GENERAL REPORT

ON THE OPERATIONS

OF THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA,

DURING

1875-76,

Prepared for submission to the Government of India.

BY

J. B. N. HENNESSEY, ESQ., M.A., F.R.S., &C.,

OFFG. SUPERINTENDENT OF THE SURVEY.

Dehra Dun:

PRINTED AT THE OFFICE OF THE SUPERINTENDENT G. T. SURVEY.

M. J. O'CONNOR.

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List of operations during 1875-76 of the Great Trigonometrical Survey of India showing the pages where they will be found described hereafter in the Report and its Appendix:—

			Report.	Appendix.
		Summary.	2	
No.	I.	*Trigonometrical.* The Madras Coast Series and Ceylon Connecting Triangulation.	5	3—a
„	II.	*Trigonometrical.* The Operations in the Assam Valley. ...	6	5—a
„	III.	*Trigonometrical.* The Secondary Triangulation in Burmah. ...	7	8—a
„	IV.	*Trigonometrical.* The Eastern Frontier Series, Burmah. ...	9	11—a
„	V.	*Trigonometrical.* The Jodhpur Meridional Series and the Eastern Sind Series.	11	15—a
„	VI.	*Spirit Levelling.* Operations in Cutch, Kattywar, &c. ...	12	16—a
„	VII. VIII.	*Geodetic.* Electro-telegraphic determinations of Difference of Longitude.	13	20—a 26—a
„	IX.	*Topographical.* The Surveys in the Dehra Dún District and in the Siwálik Hills.	16	28—a
„	X.	*Topographical.* The Survey of Kattywar.	18	33—a
„	XI.	*Topographical.* The Survey of Guzerat.	20	38—a
„	XII.	*Computing Office.* Calculating and Printing Branches. ...	22	45—a
„	XIII.	*Computing Office.* Drawing and Photozincographing Branches.	24	55—a

Summary of Operations during 1875-76.

Principal Triangulation has been executed by three field parties, *viz.* Nos. I, IV and V of this report: No. I operated along the southern limit of the Coromandel Coast, District Madura, and on the Ceylon Connecting Series; No. IV in Burmah, Province Martaban; and No. V in Rajputana, Bahâwalpur and Sind. The angles as usual were measured with great theodolites whose azimuthal circles are 24 inches in diameter and are read by 5 Micrometer-microscopes. The average theoretical probable error of an angle and the average geometrical error of a triangle (*i.e.* the difference between the sum of the three observed angles of a triangle and 180° + the spherical excess) are shown in the marginal table here given. The total final out-turn is represented by 48 triangles, which if united would exhibit a chain 217 miles in length and 4182 square miles in area. Similarly the total *preparatory* out-turn executed in advance for 1876-77 is represented by 59 stations and a chain of triangles 270 miles in length. A complete set of astronomical observations was taken for verification of azimuth. In all 71 pillars, platforms, scaffolds and towers, at stations of observation, were constructed; 45 stations were closed and protected; and 54 transferred to the care of District Officers.

Section.	Probable Errors of Observed Angles.		Geometrical Errors of Triangles.	
	Number	Amount	Number	Amount
I	40	±0″·19	12	0″·63†
I	24	·20	10	2 ·21*
IV	54	·26	18	·34‡
V	27	·15	9	·48§
Averages...	...	±0″·21	...	0″·82

Secondary Triangulation has been performed as usual by the field parties Nos. I, IV and V above named, and in particular by No. V which completed a very considerable chain in Rajputana designated the Balmer Series. In addition, Nos. II and III have been employed, exclusively, as during the preceding year, in conducting special series, for the determination of prominent points, respectively in the Assam valley and in Burmah, where known points, on which to base other surveys, are much needed: these special series, it must be understood, are classed as secondary, in the sense that their angles are measured with smaller and more portable instruments, read by verniers, in place of great theodolites; otherwise these chains of triangulation are carried on with every due care and precision. Besides the above mentioned field establishments, the topographical survey parties in Guzerat, Kattywar and Dehra Dún have continued their operations, in closely covering the country about to be delineated with the points of secondary triangulation essential for topographical purposes. The total out-turn of all the field parties is represented by 363 triangles in which the three angles were measured; of these triangles 103 were disposed in series, which if united would exhibit a chain 439 miles in length; besides, over 3000 triangles were established for fixing points. The total area covered by all the preceding triangulation amounts to some 9000 square miles, of which 3500 were closely dotted with points for the topographical surveyor; further, the area included by other triangles to distant hill peaks amounts to nearly 7000 square miles. Of heights, 633 have been determined trigonometrically, and 245 differentially by means of the Aneroid barometer. And as regards pillars, and other forms of construction for stations of observation, 220 such structures have been built.

Topographical Operations have been conducted by field parties Nos. IX, X and XI, respectively, in Dehra Dún including the Siwâlik hills and Jaunsár Báwar, Kattywar and Guzerat. The area delineated on scale 4 inches = 1 mile amounts to 1047 square miles, and on scale 2 inches = 1 mile to 3629 square miles: in course of these operations about 2900 miles of boundaries and check lines have

† Stations situated on low ground along the sea coast.

* Obtained from the Ceylon Connecting Series, the stations of which were unavoidably placed on small islands but little raised above sea level and much exposed to inclement weather: the observations were thus taken under considerable disadvantages.

‡ The stations of this section with one exception are all situated on hills.

§ On sand hills.

been traversed with the chain, and some 1800 points fixed by the same means, subject to trigonometrical checks, in localities unsuited for triangulation. As regards the province of Guzerat, it having been decided by the Government of India, that in future the scale of survey should be restricted to the 2-inch scale, further delineations on scale 4 inches = 1 mile will be discontinued.

Surveys Completed. The operations under review are so far distinctive in feature, that by their means no less than three separate surveys have been conducted to final and satisfactory completion: *viz.*, the Jodhpur Meridional Series of principal triangles on the meridian of 72½°, running through the Jodhpur, Jesalmer and Bikaner States of Rajputana and Baháwalpur; the topographical survey of the well known and beautiful valley of Dehra Dún, including its outlying subdivision of Jaunsár Báwar and the Siwálik hills; and the Ceylon Connecting Series. By means of the latter, complete unity can now be introduced between the surveys of Ceylon and India, and the required electro-telegraphic measures, in uniting India and Greenwich longitudinally, will now also establish a similar connection for Ceylon.

Spirit Levelling Operations, chiefly in Cutch and Kattywar, Bombay Presidency, have been carried over 421 linear miles, passing through the towns of Rájkot, Muli, Wadhwán, Viramgám, Pátri and Ahmedabad; 166 Bench-Marks were established along the course followed. The results obtained, from the line of levels executed in 1874-75, connecting the three tidal stations of Okhá, Nawanár and Hanstal on the Gulf of Cutch, appear to indicate, that the mean sea level stands progressively higher, as the tidal station is further removed from the open sea up the Gulf.

Calculations and Publications. The subsidary computations of the Sectional Figure South-East Quadrilateral have been completed; also materials for the 6 Synoptical Volumes of this figure have been well advanced: considerable progress has been made in printing all the preceding results, so that a large portion of the pages for 2 Principal and 6 Synoptical Volumes stand passed through the press. The Synoptical Volume which treats of the North-West Himalaya Series has been published, and Principal Volumes III and IV have been bound. A large portion of the North-East Quadrilateral has been reduced by the method of least squares. As regards Cartographical publications, 7 Numerical Charts of Triangulation and 8 of Spirit Levelled Heights, 43 Maps Topographical and 3 of Explorations, besides minor subjects, have been printed and issued: in all 2,475 Charts, 7,931 Maps and 18,000 Professional forms have been supplied.

Miscellaneous. In all 2,725 principal stations situated in 313 districts have been protected and placed under the care of District officers during the past 11 years. Meteorological observations have been taken twice a day throughout the year and the results communicated to the Reporter to Government North-West Provinces. The Records and Library have been maintained in good condition. &c., &c.

Retirements. The department has suffered serious loss by the retirement of its Senior Deputy Superintendent, Colonel T. G. Montgomerie, R.E., F.R.S., and of Mr. W. C. Rossenrode, Deputy Superintendent 3rd Grade; the latter event stands alluded to in art. (49); the omission of the former would leave this report incomplete, notwithstanding that the present opportunity admits only of very brief notice. Lieutenant Montgomerie entered the department in October 1852: soon after he was present at the Base-lines of Chach and Karáchi, in both of which measurements he took a leading share; besides other work, in 1855 he commenced the Topographical survey of the dominions of His Highness the Maharaja of Kashmir, which he finished within the next 9 years. The scale adopted was suitably varied from 2 to 8 miles per inch; the area included some 20 square degrees, or about 77,000 square miles, on which stand the stupendous mountain ranges of Kárákuram, Chángchenmo, Bárálácha, Mustágh, &c.; the chief towns fixed were Jummoo, Srinagar, Leh, Skardo, Hanle, Muzaffrabad, Kishtwár, Bhadrawár, Bárámúla, Drás, Bij Behára, Naushahra, Rajauri, Kargil, &c.; the principal rivers traced were the Indus, Jhelum, Chenab, Zánskar, Shook, Kishanganga, Astor, Kárákásh, &c.; and of snowy peaks (rising from 16,000 to

the culminating height 28,250 feet of peak at N.E. head of Báltoro Glacier) may be mentioned, Nanga-Parbat, Harámukh, Haramosh, Rákipúshi, Ser Mer, Kárákuram, Bárálácha, &c.: the area of Glaciers extended over more than 1,400 square miles; and the heights ascended, surpassed those recorded as reached by man unaided by balloons.* Lieutenant Montgomerie's name will long continue to be most honorably associated with these operations, which for magnitude, merit and importance are at least unsurpassed.

Returning in 1866 from an absence on furlough for two years, Captain Montgomerie directed the survey of Kumaun and Garhwál with much success. As respects local surveys, those of Mussooree, Kosi Valley and Ránikhet were conducted by him: the last presents an instance of uncommon despatch; it was begun in January 1870 and its 11 maps stood published in the following November. Lastly, he superintended the Trans-Himalayan Explorations, which have contributed so largely to our knowledge of countries that before were almost unknown. It is exceedingly difficult to give an idea of the provinces thus pierced or circumscribed; a brief attempt is however made in the following descriptions of the routes traversed. From Kumaun, northwards to the sources of the Sutlej and Indus, and along a great length of the Brahmaputra eastward through Great Tibet to Lhasa. From Darjeeling, westward to Katmandu, thence over the Dingri Maidan to Shigatze in Great Tibet, onwards in a north-easterly direction round the Tengri Nur Lake, and then southwards to Lhasa. From Kabul *viâ* Bámián and Balkh to Faizabad and Kila Panjah, thence onwards through the Pamirs to Yárkand and Kashghar in Eastern Turkestan, and so back to the Kárákuram pass. From Balkh near the Oxus to Karshi and Bokhara. From Pesháwar to Dír, Chitrál and Zebak in Badakshán. &c., &c. These routes represent a total length of fully 4,500 miles, *along* which, at least, our geographical knowledge has been substantially established.

Lastly, Colonel Montgomerie officiated as Superintendent of Topographical Survey for a while, and as Superintendent of the Great Trigonometrical Survey for 2 years: in addition, his services have repeatedly been honorably mentioned by the Secretary of State and by the Government of India: nor are distinctions at *home* wanting, for he is a Gold Medallist of the Royal Geographical Society as well as a Fellow of the Royal Society. His distinguished services in this Department will long be remembered in connection with his works, and many kind wishes, from those with whom he was here associated, will continue to follow him in his retirement.

Superintendence. The work above summarized and hereafter reported on, was executed under the directions of the Superintendent, Colonel J. T. Walker, R.E., F.R.S., who, proceeding on furlough in April 1876, was succeeded by Captain H. R. Thuillier, R.E., to act in his place. Subsequently on my return from furlough, I was appointed by the Government to relieve Captain Thuillier as Officiating Superintendent: I accordingly received charge on 1st November 1876 and the duty of preparing this report devolved on me.

Explanatory. It only remains to add the following explanatory remark. In compliance with orders received, the Narrative Reports of the Kattywar and Guzerat Survey parties were submitted to Government in original about the first week in last November; this review was commenced soon after, and in due course completed, so far as was practicable in the absence of the Narratives; these were received back on 20th ultimo. Meanwhile, Colonel Walker having resumed charge of the department, my ability to *finish* this report is due entirely to his courtesy.

J. B. N. HENNESSEY.

Deputy Superintendent 1*st Grade.*

late Officiating Superintendent.

DEHRA DUN:
Dated 1*st March* 1877.

* As a matter of fact, one of Lieutenant Montgomerie's assistants (Mr. W. H. Johnson) set up his theodolite on the summit of a peak on the Chángchenmo range and measured the required angles; this point is 20,866 feet above sea level.

NO. I.—TRIGONOMETRICAL.

THE MADRAS COAST SERIES AND CEYLON CONNECTING TRIANGULATION.

PERSONNEL.

Major B. R. Branfill, Deputy Superintendent 2nd Grade.
Mr. G. Belcham, Surveyor 4th Grade.
" C. D. Potter, Assistant Surveyor 1st Grade.
Mr. E. W. Laseron, Asst. Surveyor 2nd Grade.
Mr. A. Bryson, Asst. Surveyor 3rd Grade.

(1.) The Rámnád Longitudinal Series, as explained in previous reports, is based on a side of the Great Arc Series; from whence it proceeds along the parallel of 9½° in an easterly direction, and terminates at the polygon of Uttarakoshamangei, or, more briefly, at the Rámnád polygon, since one of the stations belonging to this hexagon is fixed on a bastion in the fort of Rámnád town. Again, from a southerly side of this figure, the Ceylon Connecting Series with suitable shortened sides continues in an easterly course up to the land's end, the intention being that this chain of triangles should be extended across the Palk Strait, so as to establish on the island of Neduvan suitable stations for the Surveyor General of Ceylon to connect the triangulation of that island with. Up to this stage, the operations were duly reported on in 1873-74.

(2.) During the year 1874-75 Major Branfill proceeded to complete the Ceylon Connecting Series. Also, adopting the northern side of the Rámnád polygon as a base, he finished the first portion of the Madras Coast Series, which, it is intended, shall proceed from Rámnád along the eastern coast and join on to a side of the principal triangulation in the vicinity of Madras. Taking the field early in October, the camp in due course reached Salem: here cholera of a virulent type broke out amongst the men; three deaths occurred, and the District Collector put the establishment in quarantine. On this a panic ensued and a breaking up of the party from desertions became imminent: in brief, Major Branfill had considerable difficulty in reorganizing his camp. Eventually he arrived in safety at Madura, where, dividing his establishment into five working parties, he in the first instance vigorously prosecuted the approximate operations on the Madras Coast Series. Here the country at first was barely passable, being still flooded by the late autumnal rains; however by dint of incessant hard work the required preliminaries for two hexagons were completed in course of two months. Having now arrived at the end of January, Major Branfill commenced the measurement of the principal angles, by himself taking the usual set of circumpolar star observations at the central station of his northern polygon. After this he entrusted the principal observations to Mr. Belcham, who under Major Branfill's care and instruction has proved himself a competent observer with the large theodolite; and deputing two of his assistants to continue the approximate work for next year along the coast, he proceeded to lay out the extension of the Ceylon Series, and finished this work by the end of March. Mr. Belcham followed with the great theodolite and under Major Branfill's supervision completed the required measurement of the principal angles.

(3.) The work thus performed consists of two hexagons on the Madras Coast Series and of a hexagon and a quadrilateral on the Ceylon Connecting Series, forming in all a chain of triangles 80 miles in length and including observations at 21 principal stations. One of the latter gave much anxiety from a singular cause: it was on Rámesweram Island and had been fixed there in 1873-74; the old station however had disappeared, so a new one was established; this had to be watched and protected against the strong wind, which literally blew away some 4 or 5 inches of the surface daily. As regards ray cutting, no less than 348 miles of these lines were cleared, a duty which would have involved far greater time and expense, but for the economical and effective contrivances introduced by Major Branfill for raising the signals as well as the large theodolite to the greatest reliable heights, so as to overlook the lower portion of the foliage with which the country is densely covered. And to provide a sufficient start in the succeeding year, an approximate series of 10 stations was laid out for 36 miles in advance. As already stated, a verificatory azimuth was observed.

ERRATA on this page. *For* 1873-74 *read* 1874-75 and *for* 1874-75 *read* 1875-76.

(4.) Major Branfill's duties were carried on under unusual difficulties. The stations of the Ceylon Series were necessarily all on islands, and visits to these, involving as they did voyages by sea, were not unattended with danger, since this department could not afford to employ better means of transport than those offered by the common open country boats. The series has been laid out with considerable care and skill and the completion of this connecting link between the triangulations of Ceylon and India is a matter for congratulation, not only on the score of its having been well achieved, but in that it meets a long existing desideratum: complete unity can now be introduced between the triangulations of Ceylon and India, and the required electro-telegraphic measures, believed to be not far distant, in connecting India with Greenwich, as respects longitude, will now also establish a similar connection for Ceylon: the ultimate stations fixed by Major Branfill on the island of Neduvan, are those of Amanakkamunai and Urimunai, which afford the required means of junction to the Surveyor General of Ceylon. As respects the operations on the Madras Coast Series, the figures are symmetrical and the work well executed. In concluding this notice it is only just to Major Branfill to add, that his success has been achieved under the unavoidable difficulties presented by the country and climate, and those attending his own failing health.

(5.) Major Branfill having obtained furlough, made over charge of his party on 9th May to Captain W. M. Campbell, R.E, who directed the computations during the recess in addition to his other duties.

NO. II.—TRIGONOMETRICAL.

THE OPERATIONS IN THE ASSAM VALLEY.

(6.) As was stated in the Report for 1874-75, Lieutenant Harman's services were required with the Daphla Field Force for a longer period than he had anticipated when arranging for the prosecution of the Assam Valley triangulation during his absence. Thus on resuming trigonometrical operations in March 1875, he found it impracticable to complete the final observations at all the stations selected, before the setting in of the rains and the consequent termination of the field season. On visiting the remaining stations after the recess, the shoots from tree stumps, bamboos &c. had sprung up to an "astonishing height" on the rays which had been cleared only a few months before, and it became necessary in the first instance to re-open no less than 37 miles of such rays. Proceeding vigorously with the operations, Lieutenant Harman and his assistants succeeded by the end of the season, in advancing the series *finally* from near Sibságar to a little beyond Dibrugarh, or a direct distance of 41 miles. Rays were also cut to the treasury building at Jorhát, so that its position and height were fixed. And as regards Dibrugarh, the church tower at this place was adopted as one of the principal stations of the series. Further, five Revenue Survey pillars were incorporated with the triangulation. And lastly, all the hill peaks north of the Brahmaputra valley, visible from Dibrugarh church tower were fixed.

PERSONNEL.

Lieut. H. J. Harman, R.E., Offg. Assist. Superintendent 2nd Grade.
Mr. W. O'Sullivan, Surveyor 4th Grade.
Mr. E. P. Wrixon, Assist. Surveyor 2nd Grade.
Mr. J. F. McCarthy, Assist. Surveyor 4th Grade.

(7.) From Dibrugarh, the approximate triangulation was continued in two branches. Of these, one proceeds in a south-easterly direction and connecting with Jeypur terminates at the side Deohal Revenue Survey pillar to Hilika Hill station, which is also a station of the Topographical Survey and stands on a spur of the Nágá Hills; the series consists of a chain of 8 triangles. The other and principal branch of the triangulation proceeds north-easterly, spanning the Brahmaputra river up to Sadiya, where it terminates at the side Sadiya Quarter

Guard station to Dikrang Martello Tower station; this series consists of 14 triangles, besides a succession of 3 triangles which are built up like a fan with the Nari Hill as a pivot. This hill being some 600 feet in height, its adoption as a station would carry the series over the difficult waste lands of Paropora both economically and expeditiously. Both these series seem to be well laid out and promise a speedy termination to the operations under Lieutenant Harman's guidance, provided the few long rays do not lead to delay in the final observations.

(8.) The object of adopting the hill Nari as a station is apparent from what has preceded; besides, there is a hill called Pogrosoi, some 15 miles S.W. of the former, which is also highly desirable as a station of observation; because these two hills conjointly present an excellent base for survey purposes if required hereafter, as well as suitable eminences from whence a considerable area of unknown country could be sketched now. Unfortunately both the hills are within Abar territory and therefore may not be visited without the consent of their owners. Being however impressed with the necessity for obtaining access to these hills, Lieutenant Harman, in consultation with the Deputy Commissioner, communicated with the chiefs in question, so that they assembled to meet him with the avowed intention of granting the required permission. The resulting palaver however ended in disappointment, for "each Abar chief" writes Lieutenant Harman "stood forward in turn and forbade the journey: they did not much object to my going alone provided I made no map for the Queen to see," and so on. Subsequent correspondence through Government leaves it probable that the Abar chiefs in question may yet be induced to permit a visit by Lieutenant Harman to the Nari and Pogrosoi hills.

(9.) In all, the angles of thirteen triangles have been finally measured; 35 stations have been selected; 12 post and pillar stations were constructed; and besides other work, 194 miles of rays were cleared under circumstances which make progress in such an operation slow and laborious. Lieutenant Harman's out-turn of work is not only large, but so far as I have the means of judging, it has been well executed. The progress made is very creditable to Lieutenant Harman, who was well supported by two of his assistants, *viz.* Mr. O'Sullivan and Mr. McCarthy.

No. III.—TRIGONOMETRICAL.

THE SECONDARY TRIANGULATION IN BURMAH.

(10.) This secondary triangulation, it will be remembered, was designed with the view of fixing all prominent buildings and other objects in large towns and elsewhere for the purposes of topographical and geological surveys, while lighthouses &c. along the coast were also to be determined in position for the Marine Survey. The required operations were again conducted by Mr. W. G. Beverley aided by the assistants who were under his directions during the previous year and, in addition, by Mr. J. Low, whose services were transferred to the party in order to ensure greater progress and thus to meet the urgent demand which exists for trigonometrical data in Burmah. Mr. Beverley was thus enabled to set three detachments at work in the field, whereby he not only resumed the triangulation begun the season before but extended his operations in other directions as well.

PERSONNEL.

W. G Beverley, Esq., Offg. Assistant Superintendent 1st Grade.
Mr. J. Low, Surveyor 2nd Grade.
" J. W. Mitchell, Surveyor 4th Grade.
Mr. D. J. Collins, Asst. Surveyor 4th Grade.

(11.) The Series commenced last year was projected to pass southwards through Pegu and Rangoon, but notwithstanding several attempts made, it was found impossible to connect the work with the principal stations of the Eastern Frontier Series, owing to the unfavourable state of the atmosphere which prevailed.

In fact, a sensible portion of the country appears to be under water at the commencement of the field season, and mist and haze greatly delay observations towards the termination of the operations; under these circumstances the surveyor needs to make the most of the interval, and even this is beset with unusual difficulties, as may be gleaned from Mr. Beverley's narrative. Notwithstanding, the required junction above alluded to was effected; further, this series after fixing Pegu and Rangoon was extended to China Bakir: here the old light-house had given place to a new one constructed some 5 miles out at sea; so that it became necessary to open new rays to the new structure, and to this end it was essential to take angles at the old light-house before its demolition. Mr. Beverley performed this duty in person after "wading through a mile of mud and water under a burning sun," and thereby incurred an attack of malarious fever. Approximate operations on the series were subsequently continued along the coast towards Krishna Shoal light, which under favorable circumstances may be reached during next year. The position of China Bakir light-house was supplied, so soon as known, to the Master Attendant.

(12.) Of new series, one was based on the side Myá-yábengkya H. S. to Theyekhír H. S. of the Eastern Frontier principal triangulation, and the selection of stations and other preliminary work carried on up to Tounghoo Pagoda; but this work being commenced late in the season, the haze and rainy weather soon after set in and final observations could not be completed at more than one station. It is intended that the chain of triangles should turn westward on reaching the Boundary north of Tounghoo and, following this limit, should hereafter be connected with another series, also projected in 1875-76, which spans the Irrawaddy river north of Thayetmyo.

(13.) The series last mentioned commences a little north of Thayetmyo; it proceeds along the Irrawaddy and fixing Prome passes on southwards: in a direct distance sixty miles were completed last year of this triangulation, by which moreover numerous points were determined in the civil stations of Thayetmyo and Prome, a large number of heights were obtained and an area of some 3600 square miles covered with trigonometrical points for after purposes of internal surveys: means have also been afforded of making a connection with the line of railway, for the purpose of providing the latter with a reference to sea level. The country passed over is described as densely wooded and well populated.

(14.) The last series projected in 1875-76 remaining to be noticed, is one which Mr. Beverley executed in person, in addition to a general supervision of all the other operations: it commences on the Irrawaddy a few miles north-west of Myanong and proceeding generally in a southerly direction is intended to fix Bassein and to be continued to Cape Negrais. The main ridge of hills in the Henzada district could not be utilized, while the spurs from this ridge were too densely wooded and too short to admit of their being turned to account: eventually Mr. Beverley contrived to find his way between the river and the hills, chiefly by adopting the contrivance of basing his triangles alternately on flank rays all on one flank and cross rays, so that visibility along the other flank, which was impossible, was dispensed with. In a direct distance 81 miles were completed of this triangulation, thus bringing it down to within 32 miles of Bassein.

(15.) Mr. Beverley and his assistants have executed a very satisfactory amount of work and their success is all the more creditable that they have been beset with more than ordinary difficulties.

NO. IV.—TRIGONOMETRICAL.

THE EASTERN FRONTIER SERIES, BURMAH.

PERSONNEL.

W. C. Rossenrode, Esq., Deputy Superintendent 3rd Grade.
Mr. H. Beverley, Surv. 1st Grade.
" J. C. Clancey, Assistant Surveyor 3rd Grade.
Mr. J. O. Hughes, Assistant Surveyor 3rd Grade.

(16.) The principal observations on this series were resumed at the earliest possible date in order that the work should be completed, at least where the long rays occur, before the inevitable hazy weather set in. Accordingly Mr. Rossenrode with the great theodolite took the field on 26th October; the country however was still under water, so that it was impossible to proceed along the land by marching in the usual manner: hence the entire party, with instruments, baggage, and provisions, embarked in boats, and were thus transported from the vicinity of one station to that of another until 8 stations had been completed. Arriving now at Amherst Mr. Rossenrode was able to resume his ordinary mode of locomotion on land, subject however to the usual difficulties which Burmah as yet presents to travellers. He was so far fortunate on this occasion, that the trunk road to Yeh and Tavoy fell within his operations, for though only partially finished it afforded to his party the unusual luxury of travelling along a comparatively made highway. Ordinarily Mr. Rossenrode's marches were made along foot paths cut originally by one of his own detachments in proceeding from a known station towards one as yet unknown; and not only had they no alternative in adopting these forest tracks as roadways, but in the absence of all other lines of communication they had occasionally to march back no inconsiderable distances along gaps of this kind, in order to fall into some other opening which would again conduct them in a forward direction. As to crossing the rivers where they occurred in the interior of the country, the only mode of transport offered was in the form of canoes, which however well suited to the wants of natives of the country (whose wardrobe as described by Mr. Rossenrode consists of a suit or two of palm leaf apparel) "sway, roll, and capsize" but too readily if occupied by men like ours unaccustomed to such boats. Pushing on however with his usual perseverance Mr. Rossenrode eventually found himself at the last station of the season, but only in time to be enveloped by the haze; whereupon he resolutely sat down to wait for rain, which rewarded him with heavy falls, so that the atmosphere having cleared he finished his observations and marched into recess quarters at Moulmein.

(17.) Meanwhile the approximate and secondary operations were vigorously prosecuted by Mr. H. Beverley, assisted by Messrs. Clancey and Hughes. As the pioneer of the whole establishment and enveloped in dense jungle Mr. Beverley frequently cut his way from station to station, compass in hand, followed by his camp equipage. Creeks and tidal streams added as usual to his difficulties, and when at last mounted on the required hill top, he had arrived only at the beginning of a laborious task which involved clearing the site of heavy trees so as to obtain a view around. Proceeding in this manner, he found himself in the vicinity of Yeh, where the strip of British territory is only some 25 miles from sea to Boundary, and the hill of Yetagundine obstructs the view across; under these circumstances he formed a tetragon round the hill, and being thus enabled to continue his progress, he selected an additional double polygon to complete the season's work.

(18.) In respect to general progress made:—principal observations were commenced at the Kathbatong hexagon, about 48 miles north of Moulmein, and were carried down to within some 24 miles north of Yeh, covering a direct distance of 116 miles. The chain thus completed comprises a hexagon, a pentagon, and a heptagon with an internal transverse ray, besides rather more than half of the succeeding figure around Yebudong hill station. In at least two instances Mr. Rossenrode overcame no ordinary difficulties in carrying the great theodolite to the required summit. At Wabiantong the road occupied a detachment a whole

month to fit it for a passage for the instrument; notwithstanding, the ascent proved a perilous undertaking, and when achieved it was found impossible to pitch the observatory tent. A hut supported by poles jammed into fissures between rocks was accordingly adopted as shelter for the theodolite, but the structure was so manifestly insecure that observations were taken only during the day and the instrument packed up every evening. In fact, as Mr. Rossenrode briefly remarks, one face of the hill was so perpendicular that its base could be seen from its summit. It was however at Kamákabo that he overcame almost insuperable difficulties in transporting his great theodolite to the hill summit. The hill was very precipitous with sharp projecting rocks which jutted out in every direction; it was as impossible, with his very limited means, to remove these rocks, as it was to make a road in and out around them: as a last resort, ladders from 16 to 40 feet in length were stretched from rock to rock, and along these ladders he effected a most perilous ascent and descent with no little courage. His great theodolite though one of the lightest of its class weighs 618 lbs, and its smallest case is 300 lbs in weight. "It was a day of rejoicing" says Mr. Rossenrode "when the instrument was brought down in safety". Of further progress; the approximate work of the season supplied a portion of the preceding figures: beginning with Konlah on the island of Belogyún, the selection includes the pentagon and succeeding figure already mentioned, a tetragon, and a double polygon, comprising in all a direct distance of 100 miles: 12 stations in advance remain as a commencement for next season's principal observations. Lastly, by means of secondary triangles, Martaban, Moulmein, Amherst, Double Island light-house, &c. have been amply determined, besides that the prominent peaks along the series have also been fixed.

(19.) Under favorable conditions Mr. Rossenrode's out-turn of work would be considered as a creditable performance; but circumstanced as he was under many disadvantages, he has earned my best commendations. This is Mr. Rossenrode's last contribution to the operations of the Great Trigonometrical Survey of India, for worn out with a long series of arduous and successful achievements he has recently retired from duty, recommended for a special pension in consideration of his good services. Mr. W. C. Rossenrode entered this department in 1839, when it was under the direction of Colonel G. Everest R.A., (afterwards Sir G. Everest, C.B.); subsequently he served under Colonel A. S. Waugh, R.E., (now General Sir Andrew Waugh); and since 1861, under the present Superintendent, Colonel J. T. Walker, R.E: he invariably conducted himself so as to win their confidence and good opinion. He also served with credit on the Budhon, Rangir, Pilibit, and Malancha series. In 1848 Mr. Rossenrode was selected to lay out the approximate triangulation of the Great Longitudinal, stretching across the desert from Sironj in Central India to Karáchi in Sind; and it was here, under the orders of the late Colonel A. Strange, F.R.S., that he first earned the title he has since so well maintained to rank as one of our most valued pioneers; he lead the way for Colonel Strange's operations in a manner which elicited that officer's highest commendations. Later on, he selected the Karáchi base-line of verification, and continuing to rise in the department he first succeeded to the charge of a field party in 1859. Mr. Rossenrode has since acted as the leader of one of our field establishments for nearly 17 years: during that period he has covered many a district with triangulation and in doing so has travelled many a thousand miles. The greater portion of his services have moreover been rendered in difficult ground, often through dense and uninhabited forests, subject to many dangers, including injury from wild beasts, attacks by predatory tribes, and but too frequently to the deadly and lasting influence of malaria. Through all these, Mr. Rossenrode has worked earnestly and well, and now that the time has arrived when he can toil no more, he leaves the department accompanied by many good wishes that he may long enjoy the reward of his labors in a repose so honorably won.

NO. V.—TRIGONOMETRICAL.

THE JODHPUR MERIDIONAL SERIES AND THE EASTERN SIND SERIES.

PERSONNEL.

Captain M. W. Rogers, R.E., Offg. Deputy Superintendent 3rd Grade.
Mr. W. C. Price, Surveyor 4th Grade.
Mr. C. P. Torrens, Assistant Surveyor 3rd Grade.
Mr. P. F. Prunty, Assistant Surveyor 4th Grade.

(20.) The duties devolving on Captain Rogers were peculiar in the circumstance, that he was required successively to prosecute operations which were separated by $2\frac{1}{2}^{\circ}$ of longitude: in the first instance he was desired to complete the Jodhpur Meridional Series on the meridian of $72\frac{1}{2}^{\circ}$, and then to begin a new chain of principal triangles, on the meridian of 70°, terminating to the north at the Great Indus Series and to the south at the Karáchi Longitudinal Series. The new triangulation was named the Eastern Sind Series.

(21.) The late and very heavy rains delayed the arrival of stores and men essential for Captain Rogers' field operations; he therefore applied all his available means in starting his assistants, while he proceeded to Deesa, where, at the request of the Government of Bombay and in compliance with the suggestion of the Meteorologist to the Government of India, he inspected the Meteorological Observatory, reported on the same, and laid out a short triangulation in order to connect the observatory and telegraph office with the Karáchi Longitudinal Series. Marching next to the northern terminus of the Jodhpur Meridional Series, he completed the remaining approximate work of the terminal double polygon, and then proceeding with the measurement of the principal angles he finished these operations by the 3rd January.

(22.) Subsequently Captain Rogers marched across to the proposed northern terminus of the Eastern Sind Series with the view of commencing the required triangulation at that end, while Mr. Price was deputed to operate similarly at the southern terminus. Unfortunately the river Indus had washed away several of the old stations about the most convenient locality, so that Captain Rogers was obliged to adopt an initial side west of the given meridian: gradually working on to the required meridian and then turning southwards, he at first had to operate on a country quite flat and covered with dense tree and grass jungle; but pushing onwards through these difficulties, he arrived in a region of sand hills which promises suitably elevated sites and corresponding facilities for the operations next season: his approximate work was closed at the commencement of this hilly region. At the southern terminus Mr. Price was at first unfortunate in being prostrated, with all his men, by fever, so that they resorted to Deesa for medical aid: on recovery from this attack, he made effective progress in advancing the approximate operations northwards. Meanwhile a third detachment under Mr. Torrens began and completed an extensive series of secondary triangles, named the Balmer Minor Series.

(23.) On the Jodhpur Meridional Series, the final angles were measured at 9 principal stations, of which 7 had first to be selected and otherwise prepared for observation: this work completed the terminal double polygon, 21 miles in direct length, which remained to bring the chain of triangles to a conclusion. The series thus begun and finished by Captain Rogers originates at a side of the Karáchi Longitudinal Series, from whence, stretching across the intervening distance of 311 miles, it joins on to the Sutlej Series in the same longitude as it was begun, *i.e.* $72\frac{1}{2}^{\circ}$: the country included is plentifully dotted with sand hills lying on a waste of sand, but though on the one hand these hills facilitated the operations by presenting elevated sites for stations, on the other, occurring as they do in countries thinly populated and but very scantily supplied with water, Captain Rogers' task on the whole was so arduous that he deserves every commendation for having completed it with success: in the most arid portion of the tract surveyed but three wells of drinkable water were found in a distance of 70 miles.

(24.) On the Eastern Sind Series, the operations were intentionally re-

NOTE.—The *errors* of the Jodhpur Series at its junction with the Sutlej Series are as follows; in Latitude = −0″·17; Longitude = −0″·11; Azimuth = −3″·23; Height = 11 feet; side = − 1·8 inches per mile.

stricted to approximate work: this has been prosecuted vigorously both from north and south; in the former case for 24 miles, comprising 8 stations; in the latter for 110 miles including 24 stations. Although from the primary nature of the work it cannot be exhibited on the chart of final operations which precedes this report, yet it is not to be reckoned the less to the credit of Captain Rogers, who with this excellent start will probably make a very considerable impression next season on the entire series. The secondary triangulation executed on the Balmer Series is 152 miles in length; it fixes 95 points both in geographical position and height, including three important Revenue Survey stations and other prominent and desirable objects.

NO. VI.—SPIRIT LEVELLING.

OPERATIONS IN CUTCH, KATTYWAR, &c.

PERSONNEL.

Captain A. Baird, R.E., Offg. Assistant Superintendent 1st Grade.
Mr. T. H. Rendell, Assistant Surveyor 1st Grade.
Nursing Dass and other Sub-Surveyors.

(25.) During the portion of the recess which remained when submitting his report on the operations of 1874-75, Captain Baird continued to occupy himself with the final reduction of the registrations at each tidal station, and before the resumption of field duties obtained the results which are given in paras. 2 and 3 of his narrative report. He also reduced his spirit levelling operations carried along both sides of the Gulf of Cutch, whereby, it will be remembered, the three tidal stations of Okha, Hanstal, and Nawanár were connected with one another. He was thus in a position to compare the three mean sea levels determined at the tidal stations by means of the differences of height between these stations obtained by spirit levelling; and proceeding in this manner, it will be seen, that reckoning the Bench Mark **A** at Hanstal as *datum*, the following values of mean sea level may be exhibited:—

Values of mean sea level *below* the B. M. **A** at Hanstal tidal station

	feet.
as observed by tidal observations at Hanstal	9·702
as deduced from tidal observations at Nawanár by means of the spirit levelled difference of height	9·895
as deduced from tidal observations at Okha by means of the spirit levelled difference of height	10·273

from which it appears that, provided the spirit levelling is taken as errorless, the mean sea level at Hanstal is higher than that at Nawanár by 0·193 feet, and the mean sea level at Nawanár higher than that at Okha by 0·378 feet. Of these stations it will be remembered that Okha stands furthest out to seaward on the southern margin of the Gulf of Cutch; that Nawanár is about half up the gulf and on the opposite coast; and that Hanstal is at the head of the gulf. It thus seems that the mean sea level stands progressively higher as the station of observation is removed up the gulf. Apart from these facts, the table of tidal results given by Captain Baird shows a close accordance between certain values of mean sea level at the same station; *viz.*, the value obtained from 12½ lunations in comparison with that derived from the 2 lunations which occur from March to May; an agreement which Colonel Walker predicted as very probable.

(26.) On taking the field Captain Baird divided his establishment into two portions, each including two levellers; one of these parties was placed under Mr. Rendell, the other Captain Baird retained under his own charge: both parties were to commence work at bench-marks established the previous season on the line of levels connecting the three tidal stations. Captain Baird commenced with the main line at Jorya, and proceeding south-easterly continued generally in this

course to Rájkot; from here turning north-easterly he passed through Chotila, Muli, &c., and arrived at Wadhwán: from the latter place the line was run along the Bombay Baroda and Central India Railway to Viramgám, and from thence *viâ* Ahmedabad to Mehmadabad; branch lines being projected as usual where required. Mr. Rendell began work with the loop line at Shikárpur and proceeded on to Adisar; beyond this he had to cross that part of the Runn which here divides Cutch from the Pálanpur State and this he was surprised to find under water to a depth varying from 1 to 2 feet: to overcome this difficulty he established suitable stations right across the Runn on pegs driven through the water into the ground; and planting his staves and instruments on these pegs he contrived to get across satisfactorily: he reports the bottom of the Runn here to be concave in the section he made, with a depression of some 2 feet at the centre. Mr. Rendell continued the north-easterly course in which he started to Gokatar, and from thence turning to the south-east he proceeded onwards to Pátri, and eventually closed on the bench-mark at Viramgám established by Captain Baird.

(27.) Captain Baird levelled over 249 miles, and Mr. Rendell over 171 miles, making in all the excellent out-turn of 420 miles, executed in each case by two observers and subject to the rigorous conditions of exactness which in lines of such considerable length are essential: 24 survey stations and 106 *paka* points were connected; besides which 36 bench-marks, embedded in the usual manner, were established. The main line thus executed by Captain Baird and the loop line levelled by Mr. Rendell, when combined with the line between their starting points (Jorya to Shikárpur) established a complete circuit: the difference in height, on comparison at the point common to the two parties at Viramgám, amounted to 0·536 feet, and even assuming that the whole of this error is due to the loop line, which was executed with comparatively inferior instruments, the percentage of error per mile amounts to ·004 feet.

(28.) Unfortunately Captain Baird in course of his duties suffered from fever, so that he obtained 3 months' leave and proceeded to England for a change. Meanwhile however, it had become evident, that the large mass of his tidal observations could not be reduced in this country except at the considerable cost of restricting Captain Baird to the duty of computations solely: as a more expeditious and far more economical measure, Colonel Walker recommended that advantage should be taken of Captain Baird's presence in England, where, in concert with Mr. Roberts of the Nautical Almanac Office, he should be authorized to reduce his observations. This suggestion having met with approval, Captain Baird and Mr. Roberts are now engaged on the work in England.

