GENERAL REPORT

ON THE OPERATIONS

OF THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA,

DURING

1872-73,

Prepared for submission to the Government of India.

BY

COLONEL J. T. WALKER, R.E., F.R.S., &C.,

SUPERINTENDENT OF THE SURVEY.

Dehra Doon:

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

M. J. O'CONNOR.

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THE OPERATIONS OF THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA

IN 1872-73.

The following is a summary of the several operations of the present year, given in the order in which they will be found described in this report.

			Described at pages of the	
			Report.	Appendix.
I.	*Trigonometrical.*	The Bilåspur Series, Southern Section, Meridian 82°	6	3—a
II.	*Trigonometrical.*	The Bilåspur Series, Northern Section, Meridian 82°	7	8—a
III.	*Trigonometrical.*	The operations in the Assam Valley. ...	7	9—a
IV.	*Trigonometrical.*	The Jodhpúr Series, Meridian 72½°. ...	9	11—a
V.	*Trigonometrical.*	The operations on the Meridian, 75°, and the parallel, 13°, of Mangalore.	10	13—a
VI.	*Trigonometrical.*	The Brahmaputra Series, Meridian 90°. ...	12	20—a
VII.	*Topographical.*	The Survey of Kattywar. ...	13	23—a
VIII.	*Topographical.*	The Survey of Guzerat. ...	14	30—a
IX.	*Topographical.*	Himalayan Surveys in Kumaon and Gurhwal. ...	17	36—a
X.	*Geodetic.*	Electro-telegraphic determinations of difference of longitude in the parallel of 13°.	18	43—a 52—a
XI.	*Geodetic.*	Astronomical determinations of latitude. ...	24	42—a 47—a
XII.	*Geodetic.*	The pendulum operations. ...	25	
XIII.	*Tidal.*	Determinations of mean-sea level. ...	25	65—a
XIV.	*Geographical.*	Trans-Himalayan explorations. ...	29	
XV.	*Computing Office.*	Examination, final reduction and publication of the observations.	30	71—a 77—a
XVI.	*Cartography.*	Preparation and publication of various Charts and Maps.	31	78—a

(2.) The operations carried on during the year under review have produced the following out-turn of work;—of Principal Triangulation, with the great theodolites of the Survey, 92 triangles, covering an area of 11,058 square miles, and disposed in chains which, if united, would extend over a direct length of 416 miles, and in connection with which seven astronomical azimuths of verification have been measured;—of Secondary Triangulation, with smaller theodolites, an area of 3,224 square miles has been closely covered with points for the topographical surveys, an area of 11,532 square miles has been operated in *pari passu* with the principal triangulation, and in an area of 7,290 square miles of a portion of the Himalayas, which is inhabited by independent tribes, several points have been fixed which will be valuable for preliminary geographical requirements;—of Topographical Surveying, an area of 2,734 square miles has been finally completed in the Himalayas, on the scale of one inch to the mile, and an area of 3878 square miles, on the two-inch scale, in portions of the Bombay Presidency, in the course of which 2,734 linear miles of boundary and check lines have been traversed;—and of Geodetic Operations, the amplitude of the arc of parallel between Madras and Mangalore has been determined by the electro-telegraphic method, and the pendulums of the Royal Society and those of the Russian Imperial Academy of Sciences have been swung at five stations.

(3.) The principal triangulation has been executed as usual with the largest theodolites, the azimuthal circles of which have diameters of either 36 inches, or of 24 inches. The average theoretical probable error of the angles, and the average geometrical error, of the triangles—the amount by which the sum of the three observed angles of each triangle differs from 180° + the spheroidal excess—are shown in the table given in the margin. In the course of the operations of the present season two great circuits of triangulation have been closed, one formed by the chains of triangles on the meridians of 80° and 82° and the parallels of 18° and 24°, the other by the chains on the meridians of 75° and 78° and the parallels of 13° and 18°. A series of triangles has been commenced on the meridian of 72½°, emanating from the Karáchi (Kurrachee) Longitudinal series and trending northwards, which, with another series to be executed on the meridian of 70°, will suffice to fill the gap which at present exists in the triangulation of Western India. The Brahmaputra Series, meridian 90°, has been so far advanced northwards that in all probability it will be completed during the next field season.

Series.	Probable Errors of Observed Angles.		Geometrical Errors of Triangles.		Nature of country operated in.
	Number.	Amount.	Number.	Amount.	
1.	63	±0″·16	21	0″·45	Hills.
II.	48	·21	16	·36	"
IV.	42	·15	14	·33	"
V.	75	·14	25	·65	"
VI.	48	·29	16	·94	Plains.
Averages,...	...	±0″·18	...	0·56	

(4.) The secondary triangulation which is being carried up the Assam Valley has made very little progress, the reasons of which will be found explained in Section III.

(5.) The transit instruments, chronographs, astronomical clocks and other apparatus for this Survey—the construction of which was commenced ten years ago in England and France, under Colonel Strange's superintendence, and has been reported on by him from time to time in various communications to the Royal Society and the Royal Astronomical Society—were received in this country in time to permit of their being used in the present year. They were employed in the determination of the differences of longitude between Madras, Bangalore and Mangalore by the electro-telegraphic method. The astronomical determinations of latitude were suspended to allow of the Officers usually engaged thereon being employed on the longitude operations.

(6.) The pendulum observations which were commenced in the year 1865 by Captain Basevi, and suspended on the death of that Officer in 1871, have been resumed; the operations remaining to be done in India have been completed; the pendulums have been taken back to England, and final observations are now being made at Kew, the base station.

(7.) Much attention has been paid to the requisite measures for the protection of the stations of this survey, which are scattered over all India; it has been found that a large proportion of those which were constructed even at the commencement of the present century are still forthcoming, though no steps appear to have been specially taken to ensure the protection of any of the stations until the years 1865-66, when stringent orders on the subject were issued by the Government of India, lists were circulated to the District Officials, and periodical reports on the condition of each station were called for.

(8.) The final reduction of portions of the triangulation and the publication of the Volumes of the "*Account of the Operations &c.*," which give the results of this laborious operation, have made satisfactory progress; the publication of charts shewing the preliminary results, which are deduced on the completion of each field season's operations, has been kept up to date, as has also that of the maps which are constructed by the three Topographical Parties. A second edition of the map of Turkestan, which contains much new information of the geography of Central Asia, has been published, as also various other maps which will be duly described hereafter.

(9.) During the summer of 1872 I was employed in the India Office, London, in examining the condition of the copper plates of the Indian Atlas, and in carrying out the requisite measures for the completion of such portions of the Atlas as it was considered desirable to have engraved in England rather than in India. These operations have been fully reported on in Mr. Markham's Abstracts of the Reports of the Indian surveys, published in 1872 and 1873. I need here only add that a portion of my duties in England was to acquire sufficient information of the practical details of superposing a surface of steel on an engraved copper plate, by the electro-type process, to be able to introduce the method into this country, for employment in the Surveyor General's Office in Calcutta. The requisite apparatus was duly provided in England, and on its arrival in India I proceeded from my Head Quarters in Dehra Doon to Calcutta, in order to initiate the process, which was soon placed on a satisfactory footing, and is now worked whenever necessary.

(10.) While in England my attention was drawn to the tidal investigations which were being carried on under the direction of a Committee of the British Association presided over by Sir William Thomson; I found that it was very desirable that the tidal operations in this country should, when resumed, be conducted in a similar manner, in order to contribute towards the attainment of a better knowledge of the laws of the tides. With the sanction of the Secretary of State for India I made arrangements to procure all the requisite self-registering instruments, and to acquire the practical details of the reduction of the observations by the method of harmonic analysis which is practised and recommended by the British Association. The instruments have been received in this country, thoroughly examined, and put into good working order; and all the requisite arrangements have been made for commencing operations by a series of tidal determinations on the coasts of the Gulf of Kutch, which will be immediately undertaken.

(11.) I landed at Bombay on the 31st October 1872, after an absence of nearly two years from India, and on the following day I resumed the direction of the Great Trigonometrical Survey, which had been administered during the whole term of my absence by Major T. G. Montgomerie, R.E., to whom my best thanks are due for the manner in which he conducted the duties of the Department, and whose services have already been acknowledged by the Government of India and the Secretary of State.

(12.) I now proceed as usual to report on and give an abstract of the operations of the several Survey Parties and Offices. Further details will be found in the Extracts from the Narrative Reports of the Executive Officers given in the appendix, which also contains a paper of "Notes on the maps of Central Asia and Turkestan" which have been published in this Office under my superintendence.

NO. I.—TRIGONOMETRICAL.

THE BILÁSPUR SERIES, SOUTHERN SECTION, MERIDIAN 82°.

(13.) The longitudinal chain of triangles which extends from Bombay to Bider and thence to Vizagapatam was completed during the field season of 1871-72. I then determined to utilize the opportunity afforded by the presence of Mr. Rossenrode and his party in the neighbourhood, to carry a triangulation on the meridian of 82°, from the said longitudinal series northwards, to meet the triangulation on the same meridian which was being brought down from the Calcutta Longitudinal Series by Mr. Keelan, and which could be more easily and satisfactorily executed by surveyors already familiar with and located in the country, than if it were conducted continuously from north to south by other surveyors new to the ground.

PERSONNEL.

W. C. Rossenrode Esq., Depy. Supdt. 3rd Grade.
Mr. H. Beverley, Surveyor 1st Grade.
" F. Bell, Surveyor 3rd Grade.
" E. P. Wrixon, Asst. Surveyor 3rd Grade.

(14.) Mr. Rossenrode had much difficulty in recruiting his establishment, in providing pack-bullocks—the only means of carriage available in a country which is very hilly and intricate and is almost wholly devoid of roads—and in obtaining carriers for his great theodolite; a panic had seized the indigenous hamáls or bearers in consequence of the mortality which had prevailed among them during the operations of the preceding field season, and men had to be imported from Hazaribagh who had been previously employed by Mr. Rossenrode. All the preliminary arrangements were however completed in time to permit of the party taking the field in the middle of November, the earliest date at which it is judicious to do so in this region of malaria and fevers. After a month's march from Vizagapatam Mr. Rossenrode reached the terminal stations of last season's triangulation where his work had to commence, and in the three following months he carried the final operations northwards, a distance of 96 miles, to the parallel of 20° 24′, where they formed a junction with Mr. Keelan's operations on the northern section. Principal observations were taken at 17 stations, forming three polygonal figures which cover an area of 2,360 square miles. An azimuth of verification was also determined by astronomical observations.

(15.) During the previous field season Mr. Rossenrode had been unable to have a sufficient number of secondary points fixed to render his operations as valuable as they should be for geographical purposes; he had only two assistants and was obliged to employ them chiefly in the preliminary operations for the great triangulation. During the present season this omission has been amply rectified, and a large amount of secondary triangulation has been executed, over an area of upwards of 5,000 square miles, in which there are 83 stations whose position and height have been determined, and 203 points fixed by intersection but not visited.

(16.) Mr. Rossenrode and his assistants are to be much congratulated on the satisfactory completion of these arduous operations. The country in which they were laboring is one of the most malarious and deadly in all India. It was in this region that Colonel Everest commenced his career as a Trigonometrical Surveyor, in the year 1818: a few months afterwards he was stricken down by jungle fever, the most baneful enemy of the operations of the survey. Half a century was allowed to elapse before the work was resumed; but in 1869-70 Mr. George Shelverton was deputed to take it up; he too suffered much from fever, but he remained at his post, with a steady persistance and self devotion which, in the following year, cost him his life, and lost the Government the services of an able and very deserving officer. In this last season of the operations, Mr. Rossenrode and each of his European assistants and the whole of the native subordinates and camp followers, without a single exception, suffered more or less from fever, but fortunately of a less virulent type than had been met with to the south, and the number of fatal cases was comparatively slight.

(17.) In his Narrative Report, Mr. Rossenrode gives an interesting description of the Banjáras, the class of people by whom the chief trade of the country is conducted, and whose existence appears to be devoted to purchasing grain in the valleys and plains in the interior and carrying it to the towns on the sea-coast for sale; the roads, or rather foot paths, being of the very worst description, passing over rugged hills and through tangled forests, the grain has to be transported on pack-bullocks; and the Banjára and his wife and family and all his belongings, travel with the bullocks, and have no other home than their tents and camping grounds.

(18.) In the ensuing field season Mr. Rossenrode and his party will be employed in Burma, in resuming the operations which were suspended in the year 1870.

NO. II.—TRIGONOMETRICAL.

THE BILÁSPUR SERIES, NORTHERN SECTION, MERIDIAN 82.°

PERSONNEL.

H. Keelan Esqr., Depy. Supdt. 3rd Grade.
Mr. L. H. Clarke, Surveyor 3rd Grade.
„ J. C. Clancey, Asst. Surveyor 4th Grade.

(19.) The principal triangulation which was required to form a junction between the terminal points of the operations of the previous year in this section of the series and those of the present year in the southern section, has been completed by Mr. Keelan, by observations at ten stations forming four quadrilateral figures which extend over a direct distance of 55 miles and cover an area of 680 square miles. A verificatory azimuth has also been determined by astronomical observations at one of the principal stations. This portion of the work has been well done, but in other respects the performances of the field season are not as satisfactory; no secondary triangulation was executed, nor were any attempts made to connect the stations of the Topographical and Revenue Surveys, of which there are several in the neighborhood of the Trigonometrical Stations; this work will have to be done before the operations can be considered to be complete. Mr. Keelan describes the country as the wildest tract it has ever been his lot to work in, covered with forest and presenting no well defined points to fix; his party had been materially weakened by the transfer of one of his assistants to other duties; but as the amount of the principal work which had to be performed was not very much, I am of opinion that with better arrangements and a little more enterprise the secondary work as well as the primary would have been completed.

(20.) By the junction of the two sections of this chain of triangles, the circuit formed by the Jabalpur and the Bilaspur Meridional Series and by the Calcutta and the Bider Longitudinal Series, has been closed; its length is about 1,130 miles, and the discrepancies at the side of junction—as exhibited on the completion of the preliminary calculations of the triangulation, without any correction for errors generated in the course of the circuit—are as follows; linear, 0·49 of a foot in 14·94 miles, which is equivalent to the six millionth part of the side of junction; in latitude 0″·28, in longitude 0″·02, and in height 20 feet.

NO. III.—TRIGONOMETRICAL.

THE OPERATIONS IN THE ASSAM VALLEY.

(21.) The extension of the triangulation into the upper portion of the Assam Valley has long been a desideratum, in order to connect the Revenue Surveys of the Síbságar and Lakhimpur districts—which were commenced several years ago—with the general survey, and also to fix points on the hill ranges lying to the north of the valley, for the elucidation of the geography of regions which are at present inaccessible to Europeans, being occupied by various independent hill tribes. Every effort has been made to push on this triangulation as rapidly as possible, but the difficulties met with have been very great, and the progress has been far slower than that of any similar operations of this Survey in modern times.

(22.) The difficulties arise from the following causes. *First*, the whole surface of the country, in the hills as well as the plains, is covered with patches of forest and with dense jungles of bamboo and long grass; in every instance more or less clearance is required to render the stations mutually visible; when the stations can be placed on hill peaks it is only necessary to cut the trees down to the level of the summit; but in plains the entire length of line between contiguous stations has to be cleared, and some idea of the labor may be formed from the fact that a single line occupied a party of twenty five cutters thirty six days to clear; if a rainy season intervenes between the cutting of a line and the final observations, a second clearance becomes necessary, as in these regions grass and bamboo jungle grows up very rapidly on the line during the rains. *Secondly*, the country is very sparsely inhabited; supplies and laborers have frequently to be imported from a distance, and even where large villages are met with the inhabitants can only with great difficulty be induced to render any assistance, though highly paid for it. *Thirdly*, the most healthy time of the year for field work is usually the least favorable for observations of distant points; the atmosphere is always clearest and most transparent immediately after the termination of the rainy season, and in the brief period which usually occurs between the first showers—the *chota barsát*—and the setting in of the regular rains; but at these times malaria and jungle fever are most rife and the country is very deadly, more particularly for persons employed in field operations which necessarily entail great exposure. When the dry season sets in the villagers invariably burn down the grass and bamboo jungle, and then the atmosphere becomes pervaded with smoke, which hangs like a pall over the whole country, and shuts out from view all distant objects and sometimes even near ones; at these times observations become impossible, and the surveyors have to be employed in the preliminary operations of selecting and constructing stations and clearing lines.

(23.) The Assam Series was commenced in the season of 1867-68 at the stations of the principal triangulation in the neighborhood of Gowhatty, by Lieut. Larminie, R. E., who was only able to carry it over a distance of 56 miles in that and the following field season. In his anxiety to push on the work more rapidly Lieut. Larminie took the field, at the commencement of the season of 1869-70, so soon after the cessation of the rains that most of his men were stricken down with fever, and by the time they had recovered and were fit for work the favorable season for observations had passed, and the party had to be employed in preliminary operations for future work. In 1870-71, the triangulation was advanced a direct distance of 86 miles by Mr. W. C. Rossenrode, the best season's work yet performed in the course of these operations, but due in some measure to the preliminary operations which had been previously completed by Lieut. Larminie. In the following year Mr. W. G. Beverley carried it 40 miles further.

PERSONNEL.

W. G. Beverley Esqr.	Asst. Supt.	2nd	Grade.
Mr. G. A. Harris	Asst. Surveyor	1st	„
„ W. G. O'Sullivan	„ „	1st	„
„ J. O. Hughes	„ „	4th	„

(24.) During the field season now under review several points have been fixed on the hill ranges to the north of the valley, but the principal chain of triangles has been advanced a distance of less than twenty miles. This is mainly due to the circumstance that political considerations necessitated the abondonment of the original design of carrying the operations over the northern spurs of the Nága Hills, for which arrangements had been made; Mr. Beverley was therefore compelled to turn down into the plains of the Brahmaputra River, the region of tree-forests and dense grass and bamboo jungles, where every line has to be opened by laborious clearances. I am sorry to have to add that much delay was also caused by an injudicious selection of the two stations at which the season's operations terminated; the indispensable precaution of carrying a trial line between these points before constructing the towers had been neglected, and when the final line came to be cleared a large house was found standing midway between the two stations; this house was too valuable to be pulled down and therefore the towers had to be built up to a considerable height and then high platforms had to be temporarily erected on them for the support of the lamps and heliotropes. All this caused much delay, which was the more to be regretted as it happened at a time when the atmosphere was favorable for observations, before the natives had commenced their periodic burnings of the grass jungles.

(25.) The final operations have now been carried up to points in the vicinity of the Dhansíri River, one of the stations being situated at Gola-ghat. Preliminary operations for next field season have been carried up to within seven miles of the town of Síbságar. Several high mounds and ruined temples have been met with, on the left bank of the Brahmaputra river, which are likely to be made to serve as sites for stations; but this will depend on whether corresponding sites can be met with on the long island of Majhili, which stretches from a point a little below Síbságar to a point near the junction of the Dhansíri river with the Brahmaputra. On that island it will be necessary to have five or six stations, only two of which have as yet been selected. Mr. Beverley reports "that Mr. O'Sullivan, who was employed in this duty, would probably have completed the selection had not his progress being stopped from want of provisions," and that it will be necessary next season to carry supplies for men and animals in boats from below, and to make such other arrangements as may render the surveyors wholly independent of local assistance. He also states that this is the most difficult portion of the triangulation which remains to be executed, and that when the Majhili island has been left behind the operations may be readily advanced into any portion of the Upper Assam basin.

(26.) Mr. Beverley reports that the secondary triangulation has completely defined the Dufla Hills, which form the lower range on the northern side of the valley, between the meridians of 93° and 94°; the points laid down will be useful in the projected survey operations to define the British Boundary. Some peaks have been observed in the snowy ranges beyond, but as they were only seen on two occasions, they cannot yet be considered to be definitely fixed. There is still a considerable blank in the determinations of hill peaks west of 93°, which Mr. Beverley hopes to be able to fill in at the commencement of next field season, should the atmosphere be sufficiently clear to permit of his seeing the hill ranges.

NO. IV.—TRIGONOMETRICAL.

THE JODHPUR SERIES; MERIDIAN 72½°.

(27.) Ground was broken on this series for the first time during the field season under review. In the previous season Lieutenant Rogers had been employed in completing the revision of the section of the Great Arc between the base-lines at Bangalore and at Bider, after which he returned to Bangalore to spend the recess season. He had therefore in the first instance to proceed with the greater portion of his party and instruments by rail from the centre of the Madras Presidency, to Ahmedabad, the northernmost station of the Bombay and Baroda Railway, and then to march *viâ* Deesa to Erinpúra, where he had arranged to meet the agent of the native state of Jodhpúr who had been deputed to attend him throughout his operations.

(28.) The Jodhpúr Series is one of the two internal chains of triangles which remain to complete the great figure known, departmentally, as the North-West Quadrilateral, the exterior chains of which directly connect the base-lines at Sironj (in Central India), Dehra Doon, Chach (near Attock) and Karáchi. Operations were commenced at the stations of Súnda and Bonik of the Longitudinal Series which forms the southern flank of the Quadrilateral, and they were carried northwards with a view to closing eventually on the Sutlej Series.

PERSONNEL.

Lieut. M. W. Rogers, R.E.,	Asst. Supdt. 1st Grade.
Mr. W. C. Price,	Assistant Surveyor 1st „
„ C. P. Torrens	„ „ 3rd „
„ A. Bryson,	„ „ 4th „
„ W. Oldham,	„ „ 4th „

(29.) As no opportunity had been previously afforded of undertaking the usual preliminary operations for final triangulation, Lieutenant Rogers occupied himself for some weeks in selecting sites for stations and having the necessary structures erected thereat. When this work had been sufficiently advanced to be entrusted to his assistants, he commenced the measurement of the principal angles, and fixed twelve new stations, forming two polygonal figures and a quadrilateral which extend over a direct distance of 95 miles and embrace an area of 3,706 square miles. The preliminary operations were advanced to a distance of 52 miles beyond, in readiness for next field season.

(30.) The country passed over is very favorable for our operations; it is sandy and free from the dense growth of forests and tropical vegetation which elsewhere has caused such difficulties and retarded progress; and it has numerous isolated hills and sand-hillocks which present favorable sites for stations of observation. The chief difficulty met with was in the scanty supply of water, and the bad quality of the little water that was to be had, and this difficulty will increase as the operations advance farther into the deserts of Rájputána. On the other hand the Jodhpúr Durbar—unfettered by restrictions such as are placed on the British Officials in Assam—rendered most cordial and effective assistance, and Lieutenant Rogers reports that he has never before met with so little hindrance and annoyance in the prosecution of his operations.

(31.) In addition to the principal operations, a goodly amount of secondary work was done, fixing the positions and heights of 15 visited stations and 50 unvisited stations, in an area of 2,443 square miles, mostly in the Nizam's Dominions where the operations had been arrested at the end of the preceding season by the ill health of the assistant employed on them. Two groups each of four subsidiary stations, on the Great Arc, in latitudes 19° 5′ and 20° 44′, where Captain Herschel had taken astronomical observations for latitude, were connected with the principal triangulation.

(32.) The general progress of the operations and out-turn of work is very creditable to Lieutenant Rogers and his assistants.

NO. V.—TRIGONOMETRICAL.

THE OPERATIONS ON THE MERIDIAN, 75°, AND THE PARALLEL, 13°, OF MANGALORE.

(33.) The triangulation on the meridian of Mangalore is primarily dependent on the Bombay Longitudinal Series from which it was carried southwards, in the field seasons 1865-67, by Captain Haig and Lieutenant Trotter, to the parallel of 14½°, where the operations were suspended. During the present field season it has been resumed and completed by extension southwards until it formed a junction with the Longitudinal Series which connects Mangalore with Madras.

PERSONNEL.

