–14	+13·6	+10·1	+ 4	+ 5
3	Irāq Primary, S. V. 7, S. V. 8, S. V. 171, S. V. 109, S. V. 154, S. V. 24 and S. V. 19.	Irāq Primary & Secondary	0–3–4–5–7 −6	−29·8	+15·1	−10	+14
4	S.V.7, S.V.171, S.V.100, S. V. 154 and S. V. 23.	4–14	4–5–14	+ 1·4	+10·9	+ 1	+ 2
5	S. V. 24, S. V. 102 and S. V. 105.	5–7	5–0–8–7	−21·6	− 3·4	+12	+ 1
6	Irāq Secondary, S. V. 105 S. V. 100 and S. V. 18.	Irāq Secondary	7–8–23–24	− 7·1	+71·0	−69	−16
7	S. V. 23, S. V. 102, S. V. 176, S. V. 101 and S. V. 159.	5–14	5–9–10–14	+15·2	−20·2	+16	+16
8	S. V. 176, S. V. 159, S. V. 102, S. V. 166 & 170 and S. V. 104.	9–10–25	9–8–23–25	+ 1·9	− 2·3	−17	+10
9	S. V. 101, S. V. 25, S. V. 153, S. V. 168, S. V. 167 and S. V. 160.	14–17	14–15–16 −17	− 6·9	+ 2·2	− 3	+ 6
10	S. V. 158, S. V. 163. S. V. 162 and S. V. 105.	19–18–21 −20	19–20	+ 7·8	+ 3·1	+19	+32
11	S. V. 158, S. V. 161, S. V. 156 and S. V. 155.	14–10–18 −21	14–17–16 −22–21	− 3·3	−36·2	+17	− 2
12	S. V. 156 and C. V. 200.	16–22	16–26–27 −22	+17·9	+ 6·8	− 8	+13
13	C. V. 200, C. V. 201 and S. V. 156.	26–28	26–27–28	+31·9	−24·4	− 9	+12

TABLE 3.—*Discrepancies between triangulated and measured values of the bases*

Base	Distance from preceding H.S.B.	Discrepancy*
KHANAQIN	*Miles*	
Qasr-i-Shirin	22	+ 4
Payitaq	36	− 7
Bisitūn	80	0
Khāwar	37	+14
Zuruntal	76	− 3
Pula-i-Tang	46	− 2
As 2—As 1 } As 1—As 2 }	28	+10
BĪSITŪN		
Khangvar	40	+ 6
BĪSITŪN		
Sinneh (Sufiān)	110	+ 7
Garan	30	+ 4
SINNEH		
Gulseer	70	+ 5
Khanābād	5	0
Hamadān (Geodetic)	30	−10
SINNEH		
Zafarabad	45	+ 4
Kailasur	47	+11
Karawal Khāna	30	− 7
Nalwa	45	−32
SINNEH		
Chubi-Kameshlu	65	+18
Aq-Bulāq	65	−10
Auwarghon	28	+ 9
KAILASUR		
Saruja-Khatunābād	34	− 7
Syedābād	100	+ 5
HAMADĀN		
S9—S12	50	+ 4
S1—T27 } D—Hussainābād }	64	− 4
HUSSAINĀBĀD		
S15—S16	60	− 4
HAMADĀN		
Naqqash	52	+ 2
S1—S2	44	+ 3
Saveh Base	32	− 5
NAQQASH		
Shabanak	35	+ 5
Aq-Kant	15	− 2
Oran	70	+ 8
Tehrān (Geodetic)	60	+ 2

* Measured value of the base *minus* its value by triangulation, in 5th decimal of the log.

(Continued)

TABLE 3.—*Discrepancies between triangulated and measured values of the bases.*—(concld.)

Base	Distance from preceding H.S.B.	Discrepancy*
HUSSAINĀBĀD		
Ribat	60	− 3
Miyaneh	20	+ 8
S3—S4	66	+12
Isfahān (Geodetic)	84	− 5
MIYANEH		
Najafābād	85	− 1

* Measured value of the base *minus* its value by triangulation, in 5th decimal of the log.

TABLE 4.—*Closing errors of circuits after adjustment of sides and bearings*

Circuit No.	Series entering into the circuit	Shorter Route	Longer Route	Discrepancies Shorter — Longer ΔE Metres	ΔN Metres
1	Irāq Primary, S. V. 7, S. V. 8, S. V. 26, S. V. 33, S. V. 14 and S.V. 210.	Irāq Primary & Secondary	0–3–2–1	+13·9	+17·6
2	S. V. 7, S. V. 26 and S. V. 25.	3–4–14	3–2–15–14	+ 1·8	−10·9
3	Irāq Primary, S. V. 7, S. V. 8, S. V. 171, S. V. 160, S. V. 154, S. V. 24 and S. V. 19.	Irāq Primary & Secondary	0–3–4–5–7–0	− 1·8	+21·0
4	S. V. 7, S. V. 171, S. V. 169, S. V. 154 and S. V. 23.	4–14	4–5–14	−12·8	+13·2
5	S. V. 24, S. V. 102 and S. V. 165.	5–7	5–9–8–7	− 5·2	+ 5·1
6	Irāq Secondary, S. V. 105, S. V. 100 and S. V. 18.	Irāq Secondary	7–8–23–24	−37·9	+40·1
7	S. V. 23, S. V. 102, S. V. 176, S. V. 101 and S. V. 159.	5–14	5–9–10–14	− 1·6	+ 0·8
8	S. V. 176, S. V. 159, S. V. 102, S. V. 166, & 170 and S. V. 104.	9–10–25	9–8–23–25	− 0·5	+ 4·3
9	S. V. 161, S. V. 25, S. V. 153, S. V. 168, S. V. 167 and S. V. 160.	14–17	14–15–16–17	−11·9	−14·6
10	S. V. 158, S. V. 163, S. V. 102 and S. V. 105.	19–18–21–20	19–20	+28·4	− 3·7
11	S. V. 158, S. V. 101, S. V. 156 and S. V. 155.	14–19–18–21	14–17–16–22 –21	+ 7·8	−17·2
12	S. V. 156 and C. V. 200.	16–22	16–26–27–22	+18·9	− 1·3
13	C. V. 200, C. V. 201 and S. V. 156.	26–28	26–27–28	− 4·7	+ 3·6

TABLE 5.—*List of Azimuthal Maps*

Nature of map	Area of the map	Name of centre or centres
1-centred ..	Lat. 20° N. to 60° N. Long. 40° E. to 100° E.	Abbottabad
1-centred ..	Lat. 25° N. to 45° N. Long. 55° E. to 90° E.	Abbottabad
1-centred ..	World map.	Abbottabad
1-centred ..	World map.	Belgaum
1-centred ..	World map.	Kharagpur
1-centred	Lat. 0° to 60° N. Long. 30° E. to 120° E.	Abbottabad
1-centred ..	Lat. 0° to 60° N. Long. 30° E. to 120° E.	Belgaum
1-centred ..	Lat. 0° to 60° N. Long. 30° E. to 120° E.	Kharagpur
1-centred ..	Lat. 8° N. to 38° N. Long. 50° E. to 100° E.	Abbottabad
1-centred ..	Lat. 8° N. to 38° N. Long. 50° E. to 100° E.	Belgaum
1-centred ..	Lat. 8° N. to 38° N. Long. 50° E. to 100° E.	Kharagpur
3-centred ..	Lat. 0° to 60° N. Long. 30° E. to 120° E.	Abbottabad, Belgaum and Kharagpur.
3-centred ..	Lat. 8° N. to 38° N. Long. 50° E. to 100° E.	Abbottabad, Belgaum and Kharagpur.
1-centred ..	World map.	Baghdād
1-centred ..	Lat. 0° to 60° N. Long. 0° to 90° E.	Baghdād
7-centred ..	Lat. 0° to 30° N. Long. 76° E. to 112° E.	Bangalore, Hyderabad (Dec.) Delhi, Calcutta, Cooch Behar, Dinjan and Jubbulpore. (1st Edn.).
		Bangalore, Hyderabad (Dec.) Delhi, Calcutta, Cooch Behar, Dinjan and Jubbulpore with addition of Trincomalee. (2nd Edn.).
1-centred ..	World map.	Delhi.
5-centred ..	Lat. 15° S. to 50° N. Long. 60° E. to 150° E.	Abbottabad, Delhi, Calcutta, Bangalore and Hyderabad (Dec.). (1st Edn.).
		Abbottabad, Delhi, Calcutta, Bangalore and Hyderabad (Dec.). with addition of Darjeeling. (2nd Edn.).

(Continued)

TABLE 5.—*List of Azimuthal Maps.*—(concld.)

Name of map	Area of the map	Name of centre or centres
10-centred ..	Lat. 30° S. to 40° N. Long. 30° E. to 130° E.	Mombasa, Colombo, Cocos Is., Mauritius, Abbottabad, Karāchi, Ahmadabad, Delhi, Hyderabad (Dec.) and Bangalore.
9-centred ..	Lat. 5° N. to 60° N. Long. 15° E. to 100° E.	Cairo, Baghdād, Sarafand, Tobruk, Abbottabad, Bangalore, Delhi, Ahmedabad & Karāchi. (1st Edn.).
		Cairo, Baghdād, Sarafand, Tobruk, Abbottabad, Bangalore, Delhi, Ahmedabad & Karāchi with addition of Trincomalee, Barrackpore and Tezpur. (2nd Edn.).
5-centred ..	Lat. 5° N. to 45° N. Long. 45° E. to 80° E.	Abbottabad, Baghdād, Karāchi, Delhi, and Ahmedabad.
5-centred ..	Lat. 0° to 30° N. Long. 85° E. to 110° E.	Barrackpore, Tezpur, Imphal, Chittagong, and Puri.
5-centred ..	Lat. 40° S. to 50° N. Long. 75° E. to 165° E.	Delhi, Bangalore, Barrackpore, Colombo, and Melbourne.
2-centred ..	Lat. 10° S. to 50° N. Long. 90° E. to 160° E.	Cedar (Canada) and Grande Prarie (Canada).
11-centred ..	Lat. 5° S. to 30° N. Long. 75° E. to 130° E.	Imphal, Tezpur, Chittagong, Comilla, Barrackpore, Puri, Tamu, Cox's Bazār, Bimlipatam, Colobmo and Bangalore.
11-centred ..	Lat. 30° S. to 50° N. Long. 75° E. to 155° E.	Imphal, Tezpur, Chittagong, Comilla, Barrackpore, Puri, Tamu, Cox's Bazār, Bimlipatam, Colombo and Bangalore.
7-centred ..	Lat. 10° N. to 70° N. Long. 30° E. to 150° E.	Abbottabad, Delhi, Bangalore, Hongkong, Rangoon, Shillong, and Meiktila.
9-centred ..	Lat. 15° S. to 35° N. Long. 30° E. to 150° E.	Abbottabad, Delhi, Bangalore, Cocos Is. Hongkong, Rangoon, Singapore, Shillong and Meiktila.
6-centred ..	Lat. 15° S. to 50° N. Long. 60° E. to 150° E.	Delhi, Calcutta, Hongkong, Madras, Colombo and Singapore.

CHAPTER VI

TIDES

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

61. Tidal Observations.—During the period under report, tidal registrations by automatic tide-gauges were continued by the port authorities (under the supervision of the Survey of India) at Aden, Karāchi, Bombay (Apollo Bandar), Vizagapatam and Calcutta (Kidderpore) ; and at Dublat (Saugor) up to 15th September 1943 and at Rangoon up to 15th February 1942. The tide-gauge at Dublat had to be shut down in September 1943 owing to severe erosion of the foreshore at the observatory site and has not so far been re-installed. The tidal observatory at Rangoon, including the tide-gauge, got destroyed in the Japanese bombing in February 1942 during the last war, and no provision has yet been made for its replacement.

Daylight observations on tide-poles were continued at Bhāvnagar and Chittagong, and up to 28th February 1942 at Akyab. The observations at Akyab had to be discontinued from 1st March 1942 owing to the war and have not yet been resumed. The war was also responsible for a temporary suspension of the observations at Chittagong from 1st March 1942 to 31st January 1943 and no comparisons between the tidal predictions and the "actuals" have been possible for this port during this short period.

Pending construction of a new tidal observatory and installation of a new tide-gauge at Rangoon, only daylight observations on tide-poles are being executed since 1st January 1947 at a site known as "Monkey Point" situated about 1½ miles below the old site, Brooking Street, on the Rangoon River. Data about the tidal differences between these two sites are being ascertained, to enable a comparison between the predictions (referring to Brooking Street) and the actuals (referring to Monkey Point) to be made.