(29.) Captain Baird made over charge of his party on 12th June to Major C. T. Haig, R.E., who conducted the computations during the recess in addition to his other duties.

NOS. VII AND VIII.—GEODETIC.

ELECTRO-TELEGRAPHIC DETERMINATIONS OF DIFFERENCE OF LONGITUDE.

(30.) These operations it will be remembered were begun in 1872-73 and were then conducted by Captain J. Herschel, R.E., F.R.S., assisted by Captain W. M. Campbell, R.E., who finished the two arcs Madras-Bangalore and Bangalore-Mangalore. Complete discussions by these officers of the instruments employed, the procedure followed and the work executed will be found in the appendix to the report for the year above named, the introduction to these papers by Colonel J. T. Walker, R.E., F.R.S., being placed as usual in the body of the report in

question. In course of the preceding operations it was seen that No. 1 of the pair of transit instruments and B of the two similar chronographs exhibited such serious faults in performance that it became a matter of much importance to detect and eliminate their causes. Meanwhile however Captains Herschel and Campbell proceeded successively on furlough, and on the return of the latter he was deputed to aid Colonel J. F. Tennant, R.E., F.R.S., in observing the Transit of Venus. Thus the longitude observations fell into abeyance for a time, nor were Captain Campbell's services again available for the purpose until the end of April 1875, when it was too late to begin field operations. He therefore turned his attention to the instrumental defects above mentioned, and to such excellent purpose, that he appreciably cured the faults in the transit instrument, and devised remedies for the chronograph which he entrusted to Mr. Doderet, the Mathematical Instrument Maker to Government at Madras, to execute: the details of these matters are given by Captain Campbell in the Appendix to the report for 1874-75.

(31.) During the year under review, Captain Campbell, with the aid of Captain W. J. Heaviside, R.E., undertook the more comprehensive programme of operations hereafter mentioned. He began by applying to the defective chronograph the improvements which had been devised by himself and executed by Mr. Doderet during the recess and found these entirely successful. On this he took the field and proceeded to Hyderabad where he was joined by Captain Heaviside.

(32.) The proposed programme for the season's operations involved the measurements of the following arcs

PERSONNEL.

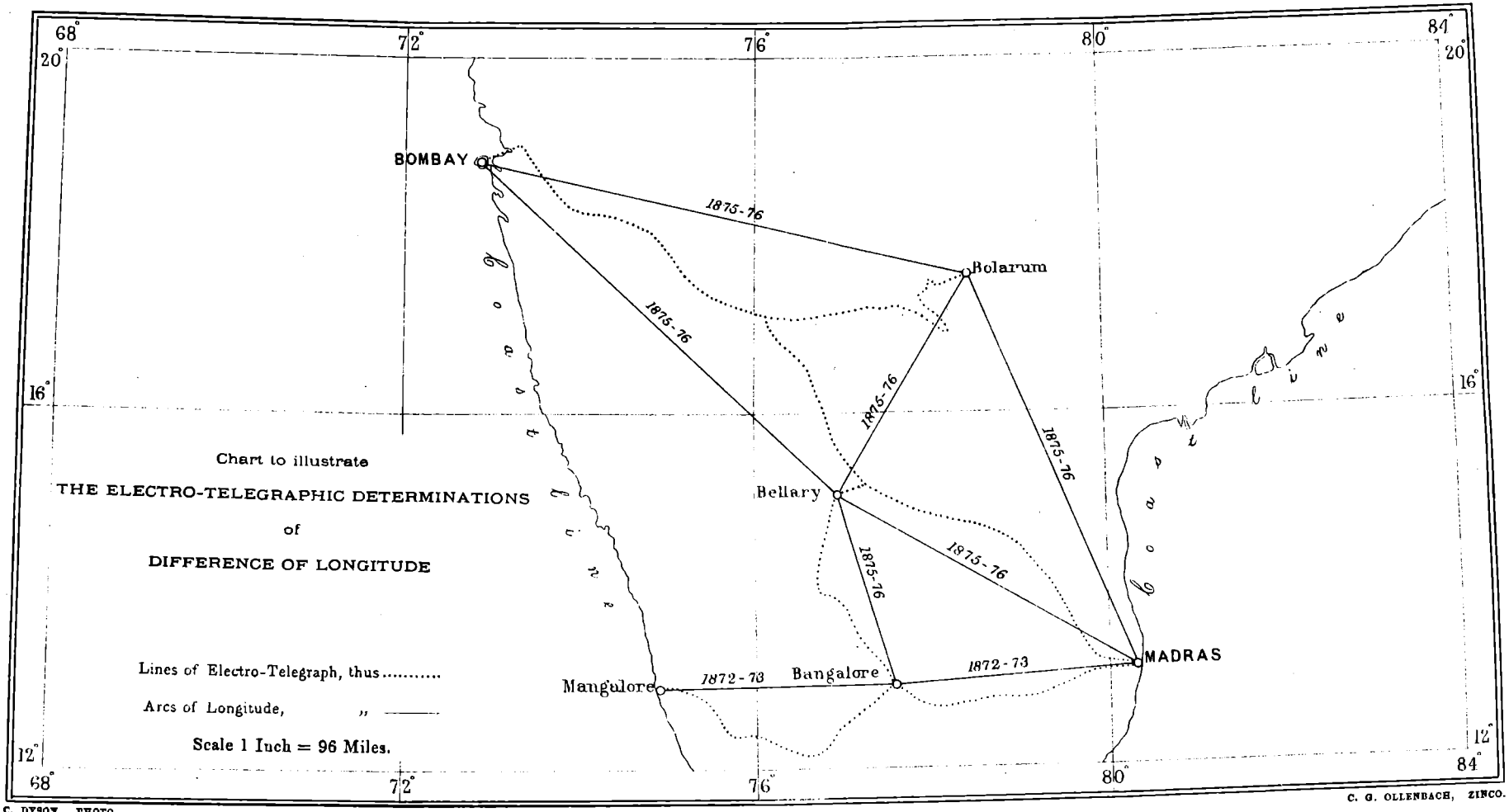
Captain W. M. Campbell, R.E., Offg. Deputy Superintendent 2nd Grade
Mr. J. Bond, Assistant Surveyor 1st Grade.

Captain W. J. Heaviside, R.E., Deputy Superintendent 3rd Grade.
Mr. H. E. T. Keelan, Surveyor 3rd Grade.

1. Hyderabad-Bombay
2. Bellary-Bombay
3. Bellary-Hyderabad
4. Madras-Hyderabad
5. Madras-Bellary
6. Bangalore-Bellary
7. Bellary-Mangalore.

Of these, 1 to 6 were successfully completed: the arc last named could not be undertaken from want of time. Arrived at Hyderabad, Captain Campbell selected a suitable station at Bolarum in preference to locating himself near the neighbouring telegraph stations at Hyderabad and Secunderabad. Here in due course Captain Heaviside under Captain Campbell's instructions acquired the instrumental and other special knowledge necessary in these operations; after which the observers proceeded to determine values of the personal equation between them, using both transit-instruments for this purpose. Subsequently Captain Heaviside dismantled and removed his instruments to Bombay, Captain Campbell standing fast at Bolarum, and thus the arc Bolarum-Bombay was begun and completed. Next Captain Campbell moved to Bellary, and in conjunction with Captain Heaviside at Bombay measured the arc Bellary-Bombay. After this Captain Campbell proceeded to Bombay, where values of personal equation were determined with Captain Heaviside's transit. Then, the latter officer moving to Bolarum and the former returning to his camp at Bellary, they measured the arc between these stations, thus completing a circuit. The next arc, Madras-Bolarum, was measured with Captain Heaviside at the latter and Captain Campbell at the former station. Subsequently, while his instruments were being shifted to Bellary, Captain Heaviside visited Captain Campbell at Madras, where values of personal equation were determined, this time with Captain Campbell's telescope: after this Captain Heaviside proceeded to Bellary and the observers finished the arc Madras-Bellary, thus completing the second circuit of the season. Finally, while his colleague stood fast at Bellary, Captain Campbell moved to Bangalore and the arc between them was duly measured. The season's operations were closed at Bangalore by determinations of values of personal equations with both the transits.

(33.) Besides the improvements already mentioned, Captain Campbell's experience and skill have enabled him to make other amendments; these will be found described in his narrative, given in the appendix to this report, to which I invite attention. The nicety of appreciation, so essential in these delicate opera-



C. DYSON, PHOTO.

C. G. OLLENBACH, ZINCO.

Photozincographed at the Office of the Superintendent, Great Trigonometrical Survey, Dehra Dún, December 1876.

tions, is apparent in his instrumental arrangements, while his own and Captain Heaviside's skill as observers, combined with their foresight, unremitting care and assiduity, have enabled them to complete an amount of work which is excellent in quality and ample in quantity. The extent of their success is also partly due to the accommodations they enjoyed in respect to the telegraph wires, through the courtesy of Colonel D. G. Robinson, R.E., Director General of Telegraphs, and his officers, whereby, during the measurements of all the arcs, save the first, the observers obtained the use of the line wire uninterruptedly during their programme for each night. In addition, Captain Campbell received every assistance and kindness from Mr. Pogson, Government Astronomer at Madras, while Captain Heaviside enjoyed similar hearty co-operation at the hands of Mr. C. Chambers, F.R.S., Superintendent of the Observatory at Bombay.

(34.) Captain Campbell having completed the necessary calculations during the past recess, has forwarded the following abstract of results, just in time to enable me to include it in this report.

ABSTRACT OF RESULTS.

Circuit I, 1875-76.

ΔL	Bolarum-Bombay, ...		$22^m\ 48^s{\cdot}866 \pm {\cdot}0084$
„	Bellary-Bombay, ...		$16\ 26{\cdot}941 \pm {\cdot}0130$
„	Bolarum-Bellary,	deduced, ...	$6\ 21{\cdot}925 \pm {\cdot}0155$
		observed, ...	$6\ 21{\cdot}875 \pm {\cdot}0126$
		Difference, ...	$0\ {\cdot}050 \pm {\cdot}0200$

Circuit II, 1875-76.

ΔL	Madras-Bolarum, ...		$6\ 54{\cdot}701 \pm {\cdot}0123$
„	Madras-Bellary, ...		$13\ 16{\cdot}591 \pm {\cdot}0124$
„	Bolarum-Bellary,	deduced, ...	$6\ 21{\cdot}890 \pm {\cdot}0175$
		observed, ...	$6\ 21{\cdot}875 \pm {\cdot}0126$
		Difference, ...	$0\ {\cdot}015 \pm {\cdot}0216$

Circuits I and II combined, 1875-76.

ΔL	Bolarum-Bombay, ...		$22\ 48{\cdot}866 \pm {\cdot}0084$
„	Madras-Bolarum, ...		$6\ 54{\cdot}701 \pm {\cdot}0123$
„ (1)	Madras-Bombay, ...		$29\ 43{\cdot}567 \pm {\cdot}0149$
„	Bellary-Bombay, ...		$16\ 26{\cdot}941 \pm {\cdot}0130$
„	Madras-Bellary, ...		$13\ 16{\cdot}591 \pm {\cdot}0124$
„ (2)	Madras-Bombay, ...		$29\ 43{\cdot}532 \pm {\cdot}0180$
	Difference between (1) & (2),		$0\ {\cdot}035 \pm {\cdot}0234$
	Mean of (1) & (2), ...		$29\ 43{\cdot}550 \pm {\cdot}0117$

Circuit III, 1872-73 and 1875-76.

ΔL	Madras-Bellary,	...	...	...	...	13^m	$16^s \cdot 591 \pm \cdot 0124$
„	Bangalore-Bellary,	...	...	...	...	2	$37 \cdot 346 \pm \cdot 0145$
„	Madras-Bangalore deduced,		...	...	...	10	$39 \cdot 245 \pm \cdot 0191$
	Do. measured in 1873,			...	...	10	$39 \cdot 079 \pm \cdot 0102$
			Difference,		...		$^*0 \cdot 166 \pm \cdot 0217$

A discussion of the error arising from the method of deducing the collimation and level corrections of the faulty telescope (No. 2) in Season 1872-73 (which will be found with the results of that season) satisfactorily accounts by actual figures for $0^s \cdot 10$ of the large discrepancy $^*(0^s \cdot 166)$ found above, while it indicates the probability of a considerably larger quantity. W. M. C.

It will be seen that circuits I and II re-enter very satisfactorily, and that in the alternative circuit formed by combining these two, a partial cancelment of their individual errors occurs. In circuit III, the arc Madras-Bangalore was measured in 1873 before the defects of transit No. 2 had been eliminated; hence the unsatisfactory re-entering discrepancy of $0^s \cdot 166$; this, as Captain Campbell shows, reduces by calculation to $0^s \cdot 066$, with an indicated probability that a further correction is due.

NO. IX.—TOPOGRAPHICAL.

THE SURVEYS IN THE DEHRA DÚN DISTRICT AND IN THE SIWALIK HILLS.

(35.) These surveys, as heretofore, have been carried on conjointly by Captain H. R. Thuillier, R.E., in charge of the Kumaun and Garhwál Party, and by Captain F. Bailey, R.E., Superintendent of Forest Surveys. The latter, working for the requirements of forestry, undertook the internal details of those portions of the country included within the boundaries of the Government forests, leaving the remainder of the ground to be mapped by Captain Thuillier: thus the operations of these officers when combined produce a complete map of the Dehra Dún district, including Jaunsár Báwar, and of the southern portions of the Siwalik Hills so far as the Government forests extend. The allotment of country to each officer will be readily seen by a glance at the index map, in which the portions assigned to Captain Bailey are not colored. Captain Thuillier continued to direct the operations intrusted to him until the end of February, when in compliance with orders he made over charge of his party to Mr. E. C. Ryall and proceeded to join the Superintendent: thus the field duties were conducted successively by Captain Thuillier and Mr. Ryall, and accordingly their separate narrative reports on the subject are given in the Appendix.

PERSONNEL.

Captain H. R. Thuillier, R.E., Offg. Deputy Superintendent 1st Grade.
E. C. Ryall, Esquire, Offg. Assistant Superintendent 2nd Grade.
Mr. C. J. Neuville, Surv. 2nd Grade.
„ W. Todd, „ 2nd „
„ H. Todd, Asst. „ 1st „
„ T. Kinney, „ „ 1st „
„ E. F. Litchfield, Asst. Surveyor 2nd Grade.
Mr. I. S. Pocock, Asst. Surveyor 3rd Grade.
Mr. R. F. Warwick, Asst. Surveyor 4th Grade.
7 Native Surveyors.

(36.) At the close of season 1874-75, the operations remaining in the Dehra valley were restricted to the Eastern Dún, and of this tract the whole had been triangulated while about one half had been traversed. In Jaunsár Báwar the entire country had been triangulated and was so far prepared for plane tabling, subject to such further additions as the subsequent operations might require. Commencing at this stage, Captain Thuillier devided his establishment into two

portions; one of these he placed under Mr. Ryall and sent into Jaunsár Báwar to survey that subdivision, while he retained the other under his immediate directions to operate on the eastern portion of the Dehra Dún. As regards the parts of Kumaun and Garhwál which could not be finished in 1874-75, it may be here stated, that these tracts were not visited: they comprise only some 1,200 square miles, but lying as they do on the north-eastern confines of the district and at considerable altitudes and thus being difficult of access, it was deemed undesirable to incur the necessary heavy outlay which the work would involve, especially in view of finishing the survey in the Dehra Dún district.

(37.) Taking the field about 20th October Captain Thuillier commenced his operations in the Eastern Dún: like the rest of the valley, the country is cut up by numerous watercourses; elsewhere it is generally covered by dense forests, so that the area under cultivation is very small: in addition, the spurs running down from the Himalayas here terminate in abrupt precipices, each succeeded by a forest-covered plateau which is so flat that the water lodges thereon and presents a huge swamp: these swamps range from 1 to 2¼ thousand feet above sea level, while the hills north of them rise to over 7,000 feet. Under such circumstances the work was not only difficult but exceedingly tedious and trying to health. Fifty-four miles of check traverses were run to test the work, and Captain Thuillier examined the hill sketching in person, both in the Dehra Dún and also in the Amláwa valley of Jaunsár Báwar.

(38.) Mr. Ryall commenced field work in Jaunsár Báwar on 22nd October. He rightly adopted various watersheds as boundaries for the different plane-tables in place of the co-ordinates which are more convenient on table land, and he established additional trigonometrical points to facilitate the topographical work in the valleys and on the remote patches of country about Sansog and Banpur. The country under survey may be regarded generally as made up of three belts or strips running east and west. The southern belt or up to the parallel of 30° 44′ lies chiefly in Jaunsár; it rises to an average height of some 6,000 feet above sea level, and the Government forests thereon are restricted only to a few detached patches. The middle belt is about 5 miles in width and is covered with rich forests all included in the Government reserves; it lies chiefly in Kándah and comprises several lofty hills as Deoban and Kalamu, rising to an average height above sea level of some 9,300 feet. The northern and remaining belt much resembles the southern strip, both in average height and general features, excepting that the former is much more plentifully covered by Government forests; it lies chiefly in Báwar. The necessity for fixing numerous points on the forest boundaries, imposed on the surveyors considerably greater labour than was anticipated, and this was enhanced by similar requirements in connection with the *khats*, which are internal sub-divisions consisting of 5 to 15 small villages or land-holdings. Along the valleys of the Jumna, the Tons, and the Pábar rivers, the mountains are extremely precipitous.

(39.) In the Dehra Dún, besides the remaining preliminary traverses, 124 square miles were surveyed on the scale of 4 inches to a mile; after which, in order to utilize the services of a few native surveyors who were not sufficiently trained for work on higher ground, the survey of Dehra, including 8 square miles, was completed on the scale of 12 inches to the mile. Besides the foregoing, 38 heights were determined trigonometrically and many others by means of the aneroid barometer. In Jaunsár Báwar, 52 points including 9 heights were fixed trigonometrically, and 430 square miles surveyed topographically on the scale of 2 inches to the mile: further, no less than 1,350 boundary pillars were laid down, and both the cart road and the bridle-road to Chakráta for a distance of 72 miles in all, lying within Jaunsár, were traversed: every endeavour was made to lay down the boundaries of the cantonment of Chakráta, and the required limits were defined so far as the necessary information on the subject could be obtained. With regard to office work, 6 maps have been finally drawn and completed for publication. The work herein reported on completes the survey of the Dehra Dún district, including Jaunsár Báwar, so far as the portions undertaken by this department are concerned; and, as will be seen hereafter, of the

parts assigned to Captain Bailey only 20 square miles in the Dehra valley remain to finish the entire work. As regards the operations under Captain Thuillier and Mr. Ryall now under review, I have carefully inspected the original plane table sheets and can vouch for the general care and accuracy with which they are delineated: they represent an amount of toil and perseverance which can be best appreciated only in presence of the difficult ground operated on, and in view of these conditions, the out-turn of work achieved is satisfactory both as respects magnitude and merit.

(40.) In submitting to Government Captain Bailey's report on his progress during 1875-76, the Officiating Superintendent, Captain Thuillier, makes the following remarks.—"The portions of country surveyed presented very intri-"cate and difficult features throughout, the hills being mostly covered with forest "and jungle, which render a faithful survey more tedious and difficult." Again, "the topography is good, and considering the intricate and rugged nature of the "ground operated on, the out-turn is satisfactory." Further, "Captain Bailey "reports very favorably of the progress made by his Native surveyors and this is "proved by the average monthly out-turn of topographical area by a party con-"sisting of 1 European and 6 Natives having increased from 7¾ square miles "during field season of 1874-75 to 12¾ square miles during the season under "review." Also, "the forest tracts in Jaunsár have been entirely completed, "and with the exception of a small portion of about 20 square miles those in the "Dehra Dún also." Lastly he adds, "having been working conjointly with "Captain Bailey in the general surveys of the Dehra Dún and Jaunsár during the "past three years, I am glad to have this opportunity of testifying to the able and "zealous manner in which he conducts the operations under his charge."

(41.) The successful completion of this survey, undertaken three years ago, reflects much credit on Captain Thuillier, Captain Bailey, Mr. Ryall and the assistants who aided them: by its means we obtain accurate maps with well delineated terrestrial features of a tract of country which is rising daily in importance and value, and which is already rich in extensive tea and other plantations. Moreover the Dehra valley presents considerable areas of land, well watered, in a favorable climate, and otherwise suited for settlements of various kinds; and besides, the country abounds in extensive Government forests the products of which are rapidly increasing in value; but in the absence of the excellent maps now secured, and amid the dense underwood and forest which alternate with open glades and tortuous ravines, it has hitherto been impossible to define a site, in connection with grants of land or for other purposes, even if the site in question could be discovered. These drawbacks now stand removed: the maps are already in local demand and, it may be predicted, will continue to rise in importance.

NO. X.—TOPOGRAPHICAL.

THE SURVEY OF KATTYWAR.

(42.) The topographical survey of this province was conducted as before by Major A. Pullan during the year under review, excepting the period of two months beginning 8th April when he availed himself of privilege leave and Mr. J. McGill officiated in his place: otherwise, the establishment was maintained at its former strength, for while on the one hand Mr. F. Bell obtained furlough for twelve months, on the other, Mr. J. Peyton was appointed instead to do duty with the party. The narrative of the field operations is without event; and notwithstanding that fever and cholera prevailed in Kattywar to some extent, the establishment was fortunate, under judicious management, in suffering only slightly from these causes.

PERSONNEL.

Major A. Pullan, S C., Offg. Deputy Superintendent 3rd Grade.
J. McGill, Esq., Offg. Assistant Supdt. 1st Grade.
Mr. J. Peyton, Surveyor 1st Grade.
„ N. C. Gwynne, „ 4th „
„ W. A. Fielding, Asst. Surveyor 2nd Grade.
Mr. W. Oldham, Asst. Surveyor 3rd Grade.
Mr. G. T. Hall, Asst. Surveyor 3rd Grade.
Mr. H. Corkery, Asst. Surveyor 4th Grade.
Visaji Ragonath Gadboli and 9 other Native Surveyors and Apprentices.

(43.) The country visited lies chiefly in the south-west portion of the province, where two of the southern sheets touch the sea coast; the ground topographically surveyed on the scale of 2 inches to the mile is included in sheets 36, 37, 38, each sheet embracing ½° of longitude and ¼° of latitude; and trigonometrical operations were conducted in advance so as to complete sheets 46, 47, and 48 and portions of 40 and 50: besides the foregoing, sheet 10_a, which borders on the Runn of Cutch, was also completed topographically. Thus, the operations under review included the principal towns of Gondal, Jetpur, Junágarh and Jhinjhuwára, of which, Junágarh is reckoned third in importance throughout the province of Kattywar: the country was fertile and well populated, fairly wooded with several kinds of trees, and watered by the rivers Ujat, Uben and Bhádar; the last of these being the largest stream in the province. Nor were prominent terrestrial features wanting, for Girnár mountain lies immediately east of the town of Junágarh, so that the latter stands at the foot of one of the western spurs. This remarkable granite mountain rises to a height of 3,666 feet above mean sea level and is terminated by three sharply defined peaks which are dedicated to deities Hindoo and Mahomedan. The mountain and surrounding country are described by Major Pullan in an interesting account, given in Appendix X.

(44.) Fully availing himself of the favorable conditions prevailing, Major Pullan and his party succeeded in completing an excellent out-turn of work, which, it will be seen below, contrasts very favorably with the amount for the preceding year and is at least equal to the large out-turn for 1873-74. The area topographically surveyed in 1875-76 includes parts of Pránts Hállár, Kattywar, Sorath and Jhalawad:—

	1873-74.	1874-75.	1875-76.	
Topographical ...	2201	1749	2253	square miles.
Trigonometrical ...	2174	2200	1850	„ „
Traverse ...	1235	1117	1600	linear „

Numerical contrasts of such work, as is well known, are in themselves quite insufficient to point to conclusions, failing as they do to impart any idea of the all important local conditions which govern progress in survey operations; but after due consideration of all the existing circumstances and inspection of the original fair drawings, I am of opinion that Major Pullan and his party are due much credit for the success attending their labors during the season 1875-76. In presence of the annual progress hitherto made, it will be seen from the Index chart given in the Appendix, that the survey of Kattywar now begins to approach completion, so that the expectation of finishing the province "within the next five years," expressed by Colonel Walker in his report to Government for 1873-74, is likely to be fully realized.

(45.) As respects fair drawing for publication by photozincography, sheets 31, 42, 43 and 44 have been completed, as usual, on the scale of 2 inches to the mile. Further, suitable delineations have been prepared for the Surveyor General's Office, in order to expedite the engraving and publication of the Atlas sheets for India.

NO. XI.—TOPOGRAPHICAL.

THE SURVEY OF GUZERAT.

(46.) The utilization of the previously executed Revenue Survey maps of certain villages in Guzerat, by combining them with the Topographical Survey of the province now in progress, has presented subjects for considerable deliberation and discussion extending over the years 1872 to 1876. The arguments advanced by the Superintendent, Colonel J. T. Walker, R.E., in support of the views entertained by himself and shared by this department, the procedure of survey adopted and the modifications introduced from time to time as experience showed to be desirable, and the consequent events developed, have all been given year by year in the Administrative reports preceding the one now in hand. The decision which has finally been arrived at, is set forth in the following extracts from letter No. 653 dated 5th August 1876 from the Government of India, in reply to Colonel Walker's letter No. $\frac{32}{328}$ dated 29th March 1876.

PERSONNEL.

Major C. T. Haig, R.E., Offg. Depy. Superintendent 1st Grade.
Lieutenant J. E. Gibbs, R.E., Offg. Assist. Superintendent 2nd Grade.
Mr. A. D'Souza, Surv. 1st Grade.
" A. D. L. Christie, Surveyor 4th Grade.
Mr. C. H. McA'Fee, Surv. 4th Grade.
" J. Hickie, Asst. Surv. 2nd "
" G. D. Cusson, " " "
" S. F. Norman, " 4th "
" C. Norman, " " "
Messrs. H. G. Ferns, Gopal Vishnu, and 14 other Native Surveyors and Apprentices.

REVENUE SURVEY.

H. D. E. Forbes, Esq., Asst. Supdt.
3 Native Surveyors.

> 2. In reply I am to state that the Governor General in Council agrees to the proposals contained in paragraphs 24—26 in respect to the future conduct of the work in Guzerat *viz.* :—
>
> 1*st* that the plan of giving every detail which the 2-inch scale sanctioned is capable of showing, with a view to the publication of the maps on the same scale, should be adopted for British Districts in Guzerat of which village maps have already been made,
>
> 2*nd* that the plan of giving no more details than can be clearly shown on half that scale, of drawing them boldly, and of exaggerating all the names of towns and villages &c., so as to permit of the maps being readily reduced by photography to the 1-inch scale, and published on that instead of the 2-inch scale should be applied to all other parts of Guzerat,
>
> 3*rd* that two sets of maps of the British Districts should be published; one on the 2-inch scale, including as much as may be required of the contiguous Native States to square the 2-inch maps off conveniently; the other on the 1-inch scale, to juxtapose with the reduced maps of the Native States,
>
> 4*th* that village maps should be utilized in distinguishing between cultivated and barren or forest tracts, in defining village boundaries, and in giving all interior topographical details which stand the test of examination by the topographical surveyors,
>
> 5*th* that the stations of the triangulation and traversing should be placed as frequently as possible at the junction point of three fields, and that the corresponding field numbers should be marked on the maps. The field junction points on the external boundary lines and the internal divisions between cultivated and barren tracts should be taken from the village maps and inserted on the topographical maps, the numbers for every 2nd or 3rd point been given on the map to facilitate identification.

(47.) These orders, restricting the scale of survey to 2 inches per mile, were received too late to be carried out in the *field* operations under notice; but the resulting maps for publication, and all others hereafter prepared, will be *drawn* on the prescribed reduced scale of 2 inches to the mile, as directed.

(48.) The operations of the Guzerat Survey were conducted as heretofore by Major C. T. Haig, R.E., during the twelve months under review, excepting the period of about three months from 13th February 1876, when he availed himself of privilege leave and Lieutenant J. Gibbs, R.E., officiated in charge of the party. Final work was carried on over two separate areas, which may be distinguished as the northern and southern portions of the season's out-turn; and

between these plots, and more particularly north of the latter, a considerable area was prepared by traversing and triangulation for topography in the year following.

(49.) The northern portion topographically surveyed comprises sheets 78 and 79, besides a small area in sheet 10_a, and includes all the Khalsa lands which were visited this year and completed, before Government orders could be made effective, on the usual 4-inch scale. The country was singularly devoid of all through drainage, nor could a single watercourse be found, of sufficient volume to reach the Runn of Cutch on the west or the Sábarmati river on the east: tanks abounded and appeared to offer sufficient receptacles for the total rainfall; besides, there was a large lake called Wanod-na-Saran which presented a surface of some 6½ miles of water when quite full. The principal towns were Viramgám, Mándal, Detroj, Kari, Bechoraji Mátha and Katosan. The Bombay Baroda and Central India Railway traverses the tract in an east and west direction. The country here surveyed includes a large part of Viramgám taluka and a small part of the Sánand taluka of the Ahmedabad collectorate, a portion of Kari Mahal, six villages of Pátan Mahal of the Gaekwar's territory, and a small part of Mahi Kánta.

(50.) The southern portion topographically surveyed comprises sheet 31 and the north-west quarter of 32, and includes the city of Broach, besides the towns of Ankleswar, Sinnar, Tankána, Sukaltirth, Diva, Chandod and Rund Bhúlod, and in addition 24 other towns and villages with populations ranging between one and two thousand souls. The river Nerbudda waters the country, across which the Bombay Baroda and Central India Railway runs for a length of some 25 miles. The tract here surveyed includes parts of Broach, Ámod and Ankleswar talukas of the Broach collectorate; also parts of Sinnar, Mahal (Gaekwar's territory), Rájpipla and Sánkhera Mewas under the Rewákánta Political agency.

(51.) The area traversed and triangulated and thus prepared for the topographical operations of the following year need not be further indicated at present, than by the statement, that it comprises sheets 28, 29 and 30 and lies between the parallels 22° 0′ and 22° 45′ and the meridians 73° 0′ and 73° 30′.

(52.) In all, the area surveyed comprises; of final topography, 924 square miles on the 4-inch and 948 square miles on the 2-inch scale: and of ground traversed and triangulated in advance, 1650 square miles. This represents an excellent out-turn of work, for which Major Haig and his assistants deserve much credit.

(53.) In respect to mapping, the work appears to have been spread unavoidably over a considerable number of sheets, of which several could not be completed though they were well advanced. Seven sections in hand, of degree sheet 11, are of this class; but the other half of this sheet was begun and finished, as also was a half section of sheet 80: the printing of names in about 14 sections was completed. Lastly, the compilation of a map of the city of Broach was undertaken, a work which required considerable care and skill, involving as it did transfers from no less than 71 other maps by the Revenue Survey.

(54.) Major Haig describes a method introduced by himself of mounting plane table sections, by which the drawing is readily removed when required and the surface of the paper is not liable to injury.

NO. XII.—THE COMPUTING OFFICE.

CALCULATING AND PRINTING BRANCHES.

(55.) The Computing Office consists in the main of a staff of Native Computers, with whom are associated two selected Surveyors from the Junior branch of the department; these form the Calculating branch, whose varied and comprehensive duties will be found reported on at length in Appendix XII. It is therefore sufficient to mention in this place, generally, that the computing office is required to examine, reduce finally and publish the results of this Survey, as well as to meet the current professional demands which emanate day by day from various sources. These duties obviously involve other professional skill in addition to that of computers; accordingly three *small* auxiliary branch offices for Printing, Drawing and Photozincographing, work in concert with the Calculating branch, and the four branches form what, thus constituted, is called the Computing Office. This office has for years past been supervised by *two* of the survey officers, directed by the Superintendent: the senior of these two (myself) being absent on furlough, the duty of supervision devolved on the remaining officer Mr. W. H. Cole M.A. The latter in turn proceeded on furlough, 21st March 1876, and the Superintendent, Colonel J. T. Walker R.E., also shortly after availed himself of leave to England: under these circumstances, the principal offices, *i.e.*, the Calculating and Printing branches, were placed under the directions of Major J. Herschel R.E., while the Drawing and Photozincographing branches were worked under orders from Captain H. R. Thuillier R.E., who also officiated for the Superintendent. The subdivisions thus temporarily formed, are reported on separately in Appendices XII and XIII. The review here in hand has now reference exclusively to the former Appendix on the Calculating and Printing branches.

Major J. Herschel, R.E., F.R.S., Dy. Supdt. 2nd Grade (in charge from 21st March 1876).
W. H. Cole, Esq. M.A., Offg. Dy. Supdt. 3rd Grade (in charge to 21st March 1876).

Computing Branch.

Mr. C. Wood, Surveyor 3rd Grade.
„ H. W. Peychers, Surveyor 4th Grade.
Baboo Gunga Pershad, Computer.
„ Cally Mohun, Ghose „
„ Kally Coomar Chatterjee, and 11 other Computers.

Printing Branch.

Mr. M. J. O'Connor, Printer.
16 Compositors and 3 Pressmen.

(56.) Major Herschel's report has reference to the thirteen months which ended on 31st October 1876: it primarily exhibits a "Tabular Statement of cost in Rupees of different kinds of Work done" and subsequently adopts for review the classification introduced into this table. The classes thus noticed are treated with so much originality and comprehensiveness as to impart additional interest to his remarks, which will be found at length in Appendix XII. It is therefore sufficient to restrict the review in hand to a general summary of the progress made, and to such brief notices, of a few leading points, as may be entered on without needless reiteration of what is given in detail hereafter. As regards the cost-table above mentioned, it deals with the classification adopted in an effective manner, and in stating the absolute expenditure on each subject, it indicates the directions into which the available working power happens to have been diverted, relatively.

(57.) Roverting for a moment to the Superintendent's administrative report for 1874-75, it was there mentioned that the triangulation of the Sectional Figure known as the South-East Quadrilateral (or S. E. Q.)* had been made consistent by the method of minimum squares, under Mr. Cole's supervision, "in a most satisfactory manner." Subsequently, the remaining computations of Principal work were finished and the printing of these results proceeded with, so that the pages of Volumes VI and VII are approaching completion. And as regards the 6 Synoptical Volumes, *i.e.*, one for each series, of the S. E. Q., considerable

* NOTE.—This figure is bounded on the north by the eastern half of the line from Calcutta to Karáchi; on the east, by the Coast line from Calcutta to Vizagapatam; on the south, by the eastern half of the line from Vizagapatam to Bombay; and on the west, by the Indian middle meridian of 78° (see Index Chart of Triangulation given with this report).

progress has been made, with the records of the Secondary triangulation involved, in correcting, revising and where necessary renewing them, and a sensible impression has been effected on the printing of the results: these volumes it will be remembered, give the facts of the Principal volumes, entitled "Account of the operations &c.," in a condensed form; besides the results of Secondary operations; so as to provide for various local wants, including those of the Geographer and the Surveyor. It may also be suitably mentioned here that Principal Volumes III and IV of the North-West Quadrilateral (or N. W. Q.) have been received back from the Book-binder's hands, and that Synoptical Volume VI, which treats of the triangulation of the Jogí-Tíla and the Sutlej Series in the Punjab, has been bound and published. This latter issue completes the Synoptical publications for the N. W. Q., excepting the volume comprising the chain of triangles which stretches from Dehra Dún to Attock: the series last named, known as the North-West Himalaya Series, includes a great number of Secondary series which are of considerable extent and establish numerous mountain points; thus the work involved, in computing, compiling and printing, as also in drawing and reproducing the several charts required, has been unusually arduous; and hence the time required for publication of this volume is necessarily far greater than for other volumes of its class. Lastly with regard to the volume on the Pendulum operations, a good deal of work was done during the early portion of the year in preparing its pages for the press.

(58.) Among the principal subjects which have occupied the office during the year under review, is that presented by the required reduction of the North East Quadrilateral (or N. E. Q.); this section as originally indicated was bounded as follows: on the south by the eastern half of the line from Calcutta to Karáchi; on the west, by the Indian middle meridian of 78°; on the north, by the British frontier generally; and on the east, by the meridian of Calcutta up northwards to the foot of the Himalayas†: subsequently the section was extended to the east, so as to include four series, *viz.*, the East Calcutta, the Brahmaputra, the Eastern Frontier and the Assam; further, the Budhon Series was excluded in the simultaneous reduction, for in fact the circuit it included was disentangled from the others. The modified section thus undertaken for reduction, by the method of minimum squares, presented several features which differed from those occurring in the Sections N. W. Q. and S. E. Q. already made consistent. In the N. E. Q., the limiting series to the west and nearly the whole of the southern chain had already been determined and fixed by the previous reductions; the circuits were shorter and the triangulation, excepting the eastern extension above mentioned, comparatively inferior in quality; on the other hand, the section in hand presented no less than 49 conditions to be satisfied simultaneously.

(59.) Major Herschel's "Gridiron Function Table", exhibits in a neat and convenient form, the leading facts which convey an idea of the labor and to some extent of the amount of entanglement prevailing in the N. W. Q., the S. E. Q. and the N. E. Q. The labor involved in what is generally the most tedious part of the reduction, is well expressed by "Number of Products forming the same" (*i.e.* Normal Equation Coefficients); the entanglement and other sources of intricacy are not susceptible of accurate numerical expression in a combined form, but a very useful indication in this direction is represented by "Average terms per normal equation"; in all, the table is a valuable contribution to the computer. Quoting Major Herschel's numbers for the three Sectional Figures, in the order N. W. Q., S. E. Q. and N. E. Q., it appears; that the "Number of Circuit triangles" are as 549 : 277 : 573; "Number of Equations of Condition", as 23 : 15 : 49; "Number of Normal Equation Coefficients", as 329 : 165 : 551; "Number of Products forming the same", as 40·0 : 16·7 : 51·0; and the "Average terms per Normal Equation", as 14 : 11 : 11: to these may be added, average number of triangles per circuit, as 162 : 123 : 77. Major Herschel has made good progress in the

† See Index Chart of Triangulation given with this report.

reduction of the N. E. Q. and the results already obtained promise a very successful conclusion to his labors.

(60.) The measures necessary for the protection of our Principal stations have been continued as heretofore, so that the work has now been nearly brought up to date. The transfer of these stations to the care of District Officers was begun in 1865, when, having obtained sanction for the necessary funds, Colonel Walker entered on the difficult and tedious duty in question. In brief, the work involves a certain amount of correspondence with at least one official in every district *all over India* where a station happens to be fixed: approximately there were 350 districts to be dealt with, and 3,000 stations to be parceled out amongst the officers for care and protection of the survey marks imbedded within the structures. These marks present known points on the earth's surface, their latitudes, longitudes and heights being determined, so that in fact, the points stand endowed with properties of considerable value, which however can benefit ourselves or posterity, obviously, only so long as the marks are preserved. Now although, from what has been stated, there are on an average only some 9 points in a district, yet the difficulties of identifying them, necessarily by means of correspondence, are not a few: the stations are fixed from 10 to 60 miles apart, very frequently in desolate or wild regions or on sites not easy of access; in some instances, considerable periods since construction had elapsed, so that local recollections of the events had died out; in others, changes in fiscal boundaries and necessarily in officials added to the difficulties of identification. Thus, descriptive district lists of stations frequently involve tedious correspondence before all the structures can be found by district officers; when this has once been effected, the district is included amongst those designated as "settled". Altogether, 313 districts have been settled, including 2,725 principal stations, leaving some 37 districts and 275 stations to be disposed of. In the work thus completed by the Superintendent, valuable aid has been rendered by Mr. C. Wood who continues to maintain his reputation as an excellent assistant.

(61.) The small auxiliary printing office, which forms part of the professional establishment essential for reduction and publication of the results of this department, has continued to work with efficiency and despatch.

(62.) The out-turn of work, performed successively under Mr. Cole's and Major Herschel's directions, presents ample and satisfactory evidence of successful supervision.

NO. XIII—COMPUTING OFFICE.

DRAWING AND PHOTOZINCOGRAPHING BRANCHES.

(63.) The duty of supervising the Drawing and Photozincographing branches having devolved on Captain H. R. Thuillier, R. E., as explained in para. (55), his report on the work performed by these offices during the twelve months ended 30th September 1876, will be found in Appendix XIII.

DRAWING BRANCH.

(64.) This small auxiliary office has continued to discharge its duties with efficiency, notwithstanding the severe loss it sustained in the early part of 1875, when the two senior and most experienced draftsmen died. The duties in question are briefly as follows. All maps and charts drawn by the Field Establishments undergo examination and, when necessary, correction under the Superintendent's direction; after

PERSONNEL.

Mr. G. W. E. Atkinson, Surveyor 3rd Grade.