Major B. R. Branfill, Depy. Supdt. 2nd Grade.
Lieut. McCullagh, R.E., Asst. „ 1st „
Mr. J. W. Mitchell, Asst. Surveyor 1st „
„ O. V. Norris, „ „ 3rd „
„ C. D. Potter, „ „ 3rd „
„ E. W. Laseron, „ „ 3rd „

(34.) The recent operations have been performed by Major Branfill and Lieutenant McCullagh, who also completed a few triangles on the Longitudinal Series the measurement of which had been arrested by a variety of untoward circumstances during the preceding field season. When the survey party commenced operations this year, so large an amount of work had to be performed to forge the remaining links which were required to connect and complete the two chains of triangles, that the chances against its being done in one season were very considerable. The work was almost too much to be finished in the given time, but on the other hand it was too little to occupy two field seasons profitably. Such instances are not of unfrequent occurrence in the operations of this Department, and they occasion much anxiety; for when triangulation is completed in one part of the country it may—and very generally does—happen that the nearest point at which the surveyors can be profitably employed is several hundred miles distant, and thus a great portion of the naturally limited and too short field season is liable to be devoted to the unremunerative occupation of marching from one place to another.

(35.) In the present instance there was not only a large amount of work to be done, but the most of it lay on the crests of the Western Ghats in a region as to which Lieutenant Trotter had reported—at the close of his operations in 1867—that "the progress of the future operations will now be necessarily slow, the physical features of the country and the bad climate being both difficult to overcome; the country over which the principal triangulation will pass is very hilly, wild and thinly populated, and carriage is only to be procured with great difficulty."

(36.) The design of the triangulation had been laid out some years previously, but there was reason to fear that this important work had not been done with sufficient circumspection and care, for two instances had already been met with in which certain of the stations selected were found to be mutually invisible, whereby great delay was occasioned, for the observations had to be suspended until new stations had been selected and constructed; thus this essential portion of the operations required to be carefully examined, which added in no small measure to the labors of the field season.

(37.) Warned by past experience of the delays to which operations in Southern India are liable when commenced early in the season, before the cessation of the autumnal rains of the north-east monsoon, Major Branfill deputed Lieutenant McCullagh to the northernmost portion of the triangulation, to commence observations in the district in which the influence of the monsoon is least felt; thus favorable weather was secured and the observations of the principal angles were carried on continuously without any hindrance. Meanwhile Major Branfill proceeded in person to examine the stations already selected, and finding that the original plan, if adhered to, would entail the crossing and recrossing of the ghats such a number of times as to cause great delay, and render it impossible to complete the operations in the desired time, he re-modelled it in such a manner as to remedy this defect as far as practicable, and thus contributed in no small measure to the success of the season's operations.

(38.) The out-turn of work is as follows; 59 angles were measured at 19 principal stations forming two polygonal and two quadrilateral figures, which extend over a direct meridional distance of 105 miles, embrace an area of 3,330 square miles and complete the connection between the Mangalore meridional and longitudinal series; the positions and heights of 74 secondary stations, and the positions of 53 unvisited points, have been fixed. These results are the more satisfactory in that much of the marching about had to be done on foot, the roads—or rather foot-paths—being in many instances impracticable for horses.

(39.) Three of the principal stations newly laid down are those at which astronomical observations for latitude had been taken last year by Captain Campbell, and one of these—in the neighbourhood of Mangalore—is the western extremity of the Madras arc of parallel, the measurement of which has been undertaken during the present season and which will be described in section X of this report. An azimuth of verification was measured by Lieutenant McCullagh at one of Captain Campbell's stations to the north, and another at the same time by Major Branfill at Mangalore, a second great theodolite having been sent round by steamer from the Mathematical Instrument Department at Calcutta for the purpose, which was returned on the conclusion of the observations.

(40.) On the return of the party to recess quarters the reduction of the principal observations was taken in hand, and it was found that the geodetic elements of the triangles from the Bider base-line and the Bombay longitudinal series agree very closely with those of the triangles from the Bangalore base, and the Mangalore longitudinal series; the length of the circuit formed by the triangulation is about 1,050 miles, and the discrepancies at the side of junction are as follows; linear, 0·06 inches per mile—or almost exactly the millionth part of the side—in latitude 0″·07, in longitude 0″·19, in azimuth 3″·09, and in height 5 feet. These results are at present provisional only, but it is improbable that they will be materially altered, and they may be accepted as a satisfactory evidence of the accuracy of the operations, when the length of the circuit of triangulation thus completed and closed is taken into consideration.

NO. VI.—TRIGONOMETRICAL.

THE BRAHMAPUTRA SERIES, MERIDIAN 90°.

(41.) The operations on this series, during the two previous field seasons 1870-72, had been entirely restricted to the preliminary work of selecting sites for stations, erecting towers on them, and clearing the intermediate lines; thus the field season now under review was mostly devoted to the measurement of the principal angles and to secondary work.

(42.) Captain Carter took the field at an early date, with an establishment composed for the most part of the surveyors who had worked with him on the spirit-leveling operations of the previous year, as the surveyors hitherto employed on the Brahmaputra Series had been transferred to the triangulation in Assam. He and all his assistants were new to the ground, but nevertheless satisfactory progress was made.

PERSONNEL.

Captain Carter, R.E., Deputy Supdt. 2nd Grade.
Mr. A. W. Donnelly, Surveyor 2nd Grade.
„ C. J. Neuville,* „ „
„ H. Healy, Assistant Surveyor 4th Grade.
Narsing Dass, Sub-surveyor.
Amjad Alli, do.

* Mr. Neuville was on leave of absence on medical certificate during the entire field season.

(43.) At the outset considerable delay was occasioned in consequence of one of the towers at the side of extension previously completed having been washed away by the river. A new station had therefore to be built and connected with those behind before any further advance could be made. 16 principal triangles—forming two polygonal figures and the greater part of a third—were completed; they embrace an area of 865 square miles, wholly in the plains, and extend over a direct distance of 56 miles.

(44.) This was Captain Carter's first season's performance in principal triangulation, his work in this Survey having hitherto been mostly topographical—in Kashmir and Ladak, and in Kumaon and Garhwal—and geographical, as when he served with the Abyssinian expedition and on the Peshawar frontier. He was much let and hindered by unfavorable atmospheric conditions throughout almost the entire field season; during the mornings for several hours after sunrise the country in which he was working was covered with a dense fog of mists and exhalations; in the evenings this was succeeded by the smoke of the village fires which were generally impenetrable to the lights of the signal lamps; thus observations during the night, which is usually the most favorable time of all for them, were rarely practicable, and as a rule they could only be taken during a few hours before sun-set to heliotropes; towards the end of March even the light reflected from heliotropes could not penetrate the dense smoke then caused by the burning of the grass and rice-stubble which is always done at that time of the year. The only chance then remaining of being able to prosecute the observations was in getting a fall of rain to clear the atmosphere; but this year little rain fell up to the end of April, by which time the whole party was more or less prostrated by fever and over-exertion. Thus Captain Carter was reluctantly obliged to close work before he had completed his last polygon, but he succeeded in carrying the operations up to a point sufficiently near the terminus of the series to render it highly probable that the triangulation will be completed during the ensuing field season.

(45.) A series of secondary triangles was carried eastwards from the principal series to fix the town of Mymensingh.

No. VII—TOPOGRAPHICAL.

THE SURVEY OF KATTYWAR.

(46.) The operations of this survey have made very good progress, an area of 2,642 square miles having been topographically surveyed, and an area of 2,680 square miles triangulated in advance for the work of next year. This large out-turn is due in some measure to the circumstance that the topographical operations lay chiefly in the northern portions of Jhalawar, in a bare and sterile country which is bordered on the north by the Runn of Kutch, and presents few features for survey as compared with the rich districts to the south. 740 miles of Taluka boundary lines have been traversed with the theodolite and chain, as well as 409 miles of lines to check the detail work of the plane-tablers.

PERSONNEL.

Captain H. Trotter, R.E., Dy. Supdt. 3rd Grade, in charge up to 6th April 1873, when relieved by Capt. A. Pullan, S.C., Offg., Dy. Supdt. 3rd Grade.
J. McGill Esqr., Assistant Superintendent.
Mr. F. Ryall, Surveyor 4th Grade.
" J. Wood, ditto 4th "
" N. C. Gwynne, Assistant Surveyor 1st Grade.
" T. Rendell, ditto 1st "
" E. Wyatt, ditto 2nd "
" W. Fielding, ditto 3rd "

Native Surveyors.

Vissaji Ragonath, Govindji Mahala, Narsu Dinkar and seven others.

(47.) The topography of the eastern half of the province has now been nearly completed, the operations having been advanced westwards to within a short distance of Rajkote, the chief town in the province. Of this town a survey will be made, on the scale of 12 inches to the mile, during the ensuing field season. When the operations of the general survey reach the shores of the Gulf of Cutch, every effort will be made to connect them with the survey of that Gulf which was made by Lieutenant Taylor, I. N.; the original maps of the survey have been lost, but Lieutenant Taylor had fortunately retained copies for his own use, and lithographs of these have been made in England and sent out to this country.

(48.) Shortly before the termination of the field season Captain Trotter was withdrawn from the charge of the operations, and his services were placed at the disposal of the Foreign Department, with a view to his joining the mission which is about to be sent by the Government of India to the Atalik Ghazi, the present Ruler of Eastern Turkestan.

(49.) The boundary traverse lines have all been reduced and found to stand the usual tests in a satisfactory manner; there are fourteen circuits whose united lengths amount to 149 miles, and which close with an average error of 0·49 per 1,000, and there are forty-five traverses between trigonometrical stations, the united lengths of which amount to 590 miles, and whose average difference from the corresponding trigonometrical values is 1·04 per 1,000; the greater discrepancy in the second instance is clearly due to a slight, but practically unimportant error in the unit of length of the measuring chains as compared with that of the triangulation.

(50.) The operations of the year have been reported on by Captain Pullan; but Captain Trotter has furnished some interesting memoranda—which will be found at page 27-a of the appendix—descriptive of the aspect of the country surveyed and of the adjoining portion of the Runn of Cutch; also of the salt works recently established by the British Government in the neighbourhood of the Runn, at Patri, which place has been connected with the Bombay and Baroda line of railway, by a branch line from the station of Viramgám.

NO. VIII—TOPOGRAPHICAL.

THE SURVEY OF GUZERAT.

(51.) The operations of this survey, during the present year, embrace the topography of portions of the Kaira collectorate, the whole of the Pitlád Mahal of the territory of the Gaikwar of Baroda, and nearly the whole of the Cambay territory. The area finally completed was 1,175 square miles, in addition to which an area of 791 square miles was triangulated, and 773 linear miles of traverses were executed in advance for future topographical operations.

PERSONNEL.

Major C. T. Haig, R.E., Offg. Dy. Supdt.		1st	Grade.
Captain A. Pullan, S.C., Asst.	Do.	1st	„
Mr. A. D'Souza,	Surveyor	2nd	„
„ A. Christie, Asst. Surveyor		1st	„
„ C. H. McAFee,	ditto	1st	„
„ E. J. Connor,	ditto	2nd	„
„ J. Hickie,	ditto	3rd	„
„ G. D. Cusson,	ditto	3rd	„
„ G. T. Hall,	ditto	4th	„

Sub-Surveyors.

Gopal Vishnu and eight others.

Revenue Surveyors.

Mr. A. Dalzell, Asst. Supdt. and 4 Native Surveyors.

(52.) When this survey of Guzerat was commenced I had reason to hope that much of the work of the elaborate Revenue Surveys of the British portions of the Province might be combined with it, so as to permit of the construction of a good topographical map on a scale considerably larger than that of the standard scale—one inch to the mile $= \frac{1}{63360}$—of the Indian Topographical Surveys. Captain Nasmyth, who had been deputed to examine the revenue maps, had reported "that "they contained a variety of details which will suffice for ordinary engineering "requirements in the laying out of railways, tramroads and canals for irrigation, "such as the growing necessities of this fruitful province are evermore urgently "demanding." Subsequently however, when the practical test of going over the ground and determining the true distances between the boundary pillars of the villages and other obligatory points was applied, by the operations of this survey, large discrepancies were met with in so many instances as to create an impression—on the part of the Executive Officers—that the revenue maps were not to be relied on for topographical purposes, and that any attempt to utilize them would be more laborious, in the long run, than to make a new survey of the entire province.

(53.) But in India topographical surveys are invariably executed by the method of plane-tabling on a basis of points fixed by triangulation or traverses, and not by the ordinary land-surveyor's method of chain measurements. For surveys on small scales, plane-tabling suffices admirably, and it is unquestionably the best method that could have been devised for the preliminary or first survey of India; it is particularly well suited for the delineation of unwooded hill tracts and broken ground; it is moreover admirably adapted for surveys of Native States which do not need to be very elaborately executed, for it may be carried on without any chain-measurements, operations which are liable to cause considerable suspicion and alarm in the native mind. But I am of opinion that it is very ill adapted for the survey of such a country as Guzerat, which is a rich and fertile plain covered with trees and habitations, and with numerous high enclosures which cut off the view in all directions, and embarrass operations which can only be carried on satisfactorily when the surveyor is able to see three or four of his surrounding fixed points. Moreover the process of plane-tabling is not susceptible of being independently checked and verified in as satisfactory a manner as that of chain measurement, and consequently much has to be trusted to the skill and integrity of the surveyor. Another objection—and one of the gravest of all—is that there is no numerical record of the angular and linear determinations, such as would facilitate references to clear up disputed points as to boundaries and other matters, or to permit of the work being mapped on a larger scale whenever it may be desirable to do so; thus before an enlarged map could be constructed it would be necessary to make a new survey of all the details of the ground, and only the triangulation and traverses on which the first survey was based would be available for the second.

(54.) For these reasons, and because geographical maps of Guzerat are already available, which—though much inferior to the preliminary maps of the Survey Department—have for many years been made to suffice for general purposes, it is obvious that the present topographical survey of Guzerat should be so conducted as to furnish maps of greater general utility than the standard preliminary maps of the Department. This can only be accomplished by supplementing the triangulation and the traverses on which the subsequent work is based by a considerable amount of accurate chain measurement of the details of the ground, and then commencing the plane-tabling, which would thus become rather an examination of the previous work and the means of giving the finishing touches, than what it now is—the sole means of acquiring all the details.

(55.) But the present organization of Topographical Survey Parties is not well adapted for operations which involve the laborious and slow process of chain measuring; it consists of a highly paid staff of surveyors—mostly Europeans—who are skilled in the use of the theodolite and the plane-table, and many of whom possess considerable artistic skill in the delineation of the features of the ground, an operation for which European agency is always desirable, as natives of this country are rarely met with who can do it well. Moreover it is not desirable to employ natives in positions in which they must be trusted and yet cannot be very closely supervised without going through examinations which are almost as laborious as the original operations. Consequently as a rule there are very few native surveyors in the establishment of a topographical party. But chain measuring is a process which natives can be readily taught to execute with all the requisite accuracy and which can be made self-verificatory, and on which it is therefore not desirable to employ a highly paid staff of Europeans. Consequently a large increase in the proportion of the native to the European element would have to be made before a topographical party would be in a position to undertake operations which involve considerable additional labor, without causing a material increase in the cost of the Survey, as measured by the relation between the actual outlay and the area surveyed.

(56.) But as all changes of organization take some time to carry out, it will be evident that the only prospect of obtaining a more detailed and elaborate survey of Guzerat than the standard preliminary survey of other parts of India, by means of the agency which was available for the purpose, lay in combining with the topographical operations the results of the extensive measurements of minute details which had already been executed by the revenue surveyors. It is true that those measurements had not been performed with any pretensions to a high order of accuracy; the idea of conducting them in such a manner as to serve the purpose of a general survey had been discussed at the outset and deliberately set aside, on the grounds that the doing so would imperil the success of the financial operations, which were deemed of greatest importance. Thus it had come to pass that each village had been surveyed and mapped separately, without any attempt to make a systematic connection of the several surveys, which were consequently isolated. Nevertheless a considerable amount of minute detail had been measured, and in many places with considerable care; the principal marks to which the measures had been referred were still in existence, and their positions could be fixed by the operations of the topographical surveyors; and thus a combination could be effected which might reasonably be expected to give a much larger amount of minute detail, and more accurate results, than mere plane-tabling over ground which is pre-eminently unsuited for such a system of survey.

(57.) The first attempts which were made to incorporate the revenue survey details failed, apparently for two seasons; *first*, the original marks which were fixed by the topographical surveyors were so few that the intermediate details had to be fitted in by combining several of the village maps together, and it was found that this could not be done satisfactorily; and *secondly*, the marks which were selected to be fixed were almost invariably situated on the exterior boundaries of the village lands and rarely in the interior, whereas—for reasons which will now be explained—the interior marks would have been best adapted for the purpose. In the Bombay Revenue Surveys a system of operation has been followed which is diametrically opposite to that of the corresponding surveys in Bengal; one or more so-called 'base lines' are always measured in the interior of the village lands, in the first instance, and all subsequent measures are referred to these lines by off-sets; whereas in Bengal the periphery of the village is first surveyed, and all the interior details are subsequently referred to it. The Bombay system necessarily gives greatest accuracy in the central portions and least on the exterior boundary lines of the villages, while the converse is the case with the Bengal system; the former is unsuited, *per se*, for effecting a combination of the village maps into a general map, whereas the latter is peculiarly well adapted for this purpose, and it is mainly owing to this circumstance that the revenue operations in Bengal have been so valuable for topographical purposes, while in Bombay every attempt to construct general maps from the revenue materials has hitherto failed altogether or met with very qualified success.

(58.) Immediately after my return to India I proceeded to Poona—where the Offices of the Guzerat and Kattywar Survey parties are established during the recess—with the object of inspecting the operations, and more particularly of ascertaining what had been or could be done towards utilizing the revenue survey materials. I found that little had been done hitherto, but that Major Haig was fully alive to the importance of the measure and much more sanguine as to its feasibility than any of his predecessors had been. I had consultations with Colonels Francis and Prescott, under whose superintendence the Revenue Surveys had been carried out, the details of which I wished to combine with the topographical operations. Eventually the conclusion was arrived at that in order to effect a satisfactory combination it would be necessary for Major Haig to be supplied with all the data of the revenue survey measurements, as given in the original field books, in addition to the lithographed village maps which had hitherto been the only materials available for the purpose. This however would necessitate a certain amount of co-operation on the part of the revenue surveyors with those of this survey, for the field books had been prepared in a manner which was intelligible only to persons familiar with the details of the operations and not to any one else; and they were written in the Guzerati language, not in English, the language in which all the records of this survey are kept; thus it was obviously desirable that a few of the revenue surveyors should be attached to the topographical survey, and placed at Major Haig's disposal, in order to enable him to reap the full benefits of the work which had been already done and to effect the requisite combination with his own work.

(59.) In the month of January a memorandum was drawn up, conjointly by Colonel Prescott and Major Haig, on the steps to be taken for detaching an officer and one of the native establishments of the Revenue Survey from their ordinary duties, and placing them at Major Haig's disposal. The said native establishments are usually comprised of surveyors only, and not of chain and flag-men or other underlings, for the services of such men are usually provided *gratis* by the villages in which the fiscal operations are being carried on. But in the operations of the professional survey these men are paid for by the Government, and their wages form a considerable portion of the cost of the survey. The sanctioned cost of a revenue native establishment is Rs. 500 per mensem, and it was found that of this sum only two-fifths could be devoted to provide for surveyors and that three-fifths were required for the underlings. It was therefore proposed that a certain number of surveyors, whose aggregate salaries would not exceed Rs. 200 a month, should be drafted into the party to be formed to work under Major Haig, and that the sum of Rs. 300 should be made available for the wages of the underlings; also that Mr. A. Dalzell, Assistant Superintendent of the Revenue Survey, should be attached to the party. These proposals were speedily sanctioned by the Bombay Government.

(60.) It was not however until the 25th February, when the greater portion of the field season had passed, that Major Haig was joined by Mr. Dalzell and the native establishment, and was able to commence the long contemplated operations. Thus not very much work could be done, and it is still premature to draw any positive conclusions as to the result of the experiment. Major Haig reports that what has been done is sufficient to prove that great use may be made of the revenue survey materials in improving the accuracy of the topographical maps, when a more extensive and systematic connection is made between the fixed points of the two surveys than had previously been attempted; he also anticipates that the combination—when supplemented by the addition of the topographical details which have hitherto been purposely omitted from the revenue maps,—will permit of the construction of topographical maps of all the British portions of Guzerat on the scale of four inches to the mile, instead of the standard scale of one inch to the mile, and that this will be effected "with a proportional amount of additional detail and accuracy in minutiæ, for which improvement the public will be indebted to the Guzerat Revenue Survey." I sincerely trust that these anticipations will be realized, and I am very sure that Major Haig and his assistants will do their best to secure so desirable a result.

NO. IX.—TOPOGRAPHICAL.

HIMALAYAN SURVEYS IN KUMAON AND GURHWAL.

PERSONNEL.

Lieut. J. Hill, R.E., Offg. Dy. Supdt.	3rd	Grade.
" H. J. Harman, R.E., Asst. Supdt.	2nd	Grade.
E. C. Ryall, Esq., Asst. Supdt.	2nd	"
Mr. J. Peyton, Surveyor,	2nd	"
" J. Low, "	3rd	"
" L. Pocock, Assistant Surveyor,	1st	"
" H. Todd, "	2nd	"
" T. Kinney, "	3rd	"
" E. F. Litchfield, "	"	"
" I. Pocock "	4th	"

(61.) Considerable progress has been made in the Survey of the British Districts of Kumaon and Gurhwal, which has been for two years under the executive charge of Lieutenant J. Hill, R.E. Topographical operations were carried on in the Mána Valley, in the lake country to the east of Nainí Tál, in the country round Lohúr Ghát, in the portions of the Gori and Rámganga valleys which lie in the vicinity of Askot, and in the part of the Sub-Himalayan tracts known as the Bhábar pergunnahs which is situated between Haldwáni and the Sardah River.

(62.) The district under survey has a range of over 25,000 feet in altitude, from the level of the lands at the southern foot of the Himalayas to that of the summits of the peaks of the great mountain chains in the interior; it consequently presents every variation of climate, from that of the lowlands of the Terai which are deadly during—and for several months after—the rainy season, to the regions of glaciers and perpetual snows which are only accessible during a few months of summer; this prevents the work being carried continuously over the entire district, and necessitates the employment of the surveyors in different localities at different times of the year, and thus entails the expenditure of a considerable portion of the field season in merely marching about; for the surveyors have frequently to be transferred considerable distances from ground where they can work no longer, to other ground where they can be advantageously employed. It is further inconvenient in retarding the completion of the maps, and preventing the publication of the successive sheets in continuous order, as is generally done in other surveys.

(63.) During the year an area of 2,734 square miles has been topographically surveyed on the scale of one inch to the mile, and 353 square miles were triangulated in advance for future operations. This is a larger out-turn of work for the number of persons engaged than I am altogether prepared to welcome; for many difficulties and drawbacks were met with. In the higher ranges the winter set in unusually early and with exceptional severity, and elsewhere there was much fog and rain; the health of the surveyors was not good, three of them breaking down altogether; and labor was very scarce and difficult to procure, in the Bhábar more particularly, where cholera was rife among the inhabitants, who were leaving their homes panic-stricken. On the other hand a considerable portion of the area topographically surveyed is at an altitude ranging from 10,000 to 25,000 feet above the sea level, where the operations were necessarily restricted to sketching the principal features of the country without any attempt to obtain great accuracy or much minutiæ of detail, and the survey could be carried on with considerable rapidity. Lieutenant Hill examined a considerable portion of the work which has been done, and his report of the performances of the several surveyors is generally most satisfactory.

(64.) Lieutenant Hill has appended to his report an interesting table showing the average rate of work *per diem*, in square miles, in different portions of the district under survey. He finds that in the higher ranges, where the operations partake of the nature of a reconnoisance, from 9 to 14 square miles were surveyed daily; but that in the moderately high ground of the Sub-Himalayas the rate was about 3 square miles; in all the instances from which these calculations were made, the ground had been triangulated before hand and points fixed for the plane-table sketching of the topographical surveyors, whose rapidity of progress and accuracy of delineation is greatly dependent on the number of points previously laid down for them on the ground, and projected on their plane-table sheets, before they commence operations.

NO. X.—GEODETIC.

ELECTRO-TELEGRAPHIC DETERMINATIONS OF DIFFERENCES OF LONGITUDE, ON THE PARALLEL OF 13°.