Table 1 gives a complete list of stations where tidal registrations have been carried out since the commencement of tidal operations in India in 1874. The stations at which automatic tide-gauges are still working are shown in italics. Minor stations were closed down after a few years when sufficient data was obtained from the registrations. A separate pamphlet is under compilation giving descriptions and details (such as B.M. of reference, M.W.L., relationship of datum with the zero of gauge, etc.) of the various tidal observatories that have been in operation up to date.

62. Inspections of Tidal Observatories.—The tidal observatory at Aden was inspected by the Port Engineer during January 1940, May 1945 and January 1947; that at Karāchi by the Harbour Surveyor of the Port Trust in June 1946; that at Bombay (Apollo Bandar) by the Port Trust Surveyor in April 1940, May 1941, March 1942, April 1943, June 1944, June 1945, May 1946 and April 1947; and that at Rangoon by the River Surveyor of the Port Commissioners in May 1941. No inspection reports were received from the Port authorities at Calcutta (Kidderpore).

All the automatic records have been fairly continuous, with only a few serious stoppages as detailed in the following table :—

Port	Dates of breaks	REMARKS
Aden ..	12 Dec. 39–2 Jan. 40	Gauge dismantled for re-construction of the pier.
	3–11 March 42	Due to defective pen-holder.
	8–28 Dec. 42	Due to faulty float.
	7–28 Jan. 43	Due to faulty clock.
	2–15 Jan. 47	Band having slipped over the stud wheel.
Bombay ..	6–10 June 44	Due to silt in the well.
	6–9 July 44	Due to silt in the well.
	3–8 Aug. 44	Due to some obstruction in the well.
	14–20 March 45	Due to some unknown obstruction.
	12–26 June 45	Due to silt in the well.
Vizagapatam ..	1 May–3 July 46	Gauge under repairs.
Calcutta (Kidderpore)	5 Feb.–2 May 47	Due to Dock-workers' strike.

There were only a few minor stoppages otherwise, the break in no case exceeding 3 days.

The records have also been satisfactory, except that at Aden during the period 1st January to 15th April 1944, due to some unknown cause, the gauge was recording incorrectly. The gauge was repaired on 15th April, since when it has been working very satisfactorily. The tidal diagrams at this port for the above short period were rejected.

63. **Harmonic Analysis.**—No rigorous harmonic analysis (by the usual method, with 370 days' observations) was carried out during the period under report.

It is proposed to introduce for future work the simple and more effective method that is now being employed at the Tidal Institute Liverpool. It is also proposed to form a touring tidal detachment which will take a short series of observations (29 days) at some ports where analysis has been based on very old observations, and at some secondary ports. These will be analysed by the Admiralty method which yields 9 harmonic constants.

Some data of 15 and 29 days' observations have been supplied by the R.I.N. for three ports. The harmonic constants derived from these observations are tabulated in Table 2.

64. **Tide-Tables.**—The Tide-Tables of the Indian Ocean and the separate tidal pamphlets for Bombay and the Hooghly River were prepared and published for each of the years under report, as usual. Publication of the separate tidal pamphlet for the Rangoon River was discontinued from 1943 to 1945 inclusive, due to the war, but has since been resumed.

Predictions for an average of 39 ports, between Suez and Singapore, were carried out by this Department and predictions for an average of 28 foreign ports (22 of which are situated in the Indian Ocean and the Far East, and 6 in the English and Mediterranean waters) were obtained on the usual exchange/payment basis from the Hydrographic Departments of Britain, France, the U.S.A. and Japan, and the Tidal Institute at Liverpool, for inclusion in our Tide-Tables. The war, however, caused dislocations in the arrangements with France and Japan, and predictions for the Indo-China and Japanese ports had therefore to be taken up either by this Department or by the Hydrographic Departments of Britain or the U.S.A. Table 3 gives details of the dates of publication of the Tide-Tables of the Indian Ocean each year, and the number of ports included therein.

The separate tidal pamphlets for Bombay, the Hooghly River and the Rangoon River included respectively the predictions for 1, 3 and 2 ports, as usual. As already stated, the pamphlet for the Rangoon River was not published for the years 1943–45 inclusive.

Advance predictions for a number of ports were sent each year in time to the British, U.S.A. and the Japanese Hydrographic Departments for inclusion in their Tide-Tables and also to the Royal Indian Navy, as usual. Despatch of advance predictions to Japan was stopped in 1942 on the outbreak of war with that country. Details are given in table below :—

Year of Prediction	No. of ports despatched to				Date of despatch
	Br. Admiralty	U.S.A.	Japan	R.I.N.	
1941	17	6	3	..	Oct.-Dec. 39
1942	17	6	3	3	Nov.-Dec. 40
1943	17	6	3	3	Nov. 41
1944	17	6	..	3	Aug.-Sept. 42
1945	17	6	..	3	Dec. 43
1946	23	6	..	3	Aug. 44
1947	23	7	..	3	Aug. & Dec. 46
1948	23	6	..	3	Oct. 46

During the war, for security reasons, the issue of the printed tide-tables was controlled by the Director of Survey, India Command, in consultation with the Naval H.Q. This control remained in force between October 1943 and September 1945.

Part II of the Tide-Tables of the Indian Ocean containing Harmonic and Non-Harmonic Tidal Constants and Tidal Differences for a number of eastern ports and anchorages was discontinued in the Tide-Tables for 1945 and onwards, since this information in Part II is of a permanent nature and can easily be had from any previous tide-tables of the Department or from the much more comprehensive quinquennial publication "The Admiralty Tide-Tables, Part II".

During the end of 1944, it was decided, in consultation with the British Admiralty, to publish the predictions from the year 1946 for all the ports in G.M.T. instead of in their respective local or standard times as was the previous practice. The G.M.T. was accordingly introduced in the Tide-Tables of the Indian Ocean, while the usual L.M.T. and standard times were adhered to in the separate tidal pamphlets for Bombay and the Hooghly and Rangoon Rivers. This was a war time measure, though the Admiralty themselves, were not able to effect this change in their tide-tables. Early this year it was again decided to revert to the local/standard times used during pre-war years and consequently, beginning with the tide-tables for the year 1949, the G.M.T. will be discontinued and the pre-war times again brought into use.

Table 4 gives details of the number of copies of tide-tables published each year and the amounts realized from their sales. The amounts refer to the period from 1st October of the previous year to the 30th September of the year stated.

Royalties received from the Burma, Ceylon and the Portuguese Governments and also the British Colonial Office during each of the years under report, in return for predictions for their ports amounted to Rs. 6,710/0/0. Sums paid to the Controller of H.M. Stationery Office for extraction of certain information from Admiralty Tide-Tables and to the Liverpool Tidal Institute annually for the supply of predictions for certain English ports for inclusion in our Tide-Tables, amounted to £ 11-11-0.

65. **Special Tidal Charts.**—During the war, tidal predictions were carried out, at the request of the Naval H. Q., for quite a number of ports in the far-eastern waters for operational purposes. The predictions were "Secret" and were supplied exclusively to the Eastern Fleet Naval H. Q. through the Director of Survey, India Command.

These predictions were supplied, not in the normal form as published in the Tide-Tables of the Indian Ocean, but in the form of printed tidal charts, from which the height of water at any time could be read.

Each chart was of size 21½ inches × 15 inches and gave the predictions for 4 months at a port. It was fully figured, titled and annotated, the printing being carried out in the Photo-Zinco Office of the Geodetic Branch, Dehra Dūn.

The demand for these charts first came in August 1943 and continued till March 1946. Demands were being received through the Director of Survey, who apart from communicating the priorities and the print order, also gave the harmonic constants for tidal predictions at these ports, either by reference to the Admiralty Tide-Tables, Part II (if the ports were already listed in there) or by special lists forwarded by the Naval Headquarters.

For a majority of the ports, including those listed in the Admiralty Tide-Tables, Part II, harmonic data of only the four main tidal components M_2, S_2, K_1 and O_1 were available. From these four known constituents eleven more were derived on the principles enunciated in the Admiralty Tide-Tables, Part III, viz., that tides of like type bear the same relation to the principal tide of that type which is derived from the equilibrium tide. The phase lag κ was assumed to be the same for all components in one group (and so, the same as the known value κ of the leading component of that group) and the amplitude was assumed to bear to the known amplitude of the leading component the same ratio as the equilibrium ratio of their mean coefficients.

The seasonal effects at intervening ports were obtained by interpolation from the known values of S_a and S_{sa} at the ports given in Admiralty Tide-Tables and the Tide-Tables of the Indian Ocean.

The mechanical application of shallow water corrections presented difficulties and the problem remained unsolved.

Production of these charts was discontinued in March 1946 under advice from the Naval H.Q., the war exigency having been over. From August 1943, when the production was first undertaken, to March 1946, a total of 455 originals were prepared in the Tidal Section for various ports numbering about 80, and about 25,000 prints were altogether supplied to the Navy. The cost of production (excluding printing) amounted to about Rs. 36,500/- and was charged to the defence expenditure.

Table 5 gives a list of these special ports for which tidal charts were produced, together with the respective periods for which predictions were carried out.

66. **Corrections to Predictions.**—Tables 6 to 15 give the empirical corrections, based on the "actuals" of recent years, that have been applied to the predictions for 6 of the open sea ports and 4 riverain ports during the years under report. These have been derived from the mean fortnightly results of comparisons between the predicted and actual times and heights for a period of about 5 years. The latest available years of comparisons have been taken in each case.

67. **Accuracy of Predictions.**—The greatest errors in the heights of low water, during the years under report, at the ports mentioned in para 61 are given in Table 16.

The detailed results of the comparisons of the predicted and available actual values show that the quality of the predictions, in general, is practically the same as in the previous years, except for Chittagong where a considerable deterioration seems to have taken place since 1943. It is considered that "actuals" of Chittagong from 1943 onwards, are suspect. Ever since the re-installation of the tide-pole in September 1943 (after the temporary break of observations between March 1942 and September 1943 due to the war), the (P—A) differences in time at this port have been very irregular and unusually erratic. The causes of this sudden departure from normal are not known, queries addressed to the port authorities on the matter not having produced any satisfactory answers. The differences are however being watched, and if these do not improve soon, it is proposed to send out a small tidal detachment to that port to get more reliable "actuals" with a view to further investigations and improvement of predictions if necessary.

The predicted times of tides at Karāchi also have not conformed well to the "actuals" during the latter part of 1946. This appears to have resulted again from faulty "actuals", due probably to excessive siltation in and near the site of the tidal observatory, consequent on the construction of a new government pier in that area for the loading and unloading of sand and other building materials. Dredging in the area has since been carried out and the recordings have returned to normal from March this year.

Considerable (P—A) differences in the heights of low water at Bhāvnagar, especially when the tide was below 9 feet, were noticed during the latter part of 1944 and onwards. Reference to the port authorities revealed that this was due to the formation of a bar in the channel, between the tidal observatory and the Ruvapuri Lighthouse of the port, which restricted the passage of ebbing water. Such differences were found to be generally occurring when the low water was below 4 feet. The effects were, however, fully investigated and analysed, and necessary empirical corrections determined to improve the predictions. These corrections have been applied to predictions, beginning with the year 1947.

Actuals not being available for Rangoon and Akyab from March 1942 onwards and for Dublat from September 1943 onwards, no comparisons of predictions with actuals have been possible for these ports after the above dates.

68. **Miscellaneous.**—The overhauling of the present methods of tidal predictions in the Department is under active consideration. As in the case of harmonic analysis, our present methods of predictions, particularly those for the riverain ports, are very much out-of-date and need revision in the light of experience and recent developments in this branch of science.

The riverain method is described on page 93 of the Survey of India handbook on Tides. The method appears more to follow some time-honoured faith than any scientific reasoning. Some of the tables on which the predictions are based were prepared over a century ago, from tidal observations at London Docks. The (P—A) residuals have to be properly analysed for periodicities and detection of shallow water constituents, and have to be scientifically dealt with instead of being haphazardly grouped monthly and fortnightly and allowed for in the way of empirical corrections as at present.

The harmonic method of predictions used for open sea ports also requires some improvement. The harmonic analysis used to derive the necessary harmonic constants has itself not been so complete and intensive as it should have been and consequently certain effects have been ignored. Provision has to be made, both in the analysis and prediction for more shallow water components than at present dealt with, to suit the peculiarities of the Indian ports. Certain improvements to the machine with a view to speeding up the predictions are also considered necessary.

Again, most of our predictions rest on observations made in the last century. It is possible that local changes in the configuration of the land and the level of the sea bed, apart from any artificial improvements in the harbour by dredging, bunds, etc., have since taken place and that our predictions are in need of improvement. "Actuals" are not being observed or recorded at a majority of ports, to enable comparisons to be made with predictions, and even in the case of the few ports for which "actuals" are being maintained, occasional negligence on the part of the tide-watchers has been noticed and they are by no means fully reliable. It is proposed to make an intensive study of the discrepancies between actual and predicted tides wherever available and to start permanent tidal observatories at some ports. In addition, a tidal touring Detachment has been formed to take 29-day series of observations at some secondary ports where no modern observations are available and for which only inferred constants are given in the Admiralty Tide-Tables.