3 Draftsmen, 3 Assistant Draftsmen, and 16 Apprentices and Map Colorists.

which they are passed to be photozincographed: other maps and charts which the Field Parties may be unable to prepare are here drawn fair. Besides, various original compilations are undertaken; as, maps of the Northern countries (Turkestan &c.), Exploration routes, charts of spirit levels, &c., &c.: also, the original drawings to illustrate the volumes of the final results are made here, and the press proofs of these and of all maps, charts, &c., are examined and passed: every print requiring coloring is tinted by the apprentices and colorists, and no less than 8502 copies were thus finished in the year under review. In addition, the office now possesses a very useful cartographical collection that needs suitable care in storing; and finally, various miscellaneous drawings are undertaken from time to time, to meet local requirements.

(65.) Of the original publications prepared during the twelve months, the maps of spirit levelled heights occupy the most prominent place in respect to number and labor. These maps are deserving of some special notice. In the original programme, the spirit levelling operations of this Survey were naturally designed for the use of the department alone; it was however soon perceived by the Superintendent, Colonel J. T. Walker, R.E., that the lines of levels might be made subservient to far wider purposes of utility. Now these main lines were necessarily executed with extreme, if not unprecedented, care, precaution and skill, for, owing to the enormous distances which exist between sea boards where alone completely satisfactory checks can be obtained, levelling with the rigour ordinarily sufficient would lead to results of insufficient value. Having established Bench-Marks along various routes, including remote inland tracts where reference to the mean sea level was hitherto unattainable, the resulting facts were printed from year to year for the information of all who were likely to benefit by them and in view of inviting junctions with the B. Ms. in question. Thus in course of time, the Public Works Department and Railway Officers connected their lines with the main lines of the Survey, and it became possible when such junctions had been effected to incorporate all the facts of levelling into a series of suitable maps, provided only that Executive Officers of other departments would contribute tracings of their lines. This condition is however by no means an easy one always to secure; for notwithstanding that the labour of compilation and publication is all undertaken here, and that unless thus preserved, valuable information may certainly be wasted after it has been made to serve its immediate end, yet, the difficulty in obtaining traces, was in a few instances overcome, only by sending a draftsman from this office to do the needful at more or less distant stations. In very many instances however, co-operation was cordially rendered, or the undertaking must have been abandoned. The result is, that up to the present date 26 sheets of spirit levelled heights have been published, and the value of the compilations stands attested by the demand that exists for them.

(66.) I am glad to add that Mr. G. W. E. Atkinson, the chief draftsman, has continued to discharge his duties with zeal and efficiency.

PHOTO-ZINCOGRAPHING BRANCH.

(67.) This small establishment has continued to prove useful and efficient as heretofore. By its means the maps and charts of the Survey are all published under competent direction and within a few months, or even weeks, of completion; the volumes of final results are illustrated with the necessary diagrams, and a large number of professional forms, representing tabulation of mathematical formulæ, are produced with the accuracy so essential in these very necessary aids to calculation.

PERSONNEL.

Mr. C. G. Ollenbach, Zincographer.
" C. Dyson, Photographer.
2 Apprentices, 1 Mapkeeper and 3 Pressmen.

(68.) The out-turn of work for the twelve months under review may be briefly stated thus.—

Trigonometrical Charts, ...	7	sheets published.
Topographical Maps of Kumaun and Garhwál, Guzerat, Kattywar and Dehra Dún Surveys, ...	43	,,
Spirit Level Charts, ...	8	,,
Exploration Maps, ...	3	,,
Indexes to Surveys, ...	6	,,
Gazetteer Maps, ...	2	,,
Miscellaneous, ...	2	,,
Reprints of Maps already published, ...	22	,,
Total,	93	

besides numerous diagrams and forms.

(69.) Contrasting the number of copies printed during the twelve months, under the usual four heads, we obtain the following out-turn of work beginning with 1870-71.

Year	Maps	Charts	Diagrams	Forms
1870-71	6,465	839	13,205	10,482
71-72	10,131	1,375	4,937	13,655
72-73	6,910	2,206	12,055	12,549
73-74	9,207	2,027	3,557	28,125
74-75	7,010	3,015	1,795	24,219
75-76	14,025	1,678	9,722	18,314

Or abstracting from the preceding table, there results as follows,

Subject.	1870-71	1871-72	1872-73	1873-74	1874-75	1875-76
Maps, Charts and Diagrams,	20,509	16,443	21,171	14,791	11,850	25,425
Forms, ...	10,482	13,655	12,549	28,125	24,219	18,314

Further; 7931 Maps and 2475 Charts were issued during the twelve months: the forms printed were all expended, and the diagrams were practically all absorbed in the volumes of final results. These facts speak for themselves and therefore need no commendation. It may be added, that new work keeps pouring in at least as fast as the old work is disposed of, so that a formidable list of subjects to be undertaken, now presents itself for despatch during the ensuing year.

THE LIBRARY.

(70.) In compliance with the orders of Government, No. 3155 of 30th September 1876, that "The state of the Library is to be mentioned in the annual report," I proceed to supply the required information; but as this subject is now noticed for the first time in an Administrative report on this department, it appears desirable to introduce the following brief preliminary statement.

(71.) The total number of printed volumes in the Field office of the Surveyor General and Superintendent Great Trigonometrical Survey amounted in the year 1860 to about 100: this collection was maintained almost exclusively for purposes of computation, so that it consisted chiefly of Numerical Tables; as Logarithms or other auxiliaries to calculation; besides some Mathematical, Astronomical and Geodesical works, and a Star Catalogue; together with occasional copies of travels and other kindred publications. In fact the requirements of the department, with respect to works of reference, were then of a very limited nature: our calculations were restricted to provisional completion of each chain or series of triangles regarded as a separate and detached work: these provisional results were transcribed in triplicate, of which, up to 1857, one copy was forwarded to the Honourable the Court of Directors, another was deposited at Calcutta and the third retained in the Field office. When however numerous chains of triangles had been provisionally completed, and the necessity became urgent, for combining these into consistent masses by the most suitable and rigorous processes due to the excellence of the triangulation, for printing our professional volumes and distributing them so as to secure eligible custodians for the results of this great Survey all over the world, and for illustrating our publications with suitable Maps, Charts and Diagrams, then the demand for works of reference, showing what had been done on other State Surveys, treating of mathematical analysis, or imparting general information, became equally urgent.

(72.) The present small Library, attached to the Computing Office, has thus been gradually formed, chiefly during the last 14 years, to meet this demand. The books are placed in a quadrangular framework* which admits of inspection both from within and without, so that the attacks by White-ants are detected at the outset, and damage from this source is unknown. At the present time, there are in all 2121 volumes in the quadrangular shelf, where they are arranged under 19 heads or classes, so that a class consists of only some 110 volumes on the average. These books constitute what is known as the *Standard* Library; their titles are entered, class by class in a Catalogue, where the date of admission is also registered; and each volume is marked on arrival with the Survey Library stamp, in which the current year is included. Books may not be taken out of the Library room, without first signing a receipt, in which the condition of the volumes taken on loan is stated and a promise made to supply new copies in case of injury to those received. The Standard Library contains only one copy of each work.

A. Mathematics,	F. Philosophical,	L. Manuals,
B. Astronomy,	G. Travels,	N. Photography,
C. { Meteorology, Magnetism,	H. { Geographical, Local,	P. Pamphlets,
D. Geodesy,	I. Historical,	T. Tables,
E. { Geology, Botany, Zoology,	J. Public Records,	U. Almanacs,
	K. Encyclopedia,	V. Catalogues,
		Z. Miscellaneous,

(73.) All duplicate copies are collected together by themselves and classified as above; they constitute what is known as the Duplicate Library and represent to a large extent works kept in stock, for supply to field establishments of this Survey and others, or for consultation and use in the Computing Office; as Numerical Tables, Pamphlets on various subjects, &c. &c..

(74.) All the foregoing are kept in one room, which is 18 feet square. The books are in good order and they are well looked after, but, as is obvious from the dimensions of the room, enlarged accommodation is much needed.

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* This quadrangle is necessarily of wood; otherwise it generally resembles the one of iron for Maps in the Ordnance Survey Office, Southampton.

(75.) I cannot conclude this report without suitable allusion to Mr. H. R. Duhan, the Personal Assistant to the Superintendent. Writing as I do of a period when I was absent on furlough, and in this instance of duties, which from their nature are rendered as frequently orally as otherwise, I am constrained to revert to the Superintendent's last report, where acknowledgment is made of Mr. Duhan's "valuable services," and to my personal knowledge of the estimation in which Captain Thuillier (my predecessor as Officiating Superintendent) held the aid rendered to him by the Personal Assistant. Apart from this general testimony and the discharge of his ordinary duties, Mr. Duhan has taken a leading share in preparing the ten years statement of expenses called for by the Secretary of State, a duty which he discharged to the satisfaction of the Surveyor General of India. During my term of office as Officiating Superintendent, I have been much indebted to Mr. Duhan for the prompt and efficient manner in which he afforded me every required assistance. Mr. L. H. Clarke continues to discharge his duties in the corresponding office, and as general store keeper, with care, punctuality and despatch.

(76.) An abstract of the out-turn of work by each of the Survey Parties, whose operations can be exhibited in a tabular form, is given on the following page.

J. B. N. HENNESSEY,

Deputy Superintendent, 1st Grade,

late Officiating Superintendent.

DEHRA DUN;

Dated 1st March 1877.

Abstract of the out-turn of work executed by the Great Trigonometrical Survey Parties, during the Survey year 1875-76.

Description of Details.	I Madras Coast Series and Ceylon Connection. 24-inch Theodolite.	II Assam Valley Triangulation 12-inch Theodolite.	III Burmah Secondary Triangulation. 12-inch Theodolite.	IV Eastern Frontier Series. 24-inch Theodolite.	V Jodhpur Meridional Series. 24-inch Theodolite.	VI Spirit Levelling Operations.	IX Dehra Dún Topographical Survey.	X Kattywar Topographical Survey.	XI Guzerat Topographical Survey.	Total.
Principal Triangulation.										
Number of Stations, newly fixed, ...	17	...	...	14	7	...	...	...	...	38
Do. Triangles, completed, ...	21	...	...	18	9	...	...	...	...	48
Average Triangular error, in seconds, ...	0·63 2·21†	...	...	0·34	0·48	...	...	...	...	...
Do. Probable errors of angles, in seconds, ±	0·19 0·20†	...	...	0·26	0·15	...	...	...	...	...
Astronomical Azimuths of verification, observed,	1	...	...	...	...	...	...	...	...	1
Length of Series, in miles, ...	80	...	...	116	21	...	...	...	...	217
Area of Triangulation, in square miles, ...	548	...	...	3323	311	...	...	...	...	4182
Number of Stations selected in advance, ...	10	...	...	17	32	...	...	...	...	59
Length of Approximate Series, in miles, ...	36	...	...	100	134	...	...	...	..	270
Number of Towers constructed, ...	...	...	...	...	2	...	...	...	...	2
Do. Scaffolds erected, ...	19	...	...	...	...	...	...	...	...	19
Do. Pillars and Platforms constructed,	21	...	...	21	8	...	...	...	...	50
Do. Stations whose elements have been computed,	17	...	...	14	7	...	...	...	...	38
Astronomical Azimuths of verification, computed,	2	...	...	...	...	...	...	...	...	2
Number of Stations finally placed under official protection,	17	...	...	18	19	...	...	...	...	54
Do. of Stations protected and closed, ...	25	...	...	18	2	...	...	...	...	45
Preliminary Charts of Triangulation, ...	1	1	...	1	2	...	...	...	...	5
Secondary Triangulation and Topographical Work.										
Number of Triangles of which all 3 angles have been observed,	...	19	41	2	47	...	...	165	95	369
Number of Triangles of which only 2 angles have been observed, ...	...	...	220	142	140	...	104	1118	324	2048
Number of Stations whose positions only have been fixed, ...	...	...	...	2	...	...	43	*	*	45?
Number of Points fixed by intersection, but not visited, ...	8	...	109	58	59	...	27	656	191	1108
Number of Revenue Survey Stations and Boundary junction pillars, fixed by Triangulation, ...	...	...	...	...	3	...	..	...	...	3
Number of Stations and Points whose heights have been determined, ...	5	...	108	6	92	...	47	295	80	633
Length of Secondary Series, in miles, ...	...	41	246	...	152	...	...	...	...	439
Area of Triangulation, in square miles, ...	...	188	3083	...	2642	...	...	1850	1650	9413
Area embraced by Triangulation to hill peaks, in square miles, ...	...	...	4607	2280	...	...	...	...	...	6887
Length of Approximate Series, in miles, ...	...	...	38	...	...	...	...	...	...	38
Number of Pillars, Platforms or Posts constructed or repaired, ...	...	27	23	1	10	...	...	159	...	220
Number of Stations and Points whose elements have been computed, ...	8	15	197	72	...	...	174	*	...	466?
Number of Points fixed by traverse and their elements, computed, ...	...	...	...	...	1	...	1792	*	*	1793?
Length of Boundary lines and Check lines traversed, in linear miles, ...	...	...	...	...	...	...	126	1600	1159	2885
Aneroid Determinations of height, ...	...	...	...	...	...	...	245	...	...	245
Area topographically surveyed on scale of 2 inches = 1 mile, in square miles, ...	...	...	...	...	...	...	430	2251	948	3629
Area topographically surveyed on scale of 4 inches = 1 mile, in square miles, ...	...	...	...	...	...	...	124	...	923	1047
Number of Maps, ...	...	...	1	...	...	...	6	12	1‡	20
Levelling Operations.										
Number of miles levelled over, ...	...	...	...	...	...	421	...	...	...	421
Do. of Permanent Bench-Marks fixed, ...	...	...	...	...	...	166	...	...	...	166
Miscellaneous.										
Number of miles of rays cleared, ...	274	250	48	2	104	...	...	...	...	678
Do. do. path-way made, ...	...	...	...	528	28	...	...	...	...	556
Do. Hill tops cleared of forest and jungle,	...	...	35	19	2	...	...	...	...	56

* See appendix. † Ceylon Series. ‡ Besides 7 sections in hand and the printing of 14 maps completed.

APPENDIX.

EXTRACTS FROM THE NARRATIVE REPORTS

OF THE

EXECUTIVE OFFICERS IN CHARGE

OF THE

SURVEY PARTIES AND OPERATIONS.

I. Extract from the Narrative Report—dated 3rd October 1876—of Major B. R. BRANFILL, Deputy Superintendent 2nd Grade, in charge of the Madras Party.

The Party leaves Bangalore for the Field, but is stopped by cholera and brought back.

(2.) The main body of the party to the number of 70, under the Tindal and Daffadar, left recess quarters at Bangalore and marched by the usual route for Madura on the 13th October 1875, but on entering Salem on the 22nd were put in quarantine by the District Collector in consequence of cholera of a virulent type having broken out amongst them, three cases proving fatal. On hearing this I proceeded to join the party at once by train with medical aid, and found them in a state of panic and deserting rapidly. All the newly engaged men refused to go on, demanding their discharge or to be taken back to their homes and families at Bangalore at once. Cholera being very prevalent in the Dindigal and Madura districts ahead, and worse in rear on the route by which they had come, I felt obliged, as they positively refused to remain where they were, to take them by railway to Mysore Territory; and no fresh cases of cholera occurring, they obtained a clean bill of health and were marched into Bangalore under Mr. Bryson on the 2nd November.

Finally takes the Field.

(3.) After recruiting the party in numbers and *morale*, the entire party again left Bangalore for the field, proceeding by rail as far as Madura on the 15th November, and commenced the approximate series operations for the season at Rámnád on the 1st December, having left the 24-inch Theodolite in deposit at Madura, there to remain till actually required for the final observations.

Plan of Operations, Approximate Series.

(4.) I made the following arrangements and disposition of the party for the prosecution of the work. The country to be traversed being low, flat, and much wooded, like that reported on last season (para. 24 of my last annual report for 1874-75), and very few stations and no rays being ready for observations, I threw our whole strength upon the approximate series, and divided the entire party into five pretty equal working parties, one each for my four assistants and myself. Mr. Belcham was to keep to the east flank stations and rays, Mr. Potter to those of the west flank, while Messrs. Laseron and Bryson (the latter in company with myself, being new to this kind of work,) were to prepare the centre of the series.

Actual Progress.

(5.) From the unusually heavy rains of the autumn, the country was at first barely passable, which hindered us much. On the east flank and centre we got on as well as we could expect, but on the west Messrs. Potter and Laseron were greatly delayed on their first rays, although they were between stations which they had themselves selected and built at the close of the last season. I need not however here particularize the share of the work taken by each of us, as it is all shown in detail in the tabular statement attached as usual to this report; suffice it to say that by the end of January, after two months incessant hard work, we had only completed two hexagons; and as it was high time to begin the final observations I sent for the regular carriers to bring the large theodolite, and began the final observations on the 9th February, taking Mr. Bryson with me to record.

The final Observing begun.

(6.) I next proceeded to the centre station Manegandi, and observed the usual azimuth of verification, in which I may remark that I found no inconvenience, want of stability nor any unusual tendency to dislevelment, in the theodolite, from the use of my high (17½ feet tripod) stand.

Island Series for Ceylon Connection prepared.

(7.) I now called in Mr. Belcham to take up the final observing with the 24-inch theodolite, leaving Messrs. Potter and Laseron to continue the approximate series in advance for next season, whilst I proceeded to complete the Rámesweram Island Series for the Ceylon Connection; which I found no great difficulty in doing during the month of March.

Final Observations continued by Mr. Belcham.

(8.) Meanwhile Mr. Belcham had observed the final angles at seven of the ten remaining stations of the main series—a good month's work I consider—and now proceeded to observe at the nine stations of the island series, all which he successfully completed on the 25th April, although he was considerably delayed by contrary winds and foul weather: at one station he obtained the first night's observations but could get no more for some days until he had raised the instrument on piles about 8 feet higher, owing to the setting in of an unusually high southerly wind which raised the waves of the intervening sea.

The Rámesweram Sand Hill Station.

(9.) The station on the sand hill near Rámesweram observed to last season could not be found, having been buried deep in the shifting sand, and it was necessary to establish a new one. This station caused me much

anxiety, and I spent much time in watching it during the observations, lest it should be blown away or buried again. It consisted merely of a long 10 feet pile of hard wood driven into the sand at the top of the highest hillock, where there remained just below the surface some of the moisture of last autumn's rains; but as fast as the sun evaporated the moisture, the wind which was uncommonly high for the season, blew away the surface sand daily to the depth of 4 or 5 inches or more; and it was only by continually replacing the sand, and by freely watering and beating it to a smooth and compact mass, that the pile and mark were preserved.

Completion of the Field Season's Work.

(10.) After seeing the completion of the island series, having obtained furlough to England, I left Mr. Belcham to observe the remaining angles of the main series at the three last stations, which he finished by the 4th May, whilst I proceeded to Bangalore to make over charge of the party to Captain W.M. Campbell, R.E.

Outturn of Work necessarily small.

(11.) Briefly stated the season's outturn of work consists of 17 new principal stations, fixed by 21 triangles forming three hexagons and a quadrilateral, extending the series 80 miles (half to the north, and half to the eastward,) besides an astronomical azimuth of verification. Owing to the flat and wooded state of the country the area of the triangulation is exceedingly small: but few secondary points or land marks could be fixed, and but two figures in advance have been prepared for next season, and I much doubt if any greater rate of progress can be expected until the country becomes more favorable for trigonometrical operations.

The Assistants.

The Surveyor, Mr. Belcham, and three Assistant Surveyors attached to the party have all worked hard and well.

Appendix to Major BRANFILL'S Narrative Report by Captain W. M. CAMPBELL, R.E., Officiating Deputy Superintendent 2nd Grade, officiating in charge of the Madras Party, dated 3rd October 1876.

Increased Height of Stations advisable. Height of Theodolite.

(2.) Major Branfill recommended my taking steps during the recess for raising the stations in order to obtain clearer rays, and gave it as his opinion that the best way of doing so would be by increasing the height of the, 17½ feet braced tripod stand for the 24-inch theodolite. This stand was used throughout last season on masonry pillars about 8 feet high, built to support the feet: thus the height of the telescope of the theodolite became 8 + 17½ + 5 (about) = 30½ feet above the ground.

Height of Signal.

(3.) The usual height of the signal platform was about 40 feet, and this Major Branfill seemed to think could not easily be increased. For my own part I felt more inclined to raise the signal if possible, than to alter the tripod stand, considering the slight trouble and expense involved in raising the masonry pillars carrying the latter, if increased height of the observing station should still be necessary. I accordingly had a trial signal platform erected and obtained a height of 58 feet without serious trouble. Mr. Belcham watched the behaviour of this platform by observing the lamp on the top through a theodolite at a convenient distance, and he found that under a strong breeze blowing in gusts the extreme deflection was not above an inch, the platform recovering itself when the wind dropped. This is, I think, highly satisfactory and shows that such a platform may be well trusted for rays averaging 10 miles in length, on which one inch subtends an angle of about 0·33 second.

Difficulty of plumbing.

(4.) Major Branfill also drew my attention to the difficulty of plumbing the lamp at such a height as 40 feet from the ground, except in the calmest weather, without some shelter for the plumb-line. To obviate this I have had cloth funnels constructed to protect the line from top to bottom.

Recess Work.

(5.) As regards the work of the recess—it has been carried on very satisfactorily under the immediate charge of Mr. Belcham, and was completed by the 21st September, on which date the original records and chart were forwarded to Head Quarters.

Apparent Error in trigonometrical Heights.

(6.) There is one point in the reductions which calls for notice, *viz*:—the remarkable and rapidly increasing difference between the sea level and that deduced from the trigonometrical heights of the triangulation running along the coast, with one flank on islands, and latterly entirely on islands, for the purpose of the Ceylon Connection. By spirit levelling connecting the tide-gauge at Tuticorin

with the Cape Comorin Base the error of the trigonometrical heights there was — 7 feet. In the season 1874-75 when the series first struck the coast, 110 miles from the Base-line, the error was found to be — 10·7 feet, increasing to — 12·4 feet in a farther distance of 30 miles. Last season starting with this error of — 12·4 feet we close with — 14·7 feet, after two figures extending 40 miles over sea and islands. The progression is by no means regular, as we have cases of — 18·7 feet and — 17·2 feet between the initial and closing errors of — 12·4 and — 14·7 feet respectively.

Causes surmised.

(7.) These facts tend to show that the refraction affecting grazing rays over the sea is so irregular as to make vertical angles untrustworthy, but I can see no reason why the result should be cumulative, as it certainly appears to be, although I have examined the chart and attempted to find some connection between the growth of the error and the relative positions of the stations as regards their heights, distances apart, and whether the ray passes chiefly over land or sea. The signals obtained were, as might be expected under the circumstances, very bad and wild, having the appearance as Mr. Belcham says of "pillars of fire".

Rough Tidal Observations.

(8.) The references to sea level are of course only approximate, but they were made with some care and cannot be more than a few inches in error. They were obtained by observing the height of the tides on a stake driven into the bed of a sheltered pool, or pit on the beach, just under the station, and measuring the actual height of the station above the mean sea level so arrived at.

(9.) I have to thank Messrs. Belcham, Potter, and Bryson, for their steady application in office.

II. Extract from the Narrative Report—dated 7th August 1876—of Lieutenant H. J. HARMAN, R.E., Assistant Superintendent 2nd Grade, in charge of the Assam Valley Triangulation.

(1.) The preliminary work of the principal series, executed in advance at the close of the field season 1874-75, consisted of 5 rays, 4 post stations, and 2 lines in progress; forming 2 triangles which had not been observed on account of the season being so far advanced, the Dimú station practically inaccessible, and the difficulty of getting at and removing some obstacles from the line Bor Ghop to Melankúr: two rays had been cut from a side of the principal series to fix the treasury building in the civil station of Jorhát. Two rays cut to the Revenue Survey pillar on the south bank of the Dikhu river, near its mouth, were also reported open.

(2.) With a party of men I left Gauháti, by steamer, and arrived at the *ghát* for Jorhát on the 3rd November 1875, starting field work the following day. In re-opening the rays forming the Jorhát triangle one line gave trouble. 2 miles of forest falling in this ray, I found that one edge of the ray required much brushing. I observed the angles of this triangle and then re-opened the triangle to the Revenue Survey pillar of para. 1, and observed the angles: this done I re-opened 4 rays of the past season's work, cut some 5 miles of pathway, repaired three stations, erected three signal platforms, observed angles at one station, and collected stores of rice and *dhán*. Thus was I occupied till the 26th November 1875, when I was joined by Messrs. W. J. O'Sullivan, E. P. Wrixon, and J. F. McCarthy, who arrived from Gauháti, by march, in charge of the main camp.

(3.) Mr. O'Sullivan unfortunately got an attack of fever &c., but was sufficiently recovered and able to start work at the Dimú station by the 14th December. Mr. E. P. Wrixon commenced work at the Dimú station on the 1st December. From that date until the 8th January 1876 he was employed in re-opening 4 miles of the ray Dimú to Tengapania (cut as a final line the previous season) and carrying it on for another two miles towards the latter station, which also he built. On December 12th I assisted him in completing the remaining 1½ miles to the Tengapania station. Mr. McCarthy joined the party at Gauháti on November 4th, marched with the main camp to the field, and began his field work on the 10th of December 1875. Between November 26th and December 10th I re-opened 2 more old rays, repaired one station, observed angles at 2 stations, and cut a trial ray (half of which had been cut the previous season) and gave to Messrs. O'Sullivan and McCarthy the data for cutting the final ray, which they finished by the 23rd December. I have now shown how Messrs. O'Sullivan and McCarthy were employed up to the 23rd December, Mr. Wrixon to the 8th January, and myself to the

13th December. So far nothing worthy of remark occurred, unless it be the heavy cutting on the ray Dimú to Tengapania which had absorbed the labor of a strong party for 2½ months.

(4.) In re-opening old rays I used to visit the line at points about half a mile apart, ascend a portable ladder, and so direct the cutting of only that growth which showed above the line of grass: it was astonishing the height to which some of the shoots from the tree stumps, bamboos &c., had sprung up in the few months that had elapsed since the lines had been cut through. In most instances I placed the signals on a frame, fastened to the wooden top fitted into an iron telegraph standard and socket, the post being isolated and fixed in position by wire stays. The signals were steady in a fresh breeze, and the height of 30 to 33 feet thus obtained for the signal proved sufficient on all the lines except one, where it was found that the distant heliotrope was obstructed by grass on a high bank, somewhere about the centre of the ray, from the instrument placed at 21 feet above ground. On this line I observed angles to grazing heliotropes and in consequence the triangle produced a large triangle error. The delay thus occasioned would not have occurred, had I provided myself with a 7 or 8 feet portable stand for the theodolite, for it is evident that with an obstruction on the ray nearer the instrument than the distant signal, an increase of 3 or 4 feet given to the height of the instrument stand is much more effective than the same increase of height given to the signal, but I did not think such a stand would be found necessary, as all the grass on the rays of the previous season had then been cut to the ground.

(5.) On the 24th December Mr. O'Sullivan began the ray Tengapania to Dihing, completing it and the building of the Dihing station on the 30th December 1876. He then took up the ray Paonriputra to Burí, finishing it and the building of the Paonriputra station by the 25th February. The tops of the posts of this station were 25 feet above ground, and it was a particularly well built and good station. He was then employed on the preliminary work of the branch series from Dibrugarh to Jaipur. On the 20th April I found it necessary that he should take up the line Rajabeta to Dibrugarh which had been over 2 months in Mr. Wrixon's hands. Mr. O'Sullivan cut an entirely new and successful line in 6 days between the 28th February and May 10th. He had cut on the branch series to Jaipur, one final ray, 8 straight narrow gaps fixing the sites of 6 stations, and had built one post station: he also erected a scaffold 80 feet high so as to obtain the line from the Timolikhat station to the Hilika hill station of the Revenue and Topographical Surveys, in the Naga hills, but bad weather prevented any observations to it. Mr. O'Sullivan closed work on the 10th of May and left for Gauháti with his party by steamer on the 13th May. He was employed at Gauháti on various work until June 1st when he proceeded on three months privilege leave. I have much pleasure in stating that I am well satisfied with the care and labour he bestowed on his work, its style, and the large amount of out-turn.

(6.) On the 8th January Mr. Wrixon took up the ray Tengapania to Sisa completing it on the 29th January: on the 5th February I assisted him in starting work on the line Rajabeta station to Dibrugarh church. The building of the Rajabeta station and the cutting of the two rays from it to the Khalkata and Burí stations, as far as the left bank of the Brahmaputra, were also entrusted to him. On the 20th April Mr. O'Sullivan took over charge of the work on the Rajabeta-Dibrugarh line, and Mr. Wrixon shifted across the river, built the Khalkata station and cleared the few trees standing on the line from it to Dibrugarh church: he then ran the next north flank ray and built the station of Saenga Jan; removed the trees on the lines from it to the Mekla station and Dibrugarh church: he then took up the next flank ray; and on May 12th, finding the line in difficult swamp and cane forest, I closed the work of his detachment for the season. On the 27th May Mr. Wrixon left by steamer for Gauháti, and reached Shillong on the 3rd June.

(7.) On the 23rd December Mr. McCarthy took up the widening of one of my narrow gaps and finished it by December 26th: on the 29th December I assisted him in starting work on the Sisa-Healmara line, which was out of hand on the 14th January. He then built the station at Healmara, ran the next flank ray and built the Burí station, cut two final rays, (data for which I had provided by two trial lines,) ran one more final ray, and cut the line Burí-Rajabeta as far as the right bank of the Brahmaputra: all the above work reported out of hand on the 25th February 1876. Mr. McCarthy completed the line Paonriputra to Khalkata on the 11th March, and then crossed over to Dibrugarh, and opened out as final rays 6 lines forming the right flank of the series, from Dibrugarh up to Pobha Revenue Survey masonry pillar; built one post station, and also all but completed the three rays from the station of Silani, (selected by him on the N. bank of the river,) to three of his stations on the S. bank. Bad weather and the rise of the river compelling him to return to Mekla he finished the building of that station on the 2nd May 1876, remaining there until the 13th of May observing to hill peaks. He then at Dibrugarh observed to the hill peaks until 24th May 1876, and on the 27th he left by steamer for Gauháti and arrived at recess quarters in Shillong on the 3rd June. Mr. McCarthy displayed considerable and unremitting energy in his work. This was his first

season's employment on triangulation, and the successful way he managed it and his large out-turn reflect great credit on him, and I have every reason to be well pleased with his season's work.

(8.) At the close of para. 3 the account of my work is brought up to the 13th December 1875. Till January 1st I was engaged in observing from three stations, on the repair of last year's station of Sisa, and the clearing away of all the trees up to the river bank on 4 lines that converge upon this station. I also ran one trial gap and afterwards widened it into a final ray. During January I cut four trial and 3 final rays, built one post station, and was for 10 days occupied in various work; such as searching for the Khalkata Revenue Survey masonry pillar; traversing to obtain data for the line Lorua to Sisa; raising a mound of earth at the Rajabeta station, and erecting there a ladder 70 feet high; laying out a ray trace as a guide for Mr. Wrixon in determining the line Rajabeta to Dibrugarh church. On 2nd February I left my head quarters at Dihingmuk to help Mr. Wrixon to start work at Rajabeta. Thence I marched to Jaipur, at the foot of the Naga hills, and settled the situation of the stations on the N. flank of the branch series Dibrugarh to Jaipur. This is intended to connect the principal triangulation with the Revenue Survey hill stations, Deohal, near Jaipur, and Hilika, about 7 miles S. of Jaipur, close above the Disang river, on the outer range of Naga hills. This latter station is also common to the Topographical Survey of the Naga hills. I cleared the Deohal hill of jungle and found the marks, both on it and the Hilika hill, intact. From Jaipur I marched across to Sadiya and met the Deputy Commissioner of Dibrugarh, to whom I explained the advantage which the survey would gain, if a certain hill peak on the outer range of the Abar hills, north of the valley, could be occupied as a station. From Sadiya I passed down the river to Dibrugarh and selected the sites of all the stations, except 3, which would form the principal series extending from Dibrugarh to Sadiya.

(9.) On the 25th February I left my head quarter camp for a Miri village at the foot of the Abar hills on the right bank of the Dirjimmu river. The Deputy Commissioner had interested himself in my project for visiting the above mentioned hill peak and I had received good information that several Abar chiefs (who had been informed) were assembled at the above Miri village and had expressed their willingness to conduct me and my men to the hill I had pointed out. But my interview with the Abar assemblage was unsatisfactory, and I had to break up the meeting, as each man in turn stood forward and forbade the journey: they said "the entrance of strangers into their hills was unprecedented"—"they did not much object to my going alone, provided I made no map for the Queen to see, who would in consequence promptly claim them as subjects"—"they could not allow my men to go and cut down their trees on the hill tops and make marks &c." I had no time to spare for a pleasure trip, and I did not go. Work to luminous signals could not well be undertaken if a strong probability existed of the signal parties being molested, hindered, or communication with them in any way obstructed: besides in the densely forest-clad country of the hills and valley north of the river, for speedy work, guides are very necessary. The above circumstances I reported to the Deputy Commissioner and to Head Quarters.

(10.) On March 3rd I went in pursuit of a runaway elephant, a fine tusker attached to Mr. Wrixon's detachment: after 3 days' tracking I came up with him, but could not get him to stand: on the fourth day I left a female elephant and a party of mahouts &c. in the forest, and marched for Dihing station to go on with the observations. During March I closed 5 stations, and was detained in all 7 days in removing from lines obstacles which wholly or partly obscured the distant heliotropes. On April 3rd I heard that the runaway elephant had been enticed into more open ground and that the efforts of the three *kunki* (trained) elephants obtained for the purpose of his capture had proved ineffectual; so I again left my work, chased him about for four days and prevented his getting sleep at night, and on the morning of 8th April, he was secured: he was in capital condition and had been loose in the forests just five weeks.

(11.) After inspecting the work on the Rajabeta-Dibrugarh line, I completed observations at 2 stations by the 13th April. On arrival at my next station Burí I was distressed to find the line Burí to Rajabeta quite wrong, and I had to cut an entirely new line from end to end; this caused me great delay and proved a difficult task. I had only 8 men with me for work; the river had risen high and filled all the side channels of the river, which were dry but a few days previously; added to this, heavy rain set in on the 21st April, mists rose on the river at night, and my observations practically ceased for 7 days: it was the 9th of May when I finally closed the stations of Burí, Rajabeta, and Paonriputra. Between May 10th and 18th I observed angles at 4 new stations of the series, visited the three detachments of the party, and then went down the river to revise the angles at Sisa and Kherkutia stations of the triangle mentioned in paragraph 4 as having a large triangular error. I got clear signals, and the new angles differed from the former values by amounts having the same sign (the new angles were both greater,) proving that the former angles were vitiated by the graze; and the difference being almost equal in amount showed that the obstruction would probably have been found near the middle

of the ray, as I thought it appeared. Having visited Lasua station to observe to hill peaks, without success, on May 18th I caught a downward steamer and reached Gauháti on the 21st May. After arranging the affairs of the party and seeing the building of the elephant shed &c. nearly completed, I left for Shillong on May 24th and arrived there on the 25th.

(12.) The collection and distribution of provisions gave much trouble and labor: nearly all the rice and *dhán* was obtained by private purchase from the villages about Jorhát and Sibságar, on account of the very high prices ruling in the Dibrugarh *bazar* and district. Excepting a few Miri villages, there are no inhabitants in the vicinity of the greater part of series: no local labor was available or procured. In getting parties of signallers &c. passed across the river and side channels of the river many vexatious delays occurred, the men often having to go long distances out of their way to get put across the water. The weather for work on the preliminary series was all that could be desired until April 21st, when very bad weather set in. The general health of the party was excellent.

(13.) Many difficulties were met with in taking the observations: most of the rays were nearly grazing rays; the greater number passed more or less over the river, and the signals at 9 A.M. and 3 A.M. were as a rule very wild. For 3 days in March and 2 in April so thick was the haze and smoke over head that the heliotropes barely showed at all; and on 2 days I got little work on account of a gale from the north west, which blew such dense clouds of sand down the river as to cause the heliotropes to be visible for only short intervals. I had very bad luck with the work to hill peaks, and did not obtain 20 angles before April 20th; afterwards I was more fortunate.

(14.) All the post stations on the south bank of the Brahmaputra except one stood on firm soil, and when the posts of the station and the instrument were properly protected from the wind by screens of grass &c., no difficulty on the score of instability arose; but not so with those stations built on the north side of the Brahmaputra, which were built on sand: the usual grass screens for the wind caused the platform to vibrate, and the tremor was communicated to the instrument. I found it best to be content with only a bit of cloth as shelter for the portable instrument stand. At Paonriputra (a remarkably strong and well built 25 feet post station) it happened that one of the huts for the men was placed about 120 feet distant from the station, and if by chance a man threw down a bundle of firewood at the door of his hut, or chopped a bit of wood, the jog given to the instrument would quite throw off the intersection of the distant signal: one day I measured a distance of 172 feet from the station pillar to where a man was seated fashioning a tent peg on a block of wood, the blows of his *dao* spoiling my angles. At every station on the north bank of the river, if a man came at all quickly up the ladder to the platform a strong tremor was visible in the telescope. To build a station different to the ordinary pattern, on sites of hard sand with a water-logged stratum only a few feet below the surface, did not suggest itself to me as necessary till after the stations had been built and observing had commenced: obviously, better isolation for the posts of the instrument, and comfortable work would have been obtained, if the uprights of the observer's platform had been spread out so that their feet were distant from the three posts, the uprights being supplied with plentiful bracing well nailed, the feet of the uprights not being sunk in the ground but resting on planks, and so forth: this season the only result has been that the observations required painful care. The average triangular error of the principal triangulation is 1·15 seconds.

(15.) The analysis of the heights observed is as follows:—(1.) On 22 rays passing over land and water, comprising 303 observations, the factor of refraction is on every ray negative, the mean value being —·066. (2.) On 2 rays passing almost entirely over the river, and respectively 10¼ and 7 miles in length, comprising 36 observations, the factor on each ray is positive, the mean value being +·068. (3.) On 6 rays converging on the lofty stations of Gaorisagar temple (90 feet) and Dibrugarh church tower (50 feet), comprising 84 observations, the factor on each ray is positive, the mean value being +·035.

(16.) The hill peaks observed to extend up to a line bearing from Dibrugarh church 20° east of north.

III. Extract from the Narrative Report—dated 19th July 1876—of W. G. BEVERLEY, Esq., Officiating Assistant Superintendent 2nd Grade, in charge of the Burmah Party.

(2.) It will have been observed from last year's Report, that the triangulation carried on in 1874-75 had not been finally connected with the Eastern Frontier Series. This work was therefore first taken in hand, so as to furnish at an early date the accurate positions of points along the coast for the

Marine Survey. A new light-house about five miles out at sea was also in course of construction, and it was necessary to get some observations from the top of the old light-house before it was dismantled, in order to obtain data for opening a ray to the new light from one of our stations on the coast. The programme of work for the season of 1875-76 was, in addition to the above, the extension of the triangulation along the coast towards the Krishna Shoal light-house, three chains of secondary triangles to start from principal sides of the Eastern Frontier Series, one *viâ* Tonghoo to the Boundary to the north, a second *viâ* Prome and Thâyetmyo to the Boundary, and the third *viâ* Bassein to Cape Negrais to the south.

(3.) I left recess quarters at the end of September to be in time to visit the old light before removal. I visited the place on the 10th of October and obtained the requisite observations, having had to wade through about ¼ mile of mud and water under a burning sun. A touch of malarious fever compelled me to abandon the work at that time; in fact it was impossible to effect any ray clearing with the country entirely under water.

(4.) In order to complete the connection of last year's work with the Eastern Frontier Series, I reconnoitred the country and selected a site for a station which was to be employed in addition to those already selected. I also took observations at three other stations, and obtained data for opening the ray Chanakpho to Chaglibá. I decided upon using the principal stations of Chaiteo, Chaideo, and Thúlú, of the Eastern Frontier Series, as the stations of origin.

(5.) After various delays I was enabled to leave Rangoon by the steamer of the 27th of November to take up the triangulation down to Cape Negrais. Before commencing, I went up to Prome to see how Mr. Low had laid out his work. I visited my first station on the 10th of December and closed work on the 15th of April.

(6.) The country traversed by me in the Henzada district was a difficult one for triangulation: it was impossible to get on to the main ridge running parallel to the Irrawaddy, while the spurs from it were not only very densely wooded but were not long enough to admit of both flank stations being selected on them. The country between the river and the foot of the hills is very well populated, but no villages exist up the lateral ravines, and the villagers decline to go beyond a certain distance from their houses from a dread of wild animals and malaria. In most large ravines timber is felled to a considerable extent and there are several cart roads made for conveying the same to points whence they can be floated down: it was not therefore difficult to procure carriage nor except occasionally was any difficulty experienced in obtaining coolies to visit the hills not remote from the villages.

(7.) The country between the river and the foot of the hills is occasionally undulating and covered with patches of dense forest: this added to the difficulties of selecting stations. I succeeded however, by using some stations in the plains on one flank and avoiding intermediate rays, in carrying the triangulation down to within 32 miles of Bassein—a direct distance of 81 miles. The hills here are very low (the forward station being probably below 200 feet) and are a series of plateaus densely wooded. The clearing of such hills in one of the hottest months of the year was likely to occupy three weeks and more, and I considered it advisable to close before the heavy rains came down and rendered the return of elephants to Rangoon a dangerous business. The haze prevented Henzada being fixed this year, the station being over 30 miles in a direct distance from the nearest trigonometrical stations on the hills; but this will be readily done at the commencement of the next field season.