(65.) All great national surveys have, for many years past, been made to contribute data for the determination of the figure of the earth; hitherto these data have mainly consisted of measurements of the distances between successive points situated on or near a common meridian, and of the astronomical arcs of amplitude between these points; it is only of late years that attempts have been made to obtain corresponding data from measurements of the distances between points situated on a common parallel of latitude, and of the astronomical arcs of amplitude between them. The reason of this is that the required astronomical data are very readily obtained in the case of meridional arcs, by determining the latitudes of the geodetic points, which is one of the simplest problems of practical astronomy; but on arcs of parallel longitudes are required instead of latitudes, and the astronomical determination of an absolute longitude—within the requisite limits of precision—is well nigh impracticable, and it could only be accomplished by observations extending over very long periods, with most expensive and elaborate instruments. Differential operations have therefore been resorted to instead of absolute determinations; the chronometric method of deducing differences of longitude has been frequently employed, and with very valuable results wherever it has been practicable to employ a large number of chronometers, and to transmit them backwards and forwards repeatedly by sea; but on land this method is not satisfactory because of the jolting to which the chronometers are more or less subjected in transport from station to station, and which necessarily tends to alter their rate and affect their performances. When however places are connected telegraphically, their differences of longitude can be determined with great precision; and thus of late years advantage has been taken of the nets of wires which overspread large portions of Europe and of America, to determine differences of longitude with the aid thus afforded. In America these operations were required for geographical purposes only; but in Europe, which is covered with a net of triangulation of which there is as yet no counterpart beyond the Atlantic, and which amply suffices for geographical purposes, their chief interest lay in their value for geodetic investigations, and they were undertaken mainly with the object of throwing light on the figure of the earth.

(66.) Exactly eleven years ago I obtained the sanction of the Secretary of State and the Government of India to a recommendation which I had submitted sometime previously that a set of first class instruments, with all the latest improvements, should be constructed in Europe and sent out here to be used for geodetic operations in connection with the triangulation of this survey and the Government lines of telegraph. In the year 1863 Colonel Strange was appointed by the Secretary of State to design and superintend the construction of the requisite instruments, or to procure such instruments as had already been constructed and were suitable for the purpose.

(67.) In 1871-72, the following instruments were received in this country; two transit instruments of 5 inches effective aperture and 5 feet focal length, designed by Colonel Strange and constructed by Messrs. Cooke and Sons of York; two astronomical clocks, by the Messrs. Frodsham of London; two chronographs designed by Mr. Foucault and constructed in Paris by Messrs. Secretan and Hardy; also various relays, batteries and other electrical apparatus.

(68.) I determined to employ these instruments, in the first instance, on the arc of parallel which crosses the southern peninsula in latitude 13°, and extends from Madras on the east to Mangalore on the west coast, passing through Bangalore about midway. There are telegraph stations at each of these places, and great facilities for communication between them, Madras being connected with Bangalore by a direct line of railroad, and with Mangalore by the railroad to the port of Beypore on the west coast, between which and the port of Mangalore steamers are constantly plying. These were very important advantages to secure at the commencement of operations the early stages of which would necessarily be of a tentative and experimental nature, for every thing had to be learnt of the capabilities of the instruments and the telegraphic lines by which the stations of observations would be connected, and thus it was most desirable that the operators should be able to meet each other readily, to discuss and elaborate their programme of operations, and also to compare their personal equations.

(69.) The arc of parallel which was selected, for the preceding reasons, as that on which to commence the electro-telegraphic determinations of longitudes, is moreover of peculiar interest in that it is situated much nearer to the equator than any similar arc which has yet been measured in any part of the globe, or is likely to be measured for many years to come, for such operations must necessarily be restricted to Europe and India until other regions have been trigonometrically surveyed as they have been. The arc may be deemed a short one, and terminating as it does at both ends on oceans it is obviously incapable of extension; yet its length is 5° 24′ 12″ or about 364 miles, which is by no means insignificant, though it is small in comparison with the lengths of the arcs which will be measured hereafter in Central and Northern India. Moreover it was on this arc of parallel that Colonel Lambton first endeavored, in the years 1802-5, to determine the length of a degree of longitude by the method of observing the astronomical latitudes and azimuths of a series of reciprocating stations along it, a method which—though ill adapted to low latitudes—was the only one then feasible for him to employ.

Thus it will be seen that circumstances have necessitated the selection of the same parallel of latitude for the commencement of the determination of longitudinal arcs, by the modern electro-telegraphic method, that was chosen at the commencement of the present century by Colonel Lambton for his corresponding investigations.

(70.) When the requisite instruments arrived in this country they were forwarded to Bangalore, where Captain J. Herschel, R.E., and Captain W. M. Campbell, R.E., were quartered. As both these officers had been employed for several years in astronomical operations, and Captain Campbell had spent several months in the office of the India Store Department in London, in assisting Colonel Strange to examine the instruments on their receipt from the makers, I selected them to carry out the operations, and I have every reason to be gratified with the manner in which they have accomplished the duty assigned to them.

(71.) They commenced proceedings by setting up the two sets of instruments at a distance of about fifty feet apart, in the compound of a house at Bangalore, to test their performances, and at the same time to acquire a practical familiarity with their manipulation; this work occupied nearly two months of the field season. In January the instruments were dismantled and removed; one set was taken to the north the other to the south end of the base-line which had been measured in the vicinity of Bangalore in the year 1868; a temporary telegraph line had been previously erected to connect the ends of the base, the length of which is nearly 7 miles; thus an opportunity was afforded of taking observations at stations sufficiently remote from each other to present difficulties similar to—though not quite so great as—those which would eventually be met with on long lines, but yet close enough to permit the operators to meet each other daily for the purpose of comparing their results and making such modifications as were found to be necessary from time to time; moreover as the stations of observation were also stations of the triangulation, the results would be valuable eventually for determinations of differences of local attraction on the prime vertical, as well as for the primary object of experimenting. The month of February was devoted to observations at the stations at the ends of the Bangalore base-line, during the first half of which Captain Herschel operated at the south end and Captain Campbell at the north end, while during the second half their positions were reversed.

PERSONNEL.

Capt. J. Herschel, R.E.,	Depy. Supdt.	2nd	Grade.
„ W. M. Campbell, R.E.,	„	3rd	„
Mr. G. Belcham, Asst. Surveyor,		1st	„
„ J. Bond,	„	2nd	„

(72.) In the following month operations were commenced on the line Madras to Bangalore. The station of observation at Madras was the well known Government Observatory which has been established there for so many years and is the point to which the longitudes of the stations of this survey have invariably been referred; at Bangalore the station was the south end of the base-line, which had been connected for the purpose with the Government telegraph lines, as the Madras Observatory had been many years previously.

(73.) And now for the first time Captains Herschel and Campbell found themselves hampered with the difficulty of employing a telegraphic wire which could only be placed at their exclusive disposal for a few periods and those very brief. Though the operations were invariably performed during the night, when the ordinary traffic on telegraph lines is comparatively little, it was found that the unrestricted use of a wire could, as a rule, be only conceded for four periods of fifteen minutes each, at intervals of two hours apart; on two nights however the use of the wire was granted for two hours at a time, but the then unfavorable state of the weather at Madras prevented this concession from being taken to account there. Under the circumstances it was fortunate that the operators had already acquired, from their previous experiments, a sufficient familiarity with the details of the operations to enable them to make the most of the golden moments thus charily presented to them.

(74.) The operations at Madras were conducted by Captain Campbell, and on their completion in April, he proceeded with his instruments to Mangalore, established an observatory at the trigonometrical station in the neighbourhood, and connected it by a temporary line of telegraph with the permanent line which passes through the town, at a distance of about three quarters of a mile. The operations at the Bangalore Station were conducted throughout by Captain Herschel.

(75.) In the Narrative Reports of Captains Herschel and Campbell—which are printed in the appendix—full details will be found of the procedure of the operations, as well as minute descriptions of the several instruments employed, with elaborate criticisms of their performances which point out both their defects and their good qualities. It is unnecessary for me to do more in this place than to give a brief summary of those reports.

(76.) Two methods of procedure were adopted, depending on the length of time for which the exclusive use of the Government telegraph line could be secured. When the period was limited to a quarter of an hour at a time, signals were interchanged for clock comparisons four times nightly, *viz.*, at 8*h* 30*m*, 10*h* 30*m*, 12*h* 30*m*, and 2*h* 30*m*; the clock at one station being placed in communication with the chronograph at the other station was made to transmit a series of signals—at successive seconds—to that station, which were duly recorded on the chronograph; then the clock at the second station was made to transmit signals to the chronograph at the first; one minute was considered the minimum duration of a set of signals, and a complete comparison of both clocks usually occupied from three to five minutes. The clock times were determined by observations of the transits of stars over the meridians of the stations, the same stars being observed at both stations; these observations were taken in the intervals between the signals for clock-comparisons; from 6 to 10 stars were observed in each interval, giving—in a full night's work—complete pairs of observations at both stations to 40 or 50 stars. For this method any star is well suited, whether its place is known or not, provided observations are also taken to a few wellknown stars, to determine the clock rates which are wanted for application to the short interval between the transit of a star over the two meridians, which corresponds to the difference of longitude. This precaution was taken and thus the choice of stars was unrestricted.

(77.) Another method of procedure was adopted on the nights when the exclusive use of the line was granted for a period of two hours; the transit observations for determining the clock times were recorded on the chronographs at both stations, first by the observer at the eastern station as a star passed over his meridian, and a few minutes afterwards by the observer at the western station when the same star reached his meridian; observations were also taken as in the other instance, for local clock rates. Of the two methods pursued this is unquestionably the most satisfactory, but it could only be employed very partially.

(78.) The operations would thus appear to be very simple and easy, and they may in truth be carried out with little trouble when the object aimed at is solely to obtain determinations of differential-longitude of a sufficient degree of accuracy for ordinary geographical purposes. But the requirements of geodesy necessitate that the utmost attainable accuracy and precision shall be secured in every stage of the operations for the solution of the problem; and this entails a careful scrutiny of all the facts of observation, and an elaborate examination of the errors which may arise from defects in the several portions of the instrumental apparatus, as well as from the "personal equations" of the operators. These errors are all very minute, and some of them are very difficult to measure and to eliminate from the observations, but they must be investigated and eliminated, or the final results will not be entirely trustworthy. They were chiefly met with in the performances of one of the transit instruments and one of the chronographs, in the management of the chronographic record, and in the transmission of signals along the line; but the determination of the personal equations of the operators was singularly satisfactory, though it happens to be the weak point of all electro-telegraphic longitude observations in Europe and America of which I possess the details.

(79.) The two transit instruments are of almost identical dimensions and were both made by Messrs. Cooke & Sons; but No. 1 was constructed partially or wholly—it is uncertain which—of aluminium bronze, and No. 2 of gun metal throughout. No. 1 appears to be faultless; but No. 2 is defective, and liable to a kind of flexure—occurring either in the tube or in the axis—which causes the horizontal collimation to vary considerably with the direction of motion of the telescope, the collimator readings being 1″ greater when the telescope is brought down from the zenith than when it is raised up from the nadir. The two chronographs are called **A** and **B**; they are apparently precisely similar in construction, but the regulator of **B** has a uniformly continuous action, whereas that of **A** acts by jerks; the fact was known to the makers but they failed to trace the cause, which is still undiscovered; the result is that **B** is considered "a miracle of regularity" while **A** is pronounced "very provoking."

(80.) The chronographic record consists of a mark made on the paper covering the revolving barrel by the passage through it of an electric spark of high tension, which is generated in a Ruhmkorff's coil by the interruption of a strong galvanic current from a Bunsen battery. Both the clock-beats and the observer's signals are thus recorded on the paper. The electric sparks pass into the paper from the points of two pens or styles—one in connexion with the clock, the other with the observer's tappet—which are attached to a frame that moves parallel to the revolving barrel. To each Ruhmkorff's coil a relay and a battery is attached. Two galvanic circuits are formed, one connecting a primary battery, a relay and its battery and coil with the clock and chronograph, the other connecting a similar apparatus with the observer and the chronograph. Signals are in all instances caused by a break of the current from a primary battery, which is performed automatically by the clock and at will by the observer.

(81.) The introduction of a relay necessarily causes a certain amount of retardation between the generation of a signal and its record on the paper, the magnitude of which is mainly dependent on the adjustments of the armature of the relay through which the current is passing, and as two relays must be employed errors may be caused by differences in their action. Fortunately such differences are susceptible of being accurately measured on the chronograph-barrel, by special operations for the purpose which are described in para. 33 of Captain Campbell's report; but it is necessary that a strict similarity of circumstances to what obtained during the actual signals should be maintained during the measurement of retardation. Captain Herschel writes that "constancy of "current is the *sine qua non* of a correct handling of retardation; *ergo* equality "under these circumstances must be attained; every relay must have its own "battery, and these must all be equal; and the line must have a battery of its "own so apportioned that the long circuit current shall balance the short circuit "current."

(82.) The line wires between the stations at Madras, Bangalore and Mangalore were connected continuously without the intervention of relays; thus the difficulties presented by relays were fortunately restricted to the observatories, where alone it was possible to measure and allow for the amount of retardation which was generated.

(83.) It was surmized that in transmitting currents along the line wires there might be a difference between the velocity of transmission of positive and of negative currents, and that the presence of earth currents might affect the velocities of the galvanic currents, accelerating in one direction and retarding in the opposite. The following values of the actual times of transmission of positive and negative currents, in both directions, were obtained on the two sections of the line, the length of wire in the eastern section being 218 miles, in the western 245 miles.

	Madras to Bangalore	Bangalore to Mangalore.
From east to west with positive current,	0·010 *second*	0·028 *second*
,, west to east ,, ,,	·010 ,,	0·022 ,,
,, east to west ,, negative ,,	·014 ,,	0·003 ,,
,, west to east ,, ,, ,,	·014 ,,	0·011 ,,

These results show that no sensible influence, in one direction more than the other, was exerted by earth currents. The velocity of the positive galvanic current was somewhat greater than that of the negative in the eastern section, but materially less in the western. Captain Campbell attributes some of the large difference in the latter instance to relay action.

(84.) The general mean of all the determinations gives a velocity of 17,000 miles per second, which is materially greater than the velocities deduced in the course of similar operations in Europe and America; as however several relays were used on those lines and none on these, such a difference is only what might have been anticipated.

(85.) It will be apparent from what I have stated that Captains Herschel and Campbell have conducted their operations with scrupulous care, and devoted themselves to the elimination of all errors, however minute, which were liable to be generated. From their reports it will be seen that they met with great difficulties in the manipulation of the Foucault-chronographs; these instruments are of a very complicated construction; moreover the recording paper on the barrels requires to be kept at a certain degree of moistness, and if it is either a little too dry or little too damp the electric spark fails to make a mark on it; its state is therefore greatly dependent on that of the atmosphere; thus in the dry climate of Bangalore in February, Captain Campbell could scarcely keep his paper damp enough, whereas a week afterwards, at Madras, he was obliged to have a lamp burning under it to prevent it from being too damp.

(86.) The employment of chronographs permits of a large number of observations being taken with very little additional trouble at the time, as compared with a corresponding increase in the number of 'eye and ear' observations. But on the other hand the subsequent labor of reducing the observations is greatly increased, for every mark on the paper has to be measured and its position tabulated numerically. Up to the present time the observations on the line Bangalore to Mangalore have been reduced as far as practicable, but they may still require certain corrections for the flexure of transit instrument No. 2; those on the line Madras to Bangalore and on the base-line at Bangalore have only been partially reduced.

(87.) The following preliminary results have been obtained, which will probably be found not to differ very materially from the final results. For the sake of comparison they are placed side by side with the corresponding differences of longitude obtained from the chain of triangles recently completed by Major Branfill.

	Telegraphic.			Trigonometrical.		
	h.	m.	s.	h.	m.	s.
I. Madras to Bangalore, ...	0	10	39·09	0	10	39·61
II. Bangalore to Mangalore, ...	0	10	56·76	0	10	57·17
Madras to Mangalore, ...	0	21	35·85	0	21	36·78

The telegraphic determinations are in both instances less than the trigonometrical, on the first section by $0^s.52$ (second of time), on the second by $0^s.41$, and on the entire line by $0^s.93$, which is equivalent to $13''.95$ (seconds of arc.)

(88.) The values of the individual sections of the telegraphic arc are somewhat impaired by reason of the defects of transit instrument No. 2 and chronograph A which have already been mentioned. But as those instruments were used at the central station throughout, while the superior instruments—transit No. 1 and chronograph B—were used at the two end stations, the errors in the sections must cancel each other to a considerable extent in the determination of the entire arc, the value of which may be legitimately compared with the corresponding trigonometrical determination.

(89.) The latitudes and longitudes of the stations of this Survey have for the last forty years been computed with the following elements of the figure of the earth, which are generally known as Everest's first set of Constants, and are given at page 115 of the *Account of the Measurement of an Arc between the Parallels of* 18° 3′ *and* 24° 7′, *London* 1830;

equatorial semi-axis 20,922,932 feet; ellipticity $\frac{1}{300.80}$.

Subsequent investigations have slightly modified these dimensions of the mean figure, and Captain Clarke gives the following elements in the appendix to his *Comparisons of the Standards of length, London* 1866;

equatorial semi-axis 20,926,062 feet; ellipticity $\frac{1}{294\cdot98}$.

(90.) Using Captain Clarke's elements instead of Colonel Everest's, the trigonometrical determination of the difference of longitude between Madras and Mangalore would be diminished by 3″·5, and thus be brought into better accordance with the telegraphic difference, which however it would still exceed by 10″·5. There is at present little reason to suppose that further investigations of the mean figure of the earth, or corrections to the telegraphic determination, will very appreciably reduce this difference. We are thus met by the fact that the telegraphic value of the arc of longitude between Madras and Mangalore is materially less than the trigonometrical value. This fact is however consistent with the results of Captain Basevi's pendulum observations, which show that the density of the strata of the earth's crust is greater under the depressed beds of oceans than it is under lands elevated above the sea level; thus the direction of the plumb line at Madras, on the east coast of the continent, is most probably deflected to the east of the normal to the mean figure, while at Mangalore the direction of the plumb line is deflected to the west of the corresponding normal; the length of the arc between the apparent zenith points is consequently diminished and must therefore be less than the length deduced from trigonometrical operations.

(91.) Captain Herschel having been compelled to take leave of absence to Europe shortly after the completion of the observations, the work of reduction has devolved mainly on Captain Campbell, who has reported very fully on it, and has also described very minutely the instruments, the *modus operandi* and the difficulties which were met with in the several stages of the operations.

(92.) Captain Campbell bears grateful testimony to the attention and courtesy which were rendered to him, on all occasions, by the officers of the Telegraph Department with whom he was brought into contact, mentioning more particularly Messrs. J. Burke and W. P. Johnston; and he adds that his best thanks are also due to Mr. Pogson, the Government Astronomer at Madras, who took a pleasure in facilitating his operations in every possible way.

No. XI.—GEODETIC.

ASTRONOMICAL DETERMINATIONS OF LATITUDE.

(93.) The observations to determine the astronomical latitudes of certain stations of this survey for geodetic purposes were held in abeyance during the present year, as the two astronomical parties under Captains Herschel and Campbell, by which they had been carried on, were both employed on the longitude observations which have just been described. The reductions of the observations of the previous year which were remaining in hand have however been completed, and Captain Campbell has devoted much attention to investigating the cause and the effects of a serious defect which has been found to exist in zenith sector No. 2, and is of the nature of flexure in the tube of the telescope. The cause has not yet been clearly traced, but the effects are found to be very sensible, and the value of the results might have been materially impaired but for the precaution which had fortunately been taken to observe pairs of north and south stars, whereby the influence of the error was eliminated. The sister zenith sector No. 1 has fortunately shown no trace of this error, and has given great satisfaction to Captain Herschel. It is a singular circumstance that one of the two zenith sectors, as well as one of the two transit telescopes, should turn out to be defective, while the other instrument of the pair is entirely satisfactory, and there is no apparent difference of construction which could cause the difference of performance.

No. XII—GEODETIC.

THE PENDULUM OPERATIONS.

(94.) Captain Heaviside, having been nominated to complete the pendulum operations which were suspended in consequence of the death of Captain Basevi, was employed for some time in acquiring a knowledge of the manipulation of the pendulums and the reduction of the observations. He then commenced operations by swinging the two pendulums appertaining to the Royal Society at Kaliana—the base-station of the operations in India—to ascertain whether they had varied in length since they were swung there in 1870, before being taken to the higher Himalayas by Captain Basevi. This was the more necessary in that on the occurrence of the sudden death of that officer, at a remote spot on the elevated table lands of Ladak, they had to be dismantled and packed up by his native servants, without supervision of any kind, no European being within a distance of several marches; that these men did their work carefully and well is shown by the fact that the results obtained by Captain Heaviside at Kaliana, are practically identical with those obtained by Captain Basevi nearly three years previously, which proves that the pendulums cannot have met with any sensible injury in the interim.

PERSONNEL.

Captain W. J. Heaviside, R. E., Deputy Superintendent 3rd Grade.
Mr. H. E. Keelan, Surveyor 3rd Grade.
„ J. W. Macdougall, Asst. Surveyor 2nd Grade.

(95.) This fact established Captain Heaviside proceeded to complete the original programme of operations, swinging the pendulums at Bombay, at Aden, in Egypt, and finally at Kew the base-station in England.

(96.) Simultaneously with the observations with the Royal Society's pendulums, Captain Heaviside has taken observations with the pair of pendulums belonging to the Russian Imperial Academy of Science which were sent out to India in 1870 for the purpose of being compared with those of the Royal Society. The Russian pendulums may be employed to determine either an absolute value of the length of the second's pendulum, or differential values of the force of gravity at different places. Absolute determinations have been made at Kaliana and at Kew, and differential ones at Bombay, Aden and Ismailia.

(97.) Captain Heaviside, when last heard from, was still in England and was preparing to repeat the determination of the length of the second's pendulum, with the same "convertible pendulum" which had been used for this purpose by Captain Kater in 1817, and which has been placed at his disposal by General Sir E. Sabine. This undertaking will form a very appropriate finale to the operations. On its completion, Captain Heaviside will return to India, and commence the final reduction of the several observations, in order that the results may be published as soon as possible.

No. XIII.—TIDAL.

DETERMINATIONS OF MEAN-SEA LEVEL.

(98.) In my administration report for 1866-67 I stated that proposals had emanated from Dr. Oldham, the Superintendent of the Geological Survey, and been sanctioned by the Government of India, to the effect that investigations should be made of the secular changes in the relative level of land and sea which were believed to be going on at various places on the coasts of the Bombay Presidency and more particularly at the head of the Gulf of Cutch. For these investigations it would be necessary to take complete series of tidal observations, at intervals of a few years apart, at a certain number of points on the coast lines, and to connect these points by very carefully executed lines of levels. I was called on to undertake the operations, and I had procured a number of self-registering tide-gauges from England and was about to have them erected and the work commenced, when I was suddenly required to take steps for an immediate and very considerable reduction of expenditure, in consequence of the financial difficulties in 1869-70 ; the operations were therefore postponed *sine die*. They are now being resumed.

(99.) The delay which has thus taken place is not to be regretted, as I am now in a position to have the investigations carried on in a more complete and elaborate manner than had been originally contemplated, and consequently to acquire fuller, more comprehensive and more accurate results than were at first desired. Happening to be present at the meeting (at Edinburgh) of the British Association for the Advancement of Science, in 1871, I ascertained that a committee of the association—presided over by Sir William Thomson—had initiated a system of tidal investigations which was anticipated to secure scientific results of the highest value. On studying the details of these operations I found that my original programme, which contemplated tidal observations of only a few week's duration, would be inadequate to detect the existence of minute secular changes in the relations of land and sea, and that no conclusive results could be obtained unless the observations were carried over a period of rather more than a year at the commencement and a corresponding period at the close of the term of the investigation. I further saw that if this were done the value of the operations would be greatly increased, for the results would not only serve the purpose for which they were originally contemplated, bnt would materially contribute towards the attainment of the better knowledge of the laws of the tides which is considered by the British Association to be so important a desideratum, and which is expected to lead to an evaluation of the mass of the moon, to definite information regarding the rigidity of the earth, to an approximation of the depth of the sea from the observed velocities of tide-waves, to the retardation of the earth's rotation due to tidal friction, and also to the various practical benefits which must accrue from accurate predictions of the height of the tide at any given time.