TABLE 1.—*List of Tidal Stations*

Serial No.	Station	Automatic or Visual observations	Date of commencement of observations	Date of closing of observations	No. of years of observations	REMARKS
1	Suez ..	Automatic	1897	1903	7	
2	Perim ..	,,	1898	1902	5	
3	*Aden* ..	,,	1879	Still working	68	
4	Maskat ..	,,	1893	1898	5	
5	Basra ..	Visual	1916	1922	7	
	Basra ..	Automatic	1922	1932	11	
6	Bushire ..	,,	1892	1901	8	
7	*Karāchi* ..	,,	1868 1881	1880 Still working	*13 66 } =79	* Small tide-gauge.
8	Navanar ..	,,	1874	1875	1	Tide-tables not published.
9	Hanstal ..	,,	1874	1875	1	,,
10	Okha Point	,,	1874 1904	1875 1906	1 1 } =2	1904–1905 excluded.
11	Porbandar ..	Visual	1893	1894	2	
	,, ..	Automatic	1898	1902	2	1898, 99, 1902 excluded.
12	Port Albert Victor ..	Visual	1881	1882	1	
	,, ..	Automatic	1900	1903	4	
13	Bhāvnagar	,,	1889	1894	5	
14	*Bombay Apollo Bandar*	,,	1878	Still working	69	
	,, (Prince's Dock) ..	,,	1888	1922	34	
15	Mormugao ..	,,	1884	1889	5	
16	Karwar ..	,,	1878	1883	5	
17	Beypore ..	,,	1878	1884	6	
18	Cochin ..	,,	1886	1892	6	
19	Minicoy ..	,,	1891	1896	5	
20	Tuticorin ..	,,	1888	1893	5	
21	Pamban Pass	,,	1878	1892	4	
22	Colombo ..	,,	1884	1890	6	
23	Galle ..	,,	1884	1890	6	
24	Trincomalee	,,	1890	1896	6	
25	Negapatam ..	,,	1881	1888	5	1883–85 excluded.
26	Madras ..	,,	1880 1895	1890 1933	10 38 } =48	
27	Cocanada ..	,,	1886	1891	5	
28	*Vizagapatam*	,,	1879 1936	1885 Still working	6 *12 } =18	* Small tide-gauge.
29	False Point..	,,	1881	1885	4	
30	Dublat (Saugar I.)	,,	1881 1933	1886 1943	5 10 } =15	

(*Continued*)

TABLE 1.—*List of Tidal Stations.*—(concld.)

Serial No.	Station	Automatic or Visual observations	Date of commencement of observations	Date of closing of observations	No. of years of observations	REMARKS
31	Diamond Harbour ..	Automatic	1881	1886	5	
32	*Kidderpore* ..	,,	1881	Still working	66	
33	Chittagong ..	,,	1886	1891	5	
34	Akyab ..	,,	1887	1892	5	
35	Diamond Island ..	,,	1895	1899	5	
36	Bassein ..	,,	1902 1923	1903 1929	2 5 } =7	
37	Elephant Point ..	,,	1880 1884 1927	1881 1888 1928	(excluded) 5 *1 } =6	*Observations were resumed at the Pilākat or Deserters' creek, about ¼ mile west of the site used in 1884–1888.
38	Rangoon ..	,,	1880	1942	62	
39	Moulmein ..	,,	1880 1909	1886 1924	6 16 } =22	
40	Amherst ..	,,	1880	1886	6	
41	Mergui ..	,,	1889	1894	5	
42	Port Blair ..	,,	1880	1925	45	

TABLE 2.—*Harmonic Tidal Constants derived from 15 or 29 days' observations by the Admiralty Method of Harmonic Analysis*

Serial No.	Place & position (with description of tide-pole site)	Period of observation and central day	Level of zero of tide-pole below: chart datum (or zero of predictions)	Level of zero of tide-pole below: B.M. of reference	Constants	Constituent: M_2	S_2	N_2	K_2	K_1	O_1	P_1	M_4	MS_4	A_0	Description of B.M. of reference
			ft.	ft.		*Indian Standard Time (05ʰ 30ᵐ fast on G.M.T.)*										
1	Karumbhar Lighthouse Lat: 22° 25′ N.; Long: 69° 35′ E. (Edge of reef in position 190°, 1.3 miles from the lighthouse).	15 days	9·8	40·8	H ft.	5·1	1·1	1·1	0·3	1·3	0·8	0·4	0·1	0·1	12·1	Cut in the NE. corner of store building in close vicinity of Lighthouse.
		29-5-42			$g°$	040	088	028	088	091	077	091	270	349		
2	Rozi* Lat: 22° 34′ N.; Long: 70° 02′ E. (Northern end of Rozi jetty).	29 days*	2·0	5·6	H ft.	7·02	1·92	1·22	0·52	2·19	0·87	0·72	0·19	0·03	11·66	Centre of a V-cut on the upper surface of a cement block 18" square and 2" high, marked BM 1942, & situated on the extreme NW. corner of the jetty.
		27-9-42			$g°$	047	093	030	093	088	076	088	024	352		
3	Ras Ormara Lat: 25° 11′ N; Long: 64° 41′ E. (Approx. 50 yards from the H.W. line, N. of a rocky ledge, situated about ¼ mile westward of NE. point of Ras Ormara headland).	29 days	4·6	28·0	H ft.	2·29	0·82	0·56	0·22	1·44	0·60	0·48	0·03	0·02	9·08	Mark Λ cut in an iron bar, cemented into the ground in the westerly corner of the small bay at the site of the tide-pole.
		11-3-47			$g°$	315	352	287	352	063	059	063	087	294		

* Another 29-day period for Port Rozi with 1-11-42 as the central day was also analysed for the above constants, but the values when used for predictions and comparisons of the actuals for this period, were found to be much less satisfactory than the ones published above and were therefore rejected.

TABLE 3.—*Preparation of the T.T.I.O.*

Year	No. of Ports predicted by Survey of India	Foreign Ports: Received on exchange basis from U.K. (Ports in Britain & Colonies)	Foreign Ports: Received on exchange basis from U.S.A. (Ports in Philippines)	Foreign Ports: Received on exchange basis from France (Ports in F.I.C.)	Foreign Ports: Received on exchange basis from Japan (Ports in Korea & Japan)	Foreign Ports: Received from Liverpool Tidal Instt. on payment (Ports in England)	Total No. of ports included in T.T.I.O.	Date of publication of T.T.I.O.	Remarks
1941	39	16	3	3	3	3	67	Sept. 40	
1942	42	16	3	..	3	3	67	Sept. 41	All 3 F.I.C. ports predicted by Survey of India.
1943	40	19	5	..	..	3	67	Sept. 42	{ 1 F.I.C. port pred. by S. of I. 2 F.I.C. & 1 Jap. port pred. by U.K. 2 Jap. ports pred. by U.S.A.
1944	39	19	5	..	..	3	66	Sept. 43	The F.I.C. port predicted by S. of I. discontinued (as not wanted).
1945	39	20	5	..	..	3	67	May 44	A new port in Malaya (Port Dickson) added by U.K.
1946	39	20	5	..	..	3	67	Feb. 45	
1947	39	20	5	..	..	3	67	April 46	
1948	39	20	5	..	..	3	67	Aug. 47	

TABLE 4.—*Publication and sale of Tide-Tables*

Year of Tide-Tables	No. of copies printed				Amounts realized from sales (exclusive of Agent's Commission and copies issued gratis)		
	T.T.I.O.	Bombay Pamphlet	Hooghly River Pamphlet	Rangoon River Pamphlet	Sales to public	Debitable to Defence	Total
					Rs. a. p.	Rs. a. p.	Rs. a. p.
1940	1200	875	1025	800	3,743 10 0	Nil	3,743 10 0
1941	1200	850	900	750	4,976 8 0	6 0 0	4,982 8 0
1942	1200	850	800	800	5,162 6 0	36 0 0	5,198 6 0
1943	1100	850	900	..	4,437 2 0	1,099 0 0	5,536 2 0
1944	2000	900	900	..	2,991 3 0	2,766 0 0	5,757 3 0
1945	3500	1200	900	..	5,796 10 0	1,534 8 0	7,331 2 0
1946	3500	1200	900	800	5,171 8 0	90 0 0	5,261 8 0
1947	2000	1200	900	800	4,419 1 0	75 0 0	4,494 1 0

TABLE 5.—*List of stations for which Tidal Charts were supplied*

Serial No.	Ref. No. in Adm. T.T. Part III	Name of Port	Period for which predicted, with No. of originals in brackets	
1	4123	Ratnagiri Bay ..	Jan.-Dec. 1944	(3)
2	4215	Chittagong	Oct.-Dec. 1943	(1)
3	4216	Kutubdia Island ..	Oct. 1943-Dec. 1945	(7)
4	4217	Cox's Bazar	Do.	(7)
5	4221	St. Martins Island ..	Do.	(7)
6	4222	Akyab	Oct. 1943-Aug. 1945	(6)
7	4223	Kyaukpyu	Oct. 1943-Dec. 1945	(7)
8	4224	Searle Point	Do.	(7)
9	4225	Sagu Island	Do.	(7)
10	4226	Andrew Bay	Do.	(7)
11	4227	Gwa Bay	Do.	(7)
12	4231	Kyaungtha	Do.	(7)
13	4232	Koronja Island ..	Do.	(7)
14	4233	Diamond Island ..	Oct. 1943-Aug. 1945	(6)
15	4234	Bassein	Oct. 1943-Dec. 1943	(1)
16	4235	Pymbong Beacon ..	Oct. 1943-Dec. 1945	(7)
17	4236	China Bakir	Do.	(7)
18	4237	Elephant Point ..	Do.	(7)
19	4238	Rangoon	Do.	(7)
20	4241	Amherst	Oct. 1943-Aug. 1946	(9)
21	4242	Feronia Crossing ..	Do.	(9)
22	4243	Moulmein	Oct. 1943-Dec. 1943	(1)
23	4244	Double Island	Oct. 1943-Dec. 1946	(10)
24	4245	Bentinck Sound ..	Oct. 1943-April 1946	(8)
25	4246	Stag Island	Oct. 1943-Aug. 1946	(9)
26	4247	Sidaw Point	Oct. 1943-April 1946	(8)
27	4248	Yé Town	Oct. 1943-Aug. 1946	(9)
28	4265	Owen Island	Do.	(9)
29	4267	Hasting's Harbour ..	Nov. 1944–Aug. 1946	(6)
30	4268	Pulau Besin	Jan. 1946–Dec. 1946	(3)
31	4269	South Bay	Jan. 1946–Aug. 1946	(2)
32	4415	Spike Island	Jan. 1944–April 1946	(7)
33	4416	Maramaka Bolin Bay ..	Nov. 1943–April 1946	(8)
34	4417	Cleugh Passage ..	Do.	(8)
35	4421	Port Cornwallis ..	Do.	(8)
36	4422	Stewart Sound ..	Do.	(8)
37	4423	Long Island	Do.	(8)
38	4425	Port Blair	Nov. 1943–Aug. 1946	(9)
39	4433	Nancowry Harbour ..	Jan. 1944–April 1946	(7)
40	4434	Galathea Bay	Do.	(7)
41	4441	Sabang	Jan. 1944–Aug. 1946	(8)
42	4443	Palau Raya	Jan. 1944–April 1946	(7)
43	4445	Molaboh	Do.	(7)
44	4447	Sinabang Bay	Do.	(7)
45	4451	Singkel	Jan. 1944–Aug. 1946	(8)
46	4453	Sibolga	Do.	(8)
47	4455	Gunung Sitoli	Jan. 1944–April 1946	(7)
48	4456	Telok Dalam	Do.	(7)
49	4481	Ulee Lhoe	Do.	(7)
50	4482	Sigli	Jan. 1944–Aug. 1946	(8)
51	4483	Lho Samawe	Do.	(8)
52	4485	Langsa Bay	Do.	(8)
53	4487	Deli River	Do.	(8)
54	4515	Puket Harbour ..	Jan. 1945–Aug. 1946	(5)
55	4533	Kedah	Sept. 1945–Aug. 1946	(3)
56	4534	Penang (George Town) ..	May 1945–Dec. 1945	(2)
57	4537	Lumut Pier	Sept. 1945–Aug. 1946	(3)
58	4546	Port Swettenham ..	May 1945–Aug. 1946	(4)
59	4547	Pinto Gedang	Jan. 1946–Aug. 1946	(2)
60	4551	Port Dickson	Nov. 1944–Dec. 1946	(7)
61	4552	Malacca	May 1945–Aug. 1946	(4)

(*Continued*)

TABLE 5.—*List of stations for which Tidal Charts were supplied.*—(concld.)