(8). Mr. Low was transferred from Head Quarters and joined the party on the 22nd of October. He was deputed to take up the triangulation from near Prome *viâ* Thâyetmyo to the British Boundary on the north. Owing to the high road to Prome being taken up for the railway, Mr. Low was compelled to have his baggage and establishment brought back from the 40th mile, and to leave Rangoon by steamer for Prome: he commenced work about the end of November.

(9). The principal station of Yongdong near Prome, one of the stations of origin for Mr. Low's triangulation, was found to have the markstones dug out, and a great oblong hole existed instead of the pillar. He was therefore directed to fall back on Kidong station and to use Yongdong, where he put in a mark as an entirely new station.

(10). The country triangulated by Mr. Low lies on both sides of the Irrawaddy river and is densely wooded. Although well populated, it was difficult to get carriage, and it was rendered more difficult by the inadequate assistance afforded him. Mr. Low's reports are a record of delays and difficulties which would have damped the ardour of a less zealous surveyor.

(11). Though new to the country and the language Mr. Low has completed a very satisfactory season's work. He has carried his triangulation up to the Boundary, a direct distance of 60 miles; fixed numerous points in the civil and military stations of Prome and Thâyetmyo; and covered with trigonometrical points an area of about 3640 square miles. Mr Low has also furnished a very large number of heights, and given the means of making a connection between the railway and trigonometrical levelling for comparison or otherwise. The party has been very much strengthened by the additon

of an officer of Mr. Low's ability and zeal. He returned to recess quarters at Moulmein on 3rd of June.

(12.) The triangulation for connecting the work of the previous season with the Eastern Frontier Series was made over to Messrs. Mitchell and Collins, to work simultaneously if possible, one in the Tenasserim district, and the other in the Rangoon division. In order to obtain correct values at an early date, Mr. Mitchell was directed to visit the station of Kalamatong of the Eastern Frontier Series, close to Moulmein, and from it to observe Rangoon and Siriam pagodas, and thereby furnish direct values of these two points to be tested by the values obtained from a series of triangles.

(13.) Mr. Mitchell went up to Kalamatong on the 28th of October and obtained his observations to Rangoon and Siriam after some delay, owing to the station being occupied by Mr. Rossenrode's signalmen, and from the mists rising up from the Gulf of Martaban, over which the rays passed. Mr. Mitchell subsequently visited three other principal stations of the Eastern Frontier Series, and completed his observations on the Tenasserim side by the 17th of December, having been delayed very much by bad signals and unfavorable weather. The distances from these three stations to Máko on the Rangoon side are between 41 and 56 miles, and from Chaiteo to Chaglíbá 55·7 miles, and these long sides considerably retarded the work of both Messrs. Mitchell and Collins; the signals shewn being at times very faint, and at other times too unsteady to intersect, due probably to the vapour ascending from the vast expanse of the Gulf of Martaban.

(14.) Mr. Mitchell also visited the four stations of Chaglíbá, Chanakpho, Máko, and Dalabán, on the Rangoon side, in order to complete the observations which Mr. Collins was unable from various causes to obtain: he also opened the ray between the first two stations. These four stations were intended for a quadrilateral, but on account of large triangular errors, two triangles were rejected. These errors appear to be due to the rays passing over marshy ground, and over rice fields. These observations were completed by the 7th of February, and Mr. Mitchell proceeded to take up the triangulation *viâ* Tonghoo. The data obtained from these observations enabled me, early in March, to furnish the Master Attendant with the approximate position of the new China Bakír light-house: this position is very near the accurate one since supplied him.

(15.) The haze which had set in when Mr. Mitchell took up the Tonghoo triangulation, prevented his taking any final observations from the starting side which is about 33 miles in length. Having visited one of the terminal stations *viz.* Myayabengkyo, he reconnoitred the ground selected and cleared five hills and laid out the triangulation up to Tonghoo, and returned to take up the observations. He was unable to take final observations from more than one station, *viz.* Toungí; and a few from Tháyekhá the other station of the starting side. The rains had now set in, and he was directed to close and return to recess quarters if he considered there was too much risk in keeping out an establishment exposed to continued rain. The observations should be carried up to Tonghoo by an early date next season, and I have every hope that the triangulation between Tonghoo and Tháyetmyo along the Boundary will be out of hand next season. Mr. Mitchell arrived in recess quarters on the 8th of June having suffered a good deal in health during the field season.

(16.) Mr. Collins took the field on the 28th of October and went to Shánteji station to take an angle there, which could not be obtained last year. The country being here still under water, he proceeded and built Máko station on the top of a high pagoda. He visited Máko, Chaglíbá, and Dalabán, in connection with Mr. Mitchell's work mentioned above, and having taken as many angles as he could obtain he returned to take up the triangulation along the coast. As it was necessary to obtain data for opening a ray from Mengálon to the new light-house, he measured a base carefully on the sea coast, as the only means whereby an accurate angle for giving the ray could be obtained. The ground between Mengálon station and the sea coast is low and swampy, and he had great difficulty in opening this ray. Later on he visited the new light out at sea and took observations off the staging between Mengálon station and Elephant Point Column. Mr. Collins reports that the sea was very rough (being the north-east monsoon) and there was a great deal of vibration from the force of the waves striking against the staging. The horizontal angles were very accordant. The side Mengálon to Elephant Point obtained from the base measured on the coast, agrees remarkably well with that deduced from computations brought down by triangulation, and was used in the approximate computation of the latitude and longitude of the new light-house.

(17.) On completion of this work Mr. Collins took up the continuation of the triangulation along the coast from the side Danot to Motyúá. He carried three trial lines between Taolán and Mengálon, a distance of 11 miles, over a tract of country where there was extreme difficulty in procuring potable water which was only obtained in very small quantities and at villages remote from the ray. He took final observations and completed one quadrilateral, opening the intervening rays; and selected the sites of 6 stations for future work. The sites selected appear to be judicious, and under favorable circumstances the triangulation will probably reach Krishna Shoal next year.

(18.) The country along the coast is low and swampy, intersected with numerous tidal creeks, with very few villages and these far apart. It is under water to about the middle of January, and there are no means of moving about except by boats: after each flood tide the ground is submerged to a good distance on each side of the creek, and Mr. Collins had to do most of his marches on foot, wading through slime and wet. The country was the most difficult and trying in Burmah, and Mr. Collins deserves credit for sticking to his work in spite of frequent attacks of illness, although his out-turn of work is small. The experience however that he has gained will be of considerable advantage to him next season. Mr. Collins returned to recess quarters on the 20th of May.

(19.) The men of the Native Establishment have not worked so satisfactorily the last season, the signallers having in repeated instances given a great deal of inconvenience and caused loss of time.

(20.) Tabular statements showing the work done by each officer, accompany this report, and I trust that considering the unfavorable circumstances under which work is obtained at all times in Burmah, the out-turn of work for the past season may be considered satisfactory.

(22.) The Master Attendant at Rangoon, Captain Arnot gave every assistance required to Mr. Collins while employed in fixing the light-house. The work of the Survey always progresses satisfactorily when the District Officers assist the Surveyors. The Deputy Commissioners of Rangoon, Henzada, and Thâyetmyo, furnished *parwanas* immediately on application, which were very serviceable, because the Burmans pay every respect to a document bearing the official stamp of the court. The Deputy Commissioner of Prome however refused to give Mr. Low a *parwana* and his refusal was confirmed by the Commissioner of the Rangoon Division. The consequence was serious delay and unnecessary expense entailed on the Government.

IV. Extract from the Narrative Report—dated 18th September 1876—of W. C. ROSSENRODE, Esq., Deputy Superintendent 3rd Grade, in charge of the Eastern Frontier Series.

(2.) The duration of fine observing weather being so short in Burma and the sides of some of the triangles being unavoidably long, owing to the inaccessible mural limestone ranges falling within the triangulation, and it being utterly impossible to make use of any point in them, I had no alternative but to resume field operations earlier this season than I usually did, to endeavour to complete the long sides before the setting in of bad weather.

(3.) Mr. J. O. Hughes was posted to this party by Department Order dated 1st September 1875, and finding that he had had some experience in Assam I determined upon detaching all my three assistants and retaining my Burman writer to record for me in the observatory as he did during the previous field season. Mr. Hughes joined on the 23rd October in a bad state of health caused by an injury he had sustained at Agra, and finding him completely prostrated, I had to alter all my arrangements.

(4.) Mr. Clancey having rejoined from privilege leave on the 23rd October was directed to assist Mr. Beverley in the office.

(5.) I took the field on the 26th October and began final observations at Toungzún H.S. near Moulmein, clouds and rain interrupted my progress. I however completed my observations on the 5th November and returned to Moulmein to rearrange my plans. Mr. Beverley was requested to take up the approximate triangulation on completion of the office work and Mr. Clancey was instructed to fix a principal station on the eastern flank, which was required to complete the figure previously formed. After selecting, building, and preparing the above station, Mr. Clancey was to visit each principal station, and to observe all the high peaks to the east, in the interior, connecting them with one of the principal stations of the series. On completing his observations at each station on the eastern flank, he was to construct a rectangular pillar on it, and make it over for safe custody to the local officials before quitting it: in this way he was to visit seriatim each principal station of the previous season.

(6.) The country being still under water it was utterly impracticable, nay impossible, to march; I therefore engaged boats for the whole party, baggage, instruments, and provisions, and proceeded to Wabiantong H.S., which is 2 miles distant from the Salween river. After the observations were completed the whole party got into the boats and dropped down the river, and encamped at the foot of Mizantong H.S. the same evening. This hill is composed entirely of limestone and the road to it was originally prepared by Mr. Beverley when he selected the station. The tindal was sent to re-cut and improve this road, as the hill was said to be most difficult of access. He and his party were employed a whole month in altering, improving, and making it practicable for conveying the 24-inch Theodolite. With

all his ingenuity and labor the instrument was taken up with difficulty after much toil. I personally superintended its transport, and had the whole establishment to assist: 4 strong new ropes were attached to the box and 6 men holding each rope commenced ascending the hill, dragging up the instrument carriers, thus assisting and supporting them to climb the steep, rugged, and narrow path, step by step. To prevent accidents from breakage of ropes, I followed with a number of men who supported the carriers in the rear, and raised the box when necessary over the obstructing rocks in the passage. The instrument reached the summit in safety, and as the observatory tent could not be pitched, owing to one face of the hill being a perpendicular precipice, the base being seen from the summit, I improvised a temporary one with wood, bamboos, and grass. The station being very much exposed, no reliance could be placed on the supports of the hut which, owing to rocks, could not be driven into them, but rested in fissures, clefts, and indentations found in the rocky surface; I therefore observed duringday light only, taking the precaution of being present all the time the instrument was in position. After sunset the theodolite was boxed, and I retired from the observatory.

(7.) Kamákabo, the most difficult station of the season was next visited: it is the centre of a pentagon and is surrounded by an extensive marsh. The hill is very precipitous, of limestone formation, with its sharp projecting rocks jutting out in every direction. Ladders were used in ascending this station, varying in length from 16 to 40 feet, and by no other means could access be obtained from one rock to the succeeding one above it. I was detained 6 days in altering, strengthening, and constructing these ladders and ramps, which had been previously made by men detached for the purpose. After testing and proving their stability, the 24-inch theodolite was carried up; and it was a day of rejoicing in camp, when the instrument was brought down in safety after the completion of the observations. Many men were wounded by the sharp rocks, notwithstanding all the precautions taken to prevent injury to their feet by pavements of wood over the portions where ladders and ramps were not required.

(8.) Tabutho, Shoisandau, and Konlah, were successively visited, by water. From the latter station I proceeded to Amherst, where the elephants of the party awaited my arrival. The boats were abandoned and I marched to Sindong H.S., and from thence to Kaikamau H.S. The stages to them were made on the Government trunk road which has been constructed from Moulmein to Amherst through a dense forest. Three staging bungalows, 2 rooms in each, have been erected on this road for the convenience of travellers.

(9.) From the 38th mile post another Government trunk road has been surveyed and marked off as far as Yeh, and is eventually to be extended to Tavoy. A portion of this line has been cleared of jungle, and the preliminary work of removing roots, cutting drains on either side, and raising it by throwing up earth, has been done for some miles. It requires bridging and metalling to complete it. In its present state it can be used only during the dry months. For 6 months last season gangs of coolies were engaged and employed under overseers and sub-overseers, but the progress was unsatisfactory: the men from sickness or from other causes either deserted or struck work, and I noticed on my return, after closing operations, that much progress had not been made. From the superabundant population of the Madras Presidency thousands of men who cannot obtain a living there emigrate annually for this Province, where work is plentiful and remunerative. They are very poor and readily take employment at first; but when they have accumulated some money, they bargain for higher wages, and eventually take up contract work, which seems to suit them best, for they can then work or idle as they please.

(10.) This high road partly metalled and partly raised and cleared, and the remainder only cleared of forest, was the only one met with during the season; and with all its imperfections, was of much use to us not only for marching, but for drawing our supplies from Moulmein, which were brought in carts as far as it was metalled and bridged, and from thence by the elephants. The dâk-men also used it throughout the season.

(11.) After completing observations at Kaikamau H.S., I proceeded to Thámindo H.S., which was reached in 5 tedious and trying stages: owing to the low marshy state of the country, detours of 2 and 3 miles had to be occasionally made to get over half or one mile of direct distance to avoid swamps, bogs, or other unsafe ground for men and cattle. Two tidal streams had to be crossed. Crossing rivers and streams in the interior of Burmah is something formidable for surveying parties equipped with large and valuable theodolites, tents, and other heavy baggage, which require large and safe boats to ferry them over. At each ferry a small canoe or two are kept for the convenience of travellers, who are mostly pedestrians and generally carry a small box containing a suit or two of clothing made of palm leaves; the indispensable *dah*, a knife with a blade 2 feet long and 2 to 3 inches wide; the umbrella; and a large bag, a receptacle for odds and ends, betelnut box, tobacco, cigars, and cooked rice for use when overtaken by hunger. With the box fastened to his back, his knife in its scabbard hanging from his shoulder by a loop of rope, the bag suspended by tape from the other

shoulder, and with the umbrella in hand, the traveller steps into the canoe and ferries himself over leaving the boat securely fastened on the other side. In the interior of Burmah ferry-men are never found at their posts owing to the uncertainty and small number of travellers; when required they are to be found in the nearest village. At civil and military stations and other important places, where the influx of travellers and trade is great, good boats, and an abundant supply of them are readily obtained, and no delay or inconvenience occurs, the men being always on the spot to collect the toll and demand their fare. In the interior however the difficulty of crossing rivers is great, as canoes are only procurable capable of carrying from 4 to 8 men. A single canoe is at all times unsafe; it sways, rolls, and capsizes if the men do not sit still in it. For crossing over the 24-inch theodolite and the heavy baggage a large number of canoes are required. To collect and lash two and three together to form rafts takes time, and I have been delayed two and even three days in crossing rivers from station to station. In the tidal streams care must be taken to cross them only during high water owing to the quagmire on either bank. Elephants and cattle cannot be landed safely at other times without danger of losing them.

(12.) From Thámindo H.S. I proceeded to Toungboung H.S. from the latter I had to return by the same route to Selúdong H.S. passing near Kaikamau H.S. These circuitous routes cannot be avoided in this province, which is devoid of roads; and to go and return by those prepared for the party becomes necessary, to save time, owing to the great delay and expense of cutting new ones. They have been cut and prepared season after season, and the men have been engaged for a month and more in preparing each road.

(13.) I reached Selúdong H.S. on the 10th day after leaving Toungboung H.S.: the haze was setting in and I was detained there a few days; on completing the observations I proceeded to Thebeye H.S., which after some days delay from bad weather, was completed, and I hurried on to Yelridong H.S., which I reached on the 4th March: here I remained until the rains set in and cleared the atmosphere and enabled me to complete my observations on the 22nd April. Owing to the thickness of the atmosphere and the daily fires on the Keoktaga and Toungboung rays, these hill stations were completely obscured most of the time I occupied the station of Yebudong.

(14.) The rains having set in I closed work and returned to Moulmein on the 1st May; Messrs. Beverley and Hughes came in a week later, and Mr. Clancey arrived a fortnight after me.

(15.) The approximate operations started with the selection of Konlah H.S., south east of Moulmein, on the island of Belogyún, close on the sea-coast. Selúdong H.S. was next fixed, 50 miles from Moulmein by the road which skirts along the western bone (*sic*) of the range stretching from Moulmein to the Siamese boundary. At first the stations were fixed on both sides of this range, keeping the centre and one of the two terminal stations of the figure on it: where the range formed the boundary between Siam and Tenasserim the most easterly stations were placed on it. The approximate triangulation has been extended from Konlah H.S. to Toungshún H.S., near Nabúley village 20 miles north of Tavoy, by two compound hexagons, a tetragon, and a double polygon. Much difficulty was experienced in the above work, especially near the town of Yeh and to the south of it. On referring to the chart accompanying this report it will be noticed that a tetragon has been introduced on the side Phalein (on the coast) and Sedong (near the Siamese frontier) where the strip of British territory between the coast and frontier is very narrow—25 to 30 miles only. Here the skill and experience of the surveyor was put to the test: wedged in as he was between the sea and frontier, and failing in a quadrilateral owing to the Yetagúndine hill obstructing the diagonal rays, Mr. Beverley who was in charge of the approximate series, extricated himself in a masterly manner by adopting the only feasible figure, a tetragon; thus achieving success and continuing the triangulation. To add to the difficulties of ground, the country between the sides Phalein-Sedong, and Painpúngún-Nakiadong was almost uninhabited, and in the central and eastern portions entirely so.

(16.) Mr. Beverley was engaged in advancing the approximate triangulation, which he conducted with his usual energy and skill notwithstanding the very difficult nature of the country, which was so densely clothed with jungle that he was obliged to clear his own paths guiding the cutters to the proposed station, his camp following him as he advanced. Creeks and tidal streams enhanced the difficulty of marching and caused considerable delay. Much time was taken up in clearing the densely wooded hill tops for want of coolies, who were collected and brought from long distances. At one station, Deobyú, which is situated 5 stages from the nearest village, it occupied him a considerable time clearing a path to the hill and providing coolies and supplies for clearing, building, and preparing the station. The native official at the large village of Hangan promptly rendered assistance.

(18.) Mr. Beverley has pioneered this party during the whole time I have held charge of it, and to his ability and skill I am greatly indebted for the success attending the operations in this, as well as on the Bider and Biláspur Series.

(19.) Mr. J. C. Clancey, Assistant Surveyor 3rd Grade, left Moulmein on the 4th December 1875, and completed the selection and preparation of Toungboung H.S. for final observations on the 8th January.

The delay was unavoidable owing to desertions of coolies who were brought from great distances, and worked most reluctantly, taking advantage of every opportunity of slipping away. He was for days left with 4 to 6 men to clear tough forest trees of great girth. By my deputing Mr. Clancey to select this station on the eastern flank Mr. Beverley was saved a long march of a fortnight's duration in returning from the station after its completion to begin his work on the western flank.

(20.) After completing Toungboung H.S. Mr. Clancey took up his legitimate duties, visiting all the stations finally completed last season. He observed hill peaks at Thámindo, Shoisandau, Tabutho, and returned the 7-inch theodolite to the depôt at Moulmein from Kamákabo H.S.; being unable from bad health to use it. He constructed all the rectangular pillars and made them over for safe custody to the local officials. He was unable to superintend personally the construction of all the rectangular pillars owing to palpitation of the heart. When climbing hills and marching became painful he proceeded to Shoay-Gheen the nearest station and placed himself under the civil-surgeon until he was able to resume work.

(21.) Mr. J. O. Hughes joined this party sick on the 23rd October last and being incapacitated for work obtained leave on medical certificate. On the expiry of his leave on the 1st February, he was directed to assist Mr. Beverley on the approximate triangulation and personally selected three stations and visited the 4th which was fixed by Mr. Beverley. The experience he has gained under Mr. Beverley will be of great use to him in this party, and I have hopes of his being usefully employed the next season on independent work.

(22.) Moung Moung, a Burman lad educated in the Mission and Government Schools at Moulmein, has been now two years with the party as a Burmese and English writer, interpreter, and recorder in the observatory: in the latter capacity he has been of much use for the last two seasons and has done good service.

(23.) The native establishment behaved very well during the field season, but on returning to recess quarters many of the Hindostani carriers took their discharge finding that they could readily obtain service elsewhere. The instrument bearers have also left, but all vacancies have been filled up and the establishment continues efficient. Men of the Madras Presidency are gradually taking the places of the Hindostanis and the establishment will eventually be composed of Madras men.

(24.) The country finally triangulated last season is hilly throughout: long ranges of hills running north and south, with shorter ranges between them, or low spurs jutting out here and there forming conecting links in the chain, extend throughout the triangulated portion in the centre of the Series. Towards the coast the hills are low and isolated and as you retreat further from it, they become more elevated. There are more strips of level ground towards the coast than in the interior. The valley of the Atteran is rather extensive. As the series advances from Moulmein towards Tavoy the population perceptibly diminishes; villages further and further removed from one another are noticed, and towards Selúdong and Thebeye single families having a hut or two occupy the small level spots which they cultivate for a living.

(25.) A large trade in boats is carried on by the people inhabiting the forest. At the base of the hills trees of immense girth are to be found: the tree is selected, felled, and shaped: the digging and scooping process is then performed, leaving the outer surface about three inches thick. The canoes thus roughly made are 20, 40 and 60 feet in length, and from 4 to 6 feet in width in the centre. They are then dragged by two or more elephants over short pieces of timber 3 to 6 inches in diameter placed on the path; these acting as rollers overcome the resistance offered by the uneven ground and the men proceed merrily on, driving the elephants. These sagacious animals are trained to their work and exert themselves to the utmost in dragging the boat to its destination near a navigable stream. The boat is then finished off and sold. The purchaser adds planks to the sides, widening and raising it to the required height. From this capacious dug-out canoe a large boat is formed capable of being taken by sea to Moulmein and Rangoon for sale in the calm winter months. All the village people assist in making the path for dragging the canoe, and each one uses it when his own boat is ready for removal to the stream.

(26.) From information obtained from Mr. Beverley and after consulting the maps of the country in advance, I am of opinion that the series should be continued in a S.S.E. direction from the side Nakiatong to Toungshún, curving it slightly so as to have all the stations on the main land till the termination of the British territory at St. Mathews Island, when as a matter of course some of the numerous islands must be used. For visiting these islands good large sea-going boats will be required for the main and detached parties and must be permanently engaged for the entire field season.

(27.) I believe a base of verification will be required in Tenasserim. If not tied down to a particular locality for the base, I would recommend its being selected at any spot between Mergui and St. Mathews Island wherever suitable ground can be found.

(28.) To Colonel Brown, the late Commissioner of the Tenasserim Division, I am in a great measure indebted for the success which has attended my operations during the entire field season: he

provided me with a *parwána* for myself and for each of my Assistants, bearing his seal and signature, and the document was promptly attended to by all the native local officials throughout his division. He was much interested in the extension of the Survey operations, and impressed on his subordinates that his wishes were to be attended to and his orders carried out, so that the public service might not suffer delay or inconvenience for want of co-operation on their part: the police were also directed to aid and assist whenever their services were needed.

V. Extract from the Narrative Report—dated 21st September 1876—of Captain M. W. ROGERS, R.E., Officiating Deputy Superintendent 3rd Grade, in charge of the Jodhpur Series.

(2) Owing to the very heavy rains of 1875, the men of the party who were on leave were much delayed in joining, and the medical and other stores of the party for the field season were stopped at Ahmedabad. However, means were found to enable Messrs. Price and Torrens to take the field on the 1st October, and I proceeded to Deesa, where I inspected the Meteorological Observatory, and laid out a small triangulation for connecting it and the Telegraph Office with the Karáchi Longitudinal Series. I then returned to Ábú, and having at length received the necessary men and stores, left for the field on the 23rd October. I marched *viâ* Jodhpur and Bikaner to the Baháwalpur territory, and commenced observations at Mansa H.S. on the 4th December. The double figure remaining to complete the series was finished on the 3rd January 1876, at Kaimsir T. S. of the Sutlej Series. Mr. Prunty was then sent to close the stations of the season's work and to finish the connection of some Revenue Survey points, whilst the main camp marched, *viâ* Baháwalpur, to the meridian of 70°, on which a new series, called the "Eastern Sind," was to be commenced. This was reached towards the end of the month, and I at once began inspecting the old stations of the Great Indus Series, with a view to fixing on an initial side: unfortunately several of these stations had been completely destroyed by the river, and the series will start from a side considerably west of the meridian.

(3.) The country immediately south of the Indus is quite flat and covered with dense tree and grass jungle, and is inundated for four or five months each year; it therefore became necessary to resort to ray tracing and tower building in the 20 miles which intervene between the river and the sand hills. This style of work was new to all the members of the party, and the progress was in consequence slow. Eight stations were selected, advancing the series 24 miles and reaching the sand hills, on which progress will be more rapid and less expensive. Two towers were built and the materials for two more collected, and 104 miles of rays cleared; leaving but a small distance to be done.

(4.) The party returned to Ábú, *viâ* Jesalmer, traversing the desert north of that town, which has hardly ever been visited previously. It differs in no respects from the portions of Bikaner, Jesalmer, and Marwar, visited during the progress of the Jodhpur Series, save in there being fewer villages, owing probably to the comparative absence of the vegetation which supports so many flocks and herds in those states. The country around the city of Jesalmer itself is very rocky, and there are no roads for wheeled vehicles, which are unknown in the city. The party reached Mount Ábú on the 26th April, after a long and fatiguing march through the desert.

(5.) This season's work finishes the Jodhpur Series, the longer of the two desert series which remain to complete this part of the principal triangulation of India; and it will not be out of place to give a short *resumé* of the work. It is 311 miles in length and was completed in 3 field seasons and one month, from the first reconnoissance for stations to the last final observed angle: it covers an area of 8,041 square miles, besides 4,318 sq. miles of secondary triangulation and, with the exception of a small portion south of the river Luni, passes over a sandy country of nearly utter desolation. The country is covered with sand hills of every form, in all directions, dotted here and there with tufts of coarse grass and stunted shrubs. The villages, few and far between, are collections of squalid wigwams, situated near spots where wells, sometimes 200 feet in depth, have been excavated with great labor, to be rewarded often with only brackish water. In the whole distance from the Luni to the Sutlej Series, 250 miles, the series met with only one place—Phalaudi—which could be dignified by the name of a town, and four which ranked as decent villages. All is barren and desolate, but perhaps the southern portion of Baháwalpur carries off the palm in this respect. There the series passed over a distance of 70 miles in which there were only three wells of drinkable water, and these were collected within a space of 10 miles.

(6.) In no native state in which I have worked, has such hearty and effective assistance been rendered to me, as by the Political Superintendent of this country. Whilst alluding to this, I also thankfully acknowledge the assistance and kindness which we experienced from the Rulers and Political Agents of Marwar, Bikaner, and Jesalmer.

(7.) The total out-turn of work of the season is as follows. Principal observations were taken at 9 principal stations forming a double polygon, fixing 5 new principal stations, embracing an area of 311 square miles and extending the series 21 miles along the meridian to its completion and junction with the Sutlej Series. A secondary series, double throughout, was selected and observed on the meridian of 71° 15′, extending 142 miles from the Jesalmer Minor Series to the Karáchi Longitudinal Series, and covering an area of 2,526 square miles, fixing 16 new secondary and a large number of intersected points. The observatory and telegraph office at Deesa were connected with the triangulation by a short series. All this secondary work was done with a 10-inch theodolite. The approximate work of the Eastern Sind Series was commenced and extended for 134 miles. 32 stations were selected and 10 built.

(8.) This season, seeing as it did the completion of one series and the commencement of another, cannot be judged by the amount of principal triangulation turned out; but the work done this year will, I trust, make itself felt in the out-turn of next year.

(13.) Mr. Price on leaving Ábú was employed on the Deesa connection, and unfortunately took his party up Jeraj H. S., the result being that both he and all his men were attacked by fever and with difficulty reached Deesa, where they had to remain for a month under medical treatment. He then marched to the southern portion of the Eastern Sind Series, and took up the approximate work. This he pushed on with his usual vigour and success, and selected 24 stations and built 8, extending the series 110 miles. This amount, considering the time lost by sickness, was very creditable to him.

(14.) Mr. Torrens was first employed on the Deesa connection which he completed, except the observations on Jeraj, which I directed should be postponed until the end of the season. He then took up the Balmer Minor Series on the meridian of 71° 15′ and selected, built, and observed along it. As it is 142 miles long and double throughout, I consider that Mr. Torrens has done a most creditable season's work.

(15.) Mr. Prunty accompanied me as observatory recorder, and on the completion of the series closed 13 stations and observed at several of the auxiliary stations necessary for fixing the Bahawalpur Revenue Survey stations. He then joined me and aided in the ray clearing &c., on the Eastern Sind Series. During the recess he observed some triangles on Mount Ábú, required to fix the position and height of the barometer which has been lately placed here by Mr. Chambers, the Meteorological Reporter of Bombay. This is the first season he has tried any triangulation, and I am much pleased with the results.

VI. Extract from the Narrative Report—dated 31st October 1876—of Captain A. BAIRD, R.E., Assistant Superintendent 1st Grade, in charge of the Tidal and Levelling Party.

Work performed during recess.

(2.) The curves of the tidal diagrams were carefully compared with the different records and in one or two cases of small interruptions in the work the curves were interpolated by a reference to the daily reports of the sub-surveyors and the inspection books. The computations at first made were those for correcting the tide-gauge clocks to true mean local time at each station for each day during the period of performances of the clocks. The determinations of the zero (and this in some cases for several diagrams of the self-registering tide-gauge) were calculated, several other minor computations were made, and then the position of the pencil for each hour, on every sheet, was corrected to true mean time throughout the entire period required; and finally the measurements of every point from the datum were most carefully made (this in duplicate). Some idea of the magnitude of this work may be formed when I state that over 30,000 points were corrected for time and nearly 30,000 final measurements were made in duplicate. Each final measurement was taken to the nearest hundredth of a foot, and as this gave an average of 4 figures for each distance the summations for the final results were heavy indeed.

You are aware that the observations at Nawanár tidal station were incomplete; however I have been enabled to eliminate almost perfect values for 1½ complete lunations to the nearest hour in 1874

viz., 9h. 1st May 1874 to 14th June 1874 (astronomical time) both hours inclusive; also 2 complete lunations to the nearest hour in 1875 *viz.*, 13 h. 7th March 1875 to 8 h. 5th May 1875, both hours inclusive. I have also tabulated the values for Okhá tidal station and Hanstal tidal station for the same period and have computed the value of mean level of the sea in each case. The following table shows the results of the different computations.

	Correct value of mean level of sea above datum by 12½ lunations.	Mean level of sea above datum by 2 lunations in 1875.	Difference from correct value of mean level of sea.	Mean level of the sea above datum by 1¼ lunations in 1874.	Difference from correct value of mean level of sea.	Mean level of sea above datum by 1¼ lunations greater or less than by 2 lunations.	Final value of B.M.A above mean level of sea.
At Okhá Tidal Station ...	9·65	9·75	+ 0·1	9·90	+ 0·25	+ 0·15	+10·424
„ Hanstal „ ...	16·33	16·33	0·0	16·51	+ 0·18	+ 0·18	+ 9·702
„ Nawanár „ ...	...	15·36	...	15·56	...	+ 0·20	+ 9·476

You will observe that the mean level of the sea for Okhá tidal station as determined by 1½ lunations in 1874 is 0·25 foot higher than the real value, and for Hanstal similarly it is 0·18 feet higher. Also for 2 complete lunations in 1875 the mean level of the sea is only 0·10 feet higher than the proper value for Okhá tidal station while at Hanstal it absolutely agrees. All this bears out what you state in your No. $\frac{4}{71}$ dated 20th January 1875 *viz.* "you will see that it is very probable that a series of tidal observations embracing a period of 2 months from about the 7th March to 7th of May will give a result very closely coinciding with the mean of the year," and on this account every effort was made to get the observations for that period, and with success. You will also observe that the difference of mean level of sea at Okhá by 1¼ lunations is 0·15 feet higher than by 2 lunations: for Hanstal it is 0·18 feet higher, and for Nawanár 0·20 higher—results which alone show the greater accuracy of the observations.

(3.) I determine the M. L. of the sea to be

feet

for Nawanár = 15·36 above datum = 9·476 below B.M.**A**,
„ Okhá = 9·65 above datum = 10·424 below B.M.**A**,
„ Hanstal = 16·33 above datum = 9·702 below B.M.**A**,

The leveling operations show the following results:

B.M.**A**, Hanstal, is 0·41 feet above B.M.**A**, Nawanár;
B.M.**A**, Okhá, is 0·151 feet higher than B.M.**A**, Hanstal;
Okhá B.M.**A** = 10·424 above mean level of sea;
Hanstal B.M.**A** = 0·151 below Okhá B.M.**A**, by leveling;

therefore Hanstal B.M.**A** = 10·273 above mean level of sea by leveling;
but Hanstal B.M.**A** = 9·702 above mean level of sea by tidal observations;

Discrepancy = 0·571

that is mean level of the sea as determined for Hanstal tidal station is 0·571 feet higher than that determined by leveling from the mean level of sea at Okhá.

B.M.**A**, Nawanár = 9·476 above mean level of sea;
Hanstal B.M.**A** = 0·419 above B.M.**A**, Nawanár by leveling;

therefore Hanstal B.M.**A** = 9·895 above mean level by leveling;
but Hanstal B.M.**A** = 9·702 above mean level of sea by tidal observation;

therefore discrepancy = 0·193

that is mean level of sea for Hanstal station as determined by tidal observations is 0·193 higher than that determined by leveling from Nawanár.

(4.) In para. 4 of your No. $\frac{49}{1433}$ dated 30th November 1875, being a reply to my letter above quoted you state "one or other of your tidal stations must be selected as the datum of your leveling operations, and Okhá from its situation nearest the sea is evidently the one to be selected for this purpose."

The mean level of sea at Okhá Tidal Station taken as datum of all leveling operations.

The datum for the leveling operations having thus been settled I was enabled to finish the whole of the abstracts of the leveling operations of the preceding field season.

(5.) In a previous communication I have stated "you will observe how well the trigonometrical heights agree with the real values, but in Cutch they seem to be all less while in Kattywar they are greater than the values determined by spirit leveling. One very interesting result of the leveling is that the mean value of the Runn between Mallia and Shikárpur is 6·781 above mean level of the sea while between Hanstal and Balumba and Jorya the level of the Runn is 9·525. Now the tide at Hanstal frequently in the cold weather rises to 8 feet above mean level and yet the Runn between Mallia and Shikárpur is perfectly dry from November till March. This shews that there must be a rise in the Runn between the line Mallia-Shikárpur and the head of the Hanstal creek."

Peculiarity of levels of the Runn.

(6.) While these computations were being completed Mr. Rendell, who had been on one month's privilege leave, joined me at Jorya on the 22nd November. After I had given him a practical insight into the method of leveling as carried out in this department, and had satisfied myself that he was *au fait* at the work, and that Damoder Ramchandra the second leveler who was to accompany him was also fit to take up the work, I started them off with their party of men to commence from Shikárpur bench-mark, in Cutch—one of the main points connected in the former season's work.

Mr. Rendell and Damoder Ramchandra instructed in leveling.

(7.) The whole of the leveling staves were compared with the standard bar, and observations were made for determining the index error of the prismatic compass in each level.

Comparison of staves &c.

(9.) The lines of levels to be executed were as follows. The main line was to be taken right across Kattywar from Jorya bench-mark to Wadhwán, the terminus of the B. B. and C. I. Railway, and thence along the railway line to Viramgám, Ahmedabad, and as far beyond as possible. This work I laid down for myself and a second leveler: of course branch lines were to be driven right and left of the main line to connect the trigonometrical stations. A loop line was to be carried by Mr. Rendell from Shikárpur bench-mark to Addysir both in Cutch; then, crossing the small portion of the Runn to the Chorar and thence into Guzerat, to be taken along the borders of the Runn to Pátri terminus, and finally to join up with the main line at Viramgám bench-mark: the small branch line to Khárághora salt works was also to be leveled over. As I was doubtful of the amount of work which Mr. Rendell and Damoder could perform, this being their first season on leveling, and also as I could not calculate how much even 2 experienced levelers could do with the small new instruments which had lately been supplied, I left the matter of the further work of the second party in abeyance for the time being.

Range of the leveling operations.

(10.) I worked the rectangular level throughout. The cylindrical level worked by Nursing Dass is also a first-rate instrument. The two small levels lately sent, and to be worked by Mr. Rendell and Damoder, were of a new pattern, by Cooke and Sons of York. Mr. Rendell says of them "at times during the cold weather they gave a little trouble on account of the inactivity of the bubble." The limiting distance for the small levels I fixed at 6 chains, and Mr. Rendell reports "at this distance in the cold weather ·001 of a foot was easily readable, but in the hotter months it was almost impossible to work at even a distance of 4 chains after 8 o'clock in the morning.

The instruments employed.

(11.) The main line emanated from Jorya bench-mark, on the main line of the series Hanstal tidal station to Okha tidal station; thence it was carried to Dhrol; the line was then taken along the made-road to Lála; thence to Pardhari and Rájkot: at Rájkot the following paka points were connected—English Church, High School, Rájkumár College. From Rájkot the line was continued along the main road towards Wadhwán as far as Kuarwa, and from this a branch line was taken to Khakhana H.S.; leaving Kuarwa the line was carried still along the main road, *viâ* Bamanbor to Chotila, and here another branch line was driven to Tarkia H S. The line then continued to Dheduki, and from thence *viâ* Dulia to Muli, whence it was carried along the main road to Wadhwán Railway Station. Leaving Wadhwán the line was taken along the permanent way of the B. B. and C. I. Railway to Viramgám, a branch line being taken from Liláput bench-mark to connect three minor triangulation stations of the Kattywar and Guzerat Surveys, and on to the head of the Nal river. From Viramgám the main line continued to Ahmedabad and thence to Mehmadabad.

The main line of levels.

(12.) As a rule the bench-marks were embedded at 10 miles apart. There were few paka points between Jorya and Rájkot but between Rájkot and Wadhwán the parapets of the bridges on the main road were used. Along the railway as a rule I connected one of the bridges every day. The bench-marks embedded along the line of railway were invariably built close to the railway station except at Viramgám, where the sub-surveyor made a mistake and built close to the wall of the town. The level of the rail opposite the centre of the booking office at every railway station was also determined to test the accuracy of the railway levels.

Bench-marks and paka points on the main line.

Levels at Ahmedabad.

(13.) At Ahmedabad the Sábarmati was crossed just above the site of the old railway bridge (the new one was under construction). The level of the bed of the river was determined; also a paka point at the Sháhibág was connected, and a bench-mark laid down between the two minarets at the railway stations. The flood line of last year as shewn me was over 40 feet above the bed of the river close to the Sháhibág.

The general appearance of the country along the main line.

(14.) The line passed over in Kattywar was very undulating but with a gradual rise from Jorya to Rájkot, which is a little over 400 feet above the mean level of the sea. There are few streams of any consequence, except the Aji river at Pardhari, on this part of the line. From Rájkot the road continued to rise steadily for about 35 miles until the maximum height along the main road was attained at Molri-nana which is 713 feet above mean level of the sea. The country just before this, *i.e.* from the Bedti river to Bamanbor, was very hilly and rugged and entailed a great deal of extra labour, in that so many more stations per mile were required. Near Bamanbor the country is not much cultivated and I believe that 20 years ago this part of the country was covered with dense forest, and that lions were found there. There is no trace of the forest now except a stunted tree here and there, but a great deal of grass is cut and stored here and sent to Rájkot. From Molri-nana to Chotila the descent begins and continues rapidly to Dulia, and from Dulia to Wadhwán the country is tolerably flat and cotton is greatly cultivated. The sudden change in the appearance of the country along our line, from Kattywar where there are few trees of any kind and hardly any large ones, to the heavily wooded country near Viramgám and all along to Ahmedabad and Mehmadabad, is most marked. Then again the ground seemed much more highly cultivated as the line passed through the Ahmedabad collectorate, and the demarcating hedges of the fields often grow to great heights, the general effect of which contrasts strongly with the open country between Wadhwán and Viramgám.

The minor triangulation stations connected.

(15.) Some of the minor triangulation stations connected were almost entirely demolished.

The loop line Shikárpur to Viramgám.

(16.) Mr. Rendell reports "the country between Shikárpur and Addysir is very low and flat except near Khanmir where it is crossed by a small range of hills running in a north-west and south-easterly direction. The soil is sandy and very barren-looking: cotton is grown here and there in small quantities, but by far the greater portion of the land is allowed to remain waste, the soil being so poor that it is not worth cultivating. There are no wells in this part of the country and the drinking water is collected in tanks during the rainy season." When Mr. Rendell arrived at Addysir he says "I was surprised to learn that the portion of the Runn which divides Cutch from the Pálanpur State and which I had to level over was covered with from one to two feet of water, and as it was necessary that the level of the surface of the Runn should be obtained, I had to devise means to secure this result."