(100.) For these reasons I submitted a proposition to the Secretary of State that Lieutenant Baird R. E., Assistant Superintendent, who was then in England on furlough, should be deputed to study the practical details of the method of tidal registration, and of the harmonic analysis of the observations, which are recommended and practised by the tidal committee of the British Association. My proposals were sanctioned and Lieutenant Baird was employed for some months under my directions in doing what was wanted.

(101.) Mr. Adie—the well known optician and mathematical instrument maker—had constructed the self-registering tide-gauges which had been previously sent out to India, and of which the most remarkable feature is their unusually long barrels (length five feet) which were provided in order that the tidal curves might be drawn on the largest scales practicable; he was requested to supply another tide-gauge on the same pattern but with a few modifications which appeared desirable, the most important of which was the substitution of a chronometer escapement instead of a pendulum or gravity escapement for the driving clock, in order to permit of the instrument being erected on positions where the concussions of the sea-waves would interfere with and perhaps stop the action of a pendulum clock. Lieutenant Baird made an experimental trial of the performances of this tide-gauge at Chatham, the results of which were very satisfactory.

(102.) It is well known that the rise and fall of the tides on a line of coast is materially influenced by the direction and force of the winds, and that it also varies inversely with changes in the barometric pressure. Thus no tidal registrations can be deemed complete without simultaneous registrations of the conditions of the atmosphere. Consequently a supply of self-recording anemometers and barometers was obtained, in order that every tidal station should be supplied with one of each of these instruments. The anemometers register both direction and velocity, and are similar in design to Beckley's anemometer, but are very much smaller in order to be light and portable; the barometers are aneroids, for no mercurial self-registering barometers were met with which could be safely carried about. These instruments were all constructed under my instructions by Mr. Adie, and though they are by no means faultless they may be relied on to give fairly approximate results which will be of some value and vastly better than nothing at all. Mr. Adie has also supplied other instruments which will materially facilitate the preparation of the diagrams for the barrels of the tide-gauges and the subsequent measurements of the curves on the diagrams.

(103.) One of the principal duties on which Lieutenant Baird was employed in England was the preparation of an account of the practical application of the harmonic analysis by which tidal observations are reduced for the British Association. The procedure leads to much more definite and conclusive results than what are afforded by any other method of reduction, but it is exceedingly intricate; though perhaps not more laborious in the long run than other methods would be, when manipulated so as to furnish results of equal precision and bearing on such a wide range of subjects, it needs very full and precise explanations for the guidance of the computers. Lieutenant Baird went through the whole of the details with Mr. Roberts of the Nautical Almanac Office by whom the tidal reductions are made for the British Association; and with that gentleman's aid he drew up a pamphlet of Notes on the subject, for the use of the Officers of this Department, which has been published by order of the Secretary of State, and fills 51 pages of closely printed octavo.

(104.) On my return to India I deputed Lieutenant Baird to make a reconnoisance of the coasts of the Gulf of Cutch, with a view to selecting tidal stations and more particularly to determine in what manner the instructions which I had received from the Government to establish a station "at a point as far into the Runn of Cutch as possible to which the tide has free access," could be best carried out. For a point to have free access with the sea it is necessary that it should always have at least 4 or 5 feet of water at lowest tides, and also that the sea should approach it directly and not through tortuous channels; the point must also be either on the edge of the main land or at no great distance beyond, because of the difficulty and expense of constructing a station on the fore-shore. From what I had previously heard of the Gulf of Cutch I was apprehensive that it might not be possible to find a point at the edge of the Runn which would satisfy all the requisite conditions.

(105.) Lieutenant Baird proceeded in the first instance to Júria Bandar (Jooria Bunder), where he fitted up a large country boat to be used in navigating the creeks and channels of the gulf, and secured the services of a good pilot to accompany him in his explorations; the selection turned out to be a very fortunate one as the pilot knew almost every creek and mud-flat on both the Cutch and the Kattywar coasts of the gulf. Embarking at Júria, Lieutenant Baird crossed to Nowanár Point on the Cutch coast, where he found a spot which is well adapted for tidal observations, having a minimum depth of 19 feet of water within 336 feet of a site for a station. He then proceeded eastwards towards the head of the gulf, along a coast which for a considerable distance presents a great breadth of fore-shore—composed of mud of great depth with mangrove bushes growing over it—and is covered at high tide and left bare at low water. After long searching he was fortunate in discovering a position near Hanstál Point, at the head of the gulf, which is well adapted for a tidal station, having a minimum depth of 72 feet of water within 160 feet of a site for an observatory. Lieutenant Baird then returned westwards along the Kattywar coast, examining all the creeks and inlets, and finding nothing but long muddy fore-shores, until he reached Okha Point at the entrance to the gulf; there he met with a rocky fore-shore having a minimum depth of 23 feet of water within 220 feet of a site for a tidal station. The three places selected appear to be well adapted for the proposed operations, which is the more fortunate in that Lieutenant Baird believes them to be the only suitable points which are to be met with for the purpose; the only matter for regret is that an intermediate point could not be found on the Kattywar coast between Okha and Hanstál, for Nowanár being on the opposite coast will require to be connected with the two other stations by a very long line of levels passing round the head of the gulf.

(106.) Lieutenant Baird derived much assistance in his explorations from the admirable charts which were constructed by Lieutenant A. D. Taylor of the Indian Navy, in 1851, copies of which, on the full scale of the original survey, had been recently lithographed in England on my recommendation.

(107.) The feasibility of establishing stations at suitable points having been thus satisfactorily ascertained, the preliminary arrangements were then taken in hand. The question whether it would be preferable to set up the tide-gauges on stages erected in the sea beyond the low water line, or on masonry platforms constructed on shore at the high water line, was carefully considered; obviously it is desirable that the communication between the surface of the ocean and the gauge which registers the momentary variations of level should be as direct as possible, in order that the tidal curve may be accurately delineated; but it would be impossible, without incurring great expense, to construct a staging in the sea of sufficient strength and permanence to serve for two series of observations, each lasting more than a year and separated by an interval of several years. For this reason it has been decided to construct the stations on shore, at the line of high water.

(108.) The following arrangement has been adopted. Masonry wells of a diameter of about three feet will be sunk at the stations to a depth of several feet below the lowest tides; in these wells iron cylinders, of a diameter slightly exceeding that of the float of the tide-gauge, will be set up vertically and eventually connected with the sea by an iron piping carried along the shore down to the low water line, where a flexible piping will be attached and carried into deep water. The cylinders will be closed below with an iron plate, to prevent the entrance of the water which may be expected to percolate through the sides of the well whenever the tide is falling. The flexible piping will terminate in a rose suspended a few feet above the bed of the sea, in order to prevent the entrance of silt as much as possible, and it will be attached to the iron piping in such a manner that it may be readily removed and cleaned whenever necessary. The interior diameter of the piping will be two inches, which has been computed to be sufficient to permit of the transmission of the tidal wave from the sea to the cylinder in the well, without sensible retardation, so that the height of the water in the cylinder may be expected to be always the same as that of the surface of the sea. The tide-gauges will be set up over the cylinders, and their iron bed-plates will indicate the planes to which the tidal measurements will be referred, and they will be connected by leveling with permanent bench-marks fixed in the ground in the vicinity of the stations.

(109.) Lieutenant Baird has been employed during several months at Bombay in making all the requisite arrangements. Cylinders have been constructed in suitable lengths to be easily transported to the tidal stations and then put together. The tide-gauges have been tested by employing them to register the tides in the harbour of Bombay for several weeks continuously, and sundry alterations and improvements have been made to them. The self-registering barometers and anemometers were tested at the same time, and the injuries they had received in transit out to this country and from the rusting of portions of the working gear have been repaired. Every thing has been done which could be thought of to ensure the instruments being found in a satisfactory condition when they are set up for work at the tidal stations. It was a matter of great importance to have all this done at Bombay, where there are excellent workshops and skilled artificers, for such advantages are not to be met with in the places where the instruments will be set up for observation. In all these operations Lieutenant Baird received much assistance from Major Merewether R.E., who permitted him to have full use of the workshops and artificers of the Bombay Harbour Defences, and allowed him a site for testing the tide-gauges.

(110.) Lieutenant Baird is now engaged in constructing the stations on the coasts of the gulf of Cutch, and when they are ready the observations will be commenced. He has worked with great assiduity and skill, and with a hearty interest which I trust will be rewarded in due time by the successful completion of the operations.

NO. XIV.—GEOGRAPHICAL.

TRANS-HIMALAYAN EXPLORATIONS.

(111.) For some years past it has been customary to publish with the annual Reports of this Survey an account by Major Montgomerie of one or more special explorations executed by his native agents. Ill health has unfortunately deprived the State of the services of this officer, but I trust for only a short time; he has gone to Europe, taking with him the maps and journals of an exploration—by one of the Pundits—from Shitgatzé north-eastwards to the great Namchú Lake, and then southwards to Lhassa, of which he was to have prepared an account for publication with this Report; but as it has not yet been received it must be published separately hereafter.

(112.) Explorations are being carried on at the present time in various directions. A Pathán has been sent to the region beyond the Hindú Kúsh range, with instructions to penetrate if possible into the *terra incognita* to the north of the river Oxus, into Shighnán, Roshán, Darwáz and Kárategin. One of the Pundits has been sent into the part of Great Thibet which lies beyond the northern watershed of the Brahmaputra River. Four of the Pundits have been attached to the Mission which has been recently sent into Eastern Turkestan, in the expectation that they may be able to make their way back to India by various routes through the Desert of Gobi and Great Thibet which are closed to Europeans.

(113.) I very much regret to state that intelligence has been received of the murder of the Mirza, whose exploration of the route from Badakshan across the Pamir steppe to Kashgar is described by Major Montgomerie in a paper accompanying my Report for 1869-70, and is a valuable contribution to the geography of those regions. The Mirza had been sent on a second exploration with his son-in-law as an assistant. He had to travel through Afghanistan and at first he was able to send in reports of his progress pretty regularly; but for several months he had not been heard of, and at last a rumor was received that he had been murdered. Enquiries have been instituted, but as yet no very definite information has been obtained. It appears probable however that he had traversed the road from Herat to Maimana, and was proceeding northwards, when he and his companion were murdered by their guides during the night while asleep; a servant is said to have escaped and given information which led to the apprehension and subsequent execution of the murderers, by order of the Governor of Maimana. At first there was reason to hope that the rumor might have been unfounded; for the Mirza was believed to have been exploring in the direction of Hissár and Kárategin, far away from the place where the crime is said to have been committed; but as no letters have been received from him for nearly a year, and he would probably have returned some months ago had he lived, it is to be feared that this faithful and intelligent emissary has fallen a victim, and that his son-in-law who accompanied him perished at the same time. Endeavors are being made to obtain full information on the subject, and to get possession of any of the Mirza's papers which may be still forthcoming.

(114.) Enquiries are being made with a view to secure the services of a few natives of Assam who are privileged to enter the hills north of the valley which are occupied by independent tribes, with a view to training them to make explorations in those hills in the first instance and afterwards in the regions beyond, and more particularly to make a survey of the portion of the Brahmaputra River which as yet has not been explored. The replies which have hitherto been received from the district officers show that there will be great difficulty in getting suitable persons for the explorations, but I still hope that it may be managed by Mr. Beverley, who is conducting the triangulation of Assam and has been requested to take this matter in hand.

(115.) But the quarter from which I have most reason to expect soon to receive valuable and exact geographical information is Eastern Turkestan. On learning from Mr. Forsyth that he was about to be deputed on a mission to the Atalik Ghazi, I strongly urged the necessity of his being accompanied by an Officer of this Department, to undertake the duties of a geographer and turn to account any opportunities which might be presented of exploring regions of which little or nothing is at present known. Mr. Forsyth cordially entered into my views, and supported the proposals which I submitted to the Government of India, by whom they were favourably received. Captain Henry Trotter, R.E., who was then conducting the Survey of Kattywar, was consequently placed at the disposal of the Foreign Department and appointed a member of Mr. Forsyth's Mission. Pending the return from Constantinople of the Atalik Ghazi's Envoy who was to accompany the Mission, Captain Trotter spent some time at my head-quarters in practising such astronomical observations as would be required, and more particularly those for the determination of absolute longitudes; forms were prepared and printed for facilitating the reduction of the observations, in order that they might be computed out on the spot and immediately utilized in the construction of a map of the country, because far more comprehensive and satisfactory results should thus be obtained than when the observations are reduced and the map constructed some time afterwards. Captain Trotter was well equipped with instruments, all of which are of the lightest and most portable kinds suited to his requirements, and he was furnished with charts on which the fixed points of the Indian triangulation to the south and the Russian astronomical determinations to the north had been projected, to facilitate his own operations in the intervening region. Two other officers attached to the Mission, Captain Chapman, R.A., and Captain Biddulph, A. D. C. to the Viceroy, spent a short time at my head-quarters in practising observations and reductions, with a view to utilizing any opportunities which may be presented should they be detached from the head-quarters of the Mission on independent explorations. A Kashmiri surveyor—of the Rajputana Survey—and four of the Pundits have been sent with Captain Trotter. I have done all in my power to promote the success of the geographical operations, and in my next annual report I hope to be able to announce that a rich harvest of results has been secured.

NO. XV.—THE COMPUTING OFFICE.

EXAMINATION, FINAL REDUCTION AND PUBLICATION OF THE OBSERVATIONS.

116. The Computing Office has been employed in its usual duties of carefully examining and reducing the observations, and publishing the ultimate results of such portions as have been finally treated and the preliminary results of the pro-

PERSONNEL.

J. B. N. Hennessey, Esq., Depy. Supdt. 1st Grade
W. H. Cole, Esq., Asst. Supdt. 1st Grade

Computing Branch.

Mr. C. Wood, Surveyor 3rd Grade
" H. W. Peychers, Asst. Surveyor 1st Grade
Baboo Gunga Purshad, Computer
" Cally Mohun Ghose. Computer
" Kully Coomar Chatterjee, Computer and 11 other Native Computers

Printing Branch.

Mr. M. J. O'Connor
and 18 Native Compositors and Distributers

Photozincographic Branch.

Mr. C. G. Ollenbach
" C. Dyson, with 2 Native Draftsmen &c.

Drawing Branch.

Mr. G. W. Atkinson, Surveyor 4th Grade,
Shaikh Saidudeen and 5 Native Draftsmen also 18 Assistants and Apprentices

tions which await further data before they can be finally disposed of. One of the principal features of the year's labors has been a re-adjustment of the secondary triangulation which is based on the several principal series appertaining to the so called North-West Quadrilateral, which embraces the operations of this Survey in the area lying to the north of a line running westwards from Sironj (in Central India) to Kurrachee, and to the west of a line running from Sironj to the Himalayas. Another important operation is the passing through the press of the observations, reductions and final results of the principal triangulation of the North-West Quadrilateral, which is now all but completed, and will furnish sufficient matter to fill two thick quarto volumes which will be numbered III and IV of the *Account of the Operations &c.*

117. As the whole of the contents of these volumes will not be needed by geographers and surveyors, an abstract or synopsis is being prepared which will give the descriptions and co-ordinates of the stations, and the sides and angles of the triangles, of the principal triangulation, and also the corresponding data of the secondary triangulation. This information will be published in a separate volume for each of the principal series, in which form it will be most convenient for the public in general. The first of these synopses is now nearly ready for issue; it is devoted to the operations of and emanating from or otherwise connected with the chain of triangles known as the Great Indus Series, and will contain—*inter alia*—the positions of the whole of the points that have been fixed beyond the British Frontier, points situated mostly on the spurs of the Hindú Kúsh range, and on the Safed Koh and Súlimáni ranges and their spurs.

118. The general principles on which the reduction of the observations is conducted have been described in sufficient detail in the annual reports for the last five years which have been submitted by myself and by Major Montgomerie; it is unnecessary therefore for me to say more on the subject in this place than that the operations are very laborious and require constant and vigorous supervision, and that I have every reason to be indebted to Mr. Hennessey for the assiduity with which he devotes himself to the direction of the computing office and its several branches, and to acknowledge the skill which he brings to bear on the many matters which come under his consideration. Mr. Cole also has rendered a variety of most valuable services which I am very pleased to have this opportunity of acknowledging.

NO. XVI.—CARTOGRAPHY.

119. The most interesting of the maps which have been prepared and published during the current year is the second edition of my map of Turkestan, of which the first edition was published in four consecutive sheets in 1867-68. So great has been the progress of geographical exploration in the last five years that

the map had become insufficient for present requirements, and it needed numerous corrections and additions. As the value of a map of this nature—which has necessarily to be compiled from a variety of sources, some very much more reliable than others—is greatly enhanced by a knowledge of the authorities from which the data have been derived, I drew up a memorandum on the subject in a paper which is entitled " Notes on the Maps of Central Asia and Turkestan which have been published in the Office of the Great Trigonometrical Survey of India," and of which copies were issued with the second edition of the map ; a copy is also appended to this report. While the map was passing through the press additional information was received of the geography of Khiva and portions of northern Persia which necessitated the publication of an "Addendum" with it. Shortly afterwards further information was received, and consequently Re-prints of sheets No. 1 and 3 have been published, which embody all the latest information received up to the present date. To these re-prints a note has been attached explanatory of the alterations and additions, and a copy of this note is also appended.

(120.) The northern boundary of the territories of the Maharajah of Kashmir has been brought back in the second edition of the Turkestan map to a considerable distance within the line indicated on the first edition of the map, and and in my notes I state that this had been done on the authority of Mr. Forsyth. I had followed the delineation given in the map of Eastern Turkestan which was compiled in the Surveyor General's office in 1871, under Mr. Forsyth's superintendence, to illustrate his report of his first journey to Yarkand; in that map the the altered boundary line is shown, but on the authority—as it now appears—of a map constructed by the late Mr. Hayward, which Mr. Forsyth had furnished to be used in the compilation of his own map, unfortunately without stating that he objected to the alteration. Under the circumstances it is to be regretted that any alteration was made, and that Mr. Forsyth should have been brought forward as the authority for a line of boundary to which he strenuously objects.

(121) During my absence from India Major Montgomerie commenced the compilation of a series of "Trans Frontier Maps," on the scale of 16 miles to the inch, containing all the most recent information of the regions beyond the British Frontier. These maps are prepared on a skeleton form, showing the positions of towns, villages and mountain passes and the course of the river, but omitting the hills. The following have now been published; No. 4, comprising portions of Afghanistan, Kafiristan, Badakshan, Bokhara, Karategin, Swat, Bajour, Panjkora, and Chitral; No. 7, comprising Chilas, Gilgit, Yassin, Kunjut, Sirikul, the Pamir Steppe, Kashgar, Yarkand, Khotan, and part of Chinese Thibet; and No. 9, comprising Nepaul, Sikkim and portions of Bootan and Great Thibet.

(122.) Good progress has been made with the series of Level-Charts on which the results of the leveling operations for Canals, Railways and other public works are shown, after having been connected with the main lines of level of this Survey and reduced to the same datum, *viz.* the mean sea level at Kurrachee. Sheets No. 8, 10, and 23 (see accompanying Index Chart) have been published and No. 6 and 26 are in a very advanced state.

(123.) In addition to the above, twenty preliminary charts of the triangulation in various parts of India have been published, and several final charts are in hand which will be published with the synopses of the results of the triangulation. A large amount of miscellaneous work has been performed, and an improved system has been introduced for the examination of the maps received from the Survey Parties. By the photozincographic process 21,171 copies of charts, maps and diagrams have been printed of which 8,443 have been colored by hand for issue to the public and to Government officials, and 12,549 copies of forms for calculations and office work have been zincographed for the current requirements of the department.

(124.) It now only remains for me to acknowledge the valuable services which have been rendered by my Personal Assistant Mr. H. Duhan, and by Mr. Robert Scott, whose multifarious duties in connection with the corresponding office and as general store-keeper have been very carefully performed.

(125.) An abstract of the out-turn of work executed by each of the survey parties whose work can be exhibited in this form is given on the following page. I am happy to be able to express my opinion that the progress made on all sides during the year, by the Survey Parties in the field and in recess, and by the Offices at Head Quarters, has been generally most satisfactory.

J. T. WALKER, COLONEL, R.E.,
Supdt. Great Trigonometrical Survey.

DEHRA DOON,
Dated 9th January 1874.

Abstract of the out-turn of work executed by the Great Trigonometrical Survey Parties, during the Official year 1872-73.

Description of Details.	1 Biláspur Meridian S. Sec. 36-inch Theodolite.	2 Biláspur Meridian N. Sec. 24-inch Theodolite.	3 Assam Valley Triangulation. 12-inch Theodolite.	4 Jodhpore Meridian. 24-inch Theodolite.	5 Mangalore Triangulation. 24-inch Theodolite.	6 Brahmaputra Triangulation. 24-inch Theodolite.	7 Kattywar Survey.	8 Guzerat Survey.	9 Kumaon & Gurhwal Survey.	Total.
Number of Principal Stations, newly fixed, ...	15	8	...	12	17	13	...	...	...	65
Number of Principal Triangles, completed, ...	21	16	...	14	25	16	...	...	...	92
Area of Principal Triangulation, in square miles,	2364	680	...	3706	3330	845	...	...	...	10,925
Lengths of Principal Series, in miles, ...	96	54	...	95	105	56	...	...	...	406
Average Triangular error, in seconds, ...	0·45	0·36	...	0·33	0·65	0·94	...	...	...	...
Average Probable errors of Angles, in seconds, ±	0·16	0·21	...	0·15	0·14	0·29	...	...	...	...
Azimuths of verification, ...	1	1	...	1	2	2	...	...	...	7
Number of Secondary Stations whose positions and heights have been fixed, ...	83	...	51	15	74	1	358	109	82	773
Number of Secondary Stations whose positions only have been fixed, ...	...	...	...	...	...	...	731	19	13	763
Number of Secondary Triangles of which all 3 angles have been observed, ...	108	...	2	15	91	54	244	168	22	644
Length of Secondary Series in miles, ...	...	...	10	...	...	44	...	...	...	54
Area of Secondary and Minor Triangulation in square miles, ...	5075	...	7290	2443	4064	...	2680	791	353	22,696
Number of Points fixed by intersection, but not visited, ...	205	...	56	50	53	15	945	499	66	1,889
Length of boundary lines and check lines surveyed in linear miles, ...	...	...	...	...	...	...	1148	773	573	2,494
Area Topographically surveyed on scale of 1 inch = 1 mile, in square miles, ...	...	...	...	...	...	...	...	...	2734	2,734
„ Topographically surveyed on scale of 2 inches = 1 mile, in square miles, ...	...	...	...	...	...	...	2642	1236	...	3,878
Number of Revenue Survey Stations and boundary pillars, fixed, ...	...	...	3	...	...	1	?	104	41	149
Do. of Principal Stations selected in advance, ...	...	...	8	13	7	...	...	...	...	28
Lengths of Approximate Series, Principal, in miles, ...	...	...	45	147	36	...	...	...	...	228
Number of Towers constructed, ...	...	...	...	...	1	4	...	...	...	5
Do. of Platforms constructed for Principal Stations, ...	2	6	...	25	7	5	...	...	...	45
Do. of Platforms constructed for Secondary Stations, ...	18	...	...	...	7	4	...	...	...	29
Do. Miles of Rays cleared, ...	...	...	89	...	...	34	...	...	481	604
Do. Miles of path-way made, ...	280	12	...	15	14	10	...	...	...	331
Do. Hill tops cleared of forests and jungle,	80	6	2	...	9	...	...	...	43	140
Do. Principal Stations whose elements were computed, ...	13	8	4	22	5	16	...	...	...	68
Do. Secondary Stations whose elements were computed, ...	9	...	56	102	27	54	?	?	203	451
Do. Preliminary Charts of Triangulation,	1	1	1	1	1	1	...	...	...	6
Do. Principal Stations placed under official protection, ...	30	7	4	...	20	...	...	...	...	61
Do. Stations protected and closed, ...	30	1	4	43	24	13	...	...	...	115
Do. Points whose Longitutes have been determined, ...	...	...	...	...	...	...	...	...	...	...
Do. Aneroid observations for determination of height, ...	...	...	...	...	165	...	?	?	?	165

APPENDIX.