Serial No.	Ref. No. in Adm. T.T. Part III	Name of Port	Period for which predicted, with No. of originals in brackets	
62	4554	Muar	Sept. 1945–Aug. 1946	(3)
63	4555	Kwala Batu Pahat ..	Sept. 1945–Aug. 1946	(3)
64	4556	Pulau Pisang	Sept. 1945–Aug. 1946	(3)
65	4561	Tanjong Piai	Sept. 1945–Aug. 1946	(3)
66	4563	Singapore (Inner Harbour)	May 1945–Dec. 1946	(5)
67	5106(*a*)	St. Mathew's Island ..	Nov. 1944–April 1945	(2)
68	5270	Scatt off Kamas River ..	Jan. 1946–Aug. 1946	(2)
69	5312	Tanjong Sedil Kechil ..	Do.	(2)
70	5313	Sungei Rumpin ..	Do.	(2)
71	5314	Kuantan	Do.	(2)
72	5316	Trengganu	Do.	(2)
73	5322	Sungei Besut	Do.	(2)
74	5323	Tumpat	Do.	(2)
75	5336	Koh Lak	Do.	(2)
76	5343	Bangkok bar	Do.	(2)
77	5371	Cap. St. Jacques ..	Do.	(2)
78	5380	Kin Hon	Do.	(2)
79	5394	Tourane	Do.	(2)
80		Rozi	Jan. 1944–Aug. 1946	(8)
81		Port F	Jan. 1944–April 1946	(7)
82		D.W.R. (I)	Jan. 1945–Dec. 1946	(6)
83		Pinto Gedang	Sept. 1945–Dec. 1945	(1)

TABLE 6.—*Corrections applied to the predicted times and heights at Karāchi for 1941–48.*

Year	1941–42*		1943–46†		1947‡		1948§			
	H.W. only						H.W.		L.W.	
Month	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*
January ..			0				− 3	+0·3	− 4	0·0
February ..			0				− 1	+0·4	− 2	0·0
March ..			0				0	+0·4	− 0	0·0
April ..			0				0	+0·2	− 3	−0·1
May ..			0				+ 2	+0·2	− 1	−0·1
June ..	Nil	+0·3	+ 7	+0·3	Nil	+0·3	+ 2	+0·1	− 1	−0·2
July ..			+10				+ 2	+0·2	0	0·0
August ..			+ 5				0	+0·5	− 2	+0·2
September..			+ 6				0	+0·4	− 2	+0·2
October ..			0				+ 1	+0·3	0	0·0
November..			+ 5				+ 4	+0·4	+ 2	0·0
December ..			+ 5				+ 2	+0·3	− 1	0·0
	No corrections to L. W.									

* Corrections based on (P — A) differences during 1935–39.
† ,, ,, ,, ,, ,, ,, 1936–40.
‡ ,, ,, ,, ,, ,, ,, 1939–43.
§ ,, ,, ,, ,, ,, ,, 1941–45.

TABLE 7.—*Corrections applied to the predicted times and heights at Navlakhi for 1941–48.*

Year	1941*				1942–1948†			
	H.W.		L.W.		H.W.		L.W.	
Month	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*
January ..	− 15	Nil	0	0·0	0	0·0	0	Nil
February ..	− 10		0	0·0	− 10	0·0	0	
March ..	0		+ 15	0·0	0	0·0	0	
April ..	+ 10		+ 20	−0·5	+ 10	0·0	0	
May ..	+ 10		+ 20	−0·5	0	+0·5	+ 10	
June ..	0		+ 15	−0·5	0	+0·5	+ 15	
July ..	0		+ 15	−1·0	0	0·0	+ 15	
August ..	0		+ 15	−1·0	0	0·0	+ 10	
September ..	0		+ 10	−0·5	0	0·0	+ 10	
October ..	0		+ 20	0·0	0	0·0	+ 15	
November ..	0		+ 10	−0·5	0	+0·5	+ 10	
December ..	0		0	−1·0	− 10	+0·5	0	

* Corrections based on (P — A) differences during Dec. 1931–Nov. 1932.
† Corrections based on (P — A) differences during May 1940–April 1941.

TABLE 8.—*Corrections applied to the predicted times and heights at Bhāvnagar for 1941–48.*

Year	1941–46*				1947–48†			
	H.W.		L.W.		H.W.		L.W.	
Month	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*
January ..					− 17	+0·4	+ 42	
February ..					− 18	+0·4	+ 44	
March ..					− 20	+0·5	+ 44	
April ..					− 16	+0·6	+ 42	
May ..					− 16	+0·4	+ 42	
June ..	− 15	Nil	+ 25	Nil	− 17	+0·4	+ 44	See table 8(a) next page
July ..					− 17	+0·8	+ 51	
August ..					− 15	+1·0	+ 53	
September ..					− 14	+0·8	+ 49	
October ..					− 15	+0·6	+ 48	
November ..					− 15	+0·6	+ 42	
December ..					− 14	+0·4	+ 42	

* Corrections based on (P − A) differences during 1934–38. [Corrections derived subsequently from (P − A) differences during 1935–39 and 1936–40 were not appreciably different].

† Corrections based on (P − A) differences during 1940–44.

TABLE 8 (*a*)—*Corrections applied to the predicted heights of L.W. at Bhāvnagar for 1947–48.*

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 in feet									
0	4·5	4·4	4·4	4·3	4·2	4·1	4·1	4·0	3·9	3·8
1	3·7	3·6	3·6	3·5	3·4	3·3	3·3	3·2	3·1	3·0
2	2·9	2·8	2·8	2·7	2·6	2·5	2·5	2·4	2·3	2·2
3	2·1	2·0	2·0	1·9	1·8	1·7	1·7	1·6	1·5	1·5
4	1·4	1·3	1·2	1·2	1·1	1·0	1·0	1·0	0·9	0·9
5	0·8	0·8	0·7	0·7	0·7	0·6	0·6	0·6	0·6	0·5
6	0·5	0·5	0·5	0·4	0·4	0·4	0·4	0·4	0·3	0·3
7	0·3	0·3	0·3	0·3	0·3	0·3	0·2	0·2	0·2	0·2
8	0·2	0·2	0·2	0·2	0·2	0·2	0·1	0·1	0·1	0·1
9	0·1	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
10–15	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0

These corrections have been derived from a mean graph prepared from 4 separate curves, each representing (P — A) height differences corresponding to predicted heights during the years 1940, 42, 43 and 44.

The corrections are consequent on the formation of a bar in the channel at the port as mentioned in para 67.

TABLE 9.—*Corrections applied to the predicted times and heights at Bombay for 1941–48.*

Year	1941–46	1947–48*			
		H.W.		L.W.	
Month		Time *min.*	Height *ft.*	Time *min.*	Height *ft.*
Jan. to Dec.	No corrections were applied	+ 4	+0·2	+ 4	+0·2

* Corrections based on (P — A) differences during 1939–43.

TABLE 10.—*Corrections applied to the predicted times and heights at Vizagapatam for 1941–48.*

Year	1941–46*				1947–48†			
	H.W.		L.W.		H.W.		L.W.	
Month	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*
Jan. to Dec. ..	— 20	0	— 20	0	— 20	+0·2	— 20	—0·1

* Corrections based on (P — A) differences during Jan. 1937 to Dec. 1939. [Corrections derived subsequently from (P — A) differences during Jan. 1937–Dec. 1940 were not appreciably different].

† Corrections based on (P — A) differences during 1939–43. [Corrections derived subsequently from (P — A) differences during 1940–44 and 1941–45 were not appreciably different].

TABLE 11.—*Corrections applied to the predicted times and heights at Chāndbāli for 1941–48.*

Year	1941–48*			
Month	H.W.		L.W.	
	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*
January ..	0	Nil	+ 15	Nil
February ..	0		+ 20	
March ..	+ 10		+ 20	
April ..	+ 15		+ 20	
May ..	+ 10		+ 20	
June ..	+ 10		+ 10	
July ..	− 20		+ 10	
August ..	− 30		+ 10	
September ..	− 25		+ 20	
October ..	− 15		+ 20	
November ..	0		+ 10	
December ..	0		+ 10	

* Corrections based on (P − A) differences during May 1931 to May 1932 and April 1933 to April 1935.

TABLE 12.—*Corrections applied to the predicted times and heights at Dublat (Saugar) for 1941–42.*

Year	1941*				1942†			
	H.W.		L.W.		H.W.		L.W.	
Month	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*
January ..					0		+ 6	
February ..					0		+ 6	
March ..					0		+ 6	
April ..					+ 7		+ 6	
May ..					0		+ 6	
June ..	Nil	Nil	+ 5	Nil	0	+0·4	0	+0·3
July ..					0		0	
August ..					+ 6		0	
September ..					0		0	
October ..					0		0	
November ..					0		0	
December ..					0		+ 6	

(*Continued*)

* Corrections based on (P – A) differences during 1934–38.
† ,, ,, ,, ,, ,, ,, 1935–39.

TABLE.—12 *Corrections applied to the predicted times and heights at Dublat (Saugar) for 1943–48.*—(concld.)

Year	1943–46*				1947–48†			
	H.W.		L.W.		H.W.		L.W.	
Month	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*
January ..	0		0					
February ..	0		0					
March ..	0		+ 6					
April ..	+ 7		+ 8					
May ..	0		0					
June ..	0	+0·3	0	+0·3	+ 4	+0·1	+ 4	+0·1
July ..	0		0					
August ..	+ 6		0					
September ..	+ 5		0					
October ..	0		0					
November ..	0		0					
December ..	0		+ 5					

* Corrections based on (P — A) differences during 1936–40.
† „ „ „ „ „ „ 1938–42.

TABLE 13.—*Corrections applied to the predicted times and heights at Calcutta (Kidderpore) for 1941–48.*

Year	1941*		1942†		1943–46‡			
	H.W.	L.W.	H.W.	L.W.	H.W.		L.W.	
Month	Height *ft.*	Height *ft.*	Height *ft.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*
January ..	+0·2	–0·3	+0·2	–0·2	Nil	+0·3	0	–0·2
February ..	+0·4	–0·2	+0·4	–0·2		+0·4	0	–0·1
March ..	+0·3	–0·2	+0·2	–0·2		+0·2	+ 6	–0·2
April ..	+0·3	–0·1	+0·2	–0·1		+0·2	+ 6	–0·1
May ..	+0·2	–0·1	+0·3	0·0		+0·4	0	+0·1
June ..	0·0	–0·2	+0·2	0·0		+0·3	0	0·0
July ..	–0·3	–0·8	–0·4	–0·8		–0·3	0	–0·7
August ..	+0·2	–0·7	+0·6	–0·2		+0·5	0	–0·3
Sptember ..	+0·2	–0·6	+0·1	–0·6		0·0	0	–0·6
October ..	+0·3	–0·5	+0·4	–0·3		+0·3	0	–0·3
November ..	+0·1	–0·5	+0·2	–0·4		+0·2	0	–0·4
December ..	+0·2	–0·2	+0·3	0·0		+0·3	0	0·0

(*Continued*)

* Corrections based on (P – A) differences during 1934–38.
† ,, ,, ,, ,, ,, ,, 1935–30.
‡ ,, ,, ,, ,, ,, ,, 1036–40.

NOTE.—Correction to H.W. and L.W. time in 1941 and 1942 is nil.

TABLE 13.—*Corrections applied to the predicted times and heights at Calcutta (Kidderpore) for 1941–48.*—(concld.)

Year	1947*				1948†			
	H.W.		L.W.		H.W.		L.W.	
Month	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*
January ..	+ 2	+0·1	+ 6	0·0	+ 3	+0·3	+ 8	0·0
February ..	+ 4	+0·2	+ 8	0·0	+ 5	+0·2	+ 8	0·0
March ..	+ 8	+0·2	+10	0·0	+ 4	+0·4	+ 7	0·0
April ..	+ 4	+0·3	+ 9	+0·1	+ 3	+0·4	+ 8	0·0
May ..	− 1	+0·5	+ 3	+0·2	+ 1	+0·5	+ 4	+0·2
June ..	− 1	+0·2	+ 2	−0·1	− 1	+0·3	+ 2	−0·2
July ..	+ 6	−0·5	+ 4	−0·8	+ 4	−0·4	+ 4	−0·8
August ..	+ 6	+0·3	+ 6	−0·4	+10	−0·1	+10	−0·9
September ..	+ 8	−0·2	+ 7	−0·8	+ 7	+0·1	+ 5	−0·8
October ..	+ 4	+0·3	+ 6	−0·4	+ 3	+0·6	+ 4	−0·4
November ..	+ 3	+0·4	+ 3	−0·3	+ 3	+0·4	+ 4	−0·4
December ..	+ 4	+0·5	+ 7	+0·1	+ 3	+0·6	+ 6	0·0

* Corrections based on (P − A) differences during 1939–43.
† ,, ,, ,, ,, ,, ,, 1941–45.