Arrangements for getting value of level of the Runn.

(17.) Mr. Rendell reports "accordingly I had several long pegs made up for the staves to rest upon: these pegs were driven into the ground up to a certain mark, and this distance from the mark to the top of the peg being known it was easy to get the level of the ground below. To isolate the instrument wooden pegs about 5 feet long were used; these were driven into the ground, their tops being flush with the surface of the water; on these the level stand rested, and I arranged that after I had read the staff the second leveler should read the bubble: in this way I am glad to say I managed to get over this difficult bit of ground and with very good results. There are no bench-marks in the Runn, but one has been laid down on the border at the east end and another at the west end of the line. The line of levels was taken as straight as possible in order that it may be leveled over at any future time. This portion of the Runn is not flat but concave having a depression of about 2 feet at the centre".

Across the Chorar to Pátri and Viramgám.

(18.) Mr. Rendell continues "having leveled across the Chorar where 2 bench-marks were laid down and connected, *viz*: at Piprala and Sántalpur, I closed my leveling in an easterly direction on Gokatar bench-mark: from this point the line of levels was taken direct to Pátri. A good portion of the ground passed over between Gokatar and Pátri consists of salt waste, the line being near the borders of the Runn. The portions under cultivation were of a loose sandy nature. From Pátri to Viramgám the leveling was carried along the railway line. The top flanges of the iron girders of all the bridges were fixed as well as the height of the rails at nearly all the level crossings."

Branch line from Sahij S. and Rarú S. to Mehmadabad bench-mark.

(19.) On the completion of the loop line I instructed Mr. Rendell to run a branch line from Sahij S. and Rarú S. to Mehmadabad bench-mark, which I hoped to reach before he completed the branch line, Kaira S., Kaira Church, and the mile pillars along the main road from Kaira to Mehmadabad were connected. The Sábarmati and Wátrak rivers were crossed on the branch line: there was very little water in either at the time, and the levels of the beds of the rivers were determined.

(20.) On Mr. Rendell's joining me at Mehmadabad the party with the camp equipage proceeded by rail to Surat.

Health of the party.

(21.) On the whole the health of the party was good during the last field season; in fact I may say I was the only one in the party who suffered from ill health, having had a succession of persistent attacks of fever during the whole of it.

Accuracy of the work.

(23.) The loop line emanating from Shikárpur, and closing at Viramgám, formed with the main line a circuit of about 400 miles, and the closing difference at Viramgám was 0·536 feet. On account of the greater power and smaller correction for dislevelment of the larger instruments I have considered the values of the main line to be absolutely perfect, and the difference 0·536 feet to be generated in the loop line, giving an error 0·004 per mile nearly which, considering the instruments they were using and that they had to cross the Runn when covered with water and that this was their first season's work, I consider very creditable to Mr. Rendell and his co-leveler Damoder Ramchandra. As an instance of the accuracy of the work which is done by the larger instruments worked in the rigid manner adopted by this department I may mention the following circumstance. In doing the back section Viramgám bench-mark to mile post 353 a discrepancy of one foot was discovered between the values of the white and black faces as obtained by the cylindrical level. I sent off Nursing Dass to commence from the far end, and I started from Viramgám bench-mark. On joining up and reducing we obtained a result which differed from the previous values by only 0·003 feet, or about 0·0005 feet per mile.

Personnel of the party.

(24.) Mr. Rendell has worked well throughout the entire field season. He reports very favorably on Damoder Ramchandra: of Venayek Narayen, Mr. Rendell reports that he worked hard and that he is a quick and accurate recorder and computer; and of Dhondu Venayek he says that he gives promise of becoming with a little practice a useful and efficient hand. Nursing Dass has as usual worked well throughout the field season, and Bulwant Appaji has also performed his duties in a very satisfactory manner. Sitaram Yeshwant has worked hard but he is by no means a careful recorder nor a correct computer.

(25.) I stopped field work in April, took the office to Surat, and commenced the reduction of the meteorological observations taken at the tidal observatories. The graphical measurements from the anemometer sheets were all completed.

Some of the results obtained by last season's leveling.

P.S.—(By Major Haig). By comparison of the principal and minor stations connected, it is found that the values of the principal stations as determined trigonometrically are from 2·5 feet in defect to 9·2 feet in excess of the values by spirit leveling, and the secondary stations from 2 feet to 27 feet in excess. The average error of the trigonometrically determined height of all the stations connected during this field season is 6·8 feet too great. The heights of the rails opposite the booking offices at 15 railway stations have been determined this season, and the values as given by the railway authorities are from 4·8 feet to 8·8 feet too great, or an average of + 6·9 feet—errors which are not high considering the method of procedure by which they have been obtained as compared with the rigidly accurate system of this Survey.

VII. Extract from the Narrative Report—dated 6th October 1876—of Captain W. M. CAMPBELL, R.E., Officiating Deputy Superintendent 2nd Grade, in charge of the Astronomical Party No. 2.

(1.) My last report, so far as it referred to the electro-longitude operations, was chiefly a description of the alterations then being carried out in the equipment, which at the date of the report were not quite complete. I shall commence this narrative by remarks on the completion and results of these changes.

Transit Telescope No. 2.

(2.) The experience of the past season's operations proves, that the old failings of transit telescope No. 2 have been entirely removed by the repairs which were executed by Mr. Doderet, Mathematical Instrument Maker to the Madras Government, and its line of collimation is now quite as trustworthy as that of the sister instrument. It is still inferior to the latter as regards the Bohnenberger eye piece, which is of too low a power.

Chronographs: new arrangements.

(3.) The alterations of the chronographs were just completed in time for the opening of the field season and have, I am glad to say, proved entirely successful. The saving of time, trouble, and worry by the new as compared with the original arrangements can only be appreciated by one who, like myself, has gone through a large amount of work with both. The loss of a signal now, owing to any defect in the local arrangements, is a thing almost unknown, and to effect this a minimum of attention is required. Under the original arrangement,

I think I am within the mark in saying that, with constant trouble, it was very difficult to obtain a satisfactory record of nine-tenths of the work done.

Modification of new arrangement.

(4.) While on this subject I may mention that the early experience of the field season led to a modification and simplification of the arrangement with which we began. Under my first arrangement each pen magnet was worked, under all circumstances, by a relay of the kind used in the Telegraph Department, four of which I had been able to procure on loan through the kindness of the Director General of Telegraphs. The object of this was to obtain as much uniformity as possible, and to subject all signals, local and line, to as nearly as possible the same conditions as regarded retardation; but on the other hand there was some loss in simplicity. The relays also, being intended for recording signals received through a long wire, were ill adapted for local work with small battery power, and we found that when called on to perform both duties alternately, they required a good deal of attention—the only point on which the electric parts of the chronograph gave any trouble.

(5.) The modification referred to above was carried out after the completion of the first measurement, and consisted of discarding the relays for all local work, and using them only for transmitting and receiving line signals. The pen magnets are now placed locally in simple circuits passing through clock or observer's key at pleasure, and worked by weak batteries. The line signals are received through a relay, which works either pen by its local battery. The signals transmitted through the line are sent by "translation," *i. e.* a local circuit passes through the "translating" relay which works the line circuit. The object of this was to keep local and line circuits quite distinct, in the case of the clock or observer recording through both on the local and the distant chronographs respectively; because when there is any communication between these circuits great trouble is sure to be caused in order to maintain the proper balance of currents. Another advantage is that when the line signal is sent by translation the conditions at the distant station have no effect on the local work, so that the observer at the former may receive the signals sent, or not—put the line wire to earth, or not—&c., as convenient to himself, without in any way affecting the other station.

Retardation affecting signals.

(6.) The result of the new arrangement is that when a signal is recorded on both chronographs the record on the distant one is affected by the retardation of the line and of two relays, as compared with the local record; whereas when the relays were always used in the pen circuits, this difference between the two signals was due to the line retardation alone; and on this account the change may be looked upon as objectionable.

Accuracy of results compared.

(7.) The best way of comparing the accuracy of the work under the different conditions is, I think, by taking an average probable error of the clock comparisons obtained with the several arrangements. I have carried this out with regard to (1) the original arrangements which existed during the season 1872-73: (2) and (3) my first arrangement, with which we measured one arc last season, using—(2) simple clock comparisons, —(3) comparison by longitude signals (*see* para 17): (4) the modification introduced after that arc and used for the rest of the season. The following are the results, each *p. e.* being obtained from 20 individual values of the clock difference, by simple comparison, or by longitude signals:

Mean of	10	values of *p. e.* of clock comparison under system		(1)	$= \pm$ ·00164
„	6	„	„	„	(2) $= \pm$ ·00318
„	10	„	of comp. by longitude signals	„	(3) $= \pm$ ·00395
„	40	„	of clock comparison	„	(4) $= \pm$ ·00163

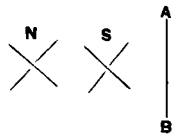
From this it would appear that the accuracy of our latest method is precisely the same as of the original arrangements used in season 1872-73, which is almost beyond my expectation, (*vide* para. 19 of last report), while that obtained by the arrangement with which we began work last season is decidedly inferior. This last result I attribute partly to our comparative inexperience generally, and to the fact that we were trying to use our relays with too small batteries, whence uncertainty of action resulted. These figures indicate also an equality of precision between the methods of direct clock comparisons and of longitude signals. The method of "longitude signals" here referred to is fully described in para. 17.

Collimators.

(8.) I referred to the collimators in my last report as an improvement on those which were used in our work of season 1872-73, and they certainly proved very complete and perfect instruments. It is difficult to judge of the degree of efficiency of the arrangement for ensuring stability of the axial direction, to which I alluded, without placing the new collimators alongside of the old ones and actually comparing their behaviour under similar circumstances, but the new instruments were certainly very stable. We have not had occasion to rely on this stability in order to combine the observations for deviation on different nights, as I thought might be done, because we hit on a method of effecting this much more certainly by means of star observations, as I shall explain in the proper place.

Method of using the Collimators.

(9.) The details of our collimation observations are somewhat novel, and as we found the method most convenient and trustworthy I shall explain it. One collimator, always placed to the north of the transit telescope and called "N", is provided with a fixed cross wire, thus ×. The other, to the south and called "S", possesses a similar fixed × and also a moveable micrometer vertical wire. The × of N was always placed as nearly as possible in the meridian, and that of S a little to one side, so that the appearance in the field of S was as shown in diagram, AB being the micrometer wire. With AB, readings were taken of N and S, and the difference e converted into terms of the transit telescope micrometer. Then with the transit telescope each of the crosses N S were observed and the difference e applied to the reading of S as a correction. The advantage of the method is that all the observations are exactly similar, *viz*: the intersection of a cross by a vertical wire. The disadvantages are, the necessity for knowing accurately the relation between the micrometer screws of the transit telescope and of S collimator, and the small computation involved in the process; neither of which we found caused any inconvenience.



Narrative of field season.

(10.) I shall now proceed to the narrative of last season's operations, in which Captain Heaviside was associated with me. The proposed programme included the measurement of the following arcs, named in the order which we had decided on as the best as regarded the prospects of clear weather and the convenience of my meeting with Captain Heaviside, who had to join me from Dehra Dún, *viz*: Hyderabad-Bombay; Bellary-Bombay; Hyderabad-Bellary; Madras-Hyderabad; Madras-Bellary; Bangalore-Bellary; Bellary-Mangalore, or Madras-Bangalore. Of these the first six were successfully completed, but time did not suffice for the last.

Proposed Programme.

Start from Bangaloro.

(11.) Captain Heaviside expected to be able to reach Hyderabad about the beginning of December, and I timed my departure from Bangalore accordingly. On 19th November Mr. Keelan started with all the equipment and establishment by road to Gooty (165 miles) whence he proceeded by rail to Hyderabad, arriving there on December 5th. Mr. Bond took the field earlier—on 26th October—for the purpose of finishing some triangulation which he had been unable to complete during the preceding field season, with orders to proceed afterwards to Bellary to select and prepare the longitude station at that place, as also to connect it with the principal triangulation. On 23rd November I left Bangalore and proceeded to Madras, where I had some arrangements to make with Mr. Pogson, after which I went on to Hyderabad, arriving there on 29th November.

Bolarum: choice and preparation of station.

(12.) Hyderabad had always been spoken of generally as the station to be observed at, but nothing could be definitely settled until I reached the place, and had an opportunity of deciding which of the three telegraph offices available in the immediate neighborhood, *viz*: Hyderabad, Secunderabad, and Bolarum, would prove the most convenient for our purpose. A very slight reconnaisance sufficed to decide me in favor of the last named station, which stands on high open ground, with admirable sites for an observatory within a few yards, capable of connection with the principal triangulation by a single triangle, using two stations of the Hyderabad Minor Series which was executed by Lieutenant (now Captain) Rogers with a 24-inch theodolite as an offshoot from the Great Arc. The best site for the station was within the compound of the D. P. W. Office where the Officiating Superintending Engineer, Major Swetenham, R.E., kindly allowed me to build the necessary pillars and gave me the use of out-houses close by, which were very conveniently placed for the accommodation of the clock and chronograph. He was also most obliging in obtaining masons and assisting me in various ways.

Captain Heaviside's arrival.

(13.) Captain Heaviside arrived on 7th December on which date, although the pillars were not quite complete, there was abundance of employment for him in taking over charge of his party. On the 9th the pillars being ready we began setting up the instruments, and from that day to 28th inclusive we were busily employed in practice observations and in settling the details for actual work, four nights' observations for personal equation being included.

He proceeds to Bombay.

Measurement Bolarum-Bombay.

(14.) On 29th December Captain Heaviside dismantled, and on 31st proceeded to Bombay, where he was ready to begin the measurement on 10th January. Our first night's attempt proved a failure, in consequence of a fault on the line; but on the 11th we were successful, and we continued the observations with very little interruption from any cause, from that day to the 21st inclusive, which completed the measurement.

(15.) The programme followed was of two kinds: we began on the old method of season 1872-73 having the line only for certain short periods and using it exclusively for comparing clocks, while during the intervals each took transits with his own clock. I also applied for and on several nights obtained the use of the line for a period of 3 to 4 hours embracing the whole of our programme, on which occasions one clock was used for transits at both stations, changing the clocks in the middle of each night; comparison of clocks being also made at certain intervals. When working on this system a comparison of clocks is not necessary, but it was always taken for two reasons: (1) to obtain a measure of their relative rate, which is useful in determining the absolute rate of each; and (2) because a comparison being obtained it becomes possible to combine transits by each observer with his own clock, in the event of any hitch in the transmission of clock signals for transits, (a case which occurred on at least one occasion) so that such failure does not involve the loss of the night's work.

Programme followed: use of line obtained for long periods.

(16.) In making my preparations for the operations of the field season, when I was only able to reckon on having the use of the wires at certain short periods, I introduced a change in the method of clock-comparison which had been followed by Captain Herschel and myself in 1872-73, *viz*: recording the two clocks alongside of each other for about a minute at a time, which I now call a "simple comparison". My objection to this method was, that unless there is a very great difference between the clock rates (which is inconvenient for other reasons) the record of such a comparison shows no appreciable change, and consequently in transcribing it one reads the same fraction of a second over and over again, which is not conducive to accuracy. I had also in view the prospect of working through cables at some future time, for which purpose clock signals at one second apart would not be suitable, being too rapid, and I wished to introduce and test a system adapted for cable work. Lastly I was influenced by the desire to avoid passing strong currents through the clocks, fearing consequent injury to their break-circuit arrangements, which would be troublesome to repair. On this head I believe my fears were exaggerated, and moreover the use of a translating relay which we adopted soon afterwards, as already noticed, obviates the necessity of passing any but very weak currents through the clocks.

Change in method of comparing Clocks.

(17.) The method adopted I call "comparison by longitude signals",* and it is carried out as follows. The original equipment included observer's keys, capable of making and breaking two separate circuits: these I applied so as to afford two simultaneous signals, one for record on the local chronograph alongside the local clock, and the other for transmission along the line and record on the distant chronograph beside the distant clock. It is obvious that each pair of signals so recorded affords a value of the clock difference, from which the retardation was eliminated by the exchange of signals in alternate directions; and any want of synchronism between the two signals generated by a key was guarded against by reversing its connection with the two circuits. This system answered perfectly in practice, but it entailed more troublesome commutator arrangements, and the record takes much more time to transcribe than that of a simple clock comparison. My object in adopting it was to a great extent satisfied by its successful working, as we have now a proved system of clock comparison to fall back upon in case of finding clock signals unsuitable for transmission to the distant station. When the line was obtained for long periods, the old method of simple clock comparisons was resumed, and I do not think it advisable to depart from it again when working with land lines.

Comparison by Longitude Signals.

Disadvantages.

(18.) At the beginning of the season we started with somewhat complicated commutators, to allow of all the different combinations: these were very greatly simplified by the abandonment of the relays for local work, and the double keys for longitude signals, with great advantage in reducing the chances of mistakes in manipulation.

Commutators simplified.

(19.) On completion of the Bolarum-Bombay measurement, I proceeded at once to Bellary and we began the measurement Bellary-Bombay on 28th January continuing without a check on the three following nights, after which I proceeded to Bombay and we took another set of observations for personal equation with Captain Heaviside's telescope. On my return from Bombay we completed the measurement by observations on 9th and 10th, losing the 8th owing to a fault on the line.

Measurement Bellary-Bombay.

Personal equation at Bombay.

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* This term is very apt: it clearly takes its name from the fact that *if the two clocks were recording true local sidereal times* a single such doubly-recorded signal *would give the difference of longitude*—subject of course to corrections for relay and line retardation—although they are not sent for that purpose. J. H.

Captain Heaviside now went to Bolarum, and the measurement Bolarum-Bellary occupied six nights, 19th to 24th February inclusive. I then proceeded to Madras while Captain Heaviside remained at Bolarum, and we completed the arc Madras-Bolarum on March 12th, being delayed for some days by cloudy weather. Captain Heaviside then moved to Bellary, taking advantage of the opportunity for visiting Madras in order to obtain another value of personal equation. Finishing the arc Madras-Bellary on 2nd April I proceeded to Bangalore and we completed the measurement Bangalore-Bellary on April 18th. The observations on the two last arcs were much obstructed by clouds. The season being too far advanced to permit of our attempting the arc Bellary-Mangalore, Captain Heaviside joined me at Bangalore, and we took a final determination of personal equation with both telescopes before closing the season's observations on April 23rd.

Bolarum-Bellary: Madras-Bellary: Personal equation at Madras. Bangalore-Bellary. Personal equation at Bangalore and close of season.

(20.) Throughout the measurement of the last five arcs we obtained the use of the line wire during the whole of our programme each night, an arrangement vastly superior to the use of short concessions, in many ways:—(1) the dealings with the telegraph officers are simpler, our connection being made once for all: (2) we were able to work by a sidereal time programme, so that exactly the same stars were used night after night—a very great object both as regards trouble at the time and in reductions afterwards: (3) the general reductions of the work will not be nearly so heavy; and, lastly, we have every reason to expect that the results will be superior.

Use of line for long periods always obtained.

(21.) We followed the same programme throughout *viz*: comparison of clocks; transits for forty minutes at each station using the same stars, (to allow of which the transit observation at west station began and ended later than those at east station by a time equal to the difference of longitude); a second clock comparison; transits again for forty minutes; and lastly a third set of clock comparisons. Each observer took level and collimation observations at convenient opportunities, at least two of the former and one of the latter being obtained each night. We used only 15 out of the 25 wires for transits. For the first set of transits E. clock, and during the second W. clock, was used at both stations. In the middle of each group of transits, and also in each set of clock comparisons, the duties of the chronograph pens were exchanged, thus reversing the sign of the pen equation, and eliminating residual error after the application of its accepted value as a correction to the record. The transit telescopes were used equally in the positions I.P.E., I.P.W. at each station, the reversal being effected with great ease, often with hardly appreciable disturbance, by means of a small wooden frame on which the telescope was bodily lifted by four men. Each observer retained the same equipment throughout the season.

Nightly programme.

(22.) As regards azimuth observations, we made a point of obtaining if possible a pair of close polar stars, one above and one below the pole, every night; and the nights on which we failed in doing so were comparatively few. I have now to notice the method of supplementing these observations, to which I referred when speaking of the collimators; a method which so far as I am aware is novel, and according to our experience very valuable.

Observations for azimuth.

(23.) It is often difficult to obtain a pair of well fixed circumpolar stars which occur at times convenient for observation, and moreover in these low latitudes there is always a great chance of losing the lower transit, particularly when the star used is a small one. For the first part of the season δ Ursæ Minoris and 51 Cephei answered our purpose admirably, but their transits became too early for convenience in February. Then there was a short interval during which there were no good stars conveniently available, after which we adopted Polaris *sub polo*, and one of Mr. Pogson's regular azimuthal stars (the data for which he supplied me with), for the rest of the season. This latter star is No. 99 of the Radcliffe Polar List and 4339 B.A.C.

Circumpolar stars.

(24.) The supplementary stars which I call "comparative azimuth stars," are of about 10° N.P.D., chosen simply for convenience of time of transit, and observed every night. The exact places of these stars were not wanted, but only an approximation close enough to permit of their change in R.A. from day to day being computed, for which purpose the places of the B.A. Catalogue (from which they were chosen) are amply sufficient. Now it is, evident that if such a star is observed every night (the observations being corrected for change in R.A.) and an absolute determination of deviation is obtained on any one night by well fixed stars, the deviation can be deduced therefrom for each night. This is an extreme case which never occurred, but we have a few instances of nights on which no absolute determination of deviation was obtained, when it is deduced by means of these comparative stars. After their introduction (February 9 and 10) we made a habit of observing at least two of these stars every night at nearly equal intervals of time from each other and from the circumpolar stars, and these observations have been given their own weight in deducing the mean

Use of comparative azimuth stars.

deviation for each night. Thus it appears that our deviation correction for each night obtained by the above method, depends generally on three or more observations of polar stars taken throughout the night.

Personal equation.

(25.) Our determination of personal equation should be as reliable as such an observation is capable of being. As already noted it depends on the observations of nine nights—two with each instrument before the commencement of the operations; one night with one telescope, and two with the other, during the season; and a night with each at the close of the work. On every occasion the method of sharing transits at the same instrument was followed; that is to say, one observer recorded the transit of a star over the first (generally ten) wires and the other taking his place observed the last ten or twelve wires. The observer who finished one transit always began the next. Twenty such transits were observed on each night, giving a value of the equation with a probable error of about ± 0ˢ·01; the equation itself being about + 0ˢ·10, to be applied to Captain Heaviside's observations to reduce to mine.

Personal equation in transcribing chronographic record.

(26.) In the process of transcribing the chronograph record there is probably just as marked a personal equation between individuals as obtains in the observations themselves. This has never been determined, but its effect has been eliminated by taking care that the work of both stations for any one night has always been transcribed by the same person—Captain Heaviside or myself. The same precaution was adopted with regard to the clock comparisons.

Recess work.

(27.) The recess work, including the transcription of the chronograph records and the reductions, is very heavy, so much so that it will be some time yet before we arrive at any final results. The work is however in a very forward state, the whole being brought up nearly equally; and so far as I can form an opinion, the results promise to be satisfactory.

Mr. Bond's work during season.

(28.) I have already remarked, that Mr. Bond began the field season by finishing some triangulation on which he had been employed under Major Branfill's orders during season 1874-75. The necessity for completion was urgent, in order that the whole might be made available for use by Captain Strahan, R.E., in the topographical survey operations which he was then about to commence. I am glad to say that Mr. Bond succeeded in the face of a good many difficulties, arising from weather, an inferior staff of signallers, and the prevalence of cholera in the neighborhood, and handed over all his records to Captain Strahan, by whom I am informed that the quality of the work is excellent. Mr. Bond's work at Bellary proved somewhat difficult, owing to the unfavorable position of the telegraph office, which, combined with the want of good signallers, made the fixing of the longitude station troublesome. He had not quite completed it when I was obliged to send him to Bombay on 13th January to assist Captain Heaviside, in place of Mr. Keelan who was sick. Mr. Bond accompanied Captain Heaviside to Bolarum, and took the necessary observations for fixing the station there, and afterwards completed the work at Bellary. I was disappointed in the progress of his work at Bellary, and making all allowance for difficulties I cannot but think that Mr. Bond's operations there were wanting in judgment and energy. I had a most efficient recorder throughout the season in my native writer Babu Harsahai.

Babu Harsahai.

Personal acknowledgements.

(29.) In conclusion of this report, I have great pleasure in recording my gratitude to the officials of the Telegraph Department for the invariable courtesy with which our wishes were met and acceded to whenever possible. I never applied for assistance of any kind without meeting with a ready and chearful response, though I fear that our operations must have caused considerable trouble in the different telegraph offices through which we worked, in many cases entailing extra work on telegraph masters and signallers.

To Mr. Pogson, Government Astronomer at Madras, I had frequent occasion to apply for assistance, and I am deeply sensible of the kindness with which he always met my wishes. I fear our work at the Madras Observatory cannot have failed to prove an annoyance to him at times, involving as it did the encampment of my small native establishment in his compound. Finally I would thank my colleague Captain Heaviside, R.E., for hearty and zealous co-operation throughout the season.

VIII. Extract from the Narrative Report—dated 5th October 1876—of Captain W. J. HEAVISIDE, R.E., Deputy Superintendent 3rd Grade, in charge of the Astronomical Party No. 1.

(1.) Having received orders to take charge of No. 1 Extra Party and commence electro-telegraphic longitude operations in association with Captain Campbell, R.E., I left Head Quarters at Dehra Dún on the 17th November and proceeded to Bombay, which is one of the places it was intended to connect.

The Colába Observatory being a fixed trigonometrical station, and connected by wire with Bombay, from which it is about 3 miles distant, its grounds were fixed upon as a suitable place for our observations: it had moreover the advantage of being the place where the pendulum experiments were carried out in 1873 and I had then found Mr. C. Chambers, the Superintendent of the Observatory, so ready to give me every assistance that I felt confident of the cordial co-operation he rendered me in this case and for which my best thanks are due to him.

(2.) Captain Campbell had communicated to me the requirements necessary in the way of space and shelter for the instruments: these are simply an open space for the transit tent, in a position which could be connected by triangulation with trigonometrical points, with an uninterrupted view of the heavens to within 8° or 10° of the horizon north and south, and a room about 10 feet square for the clock and chronograph, conveniently near the transit tent. There were several small buildings on the observatory premises that Mr. Chambers was willing to place at my disposal, and the site eventually selected was 76·6 feet north-east of the trigonometrical station of the Bombay Island Survey. While in Bombay I also visited the telegraph officials and arranged with them about the supply of batteries and the use of the line &c.

(3.) I left Bombay for Secunderabad on the 4th of December arriving there on the evening of the 5th, and on the 7th I moved up to Bolarum where Captain Campbell had selected the station. A day or two later the two transit telescopes were set up close to each other, and the two chronographs with the electrical arrangements were placed in two stalls of a stable which had been prepared to receive them, about ten yards from the transit tent. Between this date and the 28th, I took over charge of the party from Captain Campbell, and we practised work, interchanging signals, taking transits for personal equation, determining values of the micrometer screws, &c., and in general practice in the manipulation of the instruments which were new to me. I am much indebted to Captain Campbell for the instruction he gave me regarding the various instruments and their working.

(4.) Mr. Keelan left Bolarum on the 20th December to build pillars and to prepare the station at Colába, and as the Christmas holidays were impending I gave him a letter to Major Merewether, R.E., Executive Engineer Bombay Defences, who kindly sent a contractor to undertake the work and subsequently checked the contractor's bill for me. The instruments and camp equipage were sent off to Bombay on the 30th of December and I followed the next day.

(5.) The equipment did not reach Bombay until the 4th of January but the interval of three days was fully occupied in making final arrangements regarding the use of the line, and batteries, and seeing to the various connections. There are two telegraph lines between Colába and Bombay: one from the observatory is connected with the clock and time-ball in the Fort, the clock there being regulated by the observatory clock; the other wire leads from the Colába Lighthouse to the Head Telegraph Office in Bombay, and is used to signal the arrival of steamers and other matters connected with the shipping. It is the latter wire that was employed for our work, a switch being placed in the clock room through which the signals from the lighthouses to the telegraph office passed, with a key which enabled me to throw the lighthouse out of circuit and bring our local wire into circuit. At the head office the wire from Colába was connected direct with the wire to Bolarum and the line Bolarum-Bombay was then worked by a battery at each end controlled by Captain Campbell and myself. The battery I had at Colába consisted of 43 Menotti cells, a strength recommended by the telegraph officials, but after our first night's experience we found 20 cells amply sufficient for our purpose. The earth wire at Colába led to a good copper plate which was sunk near a well close by and kept constantly moist. In carrying out these arrangements we are much indebted to Mr. C. E. Pitman, Assistant Superintendent of Telegraphs, in charge of the Bombay office, whose courteous assistance, rendered often at considerable personal inconvenience, tended in no small degree to the smoothness with which our work was carried on.

(6.) Regular work was commenced on the night of the 10th January, and it was rather disquieting after all our practice to fail as we did. This failure was due partly to our working with a line battery too strong for the relays which were adjusted for the local batteries, and partly to a fault in the line; but after this first night we were singularly free from even small irregularities of action. The distance Bolarum-Bombay is almost exactly 500 miles and the line was worked from Colába with 15

cells. During the progress of the work on this arc we obtained the use of the wire on two or three nights for three consecutive hours instead of for periods of a quarter of an hour at intervals of one and a half hours, and this of course considerably facilitated the operations.

(7.) Mr. Keelan, who had been suffering for some time from inflammation of the eyes, was obliged to take sick leave at Colába from the 13th to the 31st January, and it seemed probable that the work would have to be stopped for two or three days until Mr. Bond's arrival from Bellary, but Mr. Chambers kindly lent me the services of his head-writer, by name Huri, who was accustomed to transit work and whom I found an excellent recorder.

(8.) The arc Bolarum-Bombay was finished on the 21st of January, and while Captain Campbell was moving to Bellary I employed myself in re-determining the wire intervals of the transit instrument by transit of circumpolar stars, the last determination having been made in 1872, and in checking the connection of the longitude station with the trigonometrical point.

(9.) The arc Bellary-Bombay 526 miles in length was worked from Colába with 20 cells and was completed on the 10th of February. I then moved to Bolarum commencing work there on the 19th of February. The arc Bolarum-Bellary was finished on the 24th of February and the arc Madras-Bolarum on the 12th of March. While the equipment was being moved to Bellary I went down to Madras to take some observations for personal equation with Captain Campbell, and I returned to Bellary on the 20th. The arc Madras-Bellary was completed on the 2nd of April; and Bangalore-Bellary on the 18th.

On the 20th I left for Bangalore, where Captain Campbell and I took further observations with both transit telescopes for personal equation, and this completed our field season.

(10.) The early part of the year was very favorable for star observations, the nights being singularly free from clouds up to the middle of March. Subsequent to that date we were a good deal troubled by cloudy nights, and the weather at Bellary in April had much the character of an incipient monsoon.

(11.) Captain Campbell in his report has entered fully into the system he adopted to carry out the work and the arrangements of the commutator and batteries connected therewith, so that there is but little left for me to relate on this subject. I think however he has hardly done himself full justice in detailing the improvements he has effected, in various ways, but more especially in the chronograph records. By removing the styles which were formerly employed to record the signals by the action of currents of statical electricity on chemically prepared paper, and using in their places pens which draw continuous ink lines on ordinary paper, while the batteries (Menotti's) are in circuit, and which are jerked outwards whenever the circuit is broken, he has not only got rid of the necessity for preparing the paper chemically and for keeping it of a certain degree of dampness—which, it appears, proved such a fertile source of annoyance in the season of 1872-73—but has also effected a great improvement in the distinctness of the recorded signals and in the ease with which they can in consequence be read off. It is very evident too that by getting rid of the Bunsen battery, which is spoken of by Captain Herschel in his report of 1872-73 as "perhaps the most troublesome and provoking source of failure", and by changing the relays formerly in use for others of an improved pattern, Captain Campbell has very much increased the certainty of record of all signals, without, it would appear, any detraction on the score of accuracy. In fact where there are so many sources from which hitches may arise, it more than surprised me to find things work so smoothly that throughout the season it has been quite the exception to lose a signal of any kind; and where losses have occurred, these have almost invariably been due, with me, to the entire stopping or to the very irregular rate of the chronograph, the performances of which, though good on the whole, are occasionally very puzzling.

(12.) In observing transits and determining collimation I have of course adopted the same systems as Captain Campbell describes in paras. 21 and 9 of his report; and in all other respects his systems of procedure have been followed by me. The dislevelment of the transit instrument has been invariably read by the micrometer head from the reflection of the wires in a trough of mercury.

(13.) During the field season Mr. Keelan was chiefly employed in the observatory; keeping a record of the collimation and level observations, noting the stars observed and the number of wires they were observed over, and warning me of the setting and times of transit of the stars. He prepared the station at Colába for the observations and connected it with the trigonometrical station. He has worked both in the field and during the recess with the care and industry that I have invariably found him bestow on his work, and his knowledge of delicate instruments has on several occasions proved of assistance to me.

IX. Extract from the Narrative Report—dated 23rd November 1876—of Captain H. R. THUILLIER, R.E., Officiating Deputy Superintendent 1st Grade, late in charge of the Kumaun and Garhwal Party.

The establishment of the Kumaun and Garhwál Survey Party, up to the time of my last report, had been broken up into two detachments, one operating in the higher snowy ranges of Kumaun and Garhwál and the other in the Dehra Dún. The area that remained to be surveyed in the former districts was about 1,200 square miles only, but under the directions of the Superintendent, the completion of these operations which are necessarily of a costly nature, was suspended. The party therefore has been concentrated in the surveys of the Dehra Dún and Jaunsár Báwar.

(2.) The strength of the party, which consisted in 1874-75 of three Deputy and Assistant Superintendents with ten Surveyors and Assistant Surveyors, was reduced for the season under review to two Deputy and Assistant Superintendents, and seven Surveyors and Assistant Surveyors; one of the latter of whom was on leave from 15th October 1875 to 15th April 1876.

Distribution of Party.

(3.) The area remaining to be surveyed in the Dún being small, the party was divided into two detachments, one consisting of Messrs. W. Todd, H. Todd and I. Pocock with six Native Surveyors to complete the work in the Dún, and the other consisting of Messrs. Ryall, Litchfield and Warwick with one Native Surveyor to commence the detail survey of Jaunsár Báwar, on the scale of 2 inches to a mile, the triangulation of which had been done during season 1874-75. The field operations of both detachments were commenced about 20th October.

Out-turn of work.

(4.) During the season an area of 562 square miles was topographically surveyed: of this 430 square miles was on the scale of 2 inches to a mile, 124 square miles on the 4-inch scale, and 8 square miles on the 12-inch scale. This area comprises the completion of the non-forest tract of the Dehra Dún district, and also of that portion of Jaunsár Báwar which I was directed to survey. The index maps attached to this report, on comparison with the maps attached to my preceding report, show clearly the extent of work completed by this party; the uncolored portions representing the forest tracts which have been surveyed by the Forest Survey Department under Captain Bailey, R.E., *pari passu* with our operations.

(5.) At the end of February, when in Jaunsár, I was directed by the Superintendent to return to Head Quarters at Dehra for the purpose of relieving Mr. Cole (who was proceeding on furlough) of the charge of the Drawing and Photozincographic Branches of the Head Quarters' Office, and also in order to take charge of the Superintendent's office when Colonel Walker went on furlough. I therefore at that time directed Mr. Ryall to assume the full charge of the detachment working in Jaunsár Báwar. On Colonel Walker's departure, I was appointed to officiate as Superintendent and vacated the charge of the Kumaun and Garhwál Party on the 4th April.

(6.) As Mr. Ryall was engaged on the Jaunsár survey from its commencement, and took charge of the party during the field season, he thus had the opportunity of carefully inspecting and examining the whole of the work there: I leave to him therefore, the duty of reporting on this portion of the survey, and on the amount and quality of the work performed by each of the assistants. I must however state that I carefully examined Mr. Ryall's work in the Amláwa valley and found it very accurate and good.

Topography in the Dún.

(7.) The whole of the topography has been done with the greatest care. Where the ground admitted of it, check traverse lines were run by the European Assistants, to test the accuracy of the work executed by the Native Surveyors: 54 linear miles were traversed for this object. The hill sketching by the assistants was examined by myself and the work was found to be accurately delineated.

(8.) Of the assistants employed in the Dún survey, Mr. Pocock completed the work allotted to him on 23rd February and Mr. H. Todd on 23rd March, when they were directed to join Mr. Ryall in Jaunsár. Mr. Pocock not having had much experience in hill sketching, and the scale he was employed on being new to him, his progress was slow, but his work accurate. The native surveyors finished their work on the 4-inch scale, by the beginning of March, and as they were not sufficiently trained for hill surveying without a chain, they were utilized in completing the survey of the station and environs of Dehra, on the scale of 12 inches to a mile, a work which had been previously commenced for the object of teaching them plane-tabling.

Heights.

(9.) Numerous heights have been fixed by aneroid barometers throughout the season's work, and in addition it was found necessary to determine 38 more heights trigonometrically, chiefly from previously fixed stations.

Remarks on the country.

(10.) The work was principally carried on in the Eastern Dún, where the character of the country as regards varied descriptions of ground was similar to that met with and reported on in the previous year, and was equally tedious and difficult to survey. The Eastern Dún is less cut up by deep ravines than the Western. In the latter, the slopes of the northern spurs extending towards its main drainage channel are much greater, and consequently more water worn; whereas the mountain ranges overhanging the Eastern Dún to the north end more abruptly, leaving extensive flat plateaus, chiefly covered with dense forest. The waters consequently do not run off so rapidly, and hence the existence of large swamps which cause the notorious unhealthiness of the Eastern Dún for six months during the year. Under such circumstances it is not surprising that a very small portion is under cultivation. The flats may be said to range from 1,000 feet to 2,500 feet above sea-level, and the hills to the north to over 7,000 feet.

(11.) The field operations of the Dehra Dún and Jaunsár Báwar survey have been brought to a final close. A large amount of mapping has thus been thrown on the hands of the party; on which subject Mr. Ryall will report.

Extract from the Narrative Report—dated 23rd November 1876—of E. C. RYALL, Esqr., Officiating Assistant Superintendent 2nd Grade, in charge of the Kumaun and Garhwal Party.

Introductory and general remarks on the Survey of Jaunsár Báwar.

(1.) The survey of this sub-division of the Dehra Dún District was commenced on the 22nd of October; Captain Thuillier directing me to superintend the work of the assistants.

(2.) At the commencement of the season, Messrs. Litchfield and Warwick were deputed to assist. The latter however, having been lately appointed to the Department, had had no training in surveying; I therefore kept him with me for some little time to learn his work. Later on Messrs. I. Pocock, H. Todd, and T. Kinney, were despatched to assist me. The first-named on the 23rd of February, the second on the 23rd of March, and the last on the 15th of April, the date on which his furlough for six months expired.

(3.) The area surveyed in Jaunsár Báwar amounts to about 430 square miles; this includes about 20 square miles of overlaps. In addition to this, 72 square miles were surveyed by the Forest Survey Department, making the whole area of the sub-division to be 482 square miles. This quantity exceeds by 139 square miles that given in Mr. G. R. C. Williams' "Historical and Statistical Memoir of Dehra Dún, 1874" page 51, para. 109. Further on, in page 58 of the same book, the area is also given as 219,520 acres or 343 square miles.

(4.) Generally speaking, the rule on apportioning topographical work to the assistants is to confine them to certain parallels of either spherical or rectangular co-ordinates as the case may be. This plan is very convenient in all respects in topographical surveys in the plains, where hills have not those lofty characteristics which exist everywhere in the Himalayas. This method of apportioning work in the survey of the Himalayas has been found very inconvenient; it entails much labour and consequent loss of time. I thought it better therefore to depart from this rule by distributing the work so that each surveyor would have watershed lines as limits to his piece of work. For this reason the index map of Jaunsár Báwar has not been marked off into rectangular blocks, usually called plane-table sections.

(5.) After going over the ground, I thought it advisable to lay down some additional points trigonometrically, which I felt sure would very materially facilitate the topographical work in the lower valleys. These points were laid down chiefly from stations fixed by Mr. L. Pocock in his triangulation of Jaunsár Báwar last season. In addition to this, I determined the positions of 14 points up the Pábar river: this was indispensable for the survey of those remote and detached patches of country about Sansog and Banpur, on the right bank of the Pábar. In all 52 points have been added by me to those determined last season.

(6.) The amount of labour involved in surveying Jaunsár Báwar was much greater than I at first expected. This was due to the various *khats* (proprietary boundaries) and boundaries of forest lands having to be surveyed, which involved the fixing of the very numerous pillars demarcating them.