EXTRACTS FROM THE NARRATIVE REPORTS

OF THE

EXECUTIVE OFFICERS IN CHARGE

OF THE

SURVEY PARTIES AND OPERATIONS.

Extract from the Narrative Report—dated 15th July 1873—of W. C. ROSSENRODE, ESQ., Deputy Superintendent 3rd Grade, in charge Southern Section Bilaspur Series.

(3.) On receipt of my Narrative Report and rough chart of last season, Major Montgomerie, R.E., remarked "In brief I cannot accept principal triangulation devoid of secondary work and on this point I must call your attention to letter No. $\frac{22}{994}$, dated 21st October 1868, from the Superintendent G. T. Survey."

(4.) Mr. Bell rejoined the party on the 26th October last, and before commencing field operations I arranged the following programme for accomplishing the utmost quantity of secondary work, in compliance with your orders to the late Mr. Shelverton above cited. My shortcomings the previous season were attributable, not to inattention to your orders, but to a paucity of assistants, owing to which, I could not execute the secondary work you desired. For the same reason another important duty could not be attended to; the construction of rectangular pillars, and the handing over of the stations completed to the local authorities. I endeavoured during the late field season to accomplish both, by detaching all the three assistants to carry out your wishes, retaining only a native writer to assist me in the observatory and in office duties,

MR. BEVERLEY	To determine the positions of the towns of Jaipur and Jagdalpur, the residences of the Rájas of Jaipur and Bastar; to lay down all towns and villages within the principal triangulation of the first polygon and a half, and to fix the position of the civil station of Koráput.
MR. BELL	Was assigned the remaining polygon and a half, and he was instructed to determine the positions of all important places.
MR. WRIXON	To construct rectangular pillars, and to place the completed stations under the protection of the local authorities. He was also directed to execute as much secondary work as he possibly could within the principal triangulation completed the previous season.

(5.) I had much difficulty in entertaining men and cattle to proceed with me on field duty. The inhabitants of Wálter, Vizagapatam and Vizianagaram, dread the Jaipur and Bastar jungles, owing to their unhealthiness. The men who had hired their bullocks the previous season, for conveying the baggage of the party, demanded extra hire. Fresh men were engaged by paying eight annas per bullock in excess of last season's hire; their agreements were taken on stamped paper, and by advancing them a month's hire for each bullock, I secured the full complement of baggage cattle for the whole party. The bearers who had carried the great theodolite would on no account take service, owing to 5 deaths having occurred the previous season after their return to recess quarters. I was in a measure prepared for this, and arranged for bearers from Hazáribágh who had served with me in Assám, Cachar, Tipperah, Chittagong and Arracan.

(6.) All preliminary arrangements having been made the lampmen left Wálter on the 14th November to occupy their respective stations. The main camp followed on the 20th and reached Sálúr, a large town, on the 28th by stages. Here heavy rain fell, and continued day and night without intermission until the afternoon of the 1st December.

(7.) I apprehended much sickness in camp owing to the continuous wet weather; the men were without proper food, and had to sleep on the damp ground; the straw was wet, and nothing dry could be obtained. A large quantity of wood was purchased, fires were made for the men to dry their clothes, and to keep them warm. My fears however were groundless; with the usual precaution of administering quinine to the men, and removing them at once, when the rain ceased, to the high hills of the Koráput range, the health of the party remained good.

(9.) I reached Burdwar, my first station, where I closed operations the previous season, on the 10th December, completed work on the 12th and marched next day to the secondary station of Amá. From thence I proceeded to Sirsi H.S. where I arrived on the 19th: that very night an epidemic broke out among the pack bullocks, 4 of which died on the 20th, 2 more casualties occurred the next day, and I lost five others before I reached Motigáon H.S. on the 24th December. Having lost 11 baggage bullocks I separated those which were stricken from those which had not taken the disease. The former were sent by easy stages to the station in advance where I intended observing an azimuth. This arrangement saved the cattle, but sickness broke out in camp; the Hospital Assistant, the Obsevatory Recorder, the Jamadár and 10 other men were prostrated with fever. I removed the camp from the foot of the hill in the forest to an open elevated spot near the village of Motigáon, three miles distant from the station; and after completing my observations, I marched to Karia H.S., taking the sick men with me to the station, and locating the whole camp on the summit of the hill. I lost one man on the 1st January 1873 and the others gradually recovered.

(10.) On completing my observations at Motigáon, H.S., I wrote to Mr. Beverley to join me at Karia H.S.: I had only a native recorder and he was prostrated with fever. Mr. Beverley was of very great assistance, for he not only recorded, but aided me in reading the microscopes. Karia was the centre of a hexagon and the azimuth observations were taken here, and with Mr. Beverley's assistance I completed my work rapidly. I am very much indebted to him for aiding me, and taking part in the observations. The 8 day's halt at Karia materially assisted in re-establishing the health of the camp. Fresh bullocks were purchased to replace the 11 which succumbed to the cattle plague, and being set up I made a fresh start and proceeded to Lambidongri H.S. Mr. Beverley resumed his secondary triangulation.

(11.) Lambidongri is situated on the highest point of an extensive plateau thickly wooded. The signal party who had preceded me made a good clearance for the camp: on my arrival I had many more trees felled, the grass and under growth was cut and removed, fires were lighted round the encampment after the night observations and were tended, fed and kept burning till the morning; every precaution was taken to ensure the health of the party, but during the three days I was detained there 16 fresh cases of fever occurred.

(12.) The remainder of the season the camp was never free from sickness; the Hospital Assistant suffered very much. He was a hale, hearty, active man when he left for the field; he returned a mere skeleton, devoid of energy. The Jamadár after lingering for upwards of two months died on the 4th March at Jerar village at the foot of Deodongri H.S.

(13.) It was impossible to move about with so many sick and feeble men, I therefore established depôts for them, selecting the most open, and healthy localities, and removing them as I advanced with the work. It may not be out of place to mention that at one time I had 36 men in hospital; berkandazes, kalasies, bearers and camp followers.

(14.) The final operations made good progress notwithstanding the crippled state of the establishment. The stand of the theodolite and telescope were carried by coolies, and coolies did mostly all the work, under the directions of the few effective men in camp: all the principal men including the Tindal were ill, I was myself suffering from fever. To be able to continue my duties I had recourse to large doses of quinine daily, which brought on partial deafness. I may here remark that not a single man escaped the fever of the country, even the cooks who are generally the most healthy, owing to their constant proximity to the purifying influence of fire, suffered repeatedly this season. The fever however was not of a virulent type; although it spared no one, and could not be radically driven out of the system, few casualties occurred.

(16.) I closed final operations at Attanga my last station on the 10th March, thus completing the southern section of the Biláspur Meridional Series exactly in three months. Final angles were taken at 16 principal stations, and one secondary station. A large quantity of secondary work was accomplished during the above period.

(18.) The country through which the operations, both principal and secondary, were carried on, varied in height from 5,000 to 2,000 feet above sea level. Ranges of hills were crossed, elevated plateaux traversed, every description of ground was met with, all of which was densely wooded; some portions were very difficult with scarcely a village; between the stages, other portions were cultivated, and had villages 3 and 4 miles apart. Colonel Saxton, Deputy Superintendent in charge No. 3 Topographical Survey, Central Provinces and Vizagapatam Agency, whose experience extends over many consecutive seasons, and who is quite conversant with the country and its people, remarks in one of his reports " In the physical features of the country there is little more to notice, all being hills and jungle, waste and desolation, with the scantiest population sunk in ignorance and vice."

(20.) Wild animals are numerous. Tigers are very destructive, and frequent desertions of entire villages occur annually from the ravages of these animals. At Karia H. S. one of my pack bullocks was carried off in the afternoon, and all the endeavours of the keepers and villagers to rescue the animal alive, proved ineffectual; the tiger standing over its prostrate victim deliberately satisfied himself with its blood and then retired into the jungle. Mr. Beverley who joined me at this station lost a bullock the same night. The cattle were removed the next morning to a safer locality after this second seizure and no more losses were sustained. At There H. S. one of my goats was carried away by a leopard during the day close to camp, the men were about at the time and rescued her; that very night my best milchgoat was taken and no trace of her could be found. Wild buffaloes are numerous, and very troublesome when they are met with on the line of march. A solitary bull having possesion of the path kept a few men of my camp at bay for some time until the elephant came up with the rear baggage, he decamped on seeing the elephant approach and left the path free.

(21.) There is no regular commerce in the country through which the triangulation was carried on this season, for want of roads. The export of grain is very large, and the Banjáras convey it on pack bullocks to the towns where there is a demand for it. In the Jaipur and Bastar Rája's territories, the revenue is paid partly in money and partly in grain, which latter is collected separately, each kind in its own granary, and the Banjáras purchase it and convey it to the profitable marts at Párvatipuram and Vizianagaram; from these two places it is carted to

Vizagapatam. Numerous bands of Banjáras resort to the above depôts, large quantities being readily obtained from the respective Rája's officials. The Banjáras are an interesting people and an account of them would not be amiss. I have met them frequently in the above states, and on the line of march on the high road, I have met their interminable string of bullocks. The tinkling of innumerable bells announces the approach of Banjára cattle laden with corn; the leading bullocks are decorated with plumes attached to the head between the horns. Brass sockets tastefully worked are fitted on to the upper portions of the horns, the remaining portions are enclosed with cases; the head has a covering, the neck a collar to which bells are attached; all these are ornamented. The tail pieces and packs are also decorated. Shells enter largely in ornamenting the several pieces, which are tastefully arranged and worked to adorn the useful animal. The costume of the women is very striking and picturesque; it consists of a petticoat made with strips of cloth 6 to 8 inches in width of many colors, of the brightest gayest and most gorgeous hue, which are put together to form this garment. A patchwork bodice of various colors to match the above, and a sheet edged with tinsel or red, thrown over the shoulders, completes the costume. A profusion of jewels of all metals from gold and silver to base brass are necessary to complete the toilet. Large gold nose rings, some jewelled, others plain silver, ear-rings covering the entire ear, strings of beads of all colors and sizes round the neck, the arms covered with bangles and amulets, the ankles decorated with massive metal ornaments to which are attached small bells, add greatly to the novelty of the costume of these peculiar people.

(22.) Long before daylight the trappings of the bullocks are put on and they are laden. The march begins with the leading bullock advancing with waving plumes and tinkling bells; others follow in succession, with a cock perched on the load of one, a hen on another, a child on a third, a kid on a fourth, a litter of pups on a fifth, and so on, until all their livestock and the children of the gang are accommodated. The laden cattle are followed at intervals by a damsel, robed and adorned as above, driving and vociferating to the lazy and unruly under her charge: after a few minutes a man follows, and is heard shouting and talking to the bullocks as if they understood what was said, and castigating them when necessary. Each man carries a weapon of some description to defend himself when necessary.

(23.) The whole band is escorted by dogs which are seen following the men, women or cattle all along the line of march, exercising their vigilance over all. The goats, sheep, cows with their calves, and mares with their foals, bring up the rear accompanied by the aged, sick or infirm of the gang mounted on ponies. The loads are every now and then adjusted, the cattle which entangle themselves among the forest trees, are extricated, and on the Banjára proceeds to his destination with his grain laden cattle, his worldly goods and chattels, his wife, his children, and his livestock; he leaves nothing behind. With his sheet of gunny, which he pitches for shelter from dew and rain, and with all his belongings, he is contented and happy as any other living man in the enjoyment of ease and comfort. Each band of Banjáras elects its own chief, who is implicitly obeyed. The chief settles disputes, and administers justice to all. These people seldom resort to courts of justice. They are an independent, intrepid, hardy race, going through uninhabited forests swarming with wild animals. Their encampments are well chosen, mostly on banks of streams, elevated and open. Their bullocks are picketed in rows, a long rope with knots equally placed 3 feet apart to which are attached halters answers the purpose; the ends of the rope are fastened to piles driven deep into the soil, and the halters secure the cattle. Large fires surround the encampment and are fed and kept alive by the men on guard who watch turn about. The numerous dogs with each gang guard and protect them effectually and will not allow the cattle to stray nor an intruder to approach. The dogs are of a peculiar breed, large, fierce, powerful and intelligent, and are very much attached to their owners. They live with the family and are fondled and caressed by the children.

(24.) Mr. Henry Beverley, Surveyor 1st Grade, was employed during the entire season upon secondary operations. I have already alluded to the assistance I received from him during the azimuth observations at the central station of Karia. With his usual energy and zeal he has accomplished a large quantity of work, having determined the positions of 7 important places, connected 10 Topographical stations, fixed 52 secondary stations and 102 intersected points and villages. His triangles having all three angles observed amount to 53. The heights above sea level of nearly all his secondaries have been determined. In addition to the above he has constructed rectangular pillars over six principal stations and placed them under the protection of the local authorities.

(25.) Mr. Beverley and his detachment have one and all suffered from fever, notwithstanding which he worked on and even took his stand at the theodolite with fever on him. The wavy undulating nature of the country, densely clothed with jungle, having villages scattered here and there screened or rather imbedded in the forest, might have disheartened a less experienced Surveyor in determining their positions. The difficulty of laying down the villages was great and the labor trying; he however progressed steadily and systematically, and the result has been the large quantity of secondary work which is shown in the rough chart accompanying this report.

(27.) Mr. F. Bell, Surveyor 3rd Grade, was employed throughout the season upon secondary work, and has determined the positions of 5 important places, connected 4 Topographical stations, fixed 24 secondary stations and 39 intersected points and villages, and obtained 35 triangles all three angles of which have been observed; and heights above sea level of most of his secondary stations have been determined.

(28.) Mr. Bell and his establishment suffered from fever; at one time almost all in camp, he himself included, were prostrated. He like all the members of this department bravely maintained his ground, treated himself and his men most successfully, and perseveringly advanced his operations notwithstanding the sickness in camp and the difficulties he had to encounter in the prosecution of his labors. He remained out latest in the field and did not close work until the weather became unfavorable.

(30.) Mr. E. P. Wrixon, Assistant Surveyor 3rd Grade, has throughout the season been employed in constructing rectangular pillars over principal stations and handing them over to the local authorities. He has built and made over 17 stations. In addition to this he has accomplished some secondary work in last season's triangulation. He observed at 10 principal and 7 secondary stations, obtaining 21 triangles of which all three angles have been determined, and 4 triangles of which only two angles have been observed, and determined 35 intersected points.

(31.) Mr. Wrixon and his small detachment suffered much from sickness and he lost three men from fever. At Singanáma H.S. he was so ill from fever that he intended proceeding to Colonel Saxton's camp, which was not very far removed from him, for medical aid. A favorable change taking place just then enabled him to continue his work. On his return to Wálter he had another bad attack of fever. He had to go over the ground of the previous season, visiting each station of the Bider Longitudinal Series. The very difficult ground of the Eastern Gháts which he had to traverse has been described in my last narrative report. I provided Mr Wrixon with lime for 10 rectangular pillars and he arranged for the remaining stations.

(33.) Mr. Beverley having determined the positions of the large towns of Jaipur, Jagdalpur, Koráput and Naurangpur, has furnished the following information regarding them:—

Jaipur.—The town of Jaipur is the seat of the Rája, a semi-independent Prince, the Chief of a tract of country about 200 miles in length and 50 in breadth. Jaipur is situated on low ground to the south of low undulating hills, the most southeasterly of which is Doseabata, and within six miles of the high mountains which surround it on three sides, and there is an isolated hill 2,000 feet in height to the northward. The town is therefore in a hollow and consequently unhealthy throughout the year; it consists of about 1000 huts inhabited chiefly by the retainers of the Rája and traders. A metalled road from Koráput passes through the town from east to west, all the rest are mere village paths; on both sides of this road are large thatched houses with mud walls belonging to traders and influential men; and in their midst is the residence of the Rája, a large upper-roomed paka building with a tiled roof, situated on slightly elevated ground and commanding a view of the town. The residence of the Assistant Agent and Police Officer was to the west of the town; owing to the unhealthiness of the place, this has since been abandoned, by the officials for Koráput on the Gháts, distant about 15 miles to the eastward. Jaipur is surrounded by several groves of mango trees; these are planted in rows, each about 20 yards apart, with mathematical precision, the trees in each row being the same distance from one another. The place is surrounded by a number of tanks more or less large, one to the west being half a mile in length.

Koráput.—When Mr. Turner was appointed Political Agent of Jaipur in place of Captain Smith, who was obliged to go on sick leave, on account of the notorious unhealthiness of the town of Jaipur, he was given the option of residing on the high plateau which nearly surrounds Jaipur; he took advantage of it and selected the present site about 15 miles east of Jaipur. The Public Works Department is now engaged on a good cart road from the head of the Gháts to the town of Sálúr, in the plains to the east, which when completed will facilitate considerably the export of grain from Jaipur and Bastar to the sea coast. At present the only available mode of conveying grain is by pack bullocks which makes all grain brought into Vizagapatam, very expensive.

The civil station of Koráput obtained its name from the small hamlet of Kora, "put" being an affix signifying a very small village, but it is in the lands of both the small village of Koráput and the large one of Khumba; the boundary line between the two villages passes over a small hill in the centre of the town, on this hill is the Trigonometrical station. The latter village was abandoned after the civil station was formed; the site is now occupied by the Police lines and the Sub-Magistrate's Kachahri. The site of Koráput is well chosen, it is in the centre of an extensive tableland, about 2,900 feet above sea level, bare of trees. A large square tank in the centre of the town and to the west of the Trigonometrical station, is being excavated which will supply the station with water. Koráput is in its infancy, the residences are temporary buildings, but permanent ones are in course of construction for the Agent, Superintendent of Police and for all Government offices. From Korápúte to Sálúr, the nearest native town in the plains is 48 miles, of which 25 miles is on the high tableland up to the Gháts, and 23 miles from thence to Sálúr.

Naurangpur is a pretty considerable town extending for about a mile in length from north to south, but is very narrow; it is situated about a mile from the right bank of the Indrabati river, which takes its rise in the Gháts and proceeds westward till it falls into the Godávari. During the cold weather it has a depth of 3 to 4 feet of water, but it overflows its banks during the rains, and sometimes destroys the crops a couple of miles on either side. There is but one street through the town of Naurangpur from which branch off very narrow lanes or village paths to the huts; these are of mud walls with thatched roofs, except the Rája's house and the Sub-Magistrate's Kachahri. To the east and west of the town are three large tanks respectively which supply it with water; on the bank of the centre tank, to the east, is the Trigonometrical station. A fine avenue of mango trees planted in four rows extends from Naurangpur to Magigura village about 2 miles.

Jagdalpur is the residence of the Rája of Bastar; his former place of abode was at Bastar, or Juna Bastar, the latter is now quite abandoned, and the site of the old town is a forest: a few small scattered villages at the outskirts of the forest still go by the name of Bastar. The distance from Bastar is 10 miles. Jagdalpur is on the left bank of the Indrabati river which here is deep throughout the year. The town is immediately on the bank of the river, and is inhabited only by the Rája and his retainers. In a large mango tope to the south of the town a weekly market is held, and there is a fine, large tank extending about a mile in length to the west of the town.

Mr. Bell has supplied the following notes:—*Karial,* the residence of a Rája, consists of three to four hundred huts. The Rája's residence is paka, and is built in the form of a quadrangle with a minaret at each corner. One thing I noticed as peculiar while in the Karial Táluk, *i.e.,* the people would on no account give the name of their paternal parent, although they unhesitatingly gave their mother's name. In all my travels this is the first time I have met with this peculiarity, usually it is just the reverse.

Karial is faced on the western side by a marsh extending fully the length of the town (there is first-rate snipe shooting to be had in it) it is very low and surrounded by hills on the south and southwest, the hills run in long ranges. The Táluk of Karial consists mostly of well watered strips of land dotted with hills, and is separated on the west from the Nawagarh Táluk by a high and continuous range of hills about 20 miles broad. It belongs to the Raipur District, Central Provinces.

Sihoa H.S. The hill of Sihoa is considered to be the source of the Mahánaddi River, and like all old places of note it has its legend. The following is what I picked up during my stay:—Once upon a time there lived a Jogi (hermit) in a small cave, still extant on the hill top, where he was supplied with food and water by a little girl, the daughter of one of the townsmen (for it was then a large place and of some importance). One day the child forgot to take the hermit water, which caused her great anxiety and fear; however, when the old hermit saw her distress, he questioned her as to the cause and being told, he ordered her to pass her hand thrice round the "Tombie" (gourd) and then to remove the cover. On doing what she was bid, she found to her surprise the gourd was full to the brim. One day the gourd broke, and being full at the time the contents percolated through the hill, and taking the form of a stream flowed eastward; on perceiving what had happened, the old jogi demanded what the waters meant by imitating the course of most other rivers, about that part by flowing to the east, and ordered it to go to the west; the order was obeyed, and the river having gone a short distance in an easterly direction suddenly turned and proceeded to the westward. Since that time (I could not get the date) a fair has been held annually in commemoration of the occurrence, which is largely attended. A few streamers mark the former abode of the Jogi. The hill has once been fortified, traces of which are still to be seen, and it is naturally rather formidable being almost perpendicular on three sides and consisting of rocks on the fourth side; on nearing the top of the hill it becomes very steep, and the path admits one person at a time only, being very narrow, and is completely commanded by a couple of overhanging rocks of great size like bastions. Before the use of large guns this place must have been very formidable; it was occupied by a band of marauders. Prior to the country becomming settled, Sihoa is said to have been guarded by a hundred horsemen and fifty foot, but this force has been gradually reduced to a handful of police; Sihoa is now in the Raipur District of the Central Provinces.

Extract from the Narrative Report—dated 15th July 1873—of H. KEELAN, ESQ., Deputy Superintendent 3rd Grade in charge Bilaspur Meridional Series.

(2.) The party reached Jabalpur from Head Quarters on the 9th November, and marched from thence on the 20th to the Raipur district to resume operations, and arrived at the tower station of Mahásamand on the 16th December, where it was intended to observe a second verificatory Azimuth (the first was taken about 50 miles higher up at the tower station of Pathaidi) but owing to the low swampy nature of the country around Mahásamand a suitable referring mark could not be found in the direction required, and in consequence the azimuth observations were taken at the hill station of Remai, 12 miles lower down, a station equally free from any apparent local disturbance. On the 20th, observations to δ Ursæ Minoris were begun, and completed on the 27th of December. The weather throughout these observations remained fair, though fears were entertained during the preliminary arrangements, that it would not be so, as it was daily cloudy during this time.

(4.) Immediately the observations at Remai hill station were completed, Mr. Surveyor Clarke was detached to build up all the platforms and cut roads for the large theodolite at the several hill stations selected the previous season; in the meanwhile, I returned to the tower station of Mahásamand to begin the final observations there.

(5.) During the month of December final observations were completed at Mahásamand station.

(6.) During the month of January final observations were completed at the hill stations of Khalári, Guhia, Remai, Jogi and Jatia.

(7.) During the month of February final observations were completed at the hill stations of Malewa, Bamnai, Pendra and Deodongri. These two last points define the closing side of the northern and southern sections of the Biláspur Series.

(8.) The final principal angles were commenced on the 30th December, and in order to close the work on the side of junction (Pendra H.S. to Deodongri H.S.) from the north, before the signal parties of the southern section came up, the observations were carried on steadily to the 17th February; but notwithstanding the effort to obviate clashing, a short delay of one day did occur to Mr. Rossenrode, when the above named stations were finally cleared by me for the observations connected with the southern section.

(9.) In the instruction conveyed in your Office letter of the 21st October last, a second Azimuth was to be observed at Pendra H.S., provided its position was free of local disturbances; but I had strong doubts, viewing the country from the north in the early part of the season, of securing these observations, on account of the close proximity of a formidable mass of elevated hills running south and east of Pendra, 15 miles off, and on which the station of Deodongri stands. It was eventually found on closer inspection of the country in the neighbourhood, that it would not answer for either an Azimuth or Latitude station, and the project was therefore given up. The camp then broke up at Pendra and marched up towards Jabalpur, where it arrived on the 24th March, and thence proceeded to Chanár (Chunar) *viâ* Rewah and Mirzapur. The march was long, tedious and trying; the country travelled over could not have been less than 500 miles.