TABLE 14.—*Corrections applied to the predicted times and heights at Chittagong for 1941–48.*

Year	1941*				1942†				1943–48‡			
	H.W.		L.W.		H.W.		L.W.		H.W.		L.W.	
Month	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*
Jan.	0	+0·4	+ 5	+0·6	0	+0·4	0	+0·6	0	+0·4	0	+0·6
Feb.	0	+0·5	0	+0·7	0	+0·4	0	+0·6	0	+0·4	0	+0·7
March	0	0·0	0	+0·6	0	0·0	0	+0·6	0	0·0	0	+0·6
April	0	−0·1	+ 6	+0·4	0	−0·2	+ 6	+0·3	0	−0·2	+ 6	+0·3
May	+ 5	−0·2	+ 8	+0·3	0	0·0	+ 8	+0·3	0	0·0	+ 7	+0·4
June	0	+0·3	0	+1·0	0	+0·4	0	+1·0	0	+0·4	0	+1·0
July	0	0·0	0	+0·5	0	0·0	0	+0·4	0	0·0	0	+0·5
Aug.	+ 7	+0·6	0	+0·9	+ 5	+0·8	0	+1·0	+ 5	+0·8	0	+1·0
Sept.	+14	+0·5	+12	+0·7	+13	+0·6	+12	+0·8	+13	+0·6	+12	+0·9
Oct.	+18	+0·6	+18	+0·6	+18	+0·6	+18	+0·6	+18	+0·6	+18	+0·7
Nov.	+17	+0·4	+18	+0·6	+17	+0·4	+18	+0·6	+17	+0·4	+17	+0·6
Dec.	+12	+0·4	+12	+0·7	+12	+0·5	+12	+0·8	+11	+0·5	+11	+0·7

* Corrections based on (P — A) differences during 1934–38.
† ,, ,, ,, ,, ,, ,, 1935–39.
‡ ,, ,, ,, ,, ,, ,, 1936–40.

TABLE 15.—*Corrections applied to the predicted times and heights at Rangoon for 1941–48.*

Year	1941*		1942†		1943–46‡		1947–48§			
	H.W.	L.W.	H.W.	L.W.	H.W.	L.W.	H.W.		L.W.	
Month	Time *min.*	Time *min.*	Time *min.*	Time *min.*	Time *min.*	Time *min.*	Time *min.*	Height *ft.*	Time *min.*	Height *ft.*
January ..							−12	+0·1	− 6	−0·4
February ..							−12	+0·2	− 6	−0·4
March ..							−13	+0·2	− 6	−0·3
April ..							−12	+0·2	− 6	−0·3
May ..							−13	+0·3	− 7	+0·1
June ..	−13	− 8	−14	− 8	−14	− 7	−17	+0·5	−10	+0·3
July ..							−18	+0·3	−10	+0·2
August ..							−21	+0·3	− 8	+0·2
September							−16	+0·1	− 8	−0·5
October ..							−16	+0·1	− 6	−0·5
November..							−12	+0·1	− 4	−0·6
December ..							−12	+0·2	− 4	−0·5

* Corrections based on (P − A) differences during 1934–38.
† ,, ,, ,, ,, ,, ,, 1935–39.
‡ ,, ,, ,, ,, ,, ,, 1936–40.
§ ,, ,, ,, ,, ,, ,, 1937–41.

NOTE.—Correction to H.W. and L.W. heights in 1941, 1942 and 1943–40 is nil.

TABLE 16.—*Greatest differences between the predicted and actual heights of Low Water during 1939–46.*

Port	Predicted *minus* actual	Date	REMARKS
	feet		
Aden ..	− 0·5	3 Aug. 1939.	
	− 0·7	29 Sept. 1940.	
	− 0·7	27 July 1941.	
	− 0·7	4 April & 30 May 1942.	
	− 0·6	20 May & 22 Sept. 1943.	
	− 1·1	4 May 1944.	
	− 1·3	27 Feb. 1945.	
	− 0·8	5 July } 1946.	
	+ 0·8	12 Aug. } 1946.	
Karāchi ..	+ 0·9	29 Nov. 1939.	
	− 0·9	13 Nov. 1940.	
	+ 0·8	Jan., May & June 1941.	
	− 1·0	2 Dec. 1942.	
	− 0·9	26 Dec. 1943.	
	− 1·7	1 & 2 Aug. 1944.	
	+ 1·5	22 June 1945.	
	− 1·8	5 & 6 June 1946.	
Bhāvnagar ..	− 5·6	6 Feb. 1939.	A bar has formed in the channel which obstructs the flow of water to the tide-pole, thereby affecting all tides below 0 ft.
	− 5·9	28 Jan. 1940.	The mean range of the ordinary spring tides at this port is 31·5 ft.
	− 5·3	13 May 1941.	
	− 3·6	30 June 1942.	
	− 4·0	7 March 1943.	
	− 7·0	2 Nov. 1944.	
	− 4·0	24 Oct. 1945.	
	− 4·4	18 Jan. 1946.	
Bombay (Apollo Bandar)	− 1·0	14 July & 28 Aug. 1939.	
	− 1·4	5 Nov. 1940.	
	− 1·3	17 Jan. } 1941.	
	+ 1·3	31 Jan. } 1941.	
	− 1·9	7 July 1942.	
	− 1·2	30 April 1943.	
	− 1·5	15 June 1944.	
	− 1·3	13 June 1945.	
	− 1·4	3, 4 & 7 June 1946.	
Vizagapatam ..	+ 1·0	16 July, 13, 15 & 16 Sept. 1939	
	+ 1·2	3 Oct. 1940.	
	+ 1·5	12 July 1941.	
	+ 1·0	20 May } 1942.	
	− 1·0	16 Nov. } 1942.	
	− 1·5	31 Oct. 1943.	
	+ 1·2	27 & 28 Aug. 1944.	
	+ 0·9	19 Aug. 1945.	
	+ 1·1	27 July 1946.	
Dublat ..	− 2·5	17 Aug. 1939.	Riverain port. Pneumatic gauge shut down from Dec. 1943.
	− 1·7	30 May 1940.	
	− 2·3	8 Aug. 1941.	
	− 2·7	15 Nov. 1942.	
	+ 1·9	7 Aug. 1943.	

(Continued)

TABLE 16.—*Greatest differences between the predicted and actual heights of Low Water during 1939–46.*—(concld.)

Port	Predicted *minus* actual	Date	REMARKS
Calcutta (Kidderpore)	− 3·3 − 2·6 − 2·5 − 2·1 − 2·4 + 2·4 + 2·4 + 2·0	7 Aug. 1939. 3, 5, 6 & 7 Oct. 1940. 5 May 1941. 15 & 16 Nov. 1942 26 July 1943. 2 Nov. 1944. 12 Aug. 1945. 14 Aug. 1946.	Riverain port.
Chittagong ..	− 1·6 − 2·4 − 3·2 − 1·4 − 1·6 + 2·6 + 1·9 − 1·0 − 2·1	31 July 1939. 22 Oct. 1940. 2 July 1941. 17 Jan. 1942. 18 Feb. 1943. 25 Sept. 1944. 19 April } 1945. 22 Nov. } 17 & 18 July 1946.	Riverain port. Observations discontinued, due to shortage of staff, from March 1942 to Jan. 1943.
Akyab ..	− 2·5 − 1·5 − 2·2 − 2·2 − 1·2	17 Aug. 1939. 31 Aug. 1940. 15 June } 1941. 22 & 23 Oct. } 12 Feb. 1942.	Observations stopped from March 1942 due to war and not yet resumed.
Rangoon ..	− 3·7 + 2·1 − 2·1 + 2·1 + 1·6	17 & 19 Aug. 1939. 20 Oct. 1940 10 July } 1941. 5 Nov. } 4 Jan. 1942.	Riverain port. Observations discontinued from Feb. 1942 due to war.

CHAPTER VII

OBSERVATORIES

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

69. **Routine Work.**—(*a*) Daily seismograph observations have been carried out. Results up to 30th September 1947 have been supplied to the Meteorological Department for inclusion in the Seismological Bulletin.

(*b*) The usual meteorological observations, which are taken at 8 hours and at 17 hours daily, have been continued. The phonogram system of communicating these to the local telegraph office was introduced in 1944 for quick transmission in war time and has been in use since. A whole-time observer was attached to this Observatory, by the Meteorological Department in July 1946 and is still continuing. Observations during day and night at hours other than 8 and 17 are taken by him and not by our observer.

(*c*) The two electric clocks, Shortt and Riefler, have on the whole functioned satisfactorily, and there have been very few stoppages, which were promptly rectified. The caustic soda cells required to run the Shortt Clock, which were introduced in 1935, were renewed in 1940 and again in 1945.

(*d*) The wireless rythmic signals which were taken on the old Seimens Set or on the portable wireless set R.P. 11 were not heard satisfactorily after 28th August 1941. Since then the rating of the Shortt Clock has been done by hearing the B.B.C. time pips on an ordinary wireless receiver by Phillips. This rating is correct to within 1/10 to 1½/10 seconds.

(*e*) All computational work connected with astrolabe, magnetic, astrofix, secondary levelling and standards of length observations carried out during the period of the report by the detachments of the Institute either in the field or at headquarters, was done in the Observatory Section.

(*f*) The upkeep and maintenance of the scientific instruments and stores of the Institute has been steadily carried out during all these years with the small technical staff available. A thorough checking of these stores was undertaken in 1947 after the field season 1946–47.

(*g*) The routine observational and computational work of the Magnetic Observatory came to a close in August 1943, when the observatory was flooded due to heavy rains and the magnetographs dismantled.

(*h*) Data for magnetic declination, weather and rainfall was supplied to the various survey units, military authorities and other private institutions asking for it.

70. **Research and Experiments.**—The following items were dealt with :—

(i) A good deal of experimental work was carried out in devising methods for rapid astrofix observations and their computations, useful for survey military units working under war conditions. The results of these are embodied in the War Survey Research Series Pamphlets Nos. 2, 7 and 8.

(ii) One newly designed perambulator for measuring distances under war conditions was prepared at the Observatory Workshop, and supplied to the Director of Survey, India Command.

(iii) Some experiments were conducted to evolve a rapid subtense method of executing precise traverses. This required the manufacture of elevated platforms, bipods, tripods and targets for observing and hanging the tapes which were in 2 portions of 80 metres each to form a 160-metre observing base. A bicycle wheel drum for winding these tapes and to avoid their being damaged and kinked was specially designed.

71. **Tests and Calibration.**—During the period under report about 1,000 instruments have been handled by the Observatory Section for purposes of calibration and tests. The main calibration work has been of the H.S.B. tapes for field units and the 80-metre invar tapes and this has been carried out with the 24-metre base tape of the base-line alley in catenary which was itself calibrated at different times and under different temperature conditions against the 4-metre Invar Standard Bar. The other instruments calibrated were theodolites and levels of all sorts, Wild compasses and invar levelling staves for precision work, aneroid barometers and chronometers. A 10-ft. invar tape was specially prepared by calibrating it against standard 10-ft. bar Is and the Bevelled edge bar for the purpose of calibrating invar staves which were hitherto calibrated in the 4-metre comparator by a laborious and inconvenient process.

Amongst the instruments which required special tests were (1) Paulin barometers (2) Astro-clinometer and (3) the Co-ordinatograph. Two 20-metre invar tapes with special end attachments for fixing on to the pins of the 160-metre base pillars were prepared and calibrated on different occasions for use while standardizing the 80-metre invar tapes and their lengths determined at different sags against the Invar tape base.

For the calibration of Altimeters, experiments were made with a mercury U-tube vacuum Indicator received from the Survey Stores Office for this purpose. A number of telescopic staves, which are usually marked for tacheometric purposes at alternate feet to 0·1 of a foot, were remodelled for control traverses. These markings were continued throughout the length of the staves and detachable metal foot marks were manufactured and provided for every foot.

72. **Instruction and Training.**—A class was organized for the training of levellers, traversers and rectangulators. 50 candidates were recruited and trained at different intervals and passed on to the various departmental units and circles. 9 Topo. Assistants, 6 Class II Officers and 1 Surveyor were given refresher courses in astronomical observations and computations. 2 Chinese and 2 Afghān officers were also attached to this Section for instruction.

Three instrument mechanics sent by the S.O.S. were given workshop training for short periods and tested with a view to their suitability for employment in the Department.