(7.) In the details of topography, I may here remark that upwards of 1,350 boundary pillars were laid down in Jaunsár Báwar by the party, and the accuracy of their positions is quite in keeping

with the requirements of the scale. The boundary pillars were seldom found in conspicuous places; on the contrary, they were either in thick forest or in hidden nooks and corners; it was therefore no easy matter to lay them down without erecting flags at or a few feet from them.

(8.) In order to lay down the limits of the cantonment of Chakráta, I enquired first of the Executive Engineer on special military works, for information regarding its boundaries, but there was no one in the office who was acquainted with them, and all the information I could obtain from there was a map of the cantonments showing its boundaries. But this map I unfortunately found of little or no use: it was not true to scale in the first place; and in the second, while it professed to give the boundary towards the east of the Chakráta ridge by a contour line marked out by pillars at intervals, I found the pillars as pointed out to me very far from occurring in the same level. On the west, a line had been at one time cut, as I saw slight traces of it here and there for a few hundred feet at a time, but there were no pillars to indicate the general line of boundary on that side. Towards the south however, the boundary was sufficiently defined, and so also towards the north-east portion. My next efforts were directed to the Cantonment Magistrate's office, and there I was more unsuccessful still. I was therefore obliged to confine myself to fixing such pillars as existed at the time of the survey. I am by no means sure that the pillars laid down are in their correct positions as originally marked out, for there was no one with me to represent cantonment interests, and my information as to the pillars was simply obtained through the zemindars whose possessions adjoin those of the cantonment.

(10.) The average height of the peaks in Jaunsár is about 6,000 feet above sea-level; that of Kándah, a strip of comparatively very lofty ranges of limestone, lying between the parallels of latitude 30° 44′ and 30° 49′ or thereabout and extending from the Jumna on the one side to the Tons on the other, is about 8,300 feet above sea-level. Many of the peaks however in this strip are close upon 10,000 feet high. In Báwar, the average height of the ranges is about 6,000 feet above sea-level. The great peculiarity of Jaunsár is the general absence of forests in it. Kándah is rich with foliage of many kinds, principally the oak, rhododendron, spruce fir, deodar, &c. Báwar is also very richly covered with forest, but not quite to the same extent as Kándah.

(11.) All along the banks of the Tons, the Pábar, and the Jumna rivers, the mountains are extremely precipitous; so are also the mountains of the Kándah belt. In other respects, as to minuteness of detail, the three belts of country are not much unlike one another.

(12.) I now proceed to report separately on each Officer's work.

(13.) I marched from Mussooree on the 21st of October, and after having a general look at the country in Jaunsár Báwar, I commenced operations in the Binolgadh valley where I continued plane-tabling till the 2nd of December. I then marched up to Sansog in the Pábar valley for the purpose of executing some triangulation, where I arrived on the 6th. Unfortunately when returning to camp during the evening of the same day I met with an accident and sprained my ankle, which disabled me in consequence from resuming work till the 9th, but on the 12th I succeeded in sending Mr. Litchfield the data for 14 points newly fixed, to enable him to complete the sketching of those small patches of country lying on the right bank of the Pábar. Shortly after I marched into Deoban, where I arrived on the 14th, Captain Thuillier having summoned me in order to confer about the work. I resumed the topographical sketching of the Binolgadh valley on the 16th December and finished it on the 24th. I next took up the sketching of the valley of the Amláwa river down to latitude 30° 35′, as well as a strip of country about 3½ miles broad lying to the east of the ridge which runs down from Deoban to Chakráta and thence to Pokri and Baret.

(14.) On the 26th February, Captain Thuillier arrived at Saiya, where he requested me to meet him in order to make over to me the entire charge of the operations in Jaunsár Báwar. So that in addition to my other duties, that of examining the work of each of the asssistants devolved on me. I finished work on the 30th of April and marched back to recess quarters, where I arrived on the 3rd of May.

Mr. C. J. Neuville.

(15.) Mr. Neuville was employed the whole season in the office of the party carrying on the miscellaneous current work, of which there was a large amount. He also assisted Captain Thuillier in the Dún by taking a few vertical observations with a theodolite.

Mr. W. Todd.

(16.) Mr. W. Todd began work on the 13th October on P. T. Section No. 47, of the Dehra Dún Survey, confining himself to those parts of the hills in it which were left unfinished during the previous season. The flat and raviny portions in this section were taken up by two Native Surveyors placed under Mr. Todd. Mr. Todd next took up P. T. Sections Nos. 66, 67, and 68. The two former were entirely mountainous, and the latter partly so. With the exception of a small portion done by Mr. I. Pocock in Section 66, Mr. Todd sketched these three sections. The mountains in these sections range from 4,000 to 6,500 feet above sea level, and there is a geographical peculiarity in them which may be noticed here. The slopes are very abrupt

for a short distance from the main ridge towards the south, and then the spurs run at a comparatively gentle incline, and after that they terminate in a steep fall to the Dún. The middle slopes are cultivated for the most part and have the villages on them; the terminal ends of the hilly spurs and their flat plateau-like continuations are principally covered with sál. Mr. Todd after completing the sketching of the 4 sections above-mentioned took up the sketching of P. T. Section No. 70. The work of the Native Surveyors attached to him was carefully examined by partál lines and found very accurate. Mr. Todd has turned out a fair amount of work, and for accuracy of sketching he has maintained the reputation which he has so deservedly won in the Department. He closed work on 22nd May and I regret to add that on the same day, he was prostrated from exposure to the sun and did not recover his health for some time.

Mr. H. Todd.

(17.) Mr. H. Todd commenced work on the 14th October in P. T. Section No. 56, Dehra Dún Survey, part of which had been surveyed last season. He then took up what remained of Section No. 36, a very difficult hilly piece covered with forest. His next piece of work was in Section No. 59, in which he was assisted by a Native Surveyor for the lower flat portions. This last section was also covered for the most part with forest. He also sketched into Section No. 58 up to the watershed of the Song. The mountains in Section No. 56 rise up to about 7,000 feet above sea level, and in Sections 58 and 59 he had the Kálimatti peak for his highest point which is 4,400 feet above sea level. There was a good deal of detail in the last mentioned sections. After sketching a portion of the forest-clad hill of Nalápáni, Mr. Todd was ordered to join me in Jaunsár, for which place he started on the 23rd March. On his arrival there he took up the sketching of the middle portions of the Khutní river valley, east of Chakráta, the ground in which ranges from 3,500 to 8,500 feet above sea level. This he began on the 28th March, and finished by the 28th of the following month. Mr. Todd worked very hard throughout the season, turning out a large quantity of work accurately done and drawn in a true and artistic style.

Mr. T. Kinney.

(18.) Mr. Kinney reported his return from 6 months' leave of absence on the 15th of April. As there was some doubt as to the possibility of completing the Jaunsár Survey before the setting in of the rains, I thought it advisable to have his help for the short remnant of the field season, and therefore directed him to proceed to Jaunsár to take up the survey of the ground about Shenj, Una, and Bahána villages on both banks of the Tons river. Mr. Kinney began work on the 22nd April and finished by the end of the same month, after which he returned to quarters. He worked with his usual care and artistic skill.

Mr. E. F. Litchfield.

(19.) Mr. Litchfield marched from Head Quarters on the 16th October, and took up his first piece of work which chiefly lies in Sheet No 1 of the Jaunsár Survey, about the valleys of the Tons, the Pábar and Dhárigadh rivers. In this piece he had numerous patches of Government forests, the boundaries between which and the village lands were demarcated by a very large number of pillars. Notwithstanding their numbers, and the intricate nature of the mountains which were for the most part thickly covered with forest, Mr. Litchfield managed to get through this his first piece very creditably. His next work was chiefly on the east of the Tons river up to about longitude 77° 52½', below latitude 30° 42½', and down to the confluence of the Tons with the Jumna river. Mr. Litchfield brought in a very large quantity of work, carefully and well executed. He closed work by the end of April, and marched back to quarters, where he arrived on the 3rd May.

Mr. I. Pocock.

(20.) Mr. Pocock took the field on the 16th October and began work in the Dún in P. T. Section Nos. 48, 58 and a small portion of No. 66. He was assisted in the flat and raviny portions of these two sections by 3 Native Surveyors, who also assisted him in traversing the main watercourses. He completed his work in the Dún on the 23rd February, and marched to Jaunsár where I gave him a small portion of ground lying to the west of the Chakráta and Mussooree road, between latitude 30° 30′ and 30° 35′ and east of longitude 77° 55′. His next piece of work was between latitude 30° 42½′ and 30° 45′ east of the Tons river and up to about longitude 77° 54′. Mr. Pocock after finishing the work allotted to him in Jaunsár on the 18th May, returned to quarters, where he arrived on the 25th of the same month. Mr. Pocock worked well and indefatigably.

Mr. R. Warwick.

(21.) Mr. Warwick remained with me about 5 weeks learning his work, after which I sent him to survey a piece of ground about 3½ miles in breadth along the western bank of the Jumna river, between the point of junction of the Rulina river with the Jumna and the suspension bridge on the Mussooree-Chakráta road. The next portion he undertook was to the east of the Tons river and about the village of Kándui. Mr. Warwick worked well and hard. He has the making in him of a first-rate topographical surveyor, and I feel no doubt that he will in the course of a few seasons more, justify my anticipations on this head.

(22.) Six maps in all have been completed during the recess. These are as follows:—

Mapping.

2 Skeleton Sheets Nos. VII and XXIV, scale 1 inch = 1 mile, of the Kumaun and Garhwál Survey; 1 Shaded Sheet No. XXI on the same scale of the same survey, and 3 Sheets of the Dehra Dún Survey *viz.*, Nos. VIII, XVI and XXII, scale 4 inches = 1 mile. The mapping has been very much retarded in consequence of Mr. Kinney sustaining an injury by the fracture of his right wrist. His services as a draftsman were lost to me thereby for nearly two months.

KUMAON AND GARHWAL PARTY.

SURVEY OF JAUNSAR BAWAR, DEHRA DUN DISTRICT.

Tabular Statement of out-turn of work. Season 1875-76.

Details of Triangulation.

OBSERVER'S NAME.	Instrument used.	Area triangulated in square miles.	2 Angles Observed				REMARKS.
			No. of Intersected points.	No. of Triangles.	Error per mile.	No. of Heights.	
E. C. Ryall, Esquire, ...	6-inch*	†	52	104	Inches 11	9	* Subtense instrument, one vernier only used. † Over previously triangulated ground, including 25 stations visited.

Details of Topography. Scale 2 inches = 1 mile.

NAMES.	Area surveyed in square miles.	No. of Plane Table Stations per square mile.	REMARKS.
E. C. Ryall, Esquire, ...	102	10·0	Intricate and about half covered with forest.
Mr. H. Todd, ...	38	6·7	„ „ „
„ T. Kinney, ...	9	6·0	„ but comparatively open ground.
„ E. F. Litchfield, ...	168	8·5	„ and about ⅓ covered with forest.
„ I. S. Pocock, ...	46	7·5	„ „ ½ „
„ R. F. Warwick, ...	67	7·7	„ but comparatively open ground.
Total, ...	430 Includes 20 square miles of overlaps.		

Details of Traversing.

NAMES.	Instrument.	Linear miles of Traversing.	No. of Stations.	Average error per 1000 links.	REMARKS.
One Native Surveyor, ...	*	71·96	1792	2·3	*Card board circular protractor 12 inch in diameter and Needle. Traverse carried along hill roads.
Total, ...	...	71·96	1792	...	

INDEX MAP

OF THE

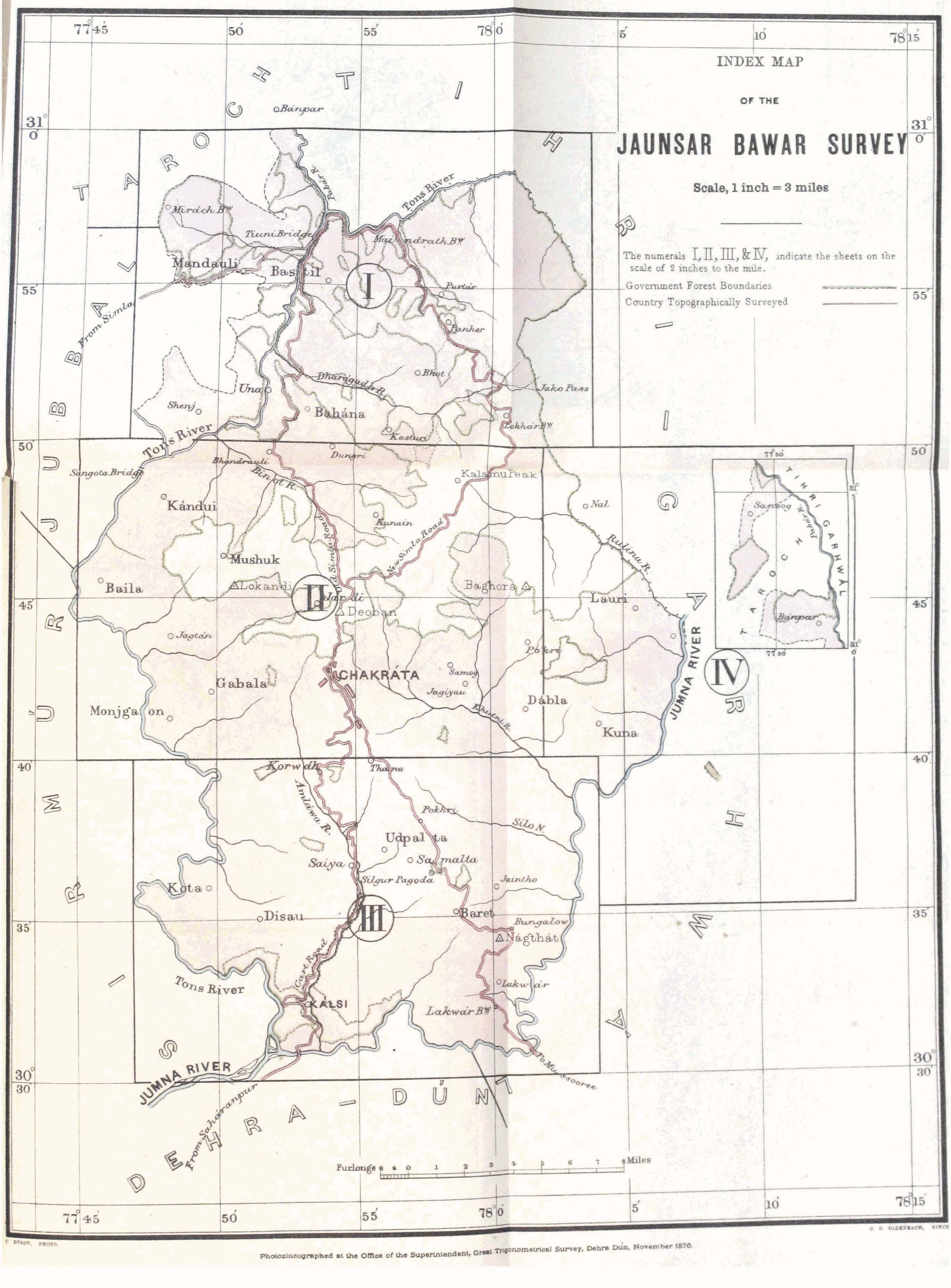
JAUNSAR BAWAR SURVEY

Scale, 1 inch = 3 miles

The numerals I, II, III, & IV, indicate the sheets on the scale of 2 inches to the mile.

Government Forest Boundaries

Country Topographically Surveyed



C. DIXON, PHOTO.

O. G. OLLENBACH, SINCO

Photozincographed at the Office of the Superintendent, Great Trigonometrical Survey, Dehra Dún, November 1876.

INDEX MAP

OF THE

DEHRA DUN AND SIWALIK SURVEY

Scale, 1 Inch = 4 miles

The Numerals I, II, III, &c., indicate the sheets on the scale of 4 inches to the mile.

The Numerals 1, 2, 3, &c., indicate the plane table sections.

Government Forest Boundaries

Country topographically surveyed up to 1875-76.

,, triangulated and traversed in advance

,, triangulated

The co-ordinates of projection are rectangular, originating from the East End Dehra Dun Base-line, the meridian of which is one of the adopted axes.

Chains 200 100 0 2 4 6 8 10 Miles

SURVEY OF DEHRA DUN AND SIWALIK HILLS.

Details of Topography. Scale 4 inches = 1 mile.

NAMES.	Area surveyed in acres.	No. of Plane Table Stations per acre.	REMARKS.
Mr. W. Todd, ...	18,564	5·4	Mountainous and for the most part covered with forest.
„ H. Todd, ...	19,492	6·4	Mountainous and intricate and for the most part covered with forest.
„ I. S. Pocock, ...	7,534	5·6	Mountainous and for the most part covered with forest.
6 Native Surveyors under the supervision of the above mentioned officers.	33,691	3·0	Flat and raviny ground and in some parts intricate and covered with forest.
Total area ...	79,281 or 124 square miles.		

X. Extract from the Narrative Report—dated 13th September 1876—of Major A. PULLAN, S.C., Officiating Deputy Superintendent 3rd Grade, in charge of the Kattywar Survey Party.

During the recess season of 1875 fair maps of Sheets 31—42, 43 and 44 of Kattywar were prepared on a scale of 2 inches to a mile for publication on the 1-inch scale; and the data connected with Degree Sheet VI of Kattywar were partially prepared. Mr. F. Bell, Surveyor 3rd Grade, worked during the recess season but did not take the field owing to ill health; Mr. Bell proceeded on one year's furlough to Australia on the 1st November 1875.

PERSONNEL.

Major A. Pullan, S. C., Deputy Supdt.
J. McGill, Esq., Asst. Supdt.

Surveyors.

Mr. J. Peyton.
„ N. C. Gwynne.

Assistant Surveyors.

Mr. W. A. Fielding.
„ W. Oldham.
„ G. T. Hall.
„ H. Corkery.

Senior Sub-Surveyor.

Mr. V. R. Gadboli.

Sub-Surveyors.

Govindji Mahalay.
Narsu Dinkar.
and eight others.

The out-turn of work for the season of 1875-76 was considerable. An area of 2253 square miles was topographically surveyed and consisted of parts of Prants Hállár, Kattywar, Sorath, and Jhalawad: 1850 square miles were trigonometrically surveyed in advance, preparatory to next year's topographical operations; and 1600 linear miles of traverse were carried over the different sheets demarcating the taluka and state boundaries and checking the details of the plane table survey.

Departure for the Field.

The party started for the field on the 20th October. The heavy baggage and horses with the subordinate Native establishment proceeded as in former seasons by "patimar" boats to Gogo which port they reached on the 2nd November. Messrs. Hall, Corkery and V. R. Gadboli were sent in advance of the main party to Gogo, and this arrangement saved several days' delay at that port, as they prepared plane tables, projected points &c, so that each surveyor on arrival found his board ready for him and was enabled to proceed without delay to his especial work.

Capt. Pullan, Depty. Superintendent, in charge.

I started from Gogo in company with Mr. McGill on the 15th November and we marched by regular marches to Mánekwára. Here Mr. McGill turned northward and proceeded to take up the triangulation of Sheet 46. I marched west to Junágarh and on arrival there I proceeded to make a careful reconnaissance of the Girnár mountain, that isolated pile of granite being a very remarkable geographical feature. Subsequently I proceeded northwards to Gondal and commenced my examination of the plane tables in Sheet 36. With the exception of a fortnight spent in correcting on the spot the hill shading of a very rugged and difficult portion of country in Sheet 45, my time throughout the field season

was spent in the examination and checking of plane table work. On the 3rd of April I left Gogo on duty to Poona, and after examining the preparation of the fair traverse sheets which were in course of execution, I availed myself on the 8th of April of 2 months' privilege leave and proceeded to Mahableshwar, having made over charge of the party to Mr. McGill, Assistant Superintendent.

J. McGill, Esq.

Mr. McGill executed the triangulation of Sheets 46, 47 and 48 in his usual admirable manner, completing in all 1650 square miles and joined me on my way to Gogo at the end of March. Mr. McGill then remained at Gogo bringing up Angle books and preparing triangle sheets for computation until the whole of the Plane Table Surveyors had completed their work.

Mr. J. Peyton.

Mr. Peyton was entrusted by me with the independent charge of Sheet 10a, the northernmost portion of Kattywar abutting on part of Guzerat to the east and having the Runn to west and north, Nilkant Vital sub-surveyor accompanied Mr. Peyton. Mr. Peyton completed the topographical survey of the sheet and proceeded to Poona to get on with the preparation of the fair sheets. Mr. Peyton himself completed 206 square miles of topography—an out-turn of field work in every way satisfactory.

Mr. N. C. Gwynne.

Mr. Gwynne worked in his usual energetic way throughout the field season. His out-turn of work was 201 square miles comprising the whole of the Girnár range, very difficult ground, sketched in a most artistic and correct manner.

Mr. W. A. Fielding.

Mr. Fielding executed 238 square miles of topography in very good style. Mr. Fielding is always most accurate and reliable and shows great tact and judgment in dealing with Native officials.

Mr. W. Oldham.

Mr. Oldham executed 139 square miles of topographical survey in a creditable manner, a portion of the ground which fell to his share, bordering as it did on the Gir Forests, was full of low spurs thickly clad with trees and small intricate ravines. Mr. Oldham also completed 200 square miles of triangulation (portions of Sheets 40 and 50).

Mr. Geo. Hall.

Mr. Hall's out-turn of work was 204 square miles of topography carefully executed.

Mr. H. Corkery.

Mr. Corkery's out-turn of 206 square miles was highly creditable to him. He has much improved in his mode of delineating ground. The hills being shown in a really artistic and graphic manner.

Mr. Visaji R. Gadboli Head Sub-Surveyor and other Native Surveyors.

Mr. Visaji Gadboli worked steadily throughout in the projection of plane tables and computations of the latitude and longitude of subsidiary points for Plane Tablers. The amount of fair mapping to be done in the recess being unusually heavy, Mr. Gadboli was sent by me to Poona in the end of February and was employed in computing traverses and preparing fair traverse sheets. Govindji Mahalay executed 201 square miles of topography in his usual neat and graphic style. His work was as good this season as in former years. Narsu Dinkar completed 232 linear miles of traverse, the ground being in many places complicated in detail and difficult to chain. Krishna Govind completed 86 square miles of topography. He is a new hand at plane tabling and was very slow, but I found his work carefully done and very correct. Bholoji Bhosekar did a good season's work as a Traverse Surveyor, his out-turn being 289 linear miles carried over a difficult country. Nilkant Vital executed 236 square miles of topography, a large and highly creditable out-turn. Keshu Vital turned out 143 square miles of topography creditably. His work of this season shows a decided improvement on that of former years. Tukaram Chowdry did a good season's work of 211 linear miles of traverse. Ganesh Ramchandra completed 214 square miles of topography in a neat and workman-like manner. Vishnu Balwant executed 179 square miles of topography very well for a beginner. And Lazarus D'Souza acted as recorder to Mr. McGill. He writes a neat hand.

General health of the district.

Throughout the field season, sickness prevailed in Kattywar, fever was rife, and cholera of a sporadic character broke out fitfully here and there. The party was exceptionally fortunate for only three deaths occurred throughout the different survey camps, although men were dying daily in the villages around.

The Girnár Range.

The most remarkable geographical feature in the country surveyed during the season under review is the Girnár mountain and its spurs. This very remarkable granite mass, rising as it does abruptly from the plain, can be seen on a clear day at a distance of 50 miles looming in haze on the verge of the horizon. The mountain lies due east of the town of Junágarh which is at the foot of one of the western spurs.

The highest peak of Girnár, known by the pundits as Ujyant, rises to an elevation of 3,666 feet above sea level; the upper part of the mountain towers almost perpendicularly above the surrounding

spurs some 500 feet, a huge mass of granite intersected diagonally by thin laminæ of quartz; this pile is broken at the summit into three sharply defined peaks, the westernmost and lowest being dedicated to Amba Devi, the middle and highest point to Goraknath, and the easternmost to Datatri Swami; round this great central mass the lower spurs wind and spread inclosing the holy mountain in a circle of hills. The next highest peak on the range is called Datar, and nestling below the granite precipices which crown the mountain is the shrine of Jamil Shah, a celebrated Pir to whose sacred tomb leprous and blind both Mahomedan and Hindu even now journey to be made whole again. One more peak Kalika Tonk may be mentioned, which though lower than Girnár or Datar, still rises to a height of 2,527 feet above sea level and attracts the eye by the grandeur and abruptness of its granite pinnacle. Girnár is held in the greatest veneration both by Brahmin, Jain, and Mahomedan. The most remarkable temples on the hill are Jain and are at the base of Amba Devi peak; they bear date "Sumwut" 1215 or A. D. 1159. As the traveller approaches from the west the sacred "Ujyant" towers above the picturesque town of Junágarh, a blue cone; on nearer approach, the mountain takes shape, and spurs and precipices appear, and enclose a good flagged road the *via sacra* of Surashtra, which leads from Junágarh through a lovely wooded valley by the green waters and temples of Damodar Kund, a haunt of fakirs and monkeys, for some 3½ miles until the foot of the mountain is reached; still there is no break in the road, the broad flagged path winds its way through brushwood and crag and along the face of granite precipices, past the Jain temples of Amba Devi, until it terminates on the topmost point of Goraknath below the hoary time-stained walls of the little temple. Only the most energetic of the pilgrims force their way beyond this point, but a determined few may be seen struggling, with painful steps and slow, over the rugged granite to the lovely little temple of Datatri.

One striking feature on the mountain is an immense perpendicular rock called Bheru Jap, from the summit of which in the days before British rule was established, hundreds of mad devotees threw themselves into the abyss below as a religious act of suicide.

The scenery of this remarkable range is unique. The enormous crags and perpendicular precipices of black granite are tinged here and there with hoary stains of time and exposure. The temples ancient and weather-worn, and the long arms of lower ranges that stretch round and wrap in crag and forest the skirts of the great central pile of Girnár, form a scene of picturesque beauty and grandeur not to be surpassed. The view from the summit of the mountain is wonderful, all Kattywar seems spread out like a map under; and at sunset when the sun's declining rays tinge temple and rock with glowing tints, and the Gulf of Cutch gleams in the horizon like a golden zone, the traveller gazes on a scene perfectly unique and singularly beautiful. The heavy forest and thick underwood which covers the Girnár range is the haunt of numerous Sambar, but they are shy and difficult to come across, leopards also hang about the ravines running into the plains in considerable numbers.

Principal Towns.

The Principal towns in the portion of country surveyed this season are :—

1*st*, *Gondal*—the principal town of the Gondal state; the chief is a Jhareja Rajput. The town is on the banks of a small stream a tributary of the Bhádhar, and is clean and well kept: the high road from Rájkot to Junágarh runs through Gondal, and a neat bridge spans the river. The Political Agent's bungalow, Public offices, Post office and Hospital, all well built edifices, combine to give Gondal a remarkably thriving look, and the town is also connected by an electric telegraph line with Rájkot and Bombay.

2*nd*, *Jetpur*—this town is the seat of a petty "Katty" chief of the Wala race. It is a walled town very picturesquely situated on the banks of the Bhádhar river over which a handsome stone bridge has just been erected by the Executive Engineer for Kattywar. Behind the town looms in the far distance the Girnár range, and the rapids of the Bhádhar in the foreground, combine to form a very pleasing picture. There is a good travellers' bungalow at Jetpur, and the high road between Rajkot and Junágarh passes close by the town.

3*rd*, *Dhoráji*—this is one of the chief towns of the Gondal taluka; it is situated on the south bank of the Bhádhar river and is a large and thriving place: there is a very good school here, and the town is connected *viâ* Jetpur, Gondal, Rájkot, and Ahmedabad with Bombay by a line of telegraph.

4*th*, *Junágarh*—this town the seat of a Mahomedan Nawáb, is situated among groves of mango and other trees, a strong wall formerly surrounded the town, but it is now falling into decay, a large fort called Uparkot looks down upon the town, but although formidable in appearance it is now uncared for and deserted. Junágarh with a population of 18,311 souls is inferior only in importance to Jámnagar and Bhaunagar, and ranks as the third town of the province. The town is surrounded on the south and west by heavy jungle stretching for miles, and on the east it is shut in by the lower spurs of the Girnár, the north approach is open and a good metalled road runs between Rájkot and Junágarh. The water supply of the city is bad and scanty. Junágarh is connected by electric tele-

graph with Gondal and Rájkot.

5th, Jhinjhuwára—this is a town of some size whose crumbling walls and massive old gateways indicate former prosperity. Not far from the town and on the edge of the Runn is the island of Jalandar on which are some curious springs of brackish water which bubble up from the ground even in the severest drought. Jhinjhuwára is the residence of a Rajput Thákur, but a Kamdar, deputed by the British Government, administers justice and collects the revenue.

Rivers.

The principal rivers which flow through the country under review are the Bhádhar, the Ujat, and the Uben. The Bhádhar the most considerable river in Kattywar rises in the low hills north of Jasdán and taking a south-western course falls into the Gulf of Cutch at Nawi Bandar. In the rainy season the Bhádhar is said to be navigable for small craft as far inland as Dhoráji near Junágarh. The Ujat rises in two forks in the plateau near Mánekwára and flowing north joins the Bhádhar about 4 miles from Nawi Bandar. The Uben rises among the northern spurs of the Girnár range and falls into the Ujat at Wauthali.

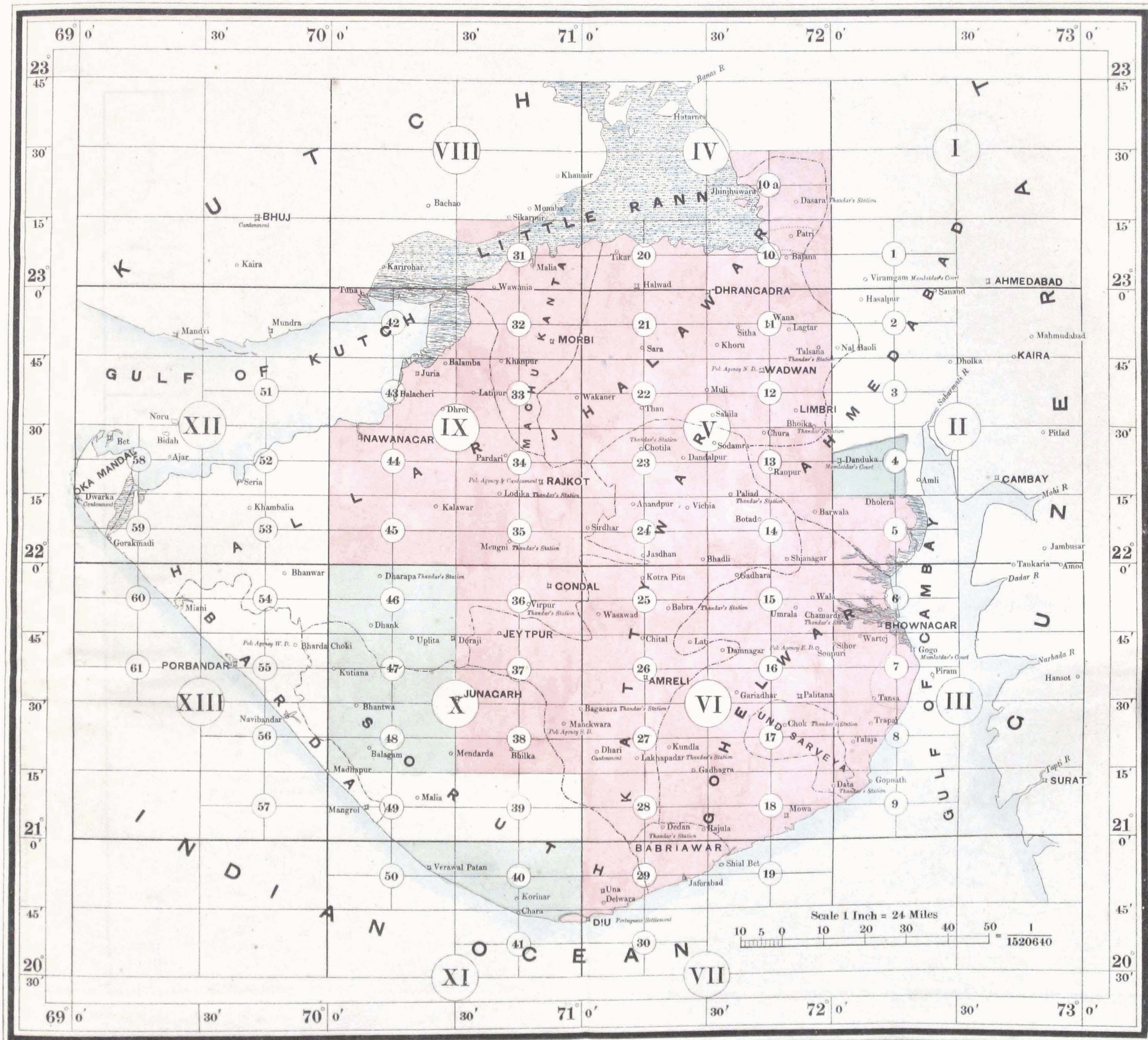
Appearance and character of the country.

The villages in the portion of Kattywar surveyed during season 1875-76, are decidedly populous, the country being fertile and, for Kattywar, well wooded, mango, tamarind, bar and pípal trees are here scattered over the plain and afford a grateful shade near villages and wells. Fine crops of bajree and cotton are grown throughout these districts, and the sugarcane is also largely cultivated.

Population.

About one third of the people of the Junágarh state are Mahomedans, the remaining two-thirds are Hindus of various castes. In the Gondal state about three-fourths of the people are Hindus, the remainder Mahomedans. Guzerati is the language of the masses, but Hindustani is well understood in all the large towns, more especially Junágarh.

INDEX CHART OF THE KATTYWAR TOPOGRAPHICAL SURVEY.



C. DYSON, Photo.
C. G. OLLENBACH, Zinco.

The numerals 1, 2, 3 &c., indicate the sheets on the scale of one inch to the mile. The numerals I, II, III &c., indicate the degree sheets, on the Scale of ¼ inch to the mile.
The one inch sheets are divided into 4 sections known as the N.E., N.W., S.E., & W., sections of the sheet; of these a few copies will be published on the Scale of the original Survey, viz., 2 inches to the mile for the use of local officials.

Denotes country Topographically Surveyed up to 1875-76.
Ditto Triangulated in advance up to 1875-76.

Photozincographed at the Office of the Superintendent, Great Trigonometrical Survey, Dehra Dún, January 1877.

TABULAR STATEMENT OF WORK EXECUTED BY THE KATTYWAR SURVEY PARTY, DURING THE FIELD SEASON 1875-76.

Details of Triangulation.

Observer's Name.	Instrument.	Area triangulated in square miles	3 Angles Observed.					2 Angles Observed.				Average No. of trigonometrical points per square mile.	Average No. of heights per square mile.	Lat. and Long. deductions.	Pillars built.	Remarks.
			No. of stations fixed.	No. of triangles.	Triangular error.	Error per mile.	No. of heights.	No. of Intersected points.	No. of triangles.	Error per mile.	No. of heights.					
					"	*Feet*				*Inches*						
Mr. J. McGill, ...	Cooke and Sons' 7-inch	1650	62	144	12·7	0·48	64	580	1000	1·10	206	0·4	0·2	317	146	
„ W. Oldham, ...	Troughton and Simms' 6-inch	200	12	21	11·8	0·68	13	76	118	1·40	12	0·5	0·1	43	13	
	Total, ...	1850	74	165	12·3	0·58	77	656	1118	1·25	218	0·45	0·15	360	159	

Details of Topography. Scale 2 inches = 1 mile.

Name.	Area surveyed in square miles.	No. of plane table stations per square mile.	Remarks.
Mr. J. Peyton, ...	206	10·7	
„ N. C. Gwynne, ...	201	5·6	
„ W. A. Fielding, ...	238	9·7	
„ W. Oldham, ...	139	12·6	
„ G. Hall, ...	204	9·9	
„ H. Corkery, ...	206	9·9	
Sub-Surveyors.			
Govindji Mahalay, ...	201	8·4	
Krishna Govind, ...	86	22·1	
Keshu Vital, ...	143	16·3	
Nilkant Vital, ...	236	12·0	
Ganesh Ramchandra, ...	214	11·4	
Vishnu Balwant, ...	177	12·4	

Details of Traversing.

Name.	Instrument.	Linear miles of traversing.	No. of stations.	Average error per 1000 links.	Average angular error per station.	Remarks.
					"	
Narsu Dinkar, ...	Cooke and Sons' 5-inch ...	465	1273	0·7	9·2	
Bholoji Bhosekar, ...	Troughton and Simms' 5¼-inch	629	1311	0·5	7·9	
Tukaram Chowdry, ...	Do. do.	506	1808	0·8	15·8	

XI. Extract from the Narrative Report—dated 30th October 1876—of Major C. T. HAIG, R.E., Officiating Deputy Superintendent 1st Grade, in charge of the Guzerat Survey Party.

(3.) The out-turn of field work consists of 924 square miles of topography on the 4-inch scale and 948 square miles on the 2-inch scale, the former being chiefly British Khálsa land and the latter chiefly Foreign territory; and 1650 square miles were prepared for final survey chiefly by traversing but with a little triangulation where it was necessary.

PERSONNEL.

Major C. T. Haig, R.E.
Lieutenant J. E. Gibbs, R.E.
Mr. A. D'Souza
„ A. D. L. Christie
„ C. H. McAFee
„ J. Hickie
„ G. D. Cusson
„ S. F. Norman
„ C. Norman

Sub-Surveyors.

Mr. H. G. Ferns
Gopal Vishnu
Bálkrishna Bábájee
Lakshumán Gharpuri
Ganesh Náráyen
Ganesh Bápuji 1st
Raoji Narayen
Balwant Govind
Mukand Dinkar
Bhao Govind
Ganesh Bapuji 2nd
Monaji Abu
Govind Gopál
Balwant Rajaram
J. V. D'Souza
Sayana Saibu

Revenue Survey

H. D. E. Forbes, Esqr.

Sub-Surveyor.

Kubar Parbhudáss
Jugal Mánsukhrám
Parbhu Kisor

(6.) The area finally surveyed comprises sheet 31 and a quarter of 32; also 78 and 79 with a small portion (56 square miles) of sheet 10a of Kattywar. This small portion was surveyed by us on the 4-inch scale as it was British Khálsa land which I thought desirable to have mapped on the same scale as the rest of the territory to which it pertained and adjoined.

(7.) The orders of Government restricting the scale to 2 inches to a mile were received too late to admit of any alteration in the field arrangements, but although the British Khálsa land was surveyed on the 4-inch scale it will all be mapped on the 2-inch scale; so that the cost will not be appreciably more than if it had been surveyed on the 2-inch scale. The field sections have been reduced to half scale in the Government Photozincographic Office here and from the reduced copies fair maps are traced.

(8.) The area topographed is, as will be seen on referring to the accompanying Index map, in two parts, which I may call the northern and southern. The northern portion includes a large part of the Viramgam taluka and a small part of the Sánand taluka of the Ahmedabad collectorate, a part of the Kari Mahal, and six villages of the Pátan Mahal of the Gaekwar's territory, and a small part of the Mahikántu. The Viramgám taluka has now been completely surveyed with the exception of 4 detached villages situated in sheets 72 and 77, and the Sánand taluka is also complete with the exception of 8 villages in sheet 7. In this northern area are the following principal towns:—

Viramgám—a taluka town; population about 20,000, with its municipality, a Mamlatdar's court, and a Railway station where the line from Khárághora (distance 14 miles), the great Government Salt station, joins the Wadhwán and Ahmedabad line.

Mándal—an important Khálsa town, with a population of about 7,000, and having a municipality and a Post office.

Detroj—a Khálsa town, with a population of about 3,000, and a branch Post office.

Kari—the chief town of the Kari Mahal, Gaekwar's territory, which has a somewhat interesting history attaching to it. It has a population of about 17,000, and a fine palace, and is fortified by a good wall from which it is styled *Kila* Kari. It is the residence of a Wahiwatdar (Manager), a Mamlatdar, and a Foujdar, and has a Post office. In 1802 it stood a siege and was taken by Sir William Clarke on the 30th April of that year from Malharao Gaekwar, who, a Jaghirdar of Kari, was nominally a dependant of the Gaekwar of Baroda to whom an annual tribute of Rupees 120,000 was payable, and who though within the Gaekwar's territories was as independent of him as the latter was of the Peishwa. Malharao rebelled against him, and perhaps but for the British troops might have maintained his independence, but on the capture of Kari he was taken prisoner, and Kari and its district were made over to the Baroda Gaekwar, who in consideration of the British services ceded the Chikhli pargana, now a taluka of the Surat collectorate, to the British Government. Malharao's father was the first Prince of Kari; he was established there by *his* father Pilaji Gaekwar in 1731. The palace and town walls were therefore probably built soon after that date.

Bechráji Mátha—a village in the Pátan Mahal, Gaekwar's territory, of only 123 inhabitants, situated near the village of Becher of 620 inhabitants, famous for its temple and its melas (fairs). A mela is held there every month, but once a year in the end of September there is a famous and very largely attended mela visited by Hindus of all castes from all parts of Guzerat.