(10.) There is no secondary triangulation executed in the last season's portion of the principal operations as there are no defined points in the country of any kind whatsoever. It is without exception the wildest tract it has ever been my lot to work in, at the same time very sparsely inhabited, on account of the numerous wild animals that overrun the district, especially wild buffaloes. The Native Doctor Moti Ram would have been killed by one of them, a solitary infuriated beast, the terror of the neighbourhood, but for the ready assistance he received from villagers who were at hand to rescue him. On the other hand, the party had only two assistants. Mr. Surveyor Clarke was employed in building platforms, cutting roads, preparing materials for building rectangular pillars and transferring them to the native officials, and Mr. Assistant Surveyor Clancey was employed in the office and in recording observations in the observatory.

(11.) The men of the Native Establishment suffered much from jungle fever; the average daily number of sick were 15, nearly all through the season.

Extract from the Narrative Report—dated 31st July 1873—of W. G. BEVERLEY, ESQ., Assistant Superintendent 2nd Grade, in charge Assam Valley Triangulation.

(2.) The camp started from Gowhatty on the 25th November. I had intended taking the field early in November as stated in my Report for 1871-72, but was unable to do so before the above date, owing to the lateness of the rains, the delay of the men in rejoining from leave, and the necessity for entertaining new men.

(4.) As there were no stations ready in advance for the final observations, I took up secondary triangulation, while the assistants were employed in selecting and clearing rays, and in building pillars. I commenced work at Bishnáth on the 8th December, and visited the hill stations of Kamakia, Kandali and Longboai for the purpose of fixing the Civil Stations of Naugong and Tezpur, such of the Revenue Survey platforms as could be seen and all the prominent peaks to the north and south of the Bráhmáputra River.

(5.) A good number of peaks were observed to at Kamakia H.S., on the 16th December; but by the time I reached Kandali on the 22nd, all the ranges to the north were completely obscured. The firing of the grass jungles had begun earlier than usual, the smoke from which, combined with the heavy fogs that sometimes did not rise up from the valley till 2 and 3 P.M., prevented my getting much secondary work. Several days were spent at Kandali and Longboai without any results, and I proceeded to take up the principal work, visiting the Revenue Survey station of Kamargáon, *en route*, where some observations to peaks were obtained after three days very heavy rain.

(6.) Final observations were commenced at Cheniabinshon H.S. towards the end of January, when the pillars at Golághát and Bor-Chapri had been built up to the required heights. The Nikori-Chapri pillar having fallen down soon after completion, I suspended the principal observations at Kankochan H.S., on 12th February, and took up approximate work and ray clearing, returning to Kankochan H.S. on the 25th with a view to fixing some peaks—weather permitting—while the pillar was being built. The observations at this station were completed on the 2nd March. From the unavoidable delay in building up the pillars, the angles at each station could not be all observed at once, and it became necessary to visit some of them a second and third time. The Bor-Chapri pentagon was out of hand on the 2nd April: the observations at two stations of this figure were taken with the 12-inch theodolite, in consequence of the injury occasioned to the 14-inch on the Golághát tower, and which was reported to you at the time. The results obtained from this instrument were very satisfactory, observations being taken on ten zeros.

(9.) The principal work for the past season is only one pentagon: this is an exceedingly small out-turn, and is due wholly to the approximate work not being well in advance. I have in last year's report drawn attention to this circumstance, and to the difficulties peculiar to Assám in selecting stations, to which may be added the very great delay in building stations from the frequent heavy falls of rain, commencing in February and continuing with few breaks throughout the field season. If the approximate work had kept well ahead of the final observations from the first year of the survey, a larger out-turn might have been more reasonably expected than we have been able to show.

During last season, Mr. O'Sullivan has been able to select six points ahead on the left bank of the Bráhmáputra, and will probably have three more in connection with them, selected on the right bank, very shortly after taking the field. I purpose employing two assistants for a short time in building the stations, and hope to have the approximate work for the future always sufficiently in advance of the final work, and thereby have a larger out-turn.

(10.) The secondary work has completely defined the lower range or Dafla hills, on the north bank of the Bráhmáputra and east of 93° 25′, and also fixed several peaks on the inner ranges between Long. 92° 30′ and 94° 15′. These points would be useful to the survey intended to define the British boundary to the north, or to any party that may accompany the rumoured expedition into the Dafla hills. Four peaks on the snowy range also have been added, but as these were only seen twice, some uncertainty for the present exists as to their positions. Three Revenue Survey stations have been connected with the G. T. Survey and some more would have been fixed had they been accessible, and not built in the depths of grass and forest jungle. In the Lotha Nága hills four or five peaks have been laid down; some of these are common to the Topographical Survey carried on last season, and serve to make a sort of connection between the two surveys. Two hills in the Civil and Military station of Tezpur as well as the Church and Lunatic Asylum have been fixed, also the Assistant Commissioner's house in the Sub-Divisional Station of Golághát. The Civil Station of Naugong could not be fixed for want of time, but this may be done in the ensuing season.

(11.) The approximate work, it will be seen, has been carried up to near Sibságar. Mr. O'Sullivan reports that the jungle on the right bank of the Bráhmáputra River, on the Majhili island, is very heavy and will be a source of considerable delay. It would therefore be advantageous to keep along the left bank up to Dibrugarh, only crossing over when the forest on that side becomes heavy. The side Bor-Ali to Gaurisâgar will be best adapted for extension up the valley, and the side Gaurisâgar to Cintamunigarh for turning into the hills. There does not appear to be any difficulty in the triangulation being taken once more into the hills at this point, as they are inhabited by more tractable tribes, and there are numerous tea gardens scattered along the boundary, and even beyond it. I would therefore propose for the ensuing season that the survey be carried along the hills entirely, after we have once entered them, or have one flank resting in the plains should there be any political objections to our going further into the interior.

(12.) The country traversed by the triangulation last season has been already described. The same difficulties in progress were experienced in the clearing and cutting of rays through patches of heavy forest and reed jungle. The country ahead, on the left bank as far as the approximate work has extended, Mr. O'Sullivan describes as less difficult; some of the rays will require little or no clearing. The stations too, have been selected on high mounds and old temples, which will be serviceable in reducing the heights of the pillars.

(13.) Inadequate carriage has been the occasion of much delay. As local labor was not available, the elephants of the party were employed to convey materials for building, provisions for the establishment and also to crush down the jungle on the rays. If two or three more elephants could be attached to the party much inconvenience would be avoided. It was necessary last season when marching from one place to another to make frequent halts, while the baggage had been sent ahead, and unfortunately neither elephants nor other animals could be obtained on hire in the Sibságar district by which time might have been saved.

(14.) Mr. Harris was employed throughout the season in building stations. Those at Golághát and Bor-Chapri were respectively raised to a height of 23 and 24 feet. The pillar at Madaigáon was built to a height of 35, and Nikori-Chapri to 25 feet. That at the latter station had to be built up a second time.

(15.) It was found necessary to erect a pillar 12 feet high on the Nigri Ting hillock, in order to overlook the numerous trees scattered over the tea gardens which extend all round and up the slopes. An ancient, high temple, surrounded by trees, crowns the summit of this hillock. It was proposed to erect a platform on the top of this temple from which a very extensive view is obtained, and by clearing the ray between it and Golághát, a double pentagon would have been obtained. The guardians of the temple gave at first their consent to our proposal, but subsequently declined on superstitious grounds to permit what they considered a desecration of the shrine. The site for the station was therefore selected outside the wall of the enclosure, on the slope towards the N. W. corner.

(16.) This pillar was completed by the 13th April, and Mr. Harris crossed the Bráhmáputra and took up the building of Rodonga and Bekhuli Mukh stations.

(17.) Mr. Harris' progress has been rendered very slow from the wet weather which prevailed almost throughout the season. The bricks after being moulded had to be protected from rain, and although dried in the sun imbibed moisture so very rapidly, (the fall of the Nikori-Chapri pillar was due entirely to this circumstance), that it became necessary to kiln-dry them before they could be used. The soil too, was in some places so ill adapted for making bricks, that they had to be moulded and baked at long distances from the stations, and conveyed thence by elephants and boats. Mr. Harris, with his usual good management, employed his materials to the best advantage, and with due regard to economy.

(19.) Mr. O'Sullivan was employed on the Approximate series. He commenced work early in December in re-clearing and carrying final rays between the stations selected the previous season.

(20.) I have mentioned in my last report the delay in cutting through the forest jungle of Assám. This forest fortunately occurs only in patches on a ray, and some idea of its nature may be formed from the fact of one ray last season having occupied Mr. O'Sullivan with a party of 25 cutters 36 days to carry. There is also much loss of time in re-clearing final rays a second season, as the grass and bamboo jungle grow very rapidly and heavy during the rains.

(21.) On completing ray clearing, Mr. O'Sullivan took up the selection of stations in advance at the beginning of March; and by the 3rd April had carried the Approximate series up to within 6·4 miles of Sibságar. Exclusive of Nigri Ting, 6 stations have been selected and fixed on the left bank of the Bráhmáputra. These points could only be determined on after reconnaissance, since no information of any kind could be obtained from the Assámís, who appear to know little or nothing of the country beyond the bounds of their villages, and the maps we relied upon were rather incomplete in some necessary details.

(22.) Mr. O'Sullivan reports the country on the left bank, in the Jorhát division, to be a little more open than on the other side, on the Majhili island, and to have scattered about high mounds—the sites of villages, old temples abandoned or ruined, and high tank banks, with numerous paths and roads. He has shewn considerable judgment in his selection of stations in advantageous positions and convenient of access, and in carrying the series over to the left bank entirely, at a point where it may be readily advanced into the hills or extended up the valley.

(23.) Mr. O'Sullivan crossed the Bráhmáputra on 14th April and selected and fixed Bekhuli Mukh station, and would have probably completed the selection of the three remaining stations on the northern flank, had not his progress been stopped from want of provisions. No assistance could be obtained from the Mauzadárs who were invariably away from their Mauzas, and applications to the district officers were of no avail. It is a remarkable coincidence that the Mauzadárs of the Sibságar District were always absent at the Sadr Station when called on by the surveyors for assistance. This is the second season that Mr. O'Sullivan and his establishment and elephants have been, as it were, starved out of the Majhili.

It will be necessary next season to carry supplies for men and animals in boats from below, and to make such other arrangements as may render it possible for us to be wholly independent of assistance from district officers or Mauzadárs.

(24.) Mr. Hughes, immediately after entering the Department, was posted to this Survey. He accompanied Mr. O'Sullivan to the field and was trained in ray carrying, and in the use of the theodolite. He joined the main camp for a short time, and acted as Observatory Recorder. Mr. Hughes has shewn much intelligence and aptitude in learning the duties of his profession, and will in time become an efficient surveyor.

(25.) The assistants have throughout the year worked cheerfully and well, and in spite of hardships and privations, and various physical discomforts and annoyances incident to field life in Assám, have continued to evince a zeal for their duties.

(26.) The field season has been unhealthy; nearly every one has sufferred more or less from malarious fevers and other complaints, returning to quarters much debilitated. One death only took place in the establishment.

(27.) The party returned to quarters at the end of May, remaining out a little longer in the field than was necessary with a chance of obtaining more work if possible, but the weather was quite opposed to progress. The low ground was under water about the 25th April from the continuous heavy rain; little work was got after the 16th of April. Unless prevented by untoward circumstances, the party will leave recess quarters towards the close of October so as to be on the ground early in November.

(28.) The accompanying chart on the scale of 8 miles to the inch, shews all the work of the Assám Valley Survey from its commencement. There is a great blank west of Long. 93° 0', and I propose to take up secondary work from Silang (Shillong) and carry the observations up the valley so as to fix points on the ranges to north and south and fill up this blank. These observations could be carried on until the principal stations ahead are ready.

Extract from the Narrative Report—dated 27th June 1873—of Lieut. M. W. ROGERS, R.E., Assistant Superintendent 1st Grade, in charge Jodhpur Meridional Series.

(2.) During the recess season I received instructions that the party was to be employed during the next field season in Rájputána, on a Meridional Series, emanating from the Karáchi Longitudinal Series, and proceeding north, on the meridian 72° 30' to meet the Sutlej Series. As the preparations of the last field season had been made with a view to doubling the Great Arc in parts between Bider and Sironj, the whole arrangements for the season had to be changed.

(3.) There still remained some stations of the last year's work to be closed, and a portion of triangulation to connect Karnúl, which Mr. Bond had been obliged to abandon last year from ill health: besides this, in the selection of the Arc, north of Bider, there were two groups of Zenith Distance Stations which had been selected for Captain Herschel last season, and at which he had observed. Until these were connected with the triangulation, his observations would be useless, I therefore despatched Messrs. Torrens and Oldham, with as many men as I could spare, as early as it was possible after the Monsoon, Mr. Torrens to take up the Karnúl triangulation and Mr. Oldham to close as many stations as he could before I required his services in the field.

(4.) The main party reached Ahmadabad on the 8th November. Having made all arrangements for the season's carriage, and left the great theodolite in charge of Lieut.-Colonel Griffiths, R.E., the Executive Engineer, I marched *viâ* Dísa to Erinpura where the guard and vakíl for the party had been sent by the Jodhpur Government.

(5.) On the road, I visited the Station of Mount Abu, to see if any place could be got for the recess quarters of the party, but I found that the demand for accommodation was far in excess of the supply. After leaving Erinpura, I employed myself in conjunction with Messrs. Price and Bryson in selecting stations and laying out the Approximate Series.

(6.) As soon as this was sufficiently advanced, the great theodolite was brought up from Ahmadabad by Mr. Oldham, and on the 31st January I commenced the principal observations at Súnda H.S. of the Karáchi Series. The observing was now pushed on as rapidly as possible, for the best portion of the observing season had been spent in the necessary preliminary operations. Delay was experienced twice (two or three days each time) on account of sudden and impenetrable mists, and at the last station of the season I was detained eight days observing two angles, and this was the first week in April, and the weather after this never cleared; so I think it will be necessary in this series to begin work sufficiently early to get the observations finished by the end of March. Observations were closed at Dodo H.S. on the 8th April; I thence marched southwards, closing, in conjunction with the detached parties, all the stations observed at during the season. The detached parties having joined the main camp on the borders of Márwár, I marched *viâ* Dísa to Ahmadabad, reaching Púna on the 8th May.

(7.) The following is a brief outline of the season's work.

The Approximate Series was commenced and carried forward 147 miles, 25 principal stations being selected and built; 14 principal stations were visited for observations and 44 angles observed, fixing 12 new principal stations by 14 triangles, embracing an area of 3,706 square miles, and extending the series northwards 95 miles. An azimuth was observed at Thob H.S., in Lat. 26°., to two circumpolar stars.

7 Zenith Distance stations were fixed on the Great Arc for Captain Herschel; besides, a good proportion of secondary work was done—58 points fixed—embracing an area of 2,443 square miles, outside the principal triangulation.

All secondary and intersected points have been fixed in height as well as in position.

As the observations, from which the season's work is in a great measure judged, were not able to be commenced until two months of the season had passed, I trust you will consider that the progress of the party has been satisfactory.

(8.) The country through which the season's operations have been carried is sandy and flat, with an elevation towards the east of about 700 feet, diminishing towards the west and the Luni river to 300 or 400. South of the Luni river small detached ranges and isolated hills are numerous. Their sides are very steep and covered with jungle. Many of them rise to a considerable height above the plains, several to over 2,000 feet.

(9.) Jallor, which is the principal town in this part, has a large fort in fair preservation, with a garrison and several pieces of old-fashioned cannon; it is on a precipitous hill, rising 1,350 feet above the plain, it is however commanded by a still higher peak of the range. I was allowed to place a mark in the fort and observe from it, and was told that I might build a principal station in it if I pleased. To the east, towards the Luni (which flowing west, across the series, turns south and skirts its western flank) the country becomes barren and sandy, generally nothing but sand hills covered with low shrubs, water scarce and brackish and villages few and far between. The hills disappear, and save the sand hills the country is level for 70 miles, as far as the Balmír hills.

(10.) North of the Luni the country becomes still more sandy and desolate, and the water is almost entirely brackish. Near Pachbadra there are extensive salt works, but there seems to be hardly any cultivation, and often such as there is, appears to have been destroyed by locusts. These were very destructive last year. The people dig trenches, square in section about one foot wide and deep, for miles around their fields. They say that when the young locusts, which will be every where about this next season, are born, they make for the fields, fall into these trenches and being unable to fly or climb the perpendicular sides, they perish in them.

(11.) There are but few villages which possess a well of fairly drinkable water, and the people supplement the supply by making small reservoirs which they call "tankas"; these are cylindrical, about six feet across and eight or ten feet deep, and are plastered with a coating of fine polished chunam; in these they collect rain water and covering them with brushwood &c., leave them until the well supply fails.

(12.) Towards the end of the season the party suffered a good deal from the badness of the water, and I am afraid that matters will be worse as the series advances.

(13.) The Jodhpur Darbár sent with me a guard of sepoys, sowárs and a vakíl, and also sent a vakíl to Mr. Price. Captain Roberts, the officiating Political Agent, also sent one of his establishment with me. Thanks to these helps I experienced no trouble in carrying out my work, and I have never had a field season in which I have met with so little hindrance or annoyance. My best thanks are due to the Jodhpur Darbár for their help to myself and my assistants.

(14.) Although there are a good many Bhîls and other thieves about, I only had one case of robbery from my men in Márwár, and in that case restitution was promptly made. In Sirohi however one of my peons going for supplies was attacked and robbed on the high road in open day, and my claims for compensation were rejected by the Political Agent for Sirohi, on the ground that the men had not engaged a Bhíl to protect them; this decision considerably increased the expenses of the signal parties, as, after it, I had of course to sanction their hiring one of the dangerous class to protect the Government property when away from the main camp.

(15.) Mr. Price had charge of the Approximate Series and pushed it forward with great zeal, sparing himself, as usual, no trouble to complete his work satisfactorily. He selected 22 principal stations, built 9, and closed 5, and showed himself in every way worthy of the promotion he received just before taking the field.

(16.) Mr. Torrens completed the Karnúl triangulation (an area of 473 square miles) and fixed that station. He then marched northwards and fixed two groups of Zenith Distance stations for Captain Herschel, in doing which he re-traversed the whole of the heavy march spoken of by Captain Herschel in his last report. On his road he closed 26 stations of the Great Arc Series. This was Mr. Torrens's first season at independent observations, and he had, unfortunately, to contend against unusual difficulties; the Zenith Distance triangulation had been laid out for the great theodolite, and the rays were many of them too long for the powers of his instrument and signallers, and before he finished his observations, he experienced the usual misty weather. His instrument was a 10-inch theodolite, and his average triangular error 2″·5. The health of his party was very bad at the commencement of the season, more than half his men being generally useless from fever; in addition, cholera was prevalent in the Karnúl district, but happily his camp escaped.

(17.) His Highness the Nizám's minister kindly attached Mansabdar Muhammad Faiázudín Khán (who was with me last year) to Mr. Torrens's camp, and thanks to his exertions, every aid and assistance was rendered to the camp. I and my party are very much indebted to the Resident and His Highness the Nizám's minister for their kindness during the last three field seasons.

(18.) Mr. Bryson joined on the 1st October from No. 2 Extra party; he was employed during the season on the Approximate Series, selecting and building. He selected 1, built 16 and closed 3 principal stations, and worked throughout the series steadily and well, affording great help to Mr. Price and myself in our exertions to get the series well started this season. I have named him to you for promotion when a vacancy occurs, and his conduct this season quite entitles him to my best recommendation.

(19.) Mr. Oldham, during the first portion of the season, was employed in closing stations on the Great Arc. He then joined me and aided in the Approximate Series. He brought the great theodolite from Ahmadabad, and acted as observatory recorder throughout the observations; he worked well during the recess and has steadily improved himself in all branches of his work. He is now a good recorder and useful assistant, and I have every reason to be satisfied with him. Besides his ordinary work he closed 6 principal stations.

(20.) During the last recess 2 double polygons and 1 very complicated compound figure were computed, together with all the secondary work of the principal and Haidarabad Minor Series and the greatest portion of the Kadapa (Cuddapah) Minor Series. Owing to the alteration in the locality of the work, and the distance the party had to go, a small portion of the season's calculations remained unfinished: these will be brought up this recess.

Extract from the Narrative Report—dated July 1873—of Major B. R. BRANFILL, Deputy Superintendent 2nd Grade, in charge Madras Party.

Recess of 1871-72.

(1.) The recess of 1872 with which this report commences, was a short one of 4 months, beginning only about the middle of June 1872, on the return of the party from the field where it had been detained by bad weather and prevented from completing the observations required to finish the Mangalur Longitudinal Series. All the stations had been visited, but 3 or 4 angles were incomplete when the onset of the Western Monsoon obliged the observing party to abandon the field.

This accounts for the comparatively small out-turn of results obtained, and for the fact that no preliminary chart was sent in. As however the office work was continually interrupted and hindered by the ill health of the members of the party, contracted in the jungles and "terai" of the Western Gháts during the previous season, little, if any more could have been done than was done.

Uncommon difficulty of the coming season's work anticipated.

(4.) I here beg to refer to paragraph 42 of Lieutenant Trotter's annual narrative report dated 29th August 1867, in which he states that the progress of the series, to the southward of the stations he closed on, Chandraguti-Hallibail, must be slow in future, in consequence of the natural difficulties of the country and climate.

Details of the difficulties to be met.

(5.) The season's work before us was indeed one that promised to task us to the utmost, and I was by no means sanguine of success.

The Western Gháts.

The series lay for above 100 miles along the crest of the Western Gháts, a tract of hills and forests, clouds and mists, rivers and torrents.

No cross roads nor villages.

Three or four roads (two of them bridged) cross the line of the series from east to west, but there are no cross country roads in the direction of the series, *i.e.*, north and south near the Gháts, nor any villages in the country, except a very few on the main roads.

The population is exceedingly scanty, dwelling in houses or huts scattered singly over the country, one or two at each patch of cultivation.

Revision of the Approximate Series necessary.

(6.) I had already determined to remodel the Meridional Series, north of Mangalur, rejecting the stations of the original (Mr. McGill's) Approximate Series below the Gháts, and carrying the series entirely above (*i.e.* east of) them. Part of this I had laid out last season, and part of the old Approximate Series of the Bombay Party could be incorporated; only, after last year's experience, it was necessary to re-examine all the rays, more particularly so as six or seven years had elapsed since their first selection; about one-third of the whole distance remained to be selected afresh. 5 stations had to be examined and repaired, 7 built, and 20 to be closed.

The two series terminating at Mangalur now completed.

(7.) I am happy to state that the whole of the principal triangulation, Meridional and Longitudinal, terminating at Mangalur has now been finished, with a large proportion of secondary points, and I can confidently assert that had I retained the original plan of the series, by which the Gháts must be crossed and re-crossed several times, it could not possibly have been done this season.

Success due to a favorable season and the assistance of an extra Officer Lieutenant McCullagh, R.E.

(8.) I attribute our success to the good fortune of a comparatively favorable and healthy season, and perhaps chiefly to the fact of my having the assistance of Lieutenant McCullagh, R. E., to whom I entrusted the conduct of the principal observations with the 24-inch theodolite which enabled me to complete the Approximate Series in person, and to spare an assistant for the minor triangulation to the southward intended to fill up the great gap in Colonel Lambton's triangulation between Kannár (Cananor) and Paniani.

(9.) Taking advantage of the first break of fine weather in the North-East Monsoon rains, the Party took the field at Bangalor on the 20th October, and after a march of about 300 miles commenced operations in the middle of November on the terminal side Chandraguti-Hallibail, of Lieutenant Trotter's triangulation of 1866-67.

Operations begun at the north end of the series.

(10.) We commenced work at the northern extremity of the season's task, to avoid, as much as possible, the region where the North-East Monsoon clouds and rains are heaviest; and this is supposed to be worse the farther south you go in this part of India in November.

Disposition statement of the party.

(11.) The disposition of the party was as follows:—I myself, with a party of 9 klassies, undertook the examination and completion of the Approximate Series. Lieutenant McCullagh had charge of the main party of 27 klassies and lampmen and conducted the final observations with the 24-inch theodolite, with Mr. Laseron as recorder and office assistant. Mr. Mitchell with a party of 11 klassies, I sent to complete the final observations of the minor series to the south-east of Mangalur which he had laid out and commenced last season, with the 12-inch theodolite.