73. **Dehra Dūn Magnetic Observatory.**—During the period 1939 to 1943 the usual programme of magnetic observations was carried out at the Dehra Dūn Observatory. It consisted of a continuous magnetographic record of declination, horizontal force and vertical force, controlled by observations of dip daily, and of declination and horizontal force thrice a week. During this period the magnetographs worked regularly and no interruptions of any consequence occurred till the 15th of August 1943, when the clock attached to V.F. Magnetographs stopped due to excessive rains and overflooding of the room of the underground observatory. On the 16th August water increased still further and stopped the declination clock as well. Inspite of the day and night bailing and pumping of water from the magnetograph room, the water level continued increasing, necessitating the removal of the instruments on the evening of the 19th August, when the water reached the tops of the pillars supporting the magnetographs.

The soil in Dehra Dūn is full of *bajri* and the water finds an easy access to an underground room through the porous gravel soil. No means have been of avail to check the flooding of underground chambers during heavy rains, which are frequent in Dehra Dūn. It is, therefore, inadvisable to have an underground observatory and the idea of restarting the old underground observatory has been abandoned, especially as the present site in the Geodetic Branch compound is now cluttered up with buildings all around it and is no longer suitable. A new site is being selected and the sanction of the Government of India has been obtained to start a new observatory.

The mean values of the magnetic elements at Dehra Dūn were as follows :—

	1939	1940	1941	1942	1943
	° ′	° ′	° ′	° ′	° ′
Declination ..	E. 0 46·6	0 44·7	0 42·1	0 38·8	{ 0 36·2* 0 35·9†
Dip ..	N. 45 39·4	45 37·7	45 39·0	45 34·2	{ 45 30·8* 45 31·5†
	C.G.S.	C.G.S.	C.G.S.	C.G.S.	C.G.S.
Horizontal Force.	0·33344	0·33397	0·33455	0·33525	{ 0·33505* 0·33610†
Vertical Force	0·34117	0·34137	0·34224	0·34200	{ 0·34172* 0·34231†

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

	1939	1940	1941	1942	1943
Declination ..	′ 1·03	′ 1·03	′ 1·03	′ 1·03	′ 1·03
Horizontal Force.	γ 4·23	γ 4·16	γ 4·18	γ { 4·22 up to June. 4·16 from July.	γ 4·10
Vertical Force	γ 11·77 to 16·60	γ 11·64 to 30·86	γ 10·87 to 24·87	γ 22·38 to 38·78	γ 14·70 to 41·80

The temperatures of the observatory during the years 1939–43 were :—

Year	Mean temperature	Maximum	Minimum
	°	°	°
1939	27·0	27·3	26·7
1940	26·9	28·0	26·2
1941	26·9	27·4	26·2
1942	26·7	27·2	26·1
1943	26·2	27·2	25·4

* Mean of first seven months.
† Mean of last five months.

The moment of inertia of magnet No. 17 was determined in April 1940 and in October 1943 and log Π^2 K was found to be 3·41408 and 3·41440. The values accepted have been 3·41438 for the year 1939 and 3·41437 for the following years. The moment of inertia of the magnet No. 5 B was determined in May 1940 and Log Π^2 K was found to be 3·37736. The value accepted has been 3·37738 throughout. The accepted values of the factor log $(1+P/r^2+Q/r^4)^{-1}$ for magnets No. 17 and No. 5 B have been $\bar{1}$·99415 and $\bar{1}$·99340 as in previous years. Mean monthly values of the elements and their annual changes are given in Table 1.

74. **Magnetic Field Work (1942-47).**—With the disbanding of the magnetic party in 1923, the activities of the Survey of India as regards magnetic observations were confined to the Dehra Dūn Observatory only and the scheme of visiting the repeat stations at intervals of five years to determine the secular change of magnetic elements was not implemented on account of lack of finance.

In 1930 it was hoped that the Kodaikanal and Toungoo observatories, which were closed down in October 1923 for reasons of economy, would be reopened and all the repeat stations in India and Burma would be reobserved in a few years, time, but this hope was not fulfilled and the repeat stations dependent on Dehra Dūn and Alibag observatories only were observed in 1930–31. Since 1931 the values of magnetic declination have continued to be supplied by the Department from a chart drawn with the help of extra-departmental data by applying rough annual changes derived from older data.

On the outbreak of World War II demand for data of greater accuracy especially for magnetic declinations for maps for military purposes greatly increased and to meet this demand reobservation of Magnetic Repeat Stations became inevitable.

In 1943, therefore, a hurried programme was chalked out to visit repeat stations spread all over India and this programme was continued till all the stations had been reobserved in 1945. The sites of several stations were found to have been rendered unsuitable due to the growth of new buildings around them and other reasons. Alternative sites were prepared and observations made at them during 1946–47 and 1947–48. The field observations were carried out under Mr. Shyam Narain, B.SC. the instruments used being a magnetometer and a dip circle. At each station the programme comprised of one set of vibration and one set of deflection observations for H.F., the dip observations made with two needles both ends dipping, and observations for declination consisting of one set of two readings, for 'mark above' and two readings for 'mark below'. The observed values at stations which were dependent on Dehra Dūn and Alibag observatories were corrected for diurnal variations and perturbations, while in other cases the observed values had to be accepted as they were. The results of observations at the repeat stations except Indore which falls in the disturbed area, are given in Table 2.

The field work was executed under very arduous conditions, railway journeys being very difficult on account of overcrowding and complete black out. Famine in Bengal, non-availability of adequate and proper rations, lack of accommodation in Dak Bungalows all made work very difficult and put a considerable strain on the personnel of the detachment.

75. **Magnetic Variation Chart for Epoch 1946.**—During the war, a lot of extra-departmental information as regards magnetic declinations was collected and compiled for preparing the latest isogonic charts for the use of the military. In India itself, the uncertainties in secular variation produced by the stoppage of the three permanent observatories and the lack of recent observations at the repeat stations were a great handicap and doubts of over 1° existed in some parts. It was not even possible to meet the military needs which required declinations on maps only to a precision of ¼° or so. The observations were carried out at all repeat stations in the year 1943–45 to supplement the existing information. For lack of observatory cover, these observations could not be corrected for diurnal variations and perturbations but still they were good enough for the purpose in hand. In 1946, a chart showing isogonals for epoch 1946 was compiled for the area bounded by latitudes 60° N. and 60° S. and longitudes 40° E. and 168° E. This is labelled as Hind Misc/7553. The following material was used in its compilation :—

(i) British Admiralty Chart of Curves of Equal Magnetic Variation, 1942, Sheet 2, Indian and Western Pacific Oceans.

(ii) Observations for Magnetic Declinations by the Survey of India.

(iii) Australian Aeronautical Series, Magnetic Sheets Nos. 1, 2 and 3, Nov. 1944.

and (iv) Observations at Cocos Island in 1946 by Messrs. Chamberlain & McCarthy of the Department of Mineral Resources, Survey of Australia.

TABLE 1.—*Monthly mean values of Magnetic elements and their annual changes, Magnetometer No. 17, Dehra Dūn, 1938 and 1939.*

MONTH	Horizontal force			Declination			Dip			Vertical force		
	1938	1939	Annual change	1938	1939	Annual change	1938	1939	Annual change	1938	1939	Annual change
	C.G.S.	C.G.S.	γ	° ′	° ′	′	° ′	° ′	′	C.G.S.	C.G.S.	γ
January ..	0·33239	0·33332	+ 93	E. 0 50·4	E. 0 46·6	−3·8	N. 45 41·5	N. 45 41·4	−0·1	0·34051	0·34144	+ 93
February ..	230	311	+ 81	50·4	47·8	−2·6	43·0	38·4	−4·6	071	064	− 07
March ..	260	327	+ 67	49·9	47·2	−2·7	39·7	35·6	−4·1	036	023	− 13
April ..	277	333	+ 56	48·6	47·8	−0·8	40·9	36·2	−4·7	077	041	− 36
May ..	289	346	+ 57	48·8	47·6	−1·2	42·0	39·1	−2·9	112	114	+ 02
June ..	284	365	+ 81	48·9	46·2	−2·7	40·9	41·9	+1·0	084	187	+103
July ..	284	351	+ 67	48·7	46·3	−2·4	40·5	39·4	−1·1	076	124	+ 48
August ..	292	348	+ 56	49·1	44·8	−4·3	39·6	39·8	+0·2	067	129	+ 62
September ..	300	339	+ 39	48·8	46·3	−2·5	40·4	39·7	−0·7	092	118	+ 26
October ..	294	355	+ 61	48·8	46·0	−2·8	41·2	42·2	+1·0	101	184	+ 83
November ..	302	358	+ 56	48·2	45·9	−2·3	42·0	39·9	−2·1	127	141	+ 14
December ..	0·33313	0·33369	+ 56	E. 0 47·9	E. 0 46·4	−1·5	N. 45 41·4	N. 45 39·0	−2·4	0·34125	0·34134	+ 09
Mean ..	0·33280	0·33344	+ 64	E. 0° 49′·1	E. 0° 46′·6	−2′·5	N. 45° 41′·1	N. 45° 39′·4	−1′·7	0·34085	0·34117	+ 32

γ = 0·00001 C.G.S.

(Continued)

TABLE 1.—*Monthly mean values of Magnetic elements and their annual changes, Magnetometer No. 17, Dehra Dūn, 1939 and 1940*—(contd.)

MONTH	Horizontal force			Declination			Dip			Vertical force		
	1939	1940	Annual change	1939	1940	Annual change	1939	1940	Annual change	1939	1940	Annual change
	C.G.S.	C.G.S.	γ	° ′	° ′	′	° ′	° ′	′	C.G.S.	C.G.S.	γ
January ..	0·33332	0·33369	+ 37	E. 0 46·6	E. 0 46·0	—0·6	N. 45 41·4	N. 45 38·5	—2·9	0·34144	0·34123	— 21
February ..	311	368	+ 57	47·8	45·7	—2·1	38·4	39·2	+0·8	064	139	+ 75
March ..	327	382	+ 55	47·2	45·5	—1·7	35·6	38·8	+3·2	023	144	+121
April ..	333	356	+ 23	47·8	45·5	—2·3	36·2	39·0	+2·8	041	122	+ 81
May ..	346	391	+ 45	47·6	44·7	—2·9	39·1	33·6	—5·5	114	051	— 63
June ..	365	420	+ 55	46·2	44·8	—1·4	41·9	35·7	—6·2	187	122	— 65
July ..	351	407	+ 56	46·3	44·4	—1·9	39·4	36·9	—2·5	124	131	+ 07
August ..	348	399	+ 51	44·8	44·8	0·0	39·8	35·0	—4·8	129	086	— 43
September ..	339	413	+ 74	46·3	44·2	—2·1	39·7	38·5	—1·2	118	170	+ 52
October ..	355	413	+ 58	46·0	43·9	—2·1	42·2	38·7	—3·5	184	173	— 11
November ..	358	418	+ 60	45·9	43·4	—2·5	39·9	38·5	—1·4	141	175	+ 34
December ..	0·33369	0·33429	+ 60	E. 0 46·4	E. 0 43·3	—3·1	N. 45 39·0	N. 45 39·7	+0·7	0·34134	0·34210	+ 76
Mean ..	0·33344	0·33397	+ 53	E. 0° 46′·6	E. 0° 44′·7	—1′·9	N. 45° 39′·4	N. 45° 37′·7	—1′·7	0·34117	0·34137	+ 20

γ = 0·00001 C.G.S.

(Continued)

TABLE 1.—*Monthly mean values of Magnetic elements and their annual changes, Magnetometer No. 17, Dehra Dūn, 1940 and 1941*—(contd.)

Month	Horizontal force			Declination			Dip			Vertical force		
	1940	1941	Annual change	1940	1941	Annual change	1940	1941	Annual change	1940	1941	Annual change
	C.G.S.	C.G.S.	γ	° ′	° ′	′	° ′	° ′	′	C.G.S.	C.G.S.	γ
January ..	0·33369	0·33438	+ 69	E. 0 46·0	E. 0 43·2	−2·8	N. 45 38·5	N. 45 41·0	+2·5	0·34123	0·34246	+123
February ..	368	434	+ 66	45·7	43·1	−2·6	39·2	40·2	+1·0	139	226	+ 87
March ..	382	429	+ 47	45·5	42·8	−2·7	38·8	39·7	+0·9	144	210	+ 66
April ..	356	443	+ 87	45·5	42·6	−2·9	39·0	37·9	−1·1	122	189	+ 67
May ..	391	466	+ 75	44·7	42·6	−2·1	33·6	38·5	+4·9	051	224	+173
June ..	420	473	+ 53	44·8	42·2	−2·6	35·7	39·8	+4·1	122	257	+135
July ..	407	462	+ 55	44·4	43·0	−1·4	36·9	38·1	+1·2	131	212	+ 81
August ..	399	464	+ 65	44·8	41·5	−3·3	35·9	38·6	+2·7	086	223	+137
September ..	413	433	+ 20	44·2	41·1	−3·1	38·5	40·1	+1·6	170	221	+ 51
October ..	413	478	+ 65	43·9	41·1	−2·8	38·7	37·7	−1·0	173	220	+ 47
November ..	418	470	+ 52	43·4	41·1	−2·3	38·5	35·6	−2·9	175	172	− 03
December ..	0·33429	0·33475	+ 46	E. 0 43·3	E. 0 40·4	−2·9	N. 45 39·7	N. 45 41·0	+1·3	0·34210	0·34282	+ 72
Mean ..	0·33397	0·33455	+ 58	E. 0° 44′·7	E. 0° 42′·1	−2′·6	N. 45° 37′·7	N. 45° 39′·0	+1′·3	0·34137	0·34224	+ 87

$\gamma = 0{\cdot}00001$ C.G.S.