Katosan—a Thákur's town under the Mahikánta Political agency. It has a population of over 2000, and has a number of dependent villages. There are other villages of over 1000 inhabitants but of no particular importance.

(9.) The whole of the northern area is without any through drainage. There is an abundance of tanks which appear to accommodate the whole of the rainfall. There is not a single watercourse which flows either into the Runn of Cutch on the west, or into the Sábarmati river on the east. A few watercourses, without even sufficient importance to carry a name, drain into tanks or lose themselves in the flat country. There is a large lake on the north-west margin called Wanod-na-Saran (from Wanod, a neighbouring taluka town under the Kattywar Political agency) which covers when it is full about 6½ square miles. Half of this falls within our margin, the other half has been surveyed by the Kattywar Party.

(10.) The country on the east of the northern area is finely wooded with Mango, Kirni, Tamarind, Banian, Pipal, Nim, Wood Apple and other trees, and undulating to an extent embarrassing to the plane tabler, as the undulations conform to no marked system of drainage, but are very irregular; so that had the country been accurately contoured, the contours would meander so as to defy eye sketching, that is to say, no two surveyors would have represented the same ground in the same way without spending a very long time over it. The west of this area is very flat and open, the trees being almost confined to the immediate vicinity of the villages. The soil also is very different on the east and west. On the west it is clay with scarcely any admixture of sand, while on the east the sand predominates, so that within a distance of 30 miles the general aspect and character of the country undergoes a very marked change.

(11.) The Bombay Baroda and Central India Railway traverses the northern area from west to east not far from its southern margin, and the Ahmedabad and Viramgám road enters the southern margin at 6½ miles from the south-east corner of sheet 79, but this road is of no importance now as an engineering work; part of it, between Sánand and Viramgám, has been taken up for the permanent way of the Railway, and the rest is sadly out of repair; east of Sánand in sheets 80 and 8 the road is in good order. The Government telegraph wire just crosses the north-east corner of this area, and about 6 miles of its length lie within the margin. There are no other engineering works in the northern area.

(12.) In this part of the country crime abounds to an alarming extent. Freebooters take advantage of the many political divisions of the country and evade the Police of one state by retreating into another. When I was at Kari a troop of the Gaekwar's cavalry halted there for a few days in the course of their search after some of these robbers. Fortunately the robbers think it politic not to molest servants of the British Government, and so none of our Surveyors were interfered with.

(13.) The southern area comprising sheet 31 and the north-west quarter of sheet 32, includes part of the Broach, Ámod and Ankleswar talukas of the Broach collectorate (which is now with the exception of a small portion of the Ankleswar taluka and a very small portion of the Ámod taluka completely surveyed), part of the Sinor Mahal of the Gaekwar's territory, also part of the Rájpipla territory and of the Sánkhera Mewas under the Rewákánta Political agency.

(14.) In the southern area are the following principal towns:—

Broach City and Civil station—with a population of about 37,000. This is apparently a city of great antiquity and said to have been known to the ancient Chinese under the name of Polee-kie-teh'e-po', the capital of a kingdom on the Nai-mo-tho or Nerbudda.* Arrian the Greek, and Ptolemy the Egyptian historian of the Augustan period, speak of it as Barigaza situated on the Narmadas; and the unknown author of the Periplus of the Erythrean Sea, geographically identifies it with Barigaza by the statement of its being "30 miles on the Narmadas" and by his accurate description of the "bore" or tidal wave of the Gulf of Cambay. Its name has at various times been much transformed from the original Brigu-kacha, literally the delta of Brigu the tutelary saint of the river whose shrine is still to be seen in old Broach. "To the Arabian travellers of the tenth and twelfth centuries it was known at different times "as Baroh, Baros, and Bahruj; the latter phonetically the same as it is now in Guzerati. It has had "at least a dozen forms in English in three generations: but Broitsh, Borich and Broach seem to be the "last." The administration of Broach and its dependent territory changed hands several times in the 18th century. It was taken in 1772 by the British who entrusted it to a Native Chief and council till 1783, when it was conferred on Máhádáji Scindia on account of his valuable aid and services in 1779; but in 1803 Scindia took up arms against the British, and in that year Broach was taken by storm and subsequently ceded by treaty to the British in whose hands it has remained ever since. Broach is now famous as a great cotton centre, and boasts of several spinning and ginning mills and presses. The town is on the Nerbudda and covers an area of about 2 miles by nearly ½ a mile. The Civil station is at the west

* From para. 10 of Mr Beyt's Report of the Revenue Settlement of the Broach Taluka, No. 1025, dated 20th October 1871. Published by Government of Bombay.

end of the town, the Railway station at the east end. It has a municipality and the usual offices to be found at every administrative centre of a district.

Ankleswar—the chief town of the taluka of that name, has a population of nearly 9,500, a Mamlatdar's court, a municipality, a Post office, and a Railway station which is nearly due south of Broach station at a distance of 6 miles. It is on the south side of the Nerbudda and about 3 miles from its present bank, but on the edge of what is the traditional old bank. The river must have changed its course very many years ago as there are several very populous towns on the lower ground between the ancient and modern banks. Ankleswar was ceded to the British by the treaty of Bassein in 1802.

Sinor—the chief town of the Gaekwari pargana of that name, has a population of nearly 6,000. Like every such town it has its Wahiwatdar, Mamlatdar, and Foujdar. It is situated on the right bank of the Nerbudda. The bank is here very precipitous and varying from 90 to 120 feet; the communication therefore between the town and the water is effected by wide ghats of masonry steps. It has also some fine entrance gateways.

Tankári—a large town of some 3,200 inhabitants; on the main track of communication between Broach and Baroda, has its traveller's bungalow, and is about 13 miles from Broach.

Sukal-tirth—population 2,900; *Janor*—population 2,600; and *Nikora*—population 2400; are three towns in the Broach taluka on the right bank of the Nerbudda, the first two are about 67 miles apart and the last intermediate between them. Sukal-tirth is about 15 miles from Broach, and is famous in having its name always connected with a notable Banian tree under which it is said Alexander the Great encamped with his army*: Pliny mentions this tree as capable of affording shelter to an army of 30,000 men. On an island in the Nerbudda nearly opposite Sukal-tirth is now a dense wood in the place where this famous tree once stood it is said alone, and from its isolation was supposed by the natives to have sprung from the tooth-pick of Kabir, a Guru who grafted the tenets of several modern creeds upon a Hindu stock so craftily as to render the question of his disciples being Hindu or otherwise still open to debate. The island is called Kabiwar from its having a temple sacred to Kabir on it in the thick of the wood but no portion of it pertains to Sukal-tirth. It is divided between Nikora and Janor and two other intermediate villages Mangaleshwar and Angareshwar, and the wood is on the part which pertains to Mangaleshwar, but nevertheless this wood which from a little distance has so regular an outline as to appear like a single huge tree is always called the Sukal-tirth Banian tree.

Diva—population 2,000, and *Bhar Bháta Bet*—population 2,000; these are two of the populous towns situated on the low ground between the ancient and modern banks of the Nerbudda mentioned in connection with the town of Ankleswar; they pertain to the Broach taluka.

Chandod—population about 3,000; on the right bank of the Nerbudda. It is a town under Mándwa in the Sánkhera Mewas under the Rewákánta Political agency. This town is on the eastern margin of sheet 31 and therefore serves well to define the extent to which the Nerbudda has been surveyed, it being mapped from Chandod to the gulf of Cambay.

Rund Bhálod—population 2,200; in the Rájpipla territory on the right bank of the Nerbudda. Rund is the old and Bhálod the new town, but both adjoin and make one large town the chief centre of a pargana and the residence of a Thanadar.

There are in this southern area 24 other towns and villages with populations ranging between 1,000 and 2,000. Among the still smaller villages is one Ratanpur remarkable for its cornelian. It is on the south of the Nerbudda in the Rájpipla territory. The cornelian is dug out of a hill near the village, and taken to Cambay where it is cut and polished chiefly by a number of blind folk, and sold to the public under the well known name of Cambay stones. Mr. Christie reported on these cornelian mines of Ratanpur in 1873 *vide* p. 34—a of Annual Report for 1872-73. There is also near Ratanpur, and within the precincts of a temple, a famous tree of ordeal, of which the trunk is cleft through and by it a man suspected of crime is made to assay to pass. His guilt or innocence is proved by the tree either contracting the opening and detaining the culprit, or by allowing him to pass through without hindrance; such is the popular superstition.

(15.) The southern area is traversed by the Nerbudda river which is tidal as far as the Gaekwari village of Ránápur about 24 miles in a direct line from Broach, but 36 miles by the river. Large native craft come up as far as the Railway bridge at Broach, but above that, craft up to 30 tons ply as far as Talakwara about 40 miles direct from Broach and 65 miles by the river. The Nerbudda has several small tributaries which flow into it from the Sátpura mountains: the western extremity of which enters the south of sheet 31; and the whole of the country between the Nerbudda and the Sátpuras is very much cut up with ravines and watercourses, making about 200 square miles of country extremely difficult to survey, particularly to hands who have been accustomed to the flat plains of British Guzerat. This part of the country is mostly very wild, thickly wooded in parts

* Vide para. 12 of Mr. Beyt's Report, No. 1025 of 20th October 1871.

with bastard teak and in parts with palm trees, and the soil is very stony. With the exception of the neighbourhood of the river, where there are many towns and villages, the interior of this part of the country is inhabited by Bhils, and the hills are the abode of tigers, panthers and other wild animals, which frequently allure the Broach sportsmen to pay them a visit. On one occasion Mr. Cusson was surveying a Nala when a tiger sprung out of a bush within 30 yards of him, on the other side of the Nala, and made off into the jungle.

(16.) With the exception of a small area of land in the vicinity of the Nerbudda called Bhâta and Gorat (both of these having a large admixture of sand in the composition of the soil) the remainder of the southern area is a great plain of black soil, which in the cold weather under the luxuriantly verdant crops presents the appearance of a sea of almost homogeneous brilliant green, beautiful to the eye of the Revenue Officer, but too monotonous to please an artist as it is not even broken by a hedge; the villages are scattered over it like islands from 3 to 6 miles apart, and a few babul trees stand out like beacons here and there.

(17.) The southern area includes 25 miles of the Bombay Baroda and Central India Railway, and the stations of Ankleswar, Broach, Chamárgám and Pálej. There are no metalled roads in this area (excepting those within Broach municipal limits) but there are several cleared roads which have the advantage of being straight, but can scarcely be called engineering works.

(18.) The Head Quarters of the party left Poona on the 8th November, and Office was opened at Broach on the 14th; but previous to leaving Poona each of the Surveyors was given his portion of work so that each went at once to his proper post. I distributed the party as follows. Triangulation and traversing in sheets 28, 29, 30, Lieutenant Gibbs and Mr. Forbes with three Native Surveyors of the Revenue Survey establishment. Topography of British Khálsa land in the northern area (sheets 78, 79) on the scale of 4 inches to a mile, Mr. D'Souza with 8 Native Surveyors including two new hands who had to be instructed in plane tabling. British Talukdari and Foreign territory in the same sheets on the scale of 2 inches to a mile, Messrs. Hickie, S. Norman and C. Norman. Topography of the southern area (sheet 31 and part of 32), Messrs. Christie and Cusson and Native Surveyors Gopal Vishnu and Bhao Govind. Drawing Office, Mr. McA'Fee, Mr. Ferns and 4 Native printers and draftsmen.

(19.) On account of the rapidity with which the plane tables on the 4-inch scale were completed in the previous season and the consequent difficulty in having boards always ready mounted and projected to take the place of boards completed, I before leaving Poona devised a means of mounting plane table sections on to the boards dry, which turned out successful in every way and enabled me to send new sections projected with graticule and data points to the surveyors by post or to give out two or three at a time to a surveyor who could take his completed section off his board and replace it with a new section in a few minutes; and so each surveyor had but one board which he never changed through the season.

(20.) The means I adopted were as follows; I fitted each plane table with a strip of deal on each of its four sides. Three screws clamped each strip to the board. The screws had flat broad heads but not broader than the thickness of the table, so that they never interfered with the play of the sight rule, and corresponding brass female screws were let flush into the sides of the table. I also adopted what is as far as I know a new method of mounting the paper on cloth. I lay the paper face down on an ordinary table, then wet and paste the cloth on the back; the overlaps of the cloth adhering to the table keep the paper and cloth perfectly tight during the process of drying. When dry the mounted sheet comes easily away from the table, and the sheet never having had its surface scrubbed with a sponge as in the ordinary process, presents a beautiful even appearance and is perfectly flat; such a sheet can readily be stretched on a plane table and secured with the deal strips and brass screws if holes are cut in it to admit the screws and made sufficiently large to admit of a little play up and down. If once made tight in the cool of an early morning it never requires further stretching.

(21.) After remaining 3 days at Broach, I began moving about sheet 31 among the plane tablers, and remained there till the 23rd of December when I went to the northern area and moved about among the plane tablers there until the 22nd of February: I then returned to Broach and in a few days called in Lieutenant Gibbs to relieve me of the charge of the Party to enable me to avail myself of three months' privilege leave which I took from the 13th of that month. I also called in Mr. Forbes and his Native Surveyors who had by that time completed a sufficiency of traversing in sheets 28 and 29 for our next season's requirements, and with the assistance of Mr. Forbes and one Native Surveyor I commenced the compilation of a map of Broach on the scale of 16 inches to a mile from the sheets of the city survey drawn on the scale of 66 feet to an inch by the Revenue Survey. This was a work requiring careful management as 71 separate maps had to be fitted together and correctly placed as to the graticule. Mr. Forbes's other two surveyors commenced the transference of fiscal details from the Revenue Survey village maps to the plane table section that had already been completed.

(22.) On my return from privilege leave on the 7th June, Lieutenant Gibbs handed me a most satisfactory memorandum giving full particulars of his management of the Party during my absence. Leaving the drawing office under Mr. McA'Fee in Broach where also he left Mr. Forbes and his Native Surveyors, he spent the remainder of the season in the southern area inspecting the different surveyor's work; and he also supplied a few points by triangulation where there was a deficiency. As the delineation of the hills in sheet 31 was something quite new to the surveyors working in that sheet, and as Lieutenant Gibbs could not possibly have found time to initiate them himself in the art of hill sketching, he wisely sent for Mr. D'Souza from sheet 79 for this purpose, and directed Mr. Hickie and Mr. C. Norman to supervise the Native Surveyors who had been working under Mr. D'Souza. On the 3rd May he rejoined the drawing office which had opened work in Poona on the 1st.

Lieutenant Gibbs.

(23.) I now state *seriatim* the work performed by each of my assistants. To Lieutenant Gibbs was entrusted the preparation by triangulation and traversing of the foreign territory in sheets 28, 29, 30 for final survey. Where he found it practicable—that is where the country was fairly open—he spread a net-work of triangles, but through the woody parts he ran a system of traverses at regular distances apart based upon the triangulation. The stations on the west flank of the Singi Meridional Series, the east flank of the Mahi Series and the net-work of sheet 31 afforded the requisite points of departure and closing for both his triangulation and traversing. He was assisted in the traversing by Gopal Vishnu, Ganesh Bápuji 1st and Ganesh Bápuji 2nd, but each of these was employed on work elsewhere during part of the season.

Mr. Forbes.

(24.) Mr. Forbes assisted by his three Native Surveyors of the Revenue Survey Department had the preparation by traversing of the British territory in sheets 28 and 29. The river Mahi may be said to be the boundary of the British territory though there are small divergences therefrom. The traversing of the British territory cannot be laid out in any regular line but has to strike upon all the tri-junctions of village boundaries as well as on each village site, for reasons which have been explained in former reports.

Mr. D'Souza.

(25.) Mr. D'Souza had the supervision of the plane table surveying on the 4-inch scale of the British territory in the northern area. I placed under him Lakshumán Gharpuri, Mukand Dinkar, Ganesh Bápuji 1st, Raoji Narayen, Govind Gopál and Balwant Rajaram; and his duty was to keep moving about among these six men inspecting their work and seeing that they made proper use of the Revenue Survey village maps. He also had under him two new hands who had to be taught, Sayana Saibu and another who turned out a failure and had to be discharged. Subsequently I had to withdraw for the drawing office Lakshumán Gharpuri and Mukand Dinkar—Sayana Saibu having meantime been taught—and later on Ganesh Bápuji 1st to help Lieutenant Gibbs with the traversing. Mr. D'Souza had to be continually on the move, and although it was not necessary for him to take up a plane table himself his work was hard enough. Towards the close of the season as stated in para. 22 he had to proceed to the southern area as an instructor in hill drawing.

Mr. Christie.

(26.) Mr. Christie was employed plane tabling in sheet 31, both British territory on the 4-inch scale and foreign on the 2-inch scale, until the middle of March when he relieved Lieutenant Gibbs in charge of the work of triangulating and traversing the foreign territory in sheets 29 and 30. His out-turn must be considered very good.

Mr. McA'Fee.

(27.) Mr. McA'Fee was employed the whole season in the drawing office; his duties were multifarious, generally supervising the drawing work and projecting the data on the plane table sections.

Mr. Hickie.

(28.) Mr. Hickie turned out 240 square miles (including overlaps) of plane tabling in the most difficult part of the northern area. Being wholly foreign territory it was all on the 2-inch scale; it is superficially the largest area surveyed by one person in the season, and keeping in view the nature of the ground, must be considered very good.

Mr. Cusson.

(29.) Mr. Cusson was employed at first on British territory on the 4-inch scale in sheet 31 and then on the foreign territory on the 2-inch scale in the same sheet. Subsequently I transferred him to other ground and then directed him to take up British territory on the 4-inch scale in sheet 32.

Mr. S. Norman.

(30.) Mr. S. Norman was at first employed in the northern area where he completed 82 square miles of plane tabling on the 2-inch scale; this he had just completed when I was compelled to transfer Mr. Cusson from Baroda to British territory, and I therefore directed Mr. S. Norman to take up the work in Baroda territory in the southern area that Mr. Cusson had to abandon, and during the remainder of the season he worked in the southern area. From the instruction he received from Mr. D'Souza and subsequent practice in the Rajpipla hills he became a very fair hill sketcher. His out-turn must be considered very good.

Mr. C. Norman.

(31.) Mr. C. Norman was employed exclusively in the northern area plane tabling on the 2-inch scale. He is an accurate and careful surveyor, but his out-turn is not so large as his brother's on account of his falling sick and being incapacitated for work in the open from the 1st of April, and also from his having to survey the city of Kari the traversing of the main thoroughfares of which detained him a week. During the latter part of the season, Lieutenant Gibbs employed him in the drawing office at Broach.

Native Surveyors.

(32.) Of the Native Surveyors, Gopal Vishnu and Ganesh Bápuji Lelé proved themselves useful hands both with the plane table and at traversing, but the latter is not so active as the former. Raoji Narayen and Bhao Govind have the best out-turns of plane tabling: the latter was sick for a month and had a very intricate piece of ground in one plane table, so that his out-turn is less than that of the former.

The Drawing Office.

(33.) During the field season the eastern half of degree sheet II was commenced and completed, and as it contains 4 sheets of the most thickly populated part of Guzerat as well as the most thickly wooded, the drawing and printing of this map was no light task. Mr. Ferns drew and printed the whole of it. Mr. Ferns had also to re-draw half a section of sheet 80 on the 4-inch scale which had been injured. The printing of 10½ sections on the 4-inch scale was commenced and completed, and that of 7 sections had been commenced in the previous recess but was completed in the field—altogether equivalent to about 14 sections. The drawing office was weakened by my employing two hands, Lakshumán Gharpuri and Mukand Dinkar in plane tabling, while two new hands were being instructed in that branch so as to utilize the services of the khalassies who would otherwise have been idle; and owing to the inability of these new hands to learn plane tabling quickly, the two Native Surveyors were absent from their posts in the drawing office till the latter end of January. From this cause and from the occupation of Mr. Ferns on degree sheet II, seven sections on the 4-inch scale remained incomplete when the office returned to Poona.

(34.) The orders of Government restricting the scale of British territory to 2 inches to the mile in place of 4 inches to the mile has somewhat burdened us with another innovation inasmuch as it entails a new style of draftsmanship, and so the preparation of these maps for reproduction on that scale has somewhat thrown our mapping into arrears, but I have made the drawing office stronger than last field season and I hope to finish off all the mapping before the Party returns again to recess quarters.

(35.) The maps published on the 2-inch scale will contain all the detail of the 4-inch scale with the exception of the fields and their numbers which were derived from the Revenue Survey maps; and that kind of detail will by no means be entirely dispensed with, as the trijunctions of fields, along the village boundaries, along the boundaries of waste land and wherever the plane table stations occur, have still to be inserted with a sufficiency of their numbers printed to enable identification of the field corners. But the drawing of these 2-inch scale maps is very much finer than that of those on the 4-inch scale and this increase in fineness of execution means increase in time of execution, so that the time we save in detail we nearly lose in superior workmanship. The maps now in course of preparation are—as works of art—superior to anything we have hitherto succeeded in producing, and I doubt not will be greatly admired by all who have to use them.

(36.) The computations of the triangulation and traversing of the past season are all approaching completion, and will be completed before we again take the field.

TABULAR STATEMENT OF WORK EXECUTED BY THE GUZERAT PARTY, DURING THE FIELD SEASON 1875-76.

Details of Triangulation.

Observer's Name.	Instrument.	Area triangulated and traversed in square miles.	No. of stations visited.	3 Angles Observed			2 Angles Observed.				Average No. of trigonometrical and traverse points per square mile.	Average No. of heights per square mile.	Remarks.
				No. of triangles.	Triangular error.	Error per mile.	No. of heights.	No. of Intersected points.	No. of triangles.	Error per mile.	No. of heights.			
					"	inches.				Feet.				
Lieut. J. E. Gibbs, R.E.,	6-inch by Cook and Sons [a]	1650	22	13[c]	17·2	...	15	50	71	0·9	7	Exclusive of traverse intersected points, 1·8	Including 107 trigl. heights, the existing levels of the B. B. and C. I. Railway, and the coming season's work of the Leveling party, there will be an ample number.	[a] 10-inch by Troughton & Simms used at few stations in the base-line work. [b] of base-lines. * [c] The third angle of one of these was observed by Mr. Christie. [d] Mean of 15 common values. [e] 17 of these stations were fixed by interpolation, 2 by two angles of a triangle, and 3 were old stations.
			9[b]	3	19·2	...	5	19	29		7			
Do. do.	Colonel DeLisle's 8-inch		7	5	11·5	4.2	2	16	22	...	1			
Mr. A. Christie,	6-inch by Troughton and Simms		29	34	18·5	6·1	24	88	169	1·8[d]	0			
			22[e]	40	...	6·8	19	18	33	2·3	0			

Details of Topography.

No.	Name.	Area surveyed in square miles			No. of plane table stations per square mile.	Remarks.
		4-inch scale.	2-inch scale.	Total,		
1	Mr. A. Christie, ...	68·27	69·01	137·28	9·3	Mr. A. D'Souza was engaged in the general supervision and examination of the work of the Native Plane tablers, and also in the instruction of Mr. S. Norman and Bhao Govind in hill sketching. *a* employed during part of the field season in the office. *b* One month sick.
2	,, J. Hickie, ...	...	235·85	235·85	11·6	
3	,, G. D. Cusson, ...	128·34	76·34	204·68	8·1	
4	,, S. Norman, ...	...	210·65	210·65	8·8	
5	,, C. Norman, *a* ...	...	143·50	143·50	11·0	
	Native Surveyor.					
1	Gopal Vishnu, ...	79·57	...	79·57	14·4	
2	Lakshuman Gharpuri, *a*	51·99	...	51·99	11·6	
3	Ganesh Bápuji Lele, ...	44·16	...	44·16	13·9	
4	Raoji Narayen, ...	92·78	112·51	205·29	9·4	
5	Balwant Govind, *a* ...	37·43	...	37·43	15·3	
6	Mukund Dinkar, *a* ...	45·13	...	45·13	10·4	
7	Bhao Govind, *b*	23·65	100·52	124·17	16·3	
8	Govind Gopál, ...	104·91	...	104·91	11·5	
9	Balwant Rájárám, ...	120·80	...	120·80	12·2	
10	Sayana Saibu, ...	72·84	...	72·84	16·7	
11	Vital Vishnu, Khalási ...	53·61	...	53·61	16·1	
	Total and Averages, ...	923·48	948·38	1871·86	11·3	Exclusive of overlap.

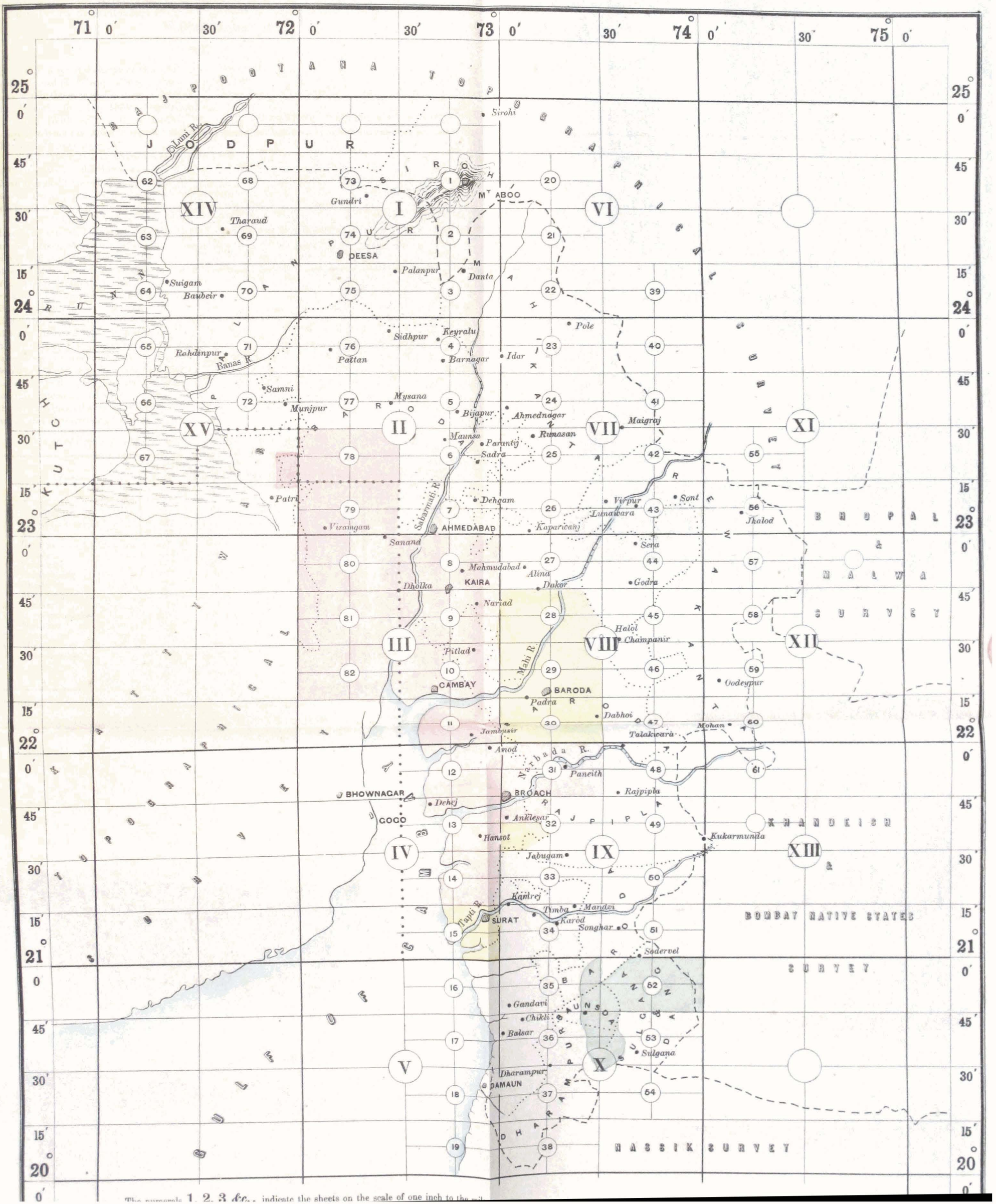
Details of Traversing.

No.	Name.	Instrument.	Linear miles of traversing.	No. of stations.	Average error per 1000 links.	Average angular error per station.	Remarks.
						"	
1	Lieut. J. E. Gibbs, R.E. ...	6-inch Theodolites by Cook and Sons.	73·802[a]	147	0·78	20·7	[a] Main traverses, which have been computed in "systems", so as to harmonize, two traverses by Gopál Vishnu having been included in the "systems".
2	Mr. A. Christie, ...		4·137[a]	5			
3	Gopal Vishnu, ...		74·204 / 91·501[b]	367	0·94[c]	30·2	
4	*Ganesh Bápuji Lele,* ...		150·226 / 14·813[b]	292	1·13[d]	15·0	
5	Ganesh Bápuji Mándre, ...		224·800 / 131·650[b]	944			
6	Lieut. Gibbs (base-lines)*		8·535				
	Revenue Survey.						
1	H. D. E. Forbes, esq. ...		43·253	180			[b] Boundary traverses. [c] from 6 traverses. [d] from 12 traverses. A sufficiency of the rest have not been computed in order to obtain averages.
2	Kubar Parbhudáss, ...		105·753	309			
3	Jugal Mánsukhrám, ...		125·310	393			
4	Parbhu Kisor, ...		83·412 / 27·374[b]	280			
			893·432 / 265·338[b]	2917			
	Total, ...		1158·770				

* Note.—Three base-lines, each making a triangle with a station of the principal series, were chained, for the purpose of starting and closing traverses. The angles of these triangles were observed with as much care as if they had pertained to ordinary triangulation.

GREAT TRIGONOMETRICAL SURVEY OF INDIA

INDEX CHART OF THE GUZERAT TOPOGRAPHICAL SURVEY



The numerals 1, 2, 3 &c., indicate the sheets on the scale of one inch to the mi

The numerals **1, 2, 3 &c.,** indicate the sheets on the scale of one inch to the mile.

The numerals **I, II, III &c.,** indicate Degree sheets, on the scale of ¼ inch to the mile.

The one inch sheets are divided into 4 sections, known as the **N.E., N.W., S.E., & S.W.,**

Note.—Sheets 79 to 82 were originally intended to be sheets 1 to 4 of the Kattywar Survey, but have been transferred to the Guzerat Survey.

Denotes country Topographically Surveyed up to 1875-76.
" " *Triangulated in advance* " "
" " *Triangulated and traversed*

Scale 1 Inch = 24 Miles

10 5 0 10 20 30 40 50 = 1/1520640

C. DYSON, Photo.

C. G. OLLENBACH, Engr.

Photozincographed at the Office of the Superintendent Great Trigonometrical Survey, Dehra Dún November 1876.

XII. Extract from the Narrative Report—dated 12th December 1876—of Major J. HERSCHEL, R.E., F.R.S., Deputy Superintendent 2nd Grade, in charge of Calculating and Printing Branches of the Computing Office.

(1.) I received charge of the office on the 21st March last from Mr. W. H. Cole, M.A., whose report, printed in the Appendix to the Superintendent's Annual Report for 1874-75, reviewed the operations of this Office, as well as those of the Drawing, Photozincographic, and Printing Offices, for the previous 17 months, from May 1874 to September 1875 inclusive.

(2.) With regard to the work done during the interval prior to Mr. Cole's departure on furlough, I have to rely on the monthly reports: including that the present account covers the 13 months from October 1875 to October 1876.

(3.) Mr. Cole's departure was somewhat sudden, and as it was followed a fortnight later by that of Colonel Walker, the charge would have proved a very onerous one had the superintendence of all the above branches devolved upon me without preparation. Colonel Walker was therefore pleased to separate the Drawing and Photozincographic Offices and to place these under Captain Thuillier, R.E., who was to officiate for him as Superintendent; leaving the Computing and Printing Offices to my care.

(4.) Within a few days of my accession to office the preparation of the usual monthly report directed my attention to a system of diary keeping which had been commenced under orders from the Superintendent about 15 months before, the object of which, as I understood it, was to obtain the actual cost of any individual piece of work, as in a factory. I could not learn that this result had ever been obtained, although the time of each workman was duly accounted for. In endeavouring to carry out what appeared to be the intention, it became evident that in the absence of any indication what special work was to be the subject of particular estimate, a very elaborate specification of details was necessary. This presented a serious difficulty, to provide for which would require a closer supervision than I could give. The only practical escape seemed to be to obtain—at any rate at first—the relative cost of classes of work. I accordingly classified as soon as I could do so, and very soon obtained what seemed a satisfactory result, which I introduce here as a guide to the order which will be observed in this report. It is necessary however to remark that, as there is an annual periodicity about some kinds of work, is would be premature to draw very close inferences from so partial a piece of statistics, which is in fact on trial. On the other hand there is reason to hope that, as each individual concerned can see in the monthly statements (of which the table shows only sum totals) the actual cost in rupees of his share of the several kinds of work on which he has been occupied, there may grow into existence, with proper help, a sort of restraining judgment as to the worth of it.

Tabular Statement of Cost in Rupees of different Classes of Work done in the Computing Office.

	Classes	July.	August.	September.	October.	November.	December.	Average per cent.
1	Records ...	10	5	5	17	12	23	1
2	Computations ...	662	391	506	463	439	514	22
3	Accounts ...	47	45	33	37	43	87	2
4	Returns ...	62	298	74	118	69	78	5
5	Supply ...	46	88	131	104	107	68	4
6	Press copy ...	626	657	786	633	434	323	25
7	Press proofs ...	377	220	225	304	348	263	13
8	Charts ...	184	122	31	21	159	129	5
9	Meteorology ...	34	35	46	52	74	14	2
10	Library ...	18	9	8	8	7	1	1
11	Correspondence ...	94	56	54	60	39	17	3
12	Stations ...	33	37	65	37	178	58	3
13	Leave ...	58	162	181	210	70	74	6
14	Holiday ...		71	58	88	76	484	6
0	Miscellaneous ...	116	171	164	95	72	44	3
	Totals ...	2367	2367	2367	2247	2127	2127	100

It will readily be understood that the designations of classes here given are often mere catchwords

* The figures for November and December have been added from later reports by desire of the Superintendent.

denoting a variety of items.

I now proceed to take the above classes in order and will use the opportunity to indicate in some detail what they represent.

(5.) *Records.* In no department of the public service probably are records more valuable than in that of Survey. They represent money sunk or funded as the case may be, and the strictest precautions have always been taken to guard against loss or destruction. The best safeguard no doubt is prompt publication, but this is not always possible. Our progress in this direction is however undoubtedly making a large mass of MS records rank chiefly as mementos of those who wrought them. Our museum of these is maintained and must continue to be maintained so long as field records continue to be annually or from time to time received. Part of the work under this head relates to the examination, indexing, paging, cataloguing, &c., of these later additions. The gradual accretion of MSS since the present accommodation was allotted has become a source of some difficulty and anxiety; and the Record Room and Library alike demand study to prevent their becoming crowded.

(6.) *Computations.* It appears desirable to restrict this class as much as possible, and further to subdivide it, with a view to facilitate the desired appraisement of different kinds of work. Having regard to the natural current of operations it is not difficult to see what the various subclasses should be. The following have been laid down as guides for the computers in preparing their several monthly accounts of work. *Subclass* (a) claims all computations directly connected with *named* series: *subclass* (b) comprises levelling and tidal reduction: *subclass* (c) astronomical and pendulum work: *subclass* (d) is devoted to the reductions of associated series, and referring to the time-honoured plan of this Survey, may fitly be known as the gridiron subclass. I must pass over (a) for the moment. In (b) I am not aware of anything requiring specific mention having been done during the twelvemonth. In (c) a good deal of work was done in the early part of the year in the course of preparing the pendulum operations for press, but I am not in a position to describe it precisely. In specifying the work under (d) it will be necessary for me to go more into detail.

(7.) Three large areas of triangulation, which have been frequently mentioned in these reports under the names of North-West Quadrilateral or N.W.Q., South-East Quadrilateral or S.E.Q., and North-East Quadrilateral or N.E.Q., have to be considered. Of these the first deals with 8 series, the second with 6, and the third with 15. Thus the three Quadrilaterals incorporate 29 distinct series of triangles, each of which owns a name and a set of records and of computations. They form as it were three quarterings of the great Indian Survey shield. The fourth quarter—the South-West Quadrilateral or S.W.Q.—need only be mentioned: we have not anything to do with it here. It will eventually consolidate 5 or 6 other series with those already mentioned.

(8.) There is little to be said here about the N.W.Q., which has already been frequently described, further than that the reduction of it embodied most of the experience which has guided us in subsequent operations of that nature. Nor is it necessary in the present connection to say much of the S.E.Q., the reduction of which was reported last year as nearly complete. The work which followed thereupon will find its place in another page. Of the N.E.Q. reduction also it would be easier to say little than much; but as this is a report I must briefly describe its features.

(9.) It was originally intended to restrict this job to those old series running north and south, between the meridians of Delhi and Calcutta, which together with a chain of triangles skirting the Himalayas and another along the parallel of Calcutta (or nearly so) gave, no doubt, the first quaint suggestion of a gridiron. These series have always had rather a bad reputation as compared with the nobler ones of more recent days, and in designing the programme of successive reductions they were assigned a third place so that they might rest upon, instead of offering a weak support to, their stronger neighbours. This was well; but to the eastward of these again lay 4 connected series which, being of the higher order of merit, would in this way run a chance of being unfairly dealt with. These were therefore included in the N.E.Q. scheme; which, in its extended character, presents 49 equations of condition.

(10.) There is one peculiarity about this third gridiron reduction which requires special notice. The first and second are independent bodies of triangulation, having nothing in common except at the corner where they meet: but as at this corner they have one side of one triangle in common, upon which each may be considered as based, the two rigid wholes become in effect one rigid whole. In the vacant areas forming the other two quarters the triangulation occupying them has to be adjusted. Thus the N.E.Q. may be considered as a piece of triangulation which has to conform to a much larger number of fixed points. The same will be the case in the fourth quarter. This in no way adds to the difficulty; on the contrary the immediate effect is to remove two equations, one of which would link together many of the others in such a way as to increase the trouble of solution of the ultimate normal equations. This last operation forms however so small a portion of the total labour that it would be a mistake to lay much stress upon

it. The great mass of the work is to be found in the formation of the coefficients, and every coefficient saved represents there an economy which far outweighs what would result from its mere absence in the final equations. If I am not mistaken 90 coefficients out of 641 are thus saved, as a direct consequence of the N.E.Q. being based upon the already completed N.W.Q. and S.E.Q.

(11.) In the annexed table I have endeavoured to present some statistics of the three quadrilateral reductions. The last two lines require a word of explanation. The more entangled a set of given conditions are *inter se* the more do they react the one upon the other. Every such reaction gives rise to a term (with its coefficient) in the ultimate equations between the indeterminate factors—also called above, and in the table, normal equations. The average number of terms in these equations is therefore, roughly, a measure of the entanglement, or as we may say, of the interdependence of parts. Again, as the parts so dependent on each other consist in every case of a number of triangles, and therefore of angles, the average proportion of the latter is some measure—probably a very rude one,—of the weakness, as the other is of the strength, of the framework considered as a whole. The inference is not entitled to much weight, but it has some small interest.

GRIDIRON FUNCTION TABLE.

	N.W.Q.	S.E.Q.	N.E.Q.
Number of Associated Series	8	6	15
„ Circuits	5	3	12
„ Circuit triangles	549	277	573
„ Non-circuit triangles	268	169	120
„ Equations of Condition	23	15	49
„ Normal Equation Coefficients	329	165	551
„ Products forming the same	40,050	16,664	50,962
„ „ „ neglecting sub-diagonals ...	23,204	9,784	29,132
Average terms per normal equation	14	11	11
„ angles concerned per term	183	151	139

(12.) A large part of the preliminary calculations for the N.E.Q. had been prepared prior to Mr. Cole's departure. The eastern series were the least advanced, as their inclusion had not been decided upon. I was enabled however to push on with the calculation of coefficients, and afterwards with the solution of the equations, of the ten western circuits. The elimination has been carried as far as the 38th equation, where it has been stopped for the present. Every equation as formed, and every elimination as completed, has been subjected to some test. For one or two of these I am indebted to Baboo Cally Mohun, who is very expert in devising these checks. That I may not be understood to imply that the introduction of checks was at all a novelty I should explain that the great increase in the number of equations rendered it impossible to adopt the arrangements of the N.W.Q. and S.E.Q.; and that in devising others more suitable to the altered circumstances, different facilities presented themselves for securing checks. These were of course taken advantage of.

(13.) Having been instructed to curtail calculation as much as possible—in view of the inferior character of the triangulation—I have given my closest attention to this point. It is often a matter of extreme difficulty to judge rightly what measure of accuracy is sufficient at each stage of a series of numerical operations, in order to secure a satisfactory conclusion. On the one hand, too much caution may entail fruitless labour; on the other, too much hardihood may lead to failure. Perhaps I have erred on the latter side. Should the event prove this, I shall be the less excusable through having had two previous sets of computation by which to be guided. At the same time there is an unavoidably greater risk of sensible error in what mathematicians call a first approximation, where the quantities to be found are (as in the N.E.Q.) comparatively large.