Messrs. Norris and Potter had each charge of a building party consisting of a mason and 2 klassies, and were sent to examine and repair the old stations used, to build the new ones, and finally to close the whole of them as soon as done with; the former on the west, and the latter on the east flank and centre of the series.

The Approximate Series completed by Major Branfill.

(12.) I took up the Approximate Series at Hukli H.S., examining and repairing the station, which had been already selected and built by the Bombay Party; afterwards visiting and observing in succession the stations of Hugadi, Sidéshwar, Kodachádri, Bissali, Sidéshwar, Hebbe, Walkunji and Sidéshwar.

Who then joins the main, or observing party.

I rejoined the main party at Ságar, on the 3rd January, having marched 481 miles (42 marches) in the 7 weeks, besides ascending and observing at 7 hill stations, each about 1,200 feet above its base; 17 of the marches being across country, and mostly performed on foot.

Lieut. McCullagh's progress with the main party, observing.

(13.) Meanwhile, Lieutenant McCullagh with the main party had completed observations at 5 principal stations, each over 1,000 feet high and 4½ marches apart, besides having had to descend and re-ascend one of the ghâts or passes to the coast.

Lieut. McCullagh chief observer, Major Branfill assisting and superintending.

(15.) After my joining the main party, Lieut. McCullagh continued the principal observations and conduct of the single parties &c., whilst I assisted him in the observatory, superintending our progress and the operations in general.

(16.) There being no roads between many of our stations, we had on several occasions to leave our camp and baggage for periods of a week or two, and on one occasion the main party was for three weeks separated from the camp and its supplies.

Amount of work done by main or observing party.

(17.) During the ten weeks ending 14th March, final observations were completed at 11 hill stations, each 1,350 feet high, on the average, and 4 days' marching apart.

42 principal angles were observed, giving an average of 1·4 angles per diem for each day's (and night's) observing.

(18.) Two sets of Azimuth observations were requisite, but in order to push on the principal triangulation to the utmost, and ensure its completion this season I had postponed them to the last.

Azimuth observations at 2 stations.

You were able to send me a spare 24-inch theodolite by sea to Mangalur for the purpose; this I proceeded to use myself, whilst Lieutenant McCullagh, after completing the principal triangulation, proceeded to Koramár H.S., one of the Zenith Distance stations (in latitude 14° 8′) observed at during the previous season by Captain W.M. Campbell. He accomplished his task on the 27th March and reached Bangalor on 15th April, thus closing a very fortunately successful season's work.

Koramár Azimuth completed, and return of main party. Principal triangulation completed.

Major Branfill leaves the main party for azimuth at Mangalur.

(19.) On the 8th March when the observations at Anúr H. S., the last station but one, were finished, I left the main party and marched to Mangalur, 100 miles distant, which with a fair road I acomplished in six days, arriving on the 14th March. It was necessary to raise a platform in order to observe from. This work occupied 4 days and was only just completed on the 19th, when the steamer arrived with Barrow's 24-inch theodolite (No. 1) which I landed, set up and began observing with, the same evening.

Mangalur Azimuth completed.

A complete set of circumpolar star observations for Azimuth to *a* Ursæ Minoris (Polaris) at western elongation (the same star used by Lieutenant McCullagh for the Azimuth at Koramár H.S.) was finished by the 24th of March, and on the 25th I packed up and despatched the instrument back to Calcutta by steamer and left for Bangalor the same day.

Brief, general statement of field work done.

(20.) Altogether 59 principal angles have been observed this season at 17 stations, of which 7 were newly selected and built, forming a double series of triangles, comprising one double polygon, one hexagon, and two quadrilaterals, covering 3,330 square miles, and extending the Mangalur Meridional Series, which is now complete, 105 miles from north to south, and at the same time completing the Madras and Mangalur Longitudinal Series at Mangalur.

Two Azimuths of verification have been observed, and 74 secondary points, with their heights complete, fixed, embracing an area of 4,064 square miles exterior to the principal triangles. About 150 barometric heights have been observed, and all the principal stations finally closed and delivered to the local civil authorities.

Connection with Colonel Lambton's stations.

(21.) 8 stations of Colonel Lambton's triangulation were found, with (⊙) mark-stones in position, and duly occupied or connected. 10 other points of the old survey have also been connected, but as no station (⊙) marks were found their identification is not exact.

Comparison of values of the common terminal side with those of the Bombay Party 1866-67.

(22.) I have compared our (the Madras Party) mean preliminary geodetic values of the final side Chandraguti-Hallibail, derived from the Calcutta Base (*viâ* Madras and Mangalur) with those of the Bombay Party derived from the Bíder Base, with the following results—which are the closing differences or errors generated in a circuit of 1,050 miles of principal triangulation—the Meridional Series extending 350 miles north and south, and the Longitudinal Series 170 miles east and west.

Closing difference, or circuit error linear = 0·1 ft. = 0·06 inches per mile.
" " " " in latitude 0″·07 = 7 feet.
" " " " " longitude 0″·19 = 19 feet.
" " " " " azimuth 3″·09
" " " " " height 5 feet.

Comparison with Colonel Lambton's heights near Chandraguti.

(23.) With regard to the last item, I have farther to remark that our heights in this (Chandraguti) neighbourhood are about 40 feet *less* than Colonel Lambton's published values of the same points, which is about the same difference in amount and sign as was obtained by a similar comparison of the heights of common stations of the Great Arc north of Bangalor; on the other hand, near Mangalur, 100 miles south of Chandraguti, our heights are 40 feet *greater* than Colonel Lambton's values of the same points.

Comparison with Colonel Lambton's values near Mangalur, in longitude.

(24.) I have not the means of making a rigorous comparison with Colonel Lambton's geodetic values of his stations near Mangalur, but I am able to state that his value of the longitudinal arc, Madras—Mangalur, is 38″ greater than ours, just about double of what the difference was midway, near Bangalor, and in the same direction.

In latitude and distance.

(25.) In latitude our values agree much more nearly with Colonel Lambton's, but there appears to be a slight cumulative difference. I have still less means for making an exact linear comparison, but I have some reason to suppose that Colonel Lambton's unit of length was too great and his numerical values of the sides of his triangles therefore too small, notwithstanding the fact that his value of the longitudinal arc is, apparently, too great.

In heights.

(26.) Reverting to a comparison of heights, whereas in the vicinity of Bangalor Colonel Lambton's values (derived from the sea at Madras like ours) were *greater* by 30 to 40 feet, near Mangalur they appear to be 40 feet *less* than ours. I have been unable yet to seek the source of this discrepancy.

A mistake in the published statement of Colonel Lambton's closing error.

(27.) On referring to Vol. X of the *Asiatic Researches*, article IV page 382, his closing error (+ 8·6 feet) when corrected for an error, which Captain Herschel detected and has pointed out to me, viz. the omission of a minus sign before 22·6 feet (the trigonometrical height of his final staton) appears to be − 36·6 feet referred to low water mark, say − 34 feet referred to mean sea level; whence our values would appear to be about 6 feet too great.

G. T. S. heights tested by reference to the sea level at Mangalur by levelling.

(28.) But we have another and independent reference to sea level. In November and December 1869 Captain Basevi, R.E., determined the sea level at Mangalur by a month's observations of high and low water, and referred it by levelling to some permanent masonry buildings. Last year, under my directions, Mr. Norris connected our Mangalur station with these, and with some new permanent stone bench-marks, placed and marked for the purpose, by a line of levels which has been checked by the Executive Engineer, and found to accord well with his own. I have therefore some confidence in stating that the Mangalur (pillar) station, near the Light house and Idgáh, is 186 feet above mean sea level, (the ground level there being 174·6 feet). But our trigonometrical value of the Mangalur station, derived from sea level at Madras is 196 feet, whence it appears that our values are 10 feet too great.

Closing error of new G.T.S. heights = + 10 feet

Cause of large closing error suggested

(29.) I am inclined to attribute this large closing error of 10 feet in a great measure to sudden variations in the local deflection of the plumb-line in the sides (of triangles) between stations above and below the Gháts: and this view is perhaps partially confirmed by the abnormally high factor of refraction obtained in these cases.

Considerable variation of local and mountain attraction to be expected.

(30.) From the configuration of the country I should expect to find greater easterly and north-easterly attraction (*i.e.* westerly and south-westerly displacement of the true Zenith) at the stations on the western edge of the Mysor highlands, which, as it were, overhang the low country, than at stations situated well out in the low lands, west of the Gháts, or at highland stations some distance inland, *i.e.* east of them.

Lieutenant J. R. McCullagh R.E., Assistant Superintendent 1st Grade.

(31.) Lieutenant McCullagh, R.E. I have much pleasure in reporting the valuable assistance I have received from this Officer. He has invariably carried out my wishes and directions, and has conducted the laborious duties entrusted to him to my, and I trust to your, entire satisfaction.

As a test of his ability to conduct the operations, and of the quality of the work obtained I need only refer to tabular statement II attached, from which it appears that although the mean triangular error is large (0″·65), as has hitherto generally been the case with the 24-inch theodolite (Troughton and Simms' No. 1, *altered*,) in use with the Madras Party, yet the probable error of the angles obtained this season is only $\pm$ 0″·144, and the mean of all 75 angular corrections computed 0″·24. I trust you agree with me in thinking this highly creditable to Lieutenant McCullagh's powers of observing and carefulness, this being his second season's practice with a 24-inch theodolite.

I beg to express my obligations to Lieutenant McCullagh for the ready and cheerful way in which he has backed me up in completing the series, and I repeat that without his assistance, I do not think it could have been effected this season.

Mr. J. W. Mitchell, Asst. Surveyor 1st Grade.

(32.) Mr. J. W. Mitchell, owing to a variety of adverse circumstances of which rainy, cloudy and hazy weather were the chief, has a very small amount of triangulation to shew for the season's work.

He visited 7 stations and completed only five triangles.

It must be allowed that the country (Kurug and the Western Ghâts) was difficult, the weather extremely bad or unfavorable, and the rays unusually long: his signalmen suffered from fever and were frightened by wild beasts.

I am glad to state that his observations seem to be very good, the average maximum difference between the extreme values in fifteen measures of each angle being 7″·4, and his mean triangular error 4″·6 (see table IV.)

Mr. O. V. Norris, Asst. Surveyor 3rd Grade.

(33.) Mr. Norris accomplished the task assigned to him. He examined and repaired 2 old stations, built 2 new platform stations, and finally closed and delivered 9, (about 50 days' work). He ascended 13 hills, each about 1,500 feet high, cleared or made about 12 miles of pathway and marched 1,165 miles in 96 days. He was delayed 40 days in a season of 199 days, 18 of them by sickness.

Mr. C. D. Potter, Asst. Surveyor 3rd Grade.

(34.) Mr. Potter performed the task I gave him moderately well. He built 5 and finally closed 9 platform stations (50 days' work) ascending 15 hills over 1,200 feet high and marched 1,068 miles in 86 days, being delayed 32 days out of 179 in the field. He also observed some secondary angles with a 7-inch theodolite at a few stations.

His progress was not rapid, and I had occasion to find fault with the insufficiency of foundation given to one or two of the stations which he built, also for the most surprising error of embedding a permanent (⊙) station mark, on one side of, instead of precisely plumbed underneath, a pole and brush signal that had been previously erected and observed, which he found inconvenient or inadvisable to remove. I need scarcely say that I ordered him to revisit the spot and place the mark-stone correctly.

Mr. E. W. Laseron, Asst. Surveyor 3rd Grade.

(35.) Mr. Laseron has done a very good season's work. He accompanied the main party for 5 months and performed the duties of observatory recorder and office assistant with his usual ability, neatness and regularity, to my entire satisfaction, and that of Lieutenant McCullagh who reports most favourably of him.

The principal angle books were kept up in duplicate, notwithstanding the rapidity of the observations when there were two observers.

After the completion of the principal triangulation, I directed him to execute some minor triangulation with the 7-inch theodolite to fix some secondary points where they appeared to be most required. This he appears to have done very well, having observed 12 measures each of 55 angles at 13 stations, forming 18 triangles with a mean triangular error of 4″·6, and fixing 9 new points, with vertical angles to each, in two months, during which he marched 345 miles in 30 days, ascending 9 hills, each about 1,100 feet high and returned to Bangalor on the 30th May.

I am very well pleased with Mr. Laseron's first essay in independent triangulation. He is already a good observer, and if he continues to take pains to improve, and gains a little more experience he promises to become a very superior trigonometrical surveyor.

Sickness in camp.

(36.) Although the progress of the main party was not actually stopped by sickness, yet the hospital was never empty, and not a member of the party escaped without suffering from the common bilious or jungle fever, or from the rheumatic complaints rife in the districts traversed.

The instruments in use with the party generally in good order.

(41.) I have to report that the instruments and equipment of the party generally are in serviceable order, or in course of repair to be made so.

The 24-inch theodolite.

The principal instrument, Troughton and Simms' 24-inch theodolite No. 1 (altered) is in good working order and adjustment. As the old cases and carrying apparatus were getting shaky, I have renewed them with lighter and more convenient ones, and I am now having a new braced tripod stand made which I trust will be as steady as, and considerably lighter than, the old one.

Observatory tent gradually renewed of late and lightened.

(43.) The observatory tent has gradually been renewed, little by little, during the last few years, and very much lightened by substituting bamboos for the heavy tie and cross rods of solid squared wood.

I think that the gain in lightness of equipment has materially aided our progress, and I am striving still to reduce the weight of every thing to be carried, to a minimum.

General appearance of the country.

(46.) The country traversed by the Series this season is one of great beauty and interest. Superficially it consists of forest clad hills and valleys of no great height or depth, diversified by open grassy glades and downs, many streams and rivers, with some prominent peaks, and many bold bluffs and precipitous cliffs.

The ridge of the Western Ghát.

(47.) The prime feature of the country is the irregular ridge line of the Western Gháts running generally N. N. W. and S. S. E., at a distance of 10 to 30 miles from the western coast, between 15° and 13° North Latitude, and rising from a height of 1,500 feet in Sunda, to 3,000 feet in Manjerabad.

The Malnád.

(48.) This part of the country is called the "Malnád" (or Male-nádu) "Rain district" from the excessive amount of rain which falls here. On the western slopes and summits of the Gháts, (by Gháts is usually intended the *hills* as well as the actual *passes* and valleys between them) the rain-fall from May to October is very heavy, from 150 to perhaps 300 inches or more, falling in a single season, and this combined with frequent dense fogs and clouds, when there is no rain, night and morning, and also with the moisture wafted in from the west by the sea breeze during the hot months of February to May, produces and reproduces such a vigorous growth of plants and trees that the people can hardly keep their clearings free from jungle.

Heavy rain-fall.

Features of the Malnád.

(49.) The head of the Naggar Malnád may be considered to be the Koté Kán or Kuduré-Mukh and the Balál Rayana Duruga; or perhaps, the parallel range of high hills a few miles to the northward running from the Varáha Parvata at Ganga Mulla near the edge or ridge of the Western Gháts where the Tunga and Bhadra rivers rise, eastward by the great Vedachala and Angrikal hills to the grand conical peak of Mérti Parvata (the "Calasa Peak" of Indian Atlas sheet No. 43.)

The drainage generally to the North and N. E.

(50.) The valleys here are from 2,500 to 3,000 feet above the sea, but fall rapidly towards the north and north-east to 2,000 feet, beyond which their slopes are more gentle and undulating, but with a decided northward and north-eastward tendency.

The Bhadra, Tunga, Choradi and Warda (Varada) all flow in this direction.

Drainage of the Naggar basin alone by the Shéravati to the N. W. The Gérsappa or Kurkanni waterfalls.

(51.) But the Shéravati which rises in the rocky fastness of Kauli Duruga, and drains the Bidárúr (vulg. Bedenore) or Naggar basin, after a north-westerly course of about 40 miles, precipitates its waters by a single drop of more than 800 feet at Kúrkanni into the Gérsappa valley or ravine, and so to the west coast. Some officers of the Indian Navy, &c., measured the main fall from a cradle suspended in front of it from a cable stretched across the chasm. They found the pool at the base of the Rája fall 829 feet below its summit and 132 feet deep. The river here is perhaps some 400 yards wide, but the main cataract falls in a narrow chasm at the north or right bank of the river only 40 or 50 yards wide. There are 3 other very beautiful cascades, but their fall is broken by projecting rocks.

The western face of the Gháts very steep or precipitous.

(52.) The declivities on the western face of the range from Kudure Mukh to Gersappa are very steep and frequently precipitous, so much so that I suppose they very commonly attain a gradient of 30°, *i.e.*, a fall of 1 in 2, the height being half the actual base.

The peaks of the Gháts.

(53.) Numerous peaks rise above the average height of the range by 500 to 1,000 feet, but few of them exceed 3,600 feet above the sea; Chandraguti (2,794) Kodachádri (4,411), and Kudure Mukh (6,215) feet stand out very conspicuously above all the rest, only equalled by Merti in the Tunga Bhadra Doáb, and only surpassed by the Chandra-drona (Moon [*i.e.* crescent] shaped) hills, also now commonly called the Bába Budan hills from the name of a Muhommedan Pír or

Kallandar who lived and died there some years ago, and is reported to have introduced the coffee plant first into Maisúr.

(54.) The gháts, or passes themselves, running east and west through the range, are numerous, being on the average only 10 miles apart, and though mostly disused and impracticable now, attest the fact that there was formerly much traffic between Maisúr and the west coast. The existing traffic is large, and is maintained by means of 4 or 5 new gháts, most of which are open and some of them already available for wheel carriage.

The numerous old passes superseded by a few new roads.

(55.) In point of fact however, trade is chiefly effected by pack cattle, some thousands of which daily throng the passes and their approaches throughout December, January and February, carrying rice, betel-nuts, pepper, cardamoms, sandalwood and other exports to the coast, to exchange for salt and manufactured goods. Many Lambánies, (or Banjáries), besides numbers of country folk from the eastward, are employed as drovers, and it is probably by these and by the Koramárs, Kerachárs and other gipsy tribes infesting the country in the dry season, that robberies are committed. Our camp was robbed four or five times without the thieves being discovered.

Traffic by means of pack cattle.

Gipsy drovers.

(56.) The population of the Nagar Malnád appears to have diminished greatly from what it must have been at some time.

Diminished population.

The large towns which once existed, and particularly the city of Nagar, named Haidar Nagar by Haidar Ali, instead of its older name Bidarur (Bamboo-town), as the Kelladi Nayak called Bidar-halli (Bamboo village) when they made it their capital, are almost deserted, and from the frequency of the deserted rice fields we observed, the rural population has also probably decreased in recent times.

Deserted towns and rice fields.

(57.) I find more difficulty in conceiving how a large town and agricultural population ever existed in the Malnád, than how it has decreased to its present state. The Rájas and Páligárs or feudal and predatory chiefs having disappeared, the merchants and artisans disappeared with them, and are only to be found in places where they can practise their craft under the protection and by the aid of a strong governing power. With these classes too the agricultural population also decreased for want of encouragement, and under stress of a difficult country and an unfavourable climate. Formerly no doubt the great attraction here lay in the fact that the rulers of the country spent their revenue here.

The seat of government removed the chief cause.

(58.) The more recently deserted rice fields noticed, indicate a further decrease in the rural population, which may be largely due to the decline of slavery or rather of domestic serfdom, which was once general in this part of the country (the Malnád), but is now disappearing.

The deserted rice fields partly due to decline of serfdom.

(59.) It is supposed that the introduction of Coffee has been one cause of the decline of serfdom. The coffee planters require labourers and offer high wages for them, and in order to obtain them, pay largely *in advance*, a temptation that serfs, who had been accustomed to receive their food and clothing &c. in kind, were unable to withstand, and therefore left their old masters for the coffee plantations.

Also to the absorption of all spare labor by the coffee plantations.

(60.) In recent times also the native merchants have "sold up" the old landholders, or supplanted many of them in their valuable areca (Kanarese *Adiké*) or betel-nut palm, pepper, and cardamom gardens, or have opened fresh gardens and coffee plantations for which they must have labourers. Like the European coffee planters before mentioned, they too pay high wages (3 or 4 annas a day for a continuance, and perhaps twice as much on occasions), and both alike, after absorbing all the labouring population of the country, obtain coolies in gangs from the South Kanara lowlands by means of large advances made to the village headmen, many of whom are large creditors and send those indebted to them up to the coffee estates and gardens to work off their debt by manual labour, (receiving their daily food only from the planters) during the open months December to March or April, after which time the coolies return regularly for the rainy season (May to October) to their homes in the lowlands.

Labourers obtained in gangs from the lowlands of South Kanara.

(61.) In this way I suppose a habit of migration is being established amongst a large class of the population, and the result to us is that no coolies, or day labourers, are to be had in the district of palm gardens and coffee estates, except from the old landholders, "Gauda" or "Heggade" (the latter are Jain) village headmen, and they have already too few domestics to cultivate all their own fields, and are unwilling to allow them to work elsewhere.

(68.) All who can, quit the Malnád when, or rather before, the rainy season begins, except jungle fowl, bison and elephants, who roam at leisure during the rains, retiring to the fastnesses and thickets of the gháts and the tarai, when the weather clears and the human population returns.

(69.) I should not omit to mention that during the last few seasons we have witnessed the apparently simultaneous seeding and death of the bamboo.

Period of the bamboo.

I believe I noticed cases of the bamboo flowering and dying in small patches in 1865-66 in Bangalor and the Eastern Gháts, and ever since that time I have yearly observed large tracts of bamboo forest simultaneously seeding or dying.

This year in the Nagar Malnád I observed very few patches of bamboo forest still alive, except in a few spots, particularly on the banks of the Bhadra River and to the west or northwest of the Bába Budan hills where we met with young bamboos of several years growth.

Mr. H. Stokes in his report on the Nagar Division of Maisúr, dated May 1838, para: 36, gives 12 years as the time for small bamboo to come to maturity and 40 years for the large kind, and he states that the small kind seeded in the beginning of 1837 round the Bába Budan hills. At Hebbe, the N.W. point of these hills, we found a very dense growth of green bamboos of the small kind, about 2 inches in diameter and 10 to 20 feet in height. These did not appear to be at all near their maturity and therefore their period cannot be one of twelve years. I have been able to get no precise information on the subject. The common belief here is that the period of the large bamboo is about 60 years and that of a smaller kind about 40.

The bamboo harvest (the seed being called "bidararisi" *i.e.* bamboo rice) is said to occur in in a year of scarcity. But the harvest is not simultaneous throughout the country; it takes several years for all the tracts of bamboo forest in a large province to seed, so that I suppose it may be only that an unusually hot, dry or peculiar season is required, after the bamboo has arrived at or near its maturity, to bring on and determine the time of its seed-bearing. The interesting fact is, that all the bamboos in the same tract, forest or patch, seed and die together, whilst those in the adjoining district seed and die together a year or two sooner or later, as if following the period of a Meteorological cycle, slightly modified by special local conditions, more or less favorable to them.

Extract from the Narrative Report—dated 1st September 1873—of Captain T. T. CARTER, R.E., Deputy Superintendent 2nd Grade, in charge Brahmaputra Series.

(2.) The principal observations in connection with the Brahmaputra Series had been stopped since the field season of 1869-70; Major Montgomerie R.E., the Officiating Superintendent decided that rather than leave these observations in abeyance for another year (when the services of one or two parties employed in principal triangulation would be available) the work should be carried on by the civil and native establishments of the No. 3 Extra or Leveling Party, in conjunction with the native establishment of the Brahmaputra Series, to which latter party Mr. H. Healy, Assistant Surveyor 4th Grade, was transferred from the Sambalpur Series.

(4.) In addition to the disadvantage of carrying on the work with an establishment that had been employed for years back on leveling operations and therefore unaccustomed to purely trigonometrical work, the principal observations had been in abeyance since the field season of 1869-70, and meanwhile the position of one at least of the pillars already built had been reported critical owing to the encroachments of the Jamúna (Brahmaputra) River; besides which the rays previously cleared would naturally have become overgrown after a period of three years, especially in a climate like Lower Bengal where the growth of vegetation is very rapid; these difficulties, anticipated on taking the field, turned out unfortunately too true.

Anticipated difficulties.