(Continued)

TABLE 1.— *Monthly mean values of Magnetic elements and their annual changes, Magnetometer No. 17, Dehra Dūn, 1941 and 1942*—(contd.)

Month	Horizontal force 1941	Horizontal force 1942	Horizontal force Annual change	Declination 1941	Declination 1942	Declination Annual change	Dip 1941	Dip 1942	Dip Annual change	Vertical force 1941	Vertical force 1942	Vertical force Annual change
	C.G.S.	C.G.S.	γ	° ′	° ′	′	° ′	° ′	′	C.G.S.	C.G.S.	γ
January ..	0·33438	0·33487	+ 49	E. 0 43·2	E. 0 40·1	−3·1	N. 45 41·0	N. 45 36·5	−4·5	0·34246	0·34207	− 39
February ..	434	498	+ 64	43·1	39·6	−3·5	40·2	36·2	−4·0	226	210	− 16
March ..	429	508	+ 79	42·8	39·4	−3·4	39·7	31·5	−8·2	210	128	− 82
April ..	443	520	+ 77	42·6	39·1	−3·5	37·9	36·1	−1·8	189	231	+ 42
May ..	466	530	+ 64	42·6	39·2	−3·4	38·5	35·1	−3·4	224	226	+ 02
June ..	473	540	+ 76	42·2	39·3	−2·9	39·8	35·6	−4·2	257	251	− 06
July ..	462	519	+ 57	43·0	39·0	−4·0	38·1	34·6	−3·5	212	204	− 08
August ..	464	533	+ 69	41·5	38·7	−2·8	38·6	33·3	−5·3	223	195	− 28
September ..	433	539	+106	41·1	37·7	−3·4	40·1	32·9	−7·2	221	188	− 33
October ..	478	538	+ 60	41·1	38·2	−2·9	37·7	32·6	−5·1	220	186	− 34
November ..	470	529	+ 59	41·1	37·6	−3·5	35·6	32·6	−3·0	172	170	− 02
December ..	0·33475	0·33547	+ 72	E. 0 40·4	E. 0 37·3	−3·1	N. 45 41·0	N. 45 33·1	−7·9	0·34282	0·34198	− 84
Mean ..	0·33455	0·33525	+ 70	E. 0° 42′·1	E. 0° 38′·8	−3′·3	N. 45° 39′·0	N. 45° 34′·2	−4′·8	0·34224	0·34200	− 24

$\gamma = 0{\cdot}00001$ C.G.S.

(*Continued*)

TABLE 1.—*Monthly mean values of Magnetic elements and their annual changes, Magnetometer No. 17, Dehra Dūn, 1942 and 1943*—(concld.)

MONTH	Horizontal force			Declination			Dip			Vertical force		
	1942	1943	Annual change	1942	1943	Annual change	1942	1943	Annual change	1942	1943	Annual change
	C.G.S.	C.G.S.	γ	° ′	° ′	′	° ′	° ′	′	C.G.S.	C.G.S.	γ
January ..	0·33487	0·33526	+ 30	E. 0 40·1	E. 0 36·9	—3·2	N. 45 36·5	N. 45 32·5	—4·0	0·34207	0·34165	— 42
February ..	498	547	+ 49	30·6	36·5	—3·1	36·2	32·7	—3·5	210	188	— 22
March ..	508	579	+ 71	39·4	36·3	—3·1	31·5	29·3	—2·2	128	155	+ 27
April ..	520	581	+ 61	39·1	36·5	—2·6	36·1	28·7	—7·4	231	147	— 84
May ..	530	570	+ 40	39·2	35·7	—3·5	35·1	31·9	—3·2	226	198	— 28
June ..	549	585	+ 36	39·3	35·7	—3·6	35·6	30·8	—4·8	251	192	— 59
July ..	519	0·33569	+ 50	39·0	E.0 35·8	—3·2	34·6	N. 45 29·8	—4·8	204	0·34156	— 48
August ..	533			38·7			33·3			195		
September ..	539			37·7			32·9			188		
October ..	538			38·2			32·6			186		
November ..	529			37·6			32·6			170		
December ..	0·33547			E. 0 37·3			N. 45 33·1			0·34198		
Mean ..	0·33525	0·33565	+ 49	E. 0° 36′·8	E. 0° 36′·2	—3′·2	N. 45° 34′·2	N. 45° 30′·8	—4′·3	0·34199	0·34172	— 37

γ = 0·00001 C.G.S.

TABLE 2.—*Repeat Stations observed in 1942-43.*

Degree Sheet No.	Station No.	Name of station	Latitude N.	Longitude E.	Height	Declination: Date of observation	Declination: Value corrected to Date	Declination: Value reduced to the epoch 1943·0
			° ′ ″	° ′ ″	*feet*		° ′	° ′
38 P	XXVII	Kundian ..	32 27 30	71 28 20	650	5 3 43	+1 46·9	+1 47·4
40 O	LXXIII	Barmer ..	25 44 35	71 26 40	650	10 3 43	+0 21·9	+0 22·3
43 G	V	Rāwalpindi ..	33 35 25	73 03 06	1700	3 3 43	+1 58·5	+1 59·0
46 O	XVI	Bhusāwal	21 03 40	75 47 00	650	19 3 43	−1 05·5	−1 04·9
53 J	..	Dehra Dūn ..	30 19 19	78 03 19	2230	9 2 43	+0 36·5	+0 36·9
						19 4 43	+0 36·0	+0 37·0
						20 4 43	+0 36·5	+0 37·5
						21 4 43	+0 36·8	+0 37·8
54 L	LV	Bīna ..	24 10 50	78 11 0	1350	15 3 43	−0 36·1	−0 35·5
55 M	XVII	Jubbulpore ..	23 09 26	79 57 09	1320	17 3 43	−1 00·3	−0 59·7
56 A	XLVII	Parbhani ..	19 15 20	76 46 50	1350	25 3 43	−1 23·5	−1 23·0
56 K	XV	Secunderābād ..	17 27 44	78 29 37	1760	27 3 43	−1 33·0	−1 32·6
58 F	..	Kodaikānal ..	10 13 50	77 27 46	7550	3 4 43	−2 42·7	−2 42·1
63 J	X	Fyzābād ..	26 48 05	82 08 05	330	28 2 43	−0 21·1	−0 20·7
66 C	XXXVII	Perambūr ..	13 06 40	80 15 00	10	31 3 43	−2 29·0	−2 28·4
72 K	L	Monghyr ..	25 23 10	86 27 50	150	25 2 43	−0 46·8	−0 46·3
74 A	LX	Berhampur (Ganjām)	19 18 10	84 48 40	80	8 4 43	−1 36·0	−1 35·4
78 D	LXV	Santahar ..	24 48 10	88 59 20	50	15 2 43	−0 44·4	−0 43·9
78 N	LXXVII	Palāsbāri ..	26 07 40	91 32 40	150	22 2 43	−0 40·6	−0 40·2
79 B	LXXIV	Barrackpore ..	22 46 29	88 21 39	20	13 2 43	−0 57·6	−0 57·3
83 D	XXI	Silchar ..	24 49 14	92 47 27	70	20 2 43	−0 50·1	−0 49·7
83 I	XXII	Dibrugarh ..	27 29 12	94 54 35	340	17 2 43	−0 44·0	−0 43·6

(Continued)

TABLE 2.—*Repeat Stations observed in 1943-44*—(contd.)

Degree sheet No.	Station No.	Name of station	Latitude N.	Longitude E.	Height	Declination: Date of observation	Declination: Value*	Dip: Date of observation	Dip: Value*	Horizontal force: Date of observation	Horizontal force: Value*
			° ′ ″	° ′ ″	feet		° ′		° ′		C.G.S.
47 L	XL	Miraj ..	16 49 10	74 38 10	1800	19 2 44	−1 42·9	19 2 44	+ 20 34·2	19 2 44	0·39018
48 M	VIII	Dhārwār ..	15 26 36	75 00 10	2400	16 2 44	−1 59·7	16 2 44	16 35·0	16 2 44	·39105
48 O	XXXIX	Birur ..	13 35 50	75 58 10	2500	1 3 44	−2 18·3	1 3 44	12 24·5	1 3 44	·39422
49 M	XXXVIII	Cannanore ..	11 52 30	75 22 00	70	10 3 44	−2 59·4	10 3 44	09 04·5	10 3 44	·39530
						11 3 44	−2 58·2				
55 H	LXIV	Amraoti ..	20 55 30	77 45 50	1120	1 2 44	−1 27·7	2 2 44	28 39·6	1 2 44	·37634
56 C	XXXIV	Hotgi ..	17 33 40	76 00 20	1530	21 2 44	−1 30·7	21 2 44	21 27·8	21 2 44	·38844
56 M	LXII	Chānda ..	19 57 50	79 17 40	770	28 1 44	−1 20·9	29 1 44	26 19·5	28 1 44	·38630
57 E	XXXV	Guntakal ..	15 10 48	77 22 57	1410	14 2 44	−2 04·9	14 2 44	16 10·6	14 2 44	·39366
57 H	VII	Bangalore ..	12 58 43	77 35 26	3000	27 2 44	−2 29·8	27 2 44	10 31·8	27 2 44	·39791
57 M	LXI	Cumbum ..	15 35 50	79 06 40	600	11 2 44	−2 29·2	12 2 44	16 47·9	11 2 44	·39587
57 O	XXXVI	Arkonam ..	13 04 30	79 40 20	300	5 3 44	−2 32·9	5 3 44	10 32·5	5 3 44	·40047
58 H	XLIV	Tinnevelly ..	8 44 00	77 42 30	130	20 3 44	−3 22·7	20 3 44	0 39·7	20 3 44	·39441
58 N	XLVI	Tanjore ..	10 46 40	79 08 20	190	14 3 44	−3 01·2	14 3 44	4 43·6	14 3 44	·39792
58 O	XLV	Mandapam ..	9 16 50	79 08 30	0	16 3 44	−3 04·8	16 3 44	1 24·9	16 3 44	·39789
63 G	XLIX	Manikpur ..	25 03 10	81 05 20	800	21 1 44	−0 36·5	23 1 44	36 16·6	23 1 44	·36766
						22 1 44	−0 37·1				
64 G	LXIII	Raipur ..	21 15 50	81 38 20	970	4 2 44	−1 12·2	4 2 44	28 53·1	4 2 44	·38398
64 O	XI	Sambalpur ..	21 27 52	83 58 35	500	2 4 44	−1 15·0	1 4 44	28 52·5	1 4 44	·38535
65 D	XLVIII	Bezwada ..	16 31 00	80 36 50	70	9 2 44	−2 08·5	10 2 44	17 57·2	9 2 44	·39706
65 O	XII	Waltair ..	17 42 23	83 17 44	10	7 2 44	−1 44·3	7 2 44	21 03·3	7 2 44	·39645
72 B	LIII	Bettiah ..	26 48 50	84 31 30	240	25 4 44	−0 22·3	25 4 44	39 07·6	25 4 44	·36224
72 D	XIV	Gaya ..	24 47 07	84 59 47	400	7 4 44	−0 52·7	7 4 44	35 23·4	7 4 44	·37608
73 F	LI	Sini ..	22 47 00	85 56 50	700	30 3 44	−1 01·3	30 3 44	31 01·0	30 3 44	·38488
73 K	LIX	Balasore ..	21 30 30	86 54 40	50	26 3 44	−1 20·0	27 3 44	28 38·1	26 3 44	·38825
78 B	XIII	Darjeeling ..	26 59 42	88 16 56	8100	18 4 44	−0 34·1	17 4 44	39 00·4	18 4 44	·36488
79 M	LXVI	Laksham ..	23 15 40	91 07 20	30	12 4 44	−0 59·0	13 4 44	+ 31 49·7	12 4 44	0·38480

* Uncorrected for diurnal variations and perturbations.