(14.) We may now return to subclass (a) of art. 6, which includes all computations directly connected with named series. The extension of the N.E.Q. to include the Assam, the East Calcutta, the Brahmaputra, and the Eastern Frontier necessitated the revision of the original computations of these series, portions of which, though the observations were taken with good instruments by good observers, had become in some sort obsolete through the introduction of better elements of origin and more refined methods of preliminary treatment. They were in part recomputed, and the results were adopted in obtaining the errors to be dispersed by the N.E.Q. Reduction.

(15.) A large amount of secondary triangulation belonging to the several series forming the S.E.Q. has been corrected, revised, or where necessary recalculated, upon the basis of the finally corrected principal elements of that section.

(16.) The height deductions along several of the meridional series of the N.E.Q. have been gone over, in anticipation of their actual requirement for publication along with the other results on those series, in order to supply the best available materials in Oudh, Rohilkhand, and N.W. Provinces, for the level sheets in course of compilation.

(17.) For the preparation of level charts the Drawing Office has acquired from various sources *data* some portion of which is scarcely inferior to that supplied by the G.T.S. levelling, and is connected with it and with occasional tower stations of the series which traverse the N.W. Provinces, Oudh, and Bengal. The trigonometrical (or *signal* as distinguished from *staff*) levelling, obtained by vertical angles measured with the theodolite, though far less trustworthy than spirit (or staff) levelling is still good enough to be valuable when connected with the more reliable *data*. Accordingly it falls to this office to harmonize the two. The adjustment which is requisite in any such case may be effected either by a direct appeal to the method of least squares or by the application of a discretionary method of allotment. I was not aware that the former had ever been given a conclusive trial and therefore applied it in one or two of the cases which arose as above. I have since understood that the method has been tried, and discarded as being too refined for its purpose. Under these circumstances there is no occasion to say more about it than that if there should hereafter be any desire to repeat the experiment the form into which the work was thrown may perhaps be found of use. It is one which I think applicable to almost any simple problem of dispersion of error by least squares, however numerous either the equations or the unknown quantities might be.

(18.) It has been usual to reckon Astronomical Azimuths as among the operations of a series. They are so, no doubt, if we regard only the fact that they are almost invariably observed by trigonometrical parties conducting the usual field operations. But considered as computations, the necessary connection disappears. In classing these it seems best to assign them a place along with other geodetic measures. There are 42 astronomical azimuths at stations of the S.E.Q.: some of these have been computed now for the first time; others have been examined and where necessary corrected; and abstracts for press have been completed, or drafted. Of the above number 15 were observed subsequent to 1863, when a different method of registering level readings was introduced. The reduction of these last has received very careful attention, in the hope of ascertaining the requisite facial corrections as well as those due on account of error of verticality of of the azimuthal rotation axis. Owing however to the necessary ignorance of the state of the pivots at different periods there appears to be very little prospect of determining the former, and in that case it will be necessary to combine observations taken "face right" with corresponding ones taken "face left", the mean of which will be cleared of the facial errors. This amounts to much the same as measuring on 5 zeros with 10 microscopes, instead of on 10 with 5.

(19.) In connection with the subject of observed azimuths I may mention that an endeavour has been made to ascertain the general effect of the final reductions of the N.W.Q. and N.E.Q. triangulations upon the disagreement of geodetic and astronomic azimuths in those quarters. For this purpose Baboo Gunga Pershad has prepared, with great care, an abstract of *all* astronomical azimuths, showing in the case of those which admit of it, the final, and in all others the preliminary, disagreement. This is not the first time that a collection has been made, but as it has never before been possible to approach so closely to the facts, the abstract repays study. Of the 179 observed azimuths, the final reductions enable us so far to compare provisional discordances with final discordances in 85 cases. Of these 85, the azimuthal correction has in 62 cases the sign proper to reduce, and in 23 to increase the discordance. Of the 62 cases in which the sign is proper, the numerical magnitude is often too great, and sometimes (in 12 instances) sufficient to produce an increased discordance with changed sign. Thus, if we consider magnitude only, there are 50 decreases against 35 increases. That this is obviously the result which was intended when, by Colonel Walker's direction, the fundamental azimuth of origin of the Survey was changed—after an investigation very similar in some respects to this—by 1″·1, scarcely needs more than recognition: a general diminution of provisional discordances was a necessary consequence. The interest does not lie here, but in the further question, Apart from this constant correction, is there evidence of a diminution which may be fairly adduced as confirming the discipline to which the triangulation has been subjected? The answer is I think affirmative, but hardly positive. In some cases there is a marked appearance of correction; but, remembering that however perfect the triangulation might be, there would always remain the uncertain discordances caused by local attraction, this is inconclusive. Lastly there is some indication, in the outstanding preponderance of negative over positive discordances, that the change of fundamental azimuth was rather too small than too great.

(20.) The result on the whole is this. The absolute attraction at Kalianpur is almost conclusively proved to cause an azimuthal deviation of somewhat more than + 1″·1, and this quantity has been allowed for in determining the influence of local attraction at all the other stations yet reached by the final reductions. When the N.W.Q. and S.E.Q. are published, there will be available 85 determinations

of deviation, which have perhaps a better claim to rank as *absolute* than any yet given to the world. There remain 94 others to which the continued building up of the framework will extend a like character. Those in the extreme south, where the effect of lateral attraction on azimuthal azimuth ceases, must be looked for, in this connection, with exceptional interest. We may now return to the more prosaic subjects of this report.

(21.) *Accounts.* There is but little to be said about these. As a class it includes all time devoted to monthly pay bills and to the keeping of pay, contingent, and map accounts. These have been conducted by Mr. Wood, whose management of them has been satisfactory.

(22.) *Returns.* This class includes indents, estimates, monthly progress reports, stock and expenditure, and work of that character. It is of more importance and requires more experience, and when as in August the indents on England are under consideration the cost is exceptional. Some of the principal items are prepared by Mr. Wood. I annex a list.

Annual Report, materials for:
„ Estimate of Stores for Indent:
„ Indent on England:
List of Books and Periodicals required for the year:
Statement of Receipts and Issues of Stores for 5 years, and of Balances:
Review of Expenditure of Stores:
Monthly Progress Reports, in detail:
„ Statement of Cost of the Department:
Stationery and occasional Indents:
Stock and Expenditure Lists of printed Forms.

(23.) *Supply.* Under the head of supply I reckon the preparation of transcripts or abstracts from the professional records to meet the wants of field parties and other applicants; as also all work in connection with applications for information of whatsoever kind, by other offices. This is often a source of trouble, if not of actual waste of time, owing to the vagueness of the demand; but the steady increase of our publications enables us to meet a continually larger proportion year by year by the despatch of a Preliminary Chart, a Level Sheet, or a Synoptical Volume. Such supplies being matter of business only make but little show in the scale of cost, compared with their utility. During the past year, in addition to MS *data* supplied to about 20 officers, some 750 despatches of maps, charts, books, and forms have been made. Under this head should also be noticed—as directly connected with the extension of the supply of materials—the compilation of a revised list of maps and charts published at Head Quarters. This we hope to be able to print. Meanwhile a copy in MS has been supplied to the Surveyor General.

(24.) *Press Copy.* If we may judge from the monthly cost of this class, it stands first in importance. And when it is considered how very long and sometimes devious a chain of procedure is traceable from the early measurements of angle, through the preliminary calculations—revised perhaps as knowledge increased—up to the final stages by which the independent work of numberless hands has been welded into one consistent whole; it is not surprizing that it rarely happens that any single page of the original records can be put into the printer's hand. Not only this: the compilation of what is suitable for publication is something very different from selection and transcription. To the calculator it is very much what composition is to the writer, only that it must hang together by much more inelastic links. There may be no weakness, on his part—no mistakes, no oversights. Thus it is really the case that the preparation of press copy occupies a very large proportion of the computers' time. Where possible—and it very often is possible—the later stages of calculation are so conducted as to form this material. But a considerable part of what is to be printed *must* be compiled. Of this kind are alphabetical and other synopses of results, especially of secondary triangulation. Alphabetical arrangements are generally troublesome in proportion to their utility, and first drafts have commonly to be revised and rearranged before they are fit for the compositor. And then they must be compared with the original materials. Mere transcripts do not require this, but compilations take so much more time to check that it is unadvisable to reserve the comparison until the matter is in type. A great part of the expenditure under this head is to be accounted for by the necessity of revising part of the copy for the N.W. Himalayan Secondary Triangulation. It must have been a terribly tough job to prepare it at all—and I believe Mr. W. Todd is entitled to much of the credit of it—but when it came to be printed it hung on the compositor's hands too heavily and I directed what remained—some 200 pages of printed matter eventually—to be transcribed. There was also some revision of the orthography of native names at the same time. This was in Mr. Wood's hands at first but afterwards in Mr. Peychers'.

(25.) The synopses of secondary triangulation of the 6 series of the S.E.Q. (which likewise form press copy) have been continued and are now complete. Recomparison is required in one case. Press

copy is otherwise ready for the whole of the Synoptical Volumes of this Section, and these are in course of printing.

(26.) One other kind of press copy may be noticed here. A good deal of letter press now accompanies numerical charts, both those called "preliminary" and those devoted to levels. The printed matter is either put upon the chart before it is photographed, or accompanies it as a pamphlet. In either case the Computing Office is answerable for its being properly printed, and to a certain extent for what is printed. In the case of charts such as the level sheets, which are compiled in the Drawing Office, my responsibility was limited. The letter press accompanying 8 of these, prepared by Mr. Atkinson, has been printed in pamphlet form. Those which had been printed in earlier years, at intervals, were of different patterns, and I was a good deal perplexed which to adopt. Foreseeing a run of the same kind it seemed worth while to form a good pattern, as these typographical details are otherwise worrying. There is now a certain uniformity about these which I hope will prove satisfactory. The manner of printing upon preliminary charts has also varied a good deal, according to circumstances, from time to time; and I have endeavoured to incorporate the best parts in those which have passed through my hands; but there is still room for improvement, as my reluctance to make any changes has only been overcome with much hesitation. I beg to bring to notice the preliminary charts of the Rámnád and Eastern Frontier Series, 1874-75, the typography of which was arranged under my instructions by Mr. Wood.

(27.) *Press Proofs.* It will be hard to find anything interesting to say on this very dull subject. And yet so much harm, as well as annoyance, directly results from misprints—to say nothing of the merely æsthetic satisfaction in good printing—that it has a certain claim of its own. The subject stands third in order of cost; but as a great part of the reading, comparing, and correcting of proofs is done by the less highly paid members, it does in fact occupy a larger share of the time and labour of the office than can be done justice to here. I therefore take occasion to express my full recognition of the results of careful training which has made it possible for printing of a really creditable order to be turned out almost wholly by Natives of this country. And in saying this I by no means underrate the critical supervision exercised by Mr. Peychers, on whose vigilance I have been able to rely more than I could have expected. Press proofs upon and accompanying preliminary charts have been dealt with almost entirely by Mr. Wood, who in this as in every part of his multifarious occupations, has shown both the desire and the capacity to give effect to my instructions.

(28.) *Charts.* The separation of the Drawing and Photozincographic branches, from the Calculating and Type-printing branches, already mentioned as having taken place early in the year, drew something of a line defining the obligations of the latter in respect of charts. The only ones with which we were concerned were those for which there was corresponding type-printing. I annex a list of these:—

N. W. Himalaya Degree Sheets, Index Map
Do. do. Nos. 1 to 21 incl.
Eastern Frontier Series Preliminary Chart 1874-75
Rámnád Longitudinal Series do. do.
Jodhpur Meridional Series do. do.
N E. Quadrilateral Extension, Skeleton Map
S.E. Quadrilateral, 6 Series, 14 Plates.

Reference has already been made in speaking of press copy, to the numerical data accompanying what are known as preliminary charts. These are drawn by the survey parties and contain, partly upon the face and partly in attached MS, the numerical results of the previous field-season. If possible the MS portion is set up in type and an impression placed upon the chart before it is photographed. If the available space is insufficient the matter in type is separately printed and attached in pamphlet form. It will readily be understood that the Computing Office is in this way to a certain extent responsible both for what appears upon and with the chart—not in respect of its numerical accuracy, which is provisional, but in regard to its general harmony. This gives rise to an indispensable scrutiny by which errors of minor consequence are sometimes detected. This is particularly the case with the orthography, descriptions, and nomenclature of stations which appear both upon the chart, and in the added matter—points in which we cannot expect perfect manuscript. It is not easy to define very clearly what share of the work thus indicated,—especially what share of the press work—is to be reckoned under the head of Charts. It would seem to claim everything which goes to the making of them, but obviously other classes have some claims on the process too.

(29.) There is one point in connection with this subject which ought to be noticed in a report. There is a steady demand—and I am bound to admit a quite legitimate one—on the part of the Drawing Office, for type-printed titles, foot-notes, &c., required for maps which are to be photographed.

These used to be attached in the Photo-Printing Office, but as they took the place of printing which would otherwise fall to the draughtsman, I suggested that it would be preferable that this should all be done in the Drawing Office, not only because it was proper that a map should be handed to the photographer complete, but because it seemed likely that by the exercise of a little foresight the petty demands on the printer would become condensed into larger and less frequent ones. This has I believe been found to be the case, and it is clear gain; because printed slips though a boon to the draughtsman are a drain on the printing power. They have long since been felt to be so much more wasteful than if the Drawing Office had its own printing appliances, that as long ago as August of last year—15 months ago—an emergent indent for I think £50 worth of plant was despatched through the Government of India to the Secretary of State. It was sanctioned; but to this day the type &c. have not been received, any more than have our own regular indents of a somewhat earlier date been met as yet. A part are I believe on their way—*vid* the Cape.

(30.) *Meteorology.* The usual observations have been recorded without interruption, and reduced: monthly abstracts have been communicated to the Meteorological Reporter to the Government, N.W.P. The usual table of monthly means and a table of wind velocities as furnished by a self-registering anemometer on the Basevi Memorial Clock-Tower are appended. The wind directions indicated by the same are also self-registered and the sheets are available for investigations of the influence of barometric tides on the lower air currents; but the office is too full of work to allow of such being undertaken except by special desire of the Meteorological Office. Observations for time have been frequently taken, by Mr. Peychers, for regulating gunfire at Mussooree and the Basevi Clock at Dehra, as well as for chronometer rating.

(31.) *Library.* A library is nothing without a catalogue, and a catalogue is next to nothing which does not serve its purpose well. The only catalogue we possess is one which having outgrown the framework constructed by me in 1863 for a comparatively modest stock of books, calls urgently for reconstruction. The subject has been present to my mind for months; but though I have a well defined idea of what has to be done the large amount of writing which it will entail has prevented much progress. As a special memorandum on the libraries in public offices was circulated by the Government of India not long since, no apology is necessary for noting briefly here what occurs to me on the subject. The foundation of the Catalogue of the British Museum Library, as well as of that invaluable annual publication the "English Catalogue",—copy of which from 1831 to the present time I happen to possess—is an alphabetical arrangement by (1) author's name (2) leading word, where the work is anonymous or only edited. Cross references are most useful, but they must be quite subordinate, and must not interfere with the plan, which consists in having one full and complete entry for each work, in its alphabetical place. There must be ample room for fresh entries, but it is not desirable that these should be currently made, unless the custodian has some literary qualification. A day-book for current acquisitions provides sufficiently for the catalogue being properly filled up from time to time.

(32.) Having perceived that such a catalogue must be prepared if possible I stopped further entries in the existing *classified* catalogue, and instituted a day-book. This is a current account of books lent as well as received, and has been kept up since. It supplements, on the Cr. side—if it does not render unnecessary—the file of receipt notes; and on the Dr. side it shows or should try to show the title and description, in full, of new acquisitions, for use in bringing up the catalogue. I may add that this latter may possibly be created, if I am allowed time, without the resources of the office being drawn upon otherwise than for printed forms.

(33.) I have already remarked upon the crowded state which the Library and Record Rooms have reached. This partly arises from the constant influx of printed sheets of the Volumes of the Operations. The annual out-turn of the printing office is partly represented by 35 to 40 reams of double royal, of professional matter alone, all of which has, for a time at least, to be stored in one or other of the rooms of the office. This mass of paper occupies much accommodation, and tends to oust both records and books. If funds were available I should propose the substitution of iron racks of greater capacity for the present somewhat incommodious wooden stages, especially in the library, where I think space would be gained—and that without risk from white ants—by following the outline of the room instead of occupying its central area. The racks which have been erected in the observatory are excellent models—though of course they would require to be differently designed for a library.

(34.) *Correspondence.* This speaks for itself; but it does not include correspondence in connection with the preservation of stations, next to be described.

(35.) *Stations.* The business and correspondence connected with the protection of survey stations has for several years been conducted by Mr. Wood, under the direct control of the superintendent. Without at all desiring to interfere with an arrangement which, if it absorbs to an uncertain extent the attention of his principal assistant, yet at the same time relieves the officer in charge of much responsi-

bility, it nevertheless appeared precarious to leave the entire knowledge of the details at the mercy of events. Mr. Wood accordingly, by my direction, drew up an account of the routine, from which the following is condensed. There are three forms in regular use viz:—A, Custody Receipts; B, Annual and District Lists; C, Final District Lists. Custody Receipts are taken by executive officers from village officials at the time of handing over stations into their charge, and are transmitted to Head Quarters, where they are filed as vouchers. I do not gather that they serve any other purpose, in themselves, as they are annually incorporated in the lists B. These are prepared by the executive officers, in the first instance, irrespective of districts, as Annual Lists; and from them are compiled here, on the same forms, the District Lists, which are sent out to the civil officers, who revise and return them with their report on the condition of the stations which they are thus officially made cognizant of as existing within their jurisdictions. From one cause and another these district lists are at first incomplete and erroneous when sent, but when thus revised they ultimately supply all the requisite means for preparing the final lists C. These are then transmitted, along with blank forms, and the district officers, taking the final lists as guides, report annually on the spare forms, stating in an appropriate column the actual condition of each station, and if necessary the estimate of its repair.

(36.) The object of this procedure is clearly to secure a complete transfer of all stations to the care of the civil administration of the districts in which they are situated, and to provide for their continued preservation. The latter purpose is effected by an allotment from Imperial funds. An annual expenditure was some years ago sanctioned which at that time averaged 4 Rs. per station. The increase in the number of stations so transferred, without a corresponding increase in the allotment, has lowered this average; but it has been found possible, so far, to defray the requisite expenditure.

(37.) There are now 313 of these Final District Lists, disposing of some 2725 principal stations, leaving perhaps 30 districts in which it has not yet been possible to get beyond the preliminary stage. To keep the system up, and to arrange for the proper expenditure, entails of course much correspondence, and requires on Mr. Wood's part a very extensive knowledge of his subject.

(38.) Although the preparation of the Final District Lists managed in this way provides for the gradual rectification of local information regarding the positions of the several stations, it is I think a pity that it has not been made a means of obtaining the vernacular names of localities specified in the descriptions. This department is fully alive to the importance of setting a good example in the matter of orthography in its publications, and it might get much help in the annual reports from districts, were the spelling in those more attended to on the spot.

(39.) In close connection with the preservation of known stations, is the recovery and identification of old ones which have been lost sight of. Formerly—I am referring to the early days of the Survey—it seemed the natural fate of a station to die out and leave no sign. I remember one which had been thus allowed to pass out of existence for half a century, and its site only was recovered by digging about in a likely part of a ploughed field. Some disappear unaccountably, while sometimes later operations re-establish a station sensibly but not identically the same as an older one. All such incidents have—since Colonel Walker placed the preservation of Trigonometrical Survey stations on its present footing—been carefully noted in a book devoted to the purpose.

(40.) PRINTING OFFICE. The tabular analysis of monthly cost which has now been gone through does not include expenditure on printer's staff. That part of it which has been assigned to press proofs should be added to the cost of the printing establishment proper, if it were desired to estimate the cost of the printed matter published here. It would no doubt be possible to obtain in this way a proportional estimate of the cost of *composing and correcting* a page of type. But to extend this estimate to printed pages would involve a consideration of the number of pages, and would yield a result of doubtful accuracy. Moreover it would leave out of consideration everything connected with material and plant. I shall not therefore venture upon this, but will merely give a continuation of the usual statement of out-turn.

Year.	Pages composed (foolscap size).	Pages printed (all sizes).
1865-66	377	53 thousand
67	756	93 ,,
68	641	127 ,,
69	697	155 ,,
70	693	106 ,,
71	819	235 ,,
72	1143	241 ,,
73	1420	273 ,,
74	1220	388 ,,
75	1319*	373* ,,
76	1179*	349* ,,

* Averages for a twelvemonth.

The falling off in the last year is due to several causes—among which must be included my inexperience as a printer. In the early months the out-turn was very small, being chiefly professional matter of unusual kinds, and letterpress containing a good sprinkling of mathematical demonstration. Later on there was difficulty in composing well from the draft of the N. W. Himalaya Degree Sheets, as has been already explained. But it is needless to trace these fluctuations minutely, since out-turn must frequently depend upon causes beyond control. I should however mention that the severe illness of our printer Mr. O'Connor, which deprived the office of his services for 6 weeks, and the failing health and ultimate death of our best pressman—events which threw a severe increase of responsibility on Baboo Gunga Pershad who was superintending at Dehra during the time—cannot, I think, thanks to his exertions, be held to explain the decrease.

(41.) Mr. O'Connor has since taken sick leave and the charge of the printing establishment has devolved upon his chief compositor Nurbeer Singh, who carries on the work surprizingly well. I have also been fortunate in replacing the pressman satisfactorily.

(42.) I cannot close this report without an expression of regret that the close of this year will bring round for the second time the half yearly period when claims to increase of salary are considered, without my being able to submit any recommendations: not because none are worthy, but because retrenchment is ordered. I have no alternative but to claim for those under me the recognition which I myself tender them—of thanks for services faithfully performed.

Mean Velocity in miles of the winds which blew at Dehra during 12 months of 1875-76 for each hour of the day.

Civil Hours.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.
0 to 1	1·35	2·88	2·58	1·50	2·21	2·74	3·47	2·43	2·05	1·43	1·32	1·83
1 „ 2	1·32	1·85	2·10	1·32	2·14	1·97	2·57	2·05	1·62	1·07	1·55	1·33
2 „ 3	1·06	1·69	1·77	1·46	2·00	2·32	2·80	2·10	1·95	1·39	1·35	1·43
3 „ 4	0·84	1·35	1·81	1·36	2·03	2·10	1·67	1·57	1·57	0·79	1·29	1·43
4 „ 5	0·45	0·65	1·58	1·25	2·07	2·03	1·57	1·19	1·19	1·46	1·16	1·37
5 „ 6	0·52	0·54	1·48	1·32	1·97	2·06	1·53	0·81	1·10	1·29	1·06	1·13
6 „ 7	0·58	0·42	1·45	1·29	1·38	1·58	1·20	0·86	1·24	1·25	0·97	0·90
7 „ 8	0·03	0·35	1·13	1·04	1·28	1·29	1·10	0·95	1·43	1·18	1·06	0·40
8 „ 9	0·10	0·50	0·94	0·93	1·34	1·26	1·17	1·81	3·05	1·43	1·42	1·07
9 „ 10	0·23	0·65	1·45	1·00	1·93	2·00	1·90	2·33	3·55	1·46	1·61	1·27
10 „ 11	0·42	1·19	1·84	1·28	2·21	2·68	2·23	3·43	3·20	1·57	2·23	1·63
11 „ 12	1·10	1·46	2·23	1·48	2·31	3·29	3·33	4·62	3·85	2·04	1·71	1·90
12 „ 13	1·26	1·52	2·77	1·93	3·10	3·87	3·80	4·59	4·14	2·45	1·90	2·00
13 „ 14	1·13	1·81	2·65	2·04	3·28	3·90	3·53	4·55	5·00	2·72	2·19	2·10
14 „ 15	1·35	2·00	2·81	2·39	3·72	4·29	3·63	5·32	6·10	2·69	2·35	2·63
15 „ 16	1·13	1·69	2·74	2·68	4·24	3·94	4·00	4·73	6·33	2·62	2·10	2·17
16 „ 17	0·74	0·58	1·03	1·86	3·72	3·71	3·40	5·18	6·00	2·14	1·90	1·67
17 „ 18	0·52	0·27	0·45	0·43	1·62	2·71	2·87	3·41	4·52	2·17	1·26	1·10
18 „ 19	0·74	1·46	0·97	0·68	1·10	1·06	1·20	2·91	4·43	1·17	0·90	1·23
19 „ 20	1·06	2·65	1·97	1·29	1·24	1·32	1·57	2·32	2·10	1·03	0·81	1·40
20 „ 21	1·39	3·12	2·74	1·64	1·97	2·00	3·17	2·77	1·00	1·07	1·00	1·47
21 „ 22	1·55	3·12	2·32	1·79	2·17	2·26	3·57	3·09	1·35	1·10	1·19	1·73
22 „ 23	1·42	3·19	2·87	1·96	2·38	2·61	3·53	3·14	1·65	1·79	1·19	1·80
23 „ 24	1·39	3·19	2·68	1·64	2·48	2·26	3·63	2·45	1·85	1·28	1·23	1·73
Sums, ...	21·68	38·13	46·36	35·56	53·89	59·25	62·44	68·61	70·27	38·59	34·75	36·72
Averages, ...	0·90	1·59	1·93	1·48	2·25	2·47	2·60	2·86	2·93	1·61	1·45	1·53

MONTHLY Meteorological results taken from the Register kept at the Office of the Superintendent, G. T. Survey of India, Dehra Dún.

YEAR & MONTH.	BAROMETER. h. m. At 9 30 A.M. Highest.	Lowest.	Monthly mean.	h. m. At 3 30 P.M. Highest.	Lowest.	Monthly mean.	HYGROMETER. h. m. At 9 30 A.M. Monthly mean Temperature of Dew point.	Monthly mean Humidity.	h. m. At 3 30 P.M. Monthly mean Temperature of Dew point.	Monthly mean Humidity.	THERMOMETER. Dry Bulb. Max: in Sun's rays.	Min: on grass.	Max: in air.	Min: in air.	Monthly mean in air.	Wet Bulb. Max: wet.	Min: wet.	Monthly mean wet.	RAIN. No. of days it fell.	Fall in inches.	WIND. Most frequent direction.	CLOUD. h. m. At 9 30 A.M.	h. m. At 3 30 P.M.
1875.	in.	in.	in.	in.	in.	in.	°	·	°	·	°	°	°	°	°	°	°	°					
October ...	27·802	27·527	27·686	27·716	27·460	27·606	61·2	·699	62·1	·568	99·6	51·1	83·6	54·0	70·1	74·8	45·2	61·1	4	1·19	N.W.	1	2
November	·908	·714	·800	·856	·662	·722	53·1	·675	54·1	·510	92·4	44·0	79·3	47·1	63·5	65·0	41·6	53·7	0	0·00	N.	1	2
December	·961	·744	·824	·844	·656	·735	46·8	·667	48·5	·495	87·8	36·2	76·7	40·2	57·9	63·6	36·5	49·5	1	0·05	N. & W.	2	2
1876.																							
January ...	27·861	27·607	27·742	27·818	27·530	27·667	44·3	·701	45·7	·494	83·1	34·2	74·7	38·1	55·7	60·0	30·3	47·3	3	1·40	W.	4	4
February	·835	·594	·699	·767	·507	·623	43·7	·616	42·6	·375	91·9	29·8	79·6	33·9	59·0	60·3	29·7	46·6	4	0·52	W.	2	4
March ...	·793	·493	·649	·731	·435	·573	49·7	·566	49·3	·398	98·0	43·2	86·3	46·2	65·2	64·0	36·7	52·3	4	1·65	W.	3	5
April ...	·716	·409	·551	·620	·322	·467	51·7	·414	49·2	·288	115·7	41·5	100·2	50·6	75·5	73·5	39·8	55·8	2	1·49	W.	1	2
May ...	·635	·376	·490	·536	·286	·403	58·3	·397	57·4	·298	116·0	58·9	102·0	61·8	83·7	91·7	50·9	64·9	4	1·44	N. & W.	2	3
June ...	·507	·269	·376	·421	·162	·289	65·7	·641	61·6	·563	118·5	61·8	106·8	65·5	88·8	80·5	58·0	69·4	5	1·37	W.	1	3
July ...	·454	·238	·348	·363	·157	·281	74·8	·853	75·5	·779	115·0	69·8	105·2	72·2	81·2	80·4	63·1	73·7	23	30·73	S.	9	8
August ...	·618	·296	·463	·531	·249	·390	74·0	·859	75·4	·813	105·5	66·0	89·0	69·8	78·7	81·0	57·0	72·2	21	27·28	S.E.	8	7
September	·732	·444	·572	·628	·359	·488	71·4	·796	73·4	·776	105·0	62·5	90·7	65·1	77·7	80·7	55·2	68·5	15	12·73	N.	6	6
October ...	·830	·581	·738	·763	·488	·651	60·2	·731	61·2	·606	98·2	49·5	84·3	53·2	68·6	72·5	41·0	58·5	8	4·00	N. & S.	2	3

NOTE.—The height of the Barometer Cistern above Mean Sea Level at Karáchi is 2232·41 feet.

Northern Section. Second Edition

GREAT TRIGONOMETRICAL SURVEY OF INDIA

INDEX TO MAIN LEVEL LINES BY THE G. T. SURVEY FOR COMPILATION OF CHARTS.

Nore.—Great Trigonometrical Survey Main Series of levels thus

Charts published are colored Red

Do. under compilation „ Green

Data in hand for compilation „ Yellow

Each rectangle drawn on this Index, represents the area included in a single sheet (or chart) of levels.

Second Edition with corrections and additions up to November 876.

COMPILED UNDER THE INSTRUCTIONS OF MAJOR T. G. MONTGOMERIE, R. E., F. R. S., &C., &TC. SUPERINTENDENT G. T. SURVEY OF INDIA, 1878.

Orthography is in accordance with the orders of Government.

Scale 1 Inch = 80 Miles or $\frac{1}{5068800}$

Photozincographed at the Office of the Superintendent G. T. Survey, Dehra Dún November 1876.

n. Second Edition

GREAT TRIGONOMETRICAL SURVEY OF INDIA

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Sheet No. 1.

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C. G. OLLENBACH, Mess.

XIII. Extract from the Narrative Report—dated 22nd December 1876—of Captain H. R. THUILLIER, R.E., Officiating Deputy Superintendent 1st Grade, in charge of Drawing and Photozincographing Branches of the Computing Office.

In consequence of Mr. Cole proceeding on furlough, I was directed to take charge of the Drawing and Photozincographic Branches of the Computing Office and assumed their direction on the 21st March.

It is necessary to state that the return of work executed in these two branches is for a period of twelve months, and therefore it is not comparable with that submitted in the preceding report, which embraced a period of 17 months for reasons therein stated.

DRAWING BRANCH.

Annual Return of work executed in the Drawing Office, during the year ended 30th September 1876.

DESCRIPTION OF WORK.	Number of sheets or diagrams. Finished	In hand	Scale 1 inch =	REMARKS.
Compilation.			*Miles*	
Map to illustrate the report on the Pandit's route through Great Tibet in 1874. Sheets 1 and 2, with hill shading.	2	...	16	For Photozincography.
Index Chart to the Degree Sheets of the N.W. Himalaya Series triangulation, with hill shading.	1	...	24	Do. Reduction to ⅔ scale.
Map of Havildar, and Mulluh's routes through Afghanistan &c., 1873-74.	1	...	16	Do.
Sheet No. 6 of Spirit Levelled Heights.... ...	1	...	2	Do.
Do. „ 13 Do.	...	1	2	Do.
Do. „ 19 Do.	...	1	2	Do.
Do. „ 21 Do.	1	...	2	Do.
Do. „ 23 Do.	1	...	2	Do.
Do. „ 25 Do.	1	...	2	Do.
Do. „ 26 Do.		1	2	Do.
Do. „ 27 Do.	1	...	2	Do.
Do. „ 28 Do.	1	...	2	Do.
Do. „ 40 Do.	1	...	2	Do.
Do. „ 41 Do.	1	...	2	Do.
Do. „ 42 Do.	1	...	2	Do.
Do. „ 45 Do.	1	...	2	Do.
Do. „ 53 Do.		1	2	Do.
Do. „ 59 Do.		1	2	Do.
Do. „ 66 Do.	1	...	2	Do.
Do. „ 1 Dehra Dún and Siwáliks with hill shading, ...	1	...	1	Do.
Do. „ 2 Do. Do.		1	1	Do.
Do. „ 24 Do. Do. Survey.		1	½	Do.
Final Charts.				
Great Arc Series, Section ; 18° to 24°.	2	...	4	Do. Reduction to ½ scale.
Calcutta Longitudinal Series.	3	...	4	Do. Do.
East Coast Series.	2	...	4	Do. Do.
Bilaspur Meridional Series.	2	...	4	Do. Do.
Jabalpur Meridional Series.	2	...	4	Do. Do.
Bider Longitudinal Series.	2	...	4	Do. Do.
Degree Charts of the North-West Himalaya Triangulation. ...	14	...	4	Do. Do.
Miscellaneous.				
Examined and reported on 41 fair original Maps of Kumaun and Garhwál, Kattywar, Guzerat and Dehra Dún and Siwáliks Surveys.	...	...	...	
Examined 113 proofs of Maps and Charts.	...	...	...	
Colored 8,502 Maps.	...	...	...	
Prepared 7 professional and office forms on drawing and transfer paper.	...	...	...	For Photozincography and Zincography.
Prepared a trace on linen of the Assam Valley Triangulation 1875-76.	...	...	...	
Prepared a trace on linen of country round the Chur Peak.	...	...	...	
Prepared an Index Chart of Triangulation of N.E. Quadrilateral eastern extension.	...	...	...	For Photozincography.
Prepared 68 Figures of the several series contained in the S.E. Quadrilateral to illustrate G.T.S. Volumes. ...	...	...	...	
Prepared 97 Diagrams and Descriptions of Bench-Marks for Sheets Nos. 6, 21, 25, 27, 28, 40, 41, 42, 45, and 66 of Spirit Levelled Heights.	...	...	...	The diagrams for Photozincography. and reduction to ½ scale.
Prepared tracings for use of various Officers and for record, and performed other miscellaneous duties. ...	...	...	...	

This Office has been principally engaged in the preparation of charts of triangulation, of which 27 have been completed, and of the series of Level charts, in which considerable progress has been made. Twelve of these sheets have been completed and four are very nearly ready for the press. The accompanying Index map shows the sheets that have been published. The map of Northern Afghanistan showing the results of the explorations of the Havildar and the Mullah, and that of the Pandit's surveys through Great Tibet, both compiled under Captain Trotter's supervision, were completed early in the year, but circumstances of which you are aware, have prevented the publication of these very interesting maps.

A large amount of miscellaneous work has been done in addition, and I am glad to be in a position to say that Mr. Atkinson, the Chief Draftsman, conducts this small branch with much efficiency and energy.

PHOTOZINCOGRAPHIC BRANCH.

The amount of work executed by this Office for the year ended 30 September 1876 is shown hereafter under the heads of Charts, Diagrams, Forms, and Maps. This work may be briefly summarized as follows:—

109 transfers have been made to zinc, 25,425 complete prints of maps and other subjects and 18,314 copies of Forms have been struck off, besides the preparation of 126 silver prints.

The out-turn bears favorable comparison with that of former years, which can be seen by reference to the abstract given in the last report by Mr. Cole, and taking into consideration the reductions which have been carried out both in this and in the Drawing Branch during the year under review, I trust the returns of these small Offices will be considered satisfactory both in quantity and quality.

In the Photozincographic Office Mr. Ollenbach continues to merit the good opinion previously expressed of his industry and supervision, while the subordinates in both branches have as a body worked satisfactorily.

Charts.

SUBJECT.	When published.	No. of parts.	No. of copies printed.
Jogí-Tilá Meridional Series Chart, Final	October 1875	1	369
Sutlej Series Chart, Final	November „	1	366
North-West Himalaya Series, Degree Sheet 1—2, Final	February 1876	1	370
„ „ „ „ „ 3—4, „	„ „	1	367
Jodhpur Series, season 1874-75, Numerical	March „	1	68
Rámnád Longitudinal Series, Season 1874-75, Numerical	April „	1	68
Eastern Frontier Series, season 1874-75, Numerical	August „	1	70
	Total ...	7	1678

Diagrams.

SUBJECT.	When published.	No. of copies printed.
Plates to illustrate Volumes of the G.T. Survey, and other Diagrams	October 1875	151
	November „	899
	December „	502
	January 1876	1537
	February „	82
	April „	1262
	May „	1026
	June „	1918
	July „	742
	August „	1253
	September „	350
	Total ...	9722
Professional and Office Forms	1875-76	18,314

Maps.

SUBJECT.	When published.	No. of parts.	No. of copies printed.
Prints of maps published in former years	...	22	1852
Kumaun and Garhwál, sheet No. 12, contoured	October 1875	1	119
" " " 22, "	" "	1	109
Guzerat Survey, sheet No. 80, section 4	" "	1	107
" " " " " 6	" "	1	107
" " " " " 10	November "	1	105
" " " " " 14	" "	1	108
Index to Guzerat Survey	" "	1	415
" Kattywar "	" "	1	444
" Dehra Dún and Siwalik Survey	" "	1	454
Dehra Dún and Siwalik Survey, sheet No, VI	" "	1	143
" " " " VII	" "	1	137
" " " " XV	" "	1	147
Kumaun and Garhwál, sheet No. 21, skeleton	" "	1	164
" " " 6, contoured	December "	1	103
" " " 38, "	" "	1	105
Kumaun Map } For N.W. Provinces' Gazetteer	" "	1	1451
Garhwál " }	" "	1	1281
Dehra Dún and Siwalik Survey, sheet No. I	" "	1	148
" " " " III	" "	1	152
" " " " V For Forest Department	" "	1	132
" " " " XI	" "	1	136
" " " " XII	" "	1	136
" " " " XIII	" "	1	139
" " " " XIV	" "	1	142
" " " " XXI For Forest Department	" "	1	135
Map illustrating the Pandit's route in 1874	" "	2	454
Index to Kumaun and Garhwál Survey	" "	1	444
Dehra Dún and Siwalik Survey, sheet No. 11	January 1876	1	140
Kumaun and Garhwál, sheet No. 23, skeleton	" "	1	159
Kattywar Survey, sheet No. 42	" "	1	127
" " " 43	" "	1	143
" " " 31	February "	1	132
Kumaun and Garhwál, sheet No. 26, skeleton	" "	1	159
" " " 6 " 2nd edition ...	" "	1	157
Map illustrating the Havildar's routes 1873-74	" "	1	481
Kattywar Survey, sheet No. 44	March "	1	137
Map of Khota Bhubur	" "	1	34
Kamaun and Garhwál, part of sheet No. 17 contoured	" "	1	34
Dehra Dún and Siwalik Survey, sheet No. IV } For Forest Department	" "	1	130
" " " " No. IX }	" "	1	140
Guzerat Survey, sheet No. 80, section 12	" "	1	127
" " " " 6	" "	1	104
" " " " 15	April "	1	106
" " 81 " 3	" "	1	107
Index to North-West Himalaya Series Degree Sheets	May "	1	399
" Triangulation, N. E. Quadrilateral Eastern Extension ...	June "	1	10
Spirit Levelling operations, No. 66	" "	1	120
" " 23	July "	1	119
" " 27	" "	1	133
Guzerat Survey, sheet No. 81, section 2	" "	1	109
" " " " 4	August "	1	113
" " " " 10	" "	1	110
Kumaun and Garhwál, sheet No. 1, skeleton, 2nd edition, ...	" "	1	162
Mussoorce and Landour Survey, sheet No. 14, skeleton, 2nd edition ...	" "	1	35
Spirit Levelling operations, No. 28	" "	1	112
" " " 40	" "	1	110
" " " 45	" "	1	115
Guzerat Survey, sheet No. 81, section 5	September "	1	109
" " " " 12	" "	1	95
Spirit Levelling operations, No. 6	" "	1	115
" " " 21	" "	1	122
Dehra Dún and Siwalik Survey, sheet No. VIII	" "	1	9
" " " " XLII	" "	1	142
	Total ...	86	14,025

Besides the foregoing, 12 Blue prints were issued, and 126 sets of Silver prints (50 subjects) were prepared on the scale of the Indian Atlas for the use of the Engravers and for Executive Officers.

GENERAL REPORT

ON THE OPERATIONS

OF THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA,

DURING

1875-76,

Prepared for submission to the Government of India.

BY

J. B. N. HENNESSEY, ESQ., M.A., F.R.S., &C.,

OFFG. SUPERINTENDENT OF THE SURVEY.

Dehra Dun:

PRINTED AT THE OFFICE OF THE SUPERINTENDENT G. T. SURVEY.

M. J. O'CONNOR.

1877.