(*Continued*)

TABLE 2.—*Repeat Stations observed in 1944-45*—(contd.)

Degree sheet No.	Station No.	Name of station	Latitude N.	Longitude E.	Height	Declination		Dip		Horizontal Force	
						Date of observation	Value*	Date of observation	Value*	Date of observation	Value*
			° ′ ″	° ′ ″	*feet*		° ′		° ′		C.G.S.
34 J	III	Quetta ..	30 12 21	66 59 55	5500	3 3 45	+1 37·7	3 3 45	+ 45 44·7	3 3 45	0·32535
35 P	II	Karāchi ..	24 49 24	67 02 28	20	13 3 45	+0 22·8	13 3 45	36 47·4	13 3 45	·35270
38 N	XXVI	Peshāwar ..	34 00 40	71 33 40	1050	21 2 45	+2 12·6	21 2 45	51 08·0	21 2 45	·30739
39 O	IV	Bahāwalpur ..	29 24 23	71 40 35	380	25 2 45	+1 14·5	25 2 45	44 29·1	25 2 45	·33476
40 A	XXIV	Ruk Junction ..	27 48 23	68 38 20	200	28 2 45	+0 38·5	28 2 45	41 53·2	28 2 45	·33999
40 G	XXXI	Mirpur Khās ..	25 31 19	69 01 40	50	8 3 45	+0 28·1	7 3 45	37 52·2	8 3 45	·35127
41 G	IX	Porbandar ..	21 37 43	69 36 39	30	8 2 45	−0 18·8	9 2 45	30 49·3	8 2 45	·37109
44 H	XXIX	Bīkaner ..	28 00 40	73 18 50	750	7 1 45	+0 19·1	7 1 45	42 05·1	7 1 45	·34494
44 I	XXV	Lahore ..	31 35 50	74 18 50	700	19 2 45	+1 09·9	19 2 45	48 03·7	19 2 45	·32283
44 O	XLIII	Sirsa ..	29 32 10	75 02 40	700	2 1 45	+0 50·1	2 1 45	44 18·9	2 1 45	·33803
45 H	I	Udaipur ..	24 34 42	73 42 46	1900	16 12 44	−0 19·1	16 12 44	35 49·5	16 12 44	·36199
								17 12 44	35 54·2		
45 J	XXX	Ajmer ..	26 27 30	74 38 30	1600	12 12 44	+0 10·6	12 12 44	39 05·0	12 12 44	·35388
46 A	XXXII	Viramgām ..	23 08 10	72 03 30	90	4 2 45	−0 22·6	5 2 45	33 16·6	4 2 45	·36586
46 C	XXVIII	Sachīn ..	21 04 40	72 52 40	40	13 1 45	−1 10·4	14 1 45	29 09·8	13 1 45	·37675
46 L	XLI	Manmād ..	20 14 40	74 26 20	1900	20 1 45	−0 43·3	18 1 45	27 20·8	19 1 45	·38015
47 B	..	Alibag ..	18 38 17	72 52 26	20	26 1 45	−0 41·7	26 1 45	24 58·3	26 1 45	·38129
						26 1 45	−0 42·1			26 1 45	·38152
						27 1 45	−0 42·3	27 1 45	25 00·9	27 1 45	·38107
						27 1 45	−0 42·3	27 1 45	24 59·4	27 1 45	·38102
						28 1 45	−0 41·9	28 1 45	25 00·2	28 1 45	·38140
						28 1 45	−0 42·5	28 1 45	25 01·5	28 1 45	0·38123
								29 1 45	+ 25 05·0		

* Uncorrected for diurnal variations and perturbations.

(*Continued*)

TABLE 2.—*Repeat Stations observed in 1944-45*—(contd.)

Degree sheet No.	Station No.	Name of station	Latitude N.	Longitude E.	Height	Declination: Date of observation	Declination: Value*	Dip: Date of observation	Dip: Value*	Horizontal Force: Date of observation	Horizontal Force: Value*
			° ′ ″	° ′ ″	feet		° ′		° ′		C.G.S.
47 J	XXXIII	Dhond ..	18 28 00	74 35 10	1690	22 1 45	−1 16·7	23 1 45	+23 40·3	22 1 45	0·38422
53 H	XLII	Delhi ..	28 40 15	77 13 48	680	28 12 44	+0 19·4	29 12 44	42 51·5	30 12 44	·34533
53 O	LVIII	Kāthgodām ..	29 15 19	79 32 50	1680	25 11 44	+0 24·1	26 11 44	43 39·8	25 11 44	·34414
54 C	LIV	Baran ..	25 05 32	76 30 30	850	24 12 44	−0 26·3	25 12 44	36 58·6	24 12 44	·36088
54 E	VI	Bharatpur ..	27 13 53	77 29 24	650	9 12 44	+0 02·0	10 12 44	40 20·4	9 12 44	·35242
62 H	LII	Katarnianghat ..	28 19 50	81 07 50	600	30 11 44	+0 02·1	1 12 44	42 01·6	30 11 44	·35188
63 B	LVII	Cawnpore ..	26 27 00	80 21 00	400	4 12 44	−0 15·1	5 12 44	+38 45·2	4 12 44	0·36166

* Uncorrected for diurnal variations and perturbations.

(*Continued*)

TABLE 2.—*Repeat Stations (old and new sites) observed in 1945-47*—(contd.)

Degree sheet No.	Station No.	Name of station		Latitude N.			Longitude E.			Height	Declination: Dates of observation	Declination: Value*	Dip: Dates of observation	Dip: Value*	Horizontal Force: Dates of observation	Horizontal Force: Value*
				°	′	″	°	′	″	*feet*		° ′		° ′		C.G.S.
34 J	III	Quetta	old	30	12	21	66	50	55	5500	23 12 46	+1 34·7	24 12 46	+45 42	23 12 46	0·32670
		,,	new	30	12	07	66	59	49	5500	22 12 46	+1 37·7	24 12 46	45 45	22 12 46	·32569
40 A	XXIV	Ruk Junction	old	27	48	23	68	38	20	200	27 12 46	+0 36·8	28 12 46	41 50	27 12 46	·34102
		Habibkot	new	27	51	53	68	39	49	200	30 12 46	+0 37·2	30 12 46	41 55	29 12 46	·34096
43 G	V	Rāwalpindi	old	33	35	25	73	03	06	1700	9 12 46	+1 56·2	10 12 46	50 34	11 12 46	·31270
		,,	new	33	35	20	73	03	06	1700	11 12 46	+1 57·0	11 12 46	50 31	10 12 46	·31246
44 H	XXIX	Bikaner	old	28	00	40	73	18	50	750	4 1 46	+0 19·1	6 1 46	42 04	5 1 46	·34560
		,,	new	27	59	50	73	19	40	750	5 1 46	+0 17·6	7 1 46	42 05	6 1 46	·34504
44 O	XLIII	Sirsa	old	29	32	10	75	02	40	700	26 12 45	+0 48·2	27 12 45	44 18	29 12 45	·33889
		,,	new	29	32	50	75	02	28	700	27 12 45	+0 45·7	28 12 45	44 23	29 12 45	·33909
46 L	XLI	Manmād	old	20	14	40	74	26	20	1900	26 1 46	−0 43·1	28 1 46	26 49	26 1 46	·37917
		,,	new	20	14	45	74	26	35	1900	27 1 46	−0 50·6	28 1 46	28 01	27 1 46	·37820
46 O	XVI	Bhusāwal	old	21	03	40	75	47	00	650	8 1 47	−1 08·5	8 1 47	28 29	9 1 47	·38201
		,,	new	21	03	40	75	46	55	650	10 1 47	−1 15·4	10 1 47	28 22	11 1 47	·38338
48 M	VIII	Dhārwār	old	15	26	36	75	00	10	2400	1 2 46	−2 01·2	3 2 46	16 28	1 2 46	·39318
		,,	new	15	26	39	74	59	53	2400	2 2 46	−2 00·9	3 2 46	16 27	2 2 46	·39281
53 O	LVIII	Kāthgodām	old	29	15	19	79	32	50	1680	21 2 47	+0 24·3	21 2 47	43 32	21 2 47	·34515
		,,	new	29	15	20	79	32	55	1680	22 2 47	+0 24·2	22 2 47	43 36	22 2 47	·34450
55 M	XVII	Jubbulpore	old	23	09	26	79	57	09	1320	17 1 47	−0 56·1	18 1 47	32 19	17 1 47	·37739
		,,	new	23	09	26	79	57	05	1320	19 1 47	−0 55·9	18 1 47	32 19	19 1 47	·37722
58 H	XLIV	Tinnevelly	old	8	44	00	77	42	30	130	20 2 46	−3 18·7	22 2 46	0 42	22 2 46	·39501
		,,	new	8	43	42	77	42	57	130	21 2 46	−3 09·2	23 2 46	+ 0 39	21 2 46	0·39580

* Uncorrected for diurnal variations and peturbations. Simultaneous observations were taken at the old and new sites on dates given in the previous column. The value given here is the mean of different observations.

(*Continued*)

TABLE 2.—*Repeat Stations (old and new sites) observed in 1945–47*—(concld.)

Degree sheet No.	Station No.	Name of station		Latitude N.	Longitude E.	Height	Declination: Dates of observation	Declination: Value*	Dip: Dates of observation	Dip: Value*	Horizontal Force: Dates of observation	Horizontal Force: Value*
				° ′ ″	° ′ ″	feet		° ′		° ′		C.G.S.
58 N	XLVI	Tanjore	old	10 46 40	79 08 20	190	14 2 46	−2 59·4	15 2 46	+ 4 37	14 2 46	0·39826
		,,	new	10 45 47	79 08 26	190	15 2 46	−2 59·4	16 2 46	+ 4 36	15 2 46	·39833
58 O	XLV	Mandapam	old	9 16 50	79 08 30	0	27 2 46	−3 04·5	28 2 46	+ 1 21	27 2 46	·39871
		,,	new	9 16 45	79 07 50	0	26 2 46	−3 04·8	28 2 46	+ 1 22	26 2 46	·39839
63 B	LVII	Cawnpore	..	26 27 00	80 21 00	400	11 2 47 12 2 47	−0 14·0	11 2 47 12 2 47	+38 39	11 2 47 12 2 47	·36277
64 G	LXIII	Raipur	old	21 15 50	81 38 20	970	10 4 46	−1 12·3	12 4 46	+28 49	10 4 46	·38465
		,,	new	21 15 57	81 38 16	970	9 4 46	−1 13·4	11 4 46	+28 47	9 4 46	·38509
65 D	XLVIII	Bezwāda	old	16 31 00	80 36 50	70	17 3 46	−2 13·1	20 3 46	+18 06	17 3 46	·39704
		,,	new	16 31 22	80 37 40	70	21 3 46	−2 11·3	20 3 46	+18 03	19 3 46	·39777
68 B	LXXV	Galle	old	6 01 50	80 12 10	10	6 3 46	−3 39·1	8 3 46	− 6 53	6 3 46	·39546
		,,	new	6 01 47	80 12 17	10	7 3 46	−3 35·1	8 3 46	− 6 59	7 3 46	·39527
73 K	LIX	Balasore	old	21 30 30	84 54 40	50	2 3 46	−1 14·6	4 3 46	+28 33	2 3 46	·38883
		,,	new	21 30 36	86 54 40	50	3 3 46	−1 14·6	4 3 46	+28 33	3 3 46	·38882
74 A	LX	Berhampur (Ganjām)	old	19 18 10	84 48 40	80	25 3 46	−1 36·7	27 3 46	+24 05	25 3 46	·39345
		,,	new	19 17 49	84 47 25	80	26 3 46	−1 45·5	27 3 46	+24 28	26 3 46	·39196
78 D	LXV	Santahar	old	24 48 10	88 59 20	50	24 4 46	−0 43·1	26 4 46	+34 57	26 4 46	·37780
		,,	new	24 48 10	88 59 27	50	25 4 46	−0 41·1	25 4 46	+34 58	27 4 46	·37726
78 G	LXXVI	Phulchari†	new	25 09 52	89 37 30	50	29 4 46	−0 46·8	30 4 46	+35 43	1 5 46	·37546
79 B	LXXIV	Barrackpore	old	22 46 29	88 21 39	20	17 4 46	−0 52·1	21 4 46	+30 52	20 4 46	·38587
		,,	new	22 46 03	88 22 33	20	19 4 46	−0 54·3	21 4 46	+30 51	20 4 46	0·38554

* Uncorrected for diurnal variations and perturbations. Simultaneous observations were taken at the old and new sites on dates given in the previous column. The value given here is the mean of different observations.

† Old site washed away.

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.*