On my arrival at Serájganj (where the party disembarked from the river steamer) I was informed by Mr. Donnelly who had preceded me with the main camp and native establishment, that the pillar at Parkoksa had been washed away during the previous rains. It was necessary at once to make arrangements to rebuild the pillar at Parkoksa on one of the old rays. A portion of the native establishment was set to work to make the necessary bricks for the new pillar, and Mr. Donnelly was deputed to superintend them, while I proceeded to Soilabari T. S. to erect the scaffolding for the observatory tent at that station which I was desirous of having done under my own superintendence, in order that the several assistants having seen one built, might be independent when employed on this work in future.

Missing tower on side of continuation.

The scaffolding at Soilabari was completed on the 26th November, when I proceeded to Parkoksa to choose a site for the new pillar, ascertain what progress was being made as regards the making of the bricks and see that no difficulties were likely to arise as would cause a delay in the speedy completion of the pillar. Leaving Mr. Donnelly to build the same, lay off new rays to such of the stations it was necessary to observe from, to fix the new station, and to build the necessary scaffoldings for observing therefrom, I left him on the 30th of November and proceeded to build the scaffolding at Rashidpur T.S. and then commence final observations at that station. On the same date Mr. Healy was deputed to proceed to four of the tower stations in advance, and build the necessary scaffoldings for observing from the same; the building of the scaffoldings at the remaining four tower stations, likely to be observed from during the season, being entrusted to Sub-Surveyor Narsing Dás.

Final Observation

Rashidpur, December 10th to 16th.
Poerbári, " 17th to 24th.
Gaborgrám " 25th to 5th January.

(5.) Observations were taken at three stations as per margin, when I proposed returning to observe from the stations necessary to complete the Basalia and Bágmára polygons, in both of which the new station of Parkoksa entered. On the 29th of December I received a letter from Mr. Donnelly reporting that the Parkoksa pillar having reached the height of 25 feet had fallen down, severely injuring two of the masons: I at once proceeded by boat down the river to make a personal inquiry into the cause, which was that the bricks were moulded out of very bad clay and not half burnt; the officer in charge of the construction was Mr. A. W. Donnelly. This second mishap to the Parkoksa pillar necessitated my changing the order of observations; the stations of the Basalia polygon and four of the Bágmára polygon, being all dependent on Parkoksa. Returning to Gaborgrám T.S. and completing observations there, they were continued at the stations as per margin. On the 18th of January the pillar at Parkoksa was reported completed, and by the 5th of February Mr. Donnelly had finished the building of the scaffoldings at the stations of Poelsa, Basalia, Aloakandi and Parkoksa and had cleared the rays to the new pillar at Parkoksa. By this date both Mr. Healy and Narsing Dás had completed the building of the scaffoldings told off to them, I was therefore independent of all my assistants, as far as my observations went, and their services were available for the approximate work and minor triangulation. After Bágmára, the final observations were continued in the order shewn, up to the 21st of April, when the work was closed for the season. A slight hitch occurred at the station of Soilabári T.S: on the lamp-man proceeding there to shew his signal, he found he could not plumb the old mark, the pillar having deflected: this difficulty was got over by inserting two new mark-stones, or rather, mark-bricks, leaving the original mark-stones (inserted by Captain Thuillier) undisturbed: this necessitated my observing from Mokimpur T.S. I had been anxious throughout the season to complete the principal work up to the side Kanchipára T.S. to Garopára H.S., as the pillar at Halkachar is within ¼ of a mile of the river, and to have observed from the two stations above named would have made the next season's work independent of it; but by the 21st of April (after nearly six months incessant work) the whole of the party were more or less indisposed. At the Hill Station of Garopára, two of the signallers had to return on account of fever, water there was scarce, and I was unwilling to run the risk of laying up the establishment at the end of the field season, especially, as they had been hard at work from the beginning of November: I determined therefore to close work for the season at Jánkipur T.S.

The Parkoksa Pillar falls down at height of 25 feet.

Boladanga T.S., January 6th to 14th.
Sádipati T.S., " 15th to 22nd.
Char-Sherpur T.S., " 23rd to 28th.
Bágmára T.S., " 30th to February 7th.

Poelsa T.S. February 8th to 14th
Basalia T.S. " 15th to 24th
Soilabári T.S. " 25th to 28th
Mokimpur T.S. March 3rd to 4th
Parkoksa T.S. " 6th to 11th
Aloakandi T.S. " 12th to 20th
Bonarpára T.S. " 22nd to 28th
Halkachar T.S. " 29th to 14th April
Jánkipur T.S. April 15th to 21st

Weather and atmosphere.

From the time the party took the field (15th November 1872) up to within a few days of its closing work (21st April), with the exception of half an hour's rain on the 2nd February and on the 4th March, there was no rain. Captain Thuillier in his report of his operations during the field season 1869-70, describes exactly the difficulties under which the observer labours while at work in these parts, and owing to the want of rain this season, the atmosphere was particularly bad. During the month of December and up to the end of February, a thick fog covers the whole country, clearing away about 10 A.M., so that no morning angles are obtainable. At sundown during these months, the inhabitants drive in their cattle and at once set fire to the heap of refuse lying near the cattle shed. Every village is soon enveloped in smoke, and as our rays always pass over three or four villages, observations to lamps at this time of the year are impossible. As the season advances, *viz.*, from the middle of February to the end of March, the people (preparatory to tilling the land for the rain crop) burn the grass on the chars (low lands bordering the river) and the rice stubble which is left standing in the fields, leaving a heavy, smoky atmosphere which makes lamps invisible, and very often, in the case of the burning grass crossing the ray, interferes with observations to afternoon heliotropes. April is not much better; then a strong wind blows, raising the sand on the banks of the river and making it very difficult to see the heliotropes when the ray crosses it. The periodical N. W. storms begin about the 1st week of April; they come on very suddenly, and though they only last a short time, perhaps 1½ hours, it often happens, if at night, that one or two of the lamp-men have been obliged to remove their lamps for safety, and of course are unable to align them till next day, so that when after a storm the atmosphere is clear and lamps can be taken, observations are often interrupted by the instrument having been dismantled or a lamp removed.

Minor Triangulation.

(6.) In a country like Lower Bengal, a minor triangulation is almost impossible owing to the number of villages and exuberant vegetation necessitating the clearing of rays; indeed, it would be cheaper to fix any large town by the main triangulation and large sides. As it is one of your orders that on no account is secondary work to be neglected, it has been usual to fix the villages in close proximity to our stations by simply taking their direction from the pillar, and measuring their distance with a perambulator; in this way, a considerable number of villages (114 in all) have been fixed sufficiently near enough for geographical purposes. An attempt was made to cut in flags on large trees from the principal stations, but this entirely failed. Another way of fixing secondary points is by carrying a traverse, and in this way, three paka buildings were fixed, which lay near the principal work: I was anxious to fix the large towns of Mymensing and Bograh if possible by triangulation; while observing therefore from the tower station of Poerbári, I visited the small out station of Jamálpur of the Mymensing district, and saw at once that it was feasible to carry a minor triangulation, emanating from the side Poerbari T.S. to Char-Sherpur T.S. along both banks of the old bed of the Brahmaputra river, which though now a comparatively small stream as compared to the Jamúna river, is still called the Brahmaputra: the jail at Jamálpur was conveniently situated for breaking down the side Poerbari T.S. to Char-Sherpur T.S. I accordingly, on the 7th of February, directed Mr. Donnelly to take up this work, and it occupied him for the rest of the season *viz.*, to the 19th of April. I am bound to state that I consider that this was very trying work, and Mr. Donnelly deserves great credit for carrying it through successfully during the months of March and April, the hottest time of the year in these parts; Mr. Donnelly at the close of his labours was much pulled down: his total out-turn of work was as follows:—

Mr. Donnelly takes up the Minor Triangulation to Mymensing.

Number of stations observed from		54
Do. of triangles of which 3 angles were observed		54
Do. of intersected points		13
Do. of miles of ray tracing		8
Do. of points fixed by ray traverse		5
Do. of heights observed		1
Do. of paka points fixed		21
Do. of paka platforms built and fixed		4
Length of secondary series	miles	44
Area of secondary triangulation	square miles	32

In addition to this, he had previously completed 34 miles of ray tracing to and from the Parkoksa pillar, and superintended the construction of 5 scaffoldings for principal observations. Unfortunately his work in recess bears a very bad comparison to his field work. It was the 6th of August before his angle books were brought up and the computation of his field work could be taken in hand.

Mr. Healy, Assistant Surveyor 4th Grade.

Approximate work.

Káshdoho T.S.
Narsingbanj T.S.
Gobindpur T.S.
Alangjáni T.S.

(7.) Mr. Healy having completed the building of the four scaffoldings allotted to him on first taking the field, he was directed on 15th January to commence the building of the four pillars as per margin, necessary to complete the series on its western flank: this work he had finished by the 31st March, when he rejoined my camp and was subsequently employed in recording, bringing up angle books, &c. I have not had an opportunity of visiting any of the pillars built under Mr. Healy's direction, but I have every reason to believe that he has exercised a careful supervision in their construction: his monthly papers, accounts &c., have been well and neatly sent in, and in office he has worked hard.

Narsing Dás, Sub-Surveyor.

(8.) About the time Mr. Healy was directed to complete the building of the remaining pillars (tower stations) of the series, Sub-Surveyor Narsing Dás was deputed to build the platform stations on the eastern flank in the Kurabári Hills, the western spurs of the Garo Hills; this piece of work he also completed, under difficulties, by the 31st of March. The majority of his establishment were laid up with fever the greater part of the time, this part of the country being very unhealthy and water scarce. Before entering into these parts, I had secured the assistance of the Deputy Commissioner at Táro (Gáro Hills) and had also procured parwanas from the Assistant Commissioner of Goalpára. Narsing Dás met with no difficulties excepting those due to the unhealthiness of the country; he found the inhabitants only too willing to assist in road making, bringing up water &c. I consider that great credit is due to Narsing Dás for successfully completing the building of these platform stations by the above date when he rejoined my camp. He has been of the greatest assistance to me in every way both in the office and the field.

Amjad Ali, Sub-Surveyor.

The other Sub-Surveyor Amjad Ali acted as my recorder during the whole of the season as well as assisting in the current office work.

Mr. C. J. Neuville, Surveyor 2nd Grade.

(9.) Mr. Neuville took no part in the field operations during the season having been granted six months leave on medical certificate from the 1st November 1872 to 1st May 1873. Since the return of the party to recess quarters he has worked hard at the various computations and given me satisfaction.

People and country.

(10.) On both sides of the Jamúna (Brahmaputra) river and bordering the same, the population is entirely Muhammadan the people appear industrious and well behaved, with large herds of cattle, good crops and comfortable villages, they seem to live an easy, independent life. The men appear to be strong and healthy and those not employed in agriculture are boatmen. Hâts or fairs are held at all the large villages some day in the week. The constant occurrence of fires in the villages must however be a source of anxiety, more as regards the loss of grain &c. stored in and around their huts, than the loss of the latter themselves, which being composed of grass and bamboos are easily replaced as both are plentiful. A mud hut is never seen, the reason being that walls built of mud or of unburnt bricks would be washed away during the heavy rains. In most of the large zamindári holdings there is one paka building called the zamindár's kachahri. The chars (name given to the ground on the banks of the river left dry as the river recedes after the rains) produce the best crops, one of the chief being jute which is grown to a great extent in the three districts of Bograh, Mymensing and Rangpur, especially in the latter. Seréjganj is the principal jute mart in this part of the country, and has become of such importance as to warrant the Bank of Bengal establishing a branch there; it is also the site of a very flourishing Jute Spinning Company, the mills of which employ some 800 natives daily, and children from four years old are to be seen working at the machinery as adroitly as in some Manchester Cotton Spinning Mill. The party being provided with six elephants there was no difficulty in moving about the camp equipage &c., but without this means of conveyance great difficulties would arise in moving from station to station. The country being low (not more than 50 feet above sea level) is intersected with khâls or watercourses and covered with bhíls or marshes.

Proposed employment during field season 1873-74.

(12.) There remains to complete the junction with the Assam Longitudinal Series either 3 quadrilaterals or two hexagons. In addition to completing the principal triangulation it will be necessary to protect the pillars at the hill stations as laid down in Departmental Orders. The assistant employed on the work will have ample time and opportunity for secondary triangulation and connecting with the G. T. Survey some of the stations of the Gáro Hill Topographical Survey, and such prominent peaks as may be visible from our hill stations. In the course of next season's work, I propose connecting the Civil Station of Bograh (should you think it desirable), but I am afraid it can only be done by a ray trace traverse, as even with small sides of one mile or so in length, a minor triangulation would be impossible, except at great expense, owing to the numerous villages that are studded about and the amount of vegetation necessitating the continual clearance of rays.

Considering the circumstances under which the party took the field, being all new to the country and work, with a native establishment, the signallers of which had grown rusty after a cessation from principal work for a period of three years, and a considerable delay being caused by marching and countermarching due to the fall of the pillar at Parkoksa, in addition to the invariably bad state of the atmosphere, I hope that the out-turn of work as given in the accompanying table may be considered fair.

Extract from the Narrative Report—dated 22nd August 1873—of Captain A. PULLAN, S. C., Officiating Deputy Superintendent 3rd Grade, in charge Kattywar Party.

Preparations for taking the field.

(1.) The party left recess quarters on the 10th November, the Assistants and Native Surveyors proceeding by rail to Viramgám and the native establishment, under Mr. E. Wyatt, by rail to Bombay, thence by boat to Gogo and from that port by road to Viramgám. Captain Trotter joined the Head Quarters Camp at Viramgám on the 25th of November.

Some few days were occupied in projecting points &c. on the plane tables and then the Surveyors proceeded to take up their respective plane tables.

Out-turn of work.

(2.) The season 1872-73 has been a satisfactory one. 2,642 square miles have been topographically surveyed on a scale of 2 inches = 1 mile; 2,680 square miles have been covered by net-work of triangulation; 739·5 linear miles of boundary traverse have been run and every boundary pillar or stone fixed, besides 409·3 linear miles of traverse, which has been carried along the margins of plane tables to test the accuracy of the detail work.

(3.) The portion of the province under survey, during the past season, was the northern portion of Jhálawár, a bare and sterile country bordered on the north by the wide salt wastes of the Rann of Kutch; the detail surveyors met with no obstacles to hinder the rapid execution of their work and thus a very considerable area of ground was topographically surveyed this year.

Captain Trotter, R.E.

(4.) Captain Trotter having been selected to accompany the British mission to Yárkand, I proceeded by order from Head Quarters to relieve that Officer at Wadwán, and took over charge of the Kattywar Party on the 6th of April, and from that day until the 28th April I remained at Wadwán conducting the current work of the office and bringing up some arrears of work. Finding that many alterations had been made in Wadwán Camp, more especially the extension of the Railway Line to the camp and the erection of several blocks of building in connection therewith, I made a re-survey of the portion of ground in question, and added the details, when complete, to Sheet 12 of Kattywar, which had already been published. I also went over all the published sheets of Kattywar, making such small corrections and addenda as were necessary previous to despatching the maps to office of the Political Agent, Rájkot, for sale.

Return to recess quarters.

(5.) On the 28th of April all the topographical Surveyors having completed their work, I started for recess quarters and opened office at Púna on the 1st of May.

John McGill Esq., Assistant Supdt. 1st Grade.

(6.) Mr. McGill, on arrival at Viramgám on the 15th November, was employed in preparing a chart of the triangles to be broken up by the net-work triangulation which he was about to take up; on the 3rd December he began work at Rájkot and carried a net-work of triangulation over Sheets 34 and 35, completing 1,400 square miles by the 26th of March on which date he closed work.

Mr. McGill is so well known as a rapid and excellent observer, and his work is always so good that it is unnecessary for me to comment further upon it.

Mr. F. Ryall, Surveyor 4th Grade.

(7.) Mr. Ryall began work on the 28th November and continued sketching ground throughout the field season. He closed work on the 10th of April, having completed 194 square miles of survey. Mr. Ryall works slowly but accurately.

Mr. J. Wood, Surveyor 4th Grade.

(8.) Mr. Wood was employed during the early part of the field season in projecting plane tables. He commenced plane tabling on the 20th December and worked until the 18th January. He was then summoned to Dhrángdra where he remained computing until 21st February. He again took up topographical work on 22nd February and closed work finally on the 6th April, having completed 164 square miles of topography.

Mr. Wood is a very valuable assistant as well in recess quarters as in the field.

Mr. N. C. Gwynne, Asst. Surveyor 1st Grade.

(9.) Mr. Gwynne on arrival at Viramgám was employed in completing fair Sheets 23, 24 and 29, and in mounting and projecting plane tables until the 16th of December, on the 18th he commenced plane tabling and closed work on the 5th April, having completed 239 square miles of topography in very good style, besides superintending and examining the work of Sub-Surveyors Govindji Mahalay and Nilkant Vittal. Mr. Gwynne is a most valuable assistant both in the field and in quarters, and his work this season is as thoroughly satisfactory as that of previous years.

Mr. T. Rendell, Asst. Surveyor 1st Grade.

(10.) Mr. Rendell was employed on his arrival at Viramgám in allotting work to the various traverse Surveyors. On the 24th of December he commenced plane tabling near Pátri, and turned out 192 square miles of accurate and neatly executed work by the 20th of March. On the 23rd March Mr. Rendell relieved Mr. McGill who was proceeding on leave, and took up the net-work triangulation in Sheet 33. This work Mr. Rendell completed on the 20th of April, having triangulated 270 square miles of country, altogether a highly satisfactory out-turn for the season.

(11.) On the 28th of November, Mr. Wyatt commenced work and proceeded to triangulate Sheets 10 and 10—*a* of Kattywar. On the 16th December he joined Mr. Rendell and computed points for the R. Plane Table N.E. Section of Sheet 10. He triangulated again from 20th December to 15th January, sketched ground in Sheet 10 from 28th January to 28th February, commenced the triangulation of Sheet 32 on the 11th March and completed it on the 21st April. Completing in all 1,010 square miles of net-work triangulation and 100 square miles of plane table sketching.

Mr. E. N. Wyatt, Assistant Surveyor 2nd Grade.

Before leaving for Masúri, Captain Trotter expressed himself much pleased with Mr. Wyatt's energy and steady hardworking qualities.

(12.) Mr. Fielding commenced work at Viramgám on the 17th November and was employed in preparing plane tables and completing the fair maps of Sheets 23, 24 and 29. On the 1st of January he began topographical work and finished on the 2nd of April as he was suffering a great deal from exposure to the sun. Mr. Fielding completed in all 283 square miles of plane table sketching of good quality and execution.

Mr. W. A. Fielding, Assistant Surveyor 3rd Grade.

(13.) Visaji Punt was employed throughout the field season with the Head Quarters Camp and was extremely useful. In April he proceeded by my orders to the Rann and took levels at a mile apart along the edge of the Rann as it passes through Sheets 10 and 20.

Visaji Punt, Senior Native Surveyor.

This piece of work extremely irksome on account of the great heat and want of water, he completed entirely to my satisfaction. He rejoined me at Wadwán on the 24th of April.

(14.) Govindji Mahalay was employed during the season in plane table sketching. His work is favorably reported on by Mr. Gwynne as far as regards Sheet 22, but I find the drawing of the low ridges and scattered brushwood jungle in Sheet 20 is much exaggerated, and calculated to convey a wrong impression of the ground.

Govindji Mahalay, Sub-Surveyor.

(15.) Vishnu Moreshwar was employed on topographical work during the season. Mr. Fielding reports favorably as to the quality of this Sub-Surveyor's work, but adds that he found him inclined to take his work somewhat too easily.

Vishnu Moreshwar, Sub-Surveyor.

(16.) Keshu Vittal was employed during the entire season as recorder to Messrs. McGill and Rendell.

Keshu Vittal, Sub-Surveyor.

(17.) These four Sub-Surveyors were employed in running boundary and check traverses during the field season. The results of their respective work will be found in the tabular statement.

Narsu Dinkar, Bholuji Bhosekar, Krishna Govind, Tukaram, Sub-Surveyors.

(18.) Shridhar Succaram and Nilkant Vittal were employed on topography throughout the season, both turned out good work and are favorably reported on by Mr. Gwynne.

Shridhar Succaram and Nilkant Vittal, Sub-Surveyors.

(19.) Having only taken over charge of this party at the termination of the field season, I am unable to do more than give the short outline sketch which I have given of the proceedings of the party during the field season. Captain Trotter before leaving expressed himself pleased with the work of all hands, and on careful comparison of the junctions of plane tables and the agreement of traverse check lines with the detail drawing, having in view also the average triangular error of the triangulation and the average linear and circuit errors of the traverses, I most readily endorse Captain Trotter's opinion of last season's work.

(20.) The work which I have laid out for the coming season is as follows :—

Arrangements for next season's operations.

1st. The net-work triangulation of Sheets 43,44,45.

2nd. The furnishing of extra points in Sheet 40 and the survey topographically of Sheets 40,41 to complete Degree Sheet XI.

3rd. The Survey topographically of Sheets 31,32,33,34,35 on a scale of 2 inches to 1 mile.

4th. The survey of the Cantonments, Civil Station and native town of Rájkot on a scale of 12 inches to 1 mile agreeably to the instructions contained in your letter $\frac{49}{953}$, dated 4th August 1873. Owing to the complicated nature of the state boundaries near Rájkot and intricate and hilly country comprised in the 5 sheets to be surveyed topographically, it may not be possible to complete the plane table sketching of the whole 5 sheets, but every endeavor will be made to do so.

TABULAR STATEMENT OF OUT-TURN OF WORK IN KATTYWAR DURING THE FIELD SEASON 1872-73.

Triangulation.

No.	Observers' Names.	Instrument used.	Area triangulated in square miles.	No. of Points Heights fixed.	No. of Points Position fixed.	No. of stations visited.	Triangles, 3 Angles observed.			Triangles, 2 Angles observed.	
							No. of triangles.	Mean triangular error.	Discrepancy per mile.	No. of triangles.	Average discrepancy per mile.
								"	Feet.		Feet.
1	J. McGill, Esq., ...	Cooke and Son's 7-inch ...	1400	244	653	69	125	8·1	0·6	1051	1·8
2	Mr. T. H. Rendell, ...	" " ...	270	21	123	16	29	16·1	0·7	186	2·2
3	" E. N. Wyatt, ...	Troughton & Simms' 6-inch	1010	93	313	59	90	17·2	0·4	566	1·9
		Total	2680	358	1089	144	244	Mean 13·8	Mean 0·6	1803	Mean 2·0

Topography.

No.	Plane Tablers.	Area surveyed Scale 2 inches = 1 mile.	Average No. of plane table stations per mile.	Remarks.
1	Mr. F. Ryall, ...	194	7·7	
2	" J. Wood, ...	164	7·3	
3	" N. C. Gwynne, ...	239	6·1	
4	" T. H. Rendell, ...	192	5·6	
5	" E. N. Wyatt, ...	100	4·3	
6	" W. A. Fielding, ...	283	5·0	
	Native Surveyors.			
7	Govindji Mahalay, ...	360	7·0	
8	Vishnu Moreshwar, ...	336	5·9	
9	Shridhar Succaram, ...	452	6·6	
10	Nilkant Vittal	322	6·5	
	Total	2612	6·2	

Traverses.

Names.	No. of Linear miles traversed.		Average error per 1000 links.	Remarks.
	Táluka Boundary.	Check Lines.		
Narsu Dinkar, ...	207	161	0·89	
Krishna Govind, ...	252	11	1·17	
Bholuji Bhosekar	280	52	1·05	
Tukaram Chowdry	0	185		
	739	409	1·04	

Extract from memoranda forwarded by Captain Trotter, R.E.—late in charge Kattywar Party—on the operations during Field Season 1872-73.

(1.) As Captain Pullan took charge of the party before the close of the field season and has had an opportunity of carefully inspecting and examining the whole of the work, I leave to him the duty of reporting on the amount and quality of the work performed by each individual as well as of the cost of the survey and other details usually contained in the General Report.

Captain Pullan's report.

(2.) The country surveyed has been as usual in Kattywar of a very varied character; adjoining a large flat tract of salt waste, the surveyor comes upon rich, well cultivated soil, bounded perhaps on the other side by two ridges of sandstone absolutely devoid of vegetation. The whole of the eastern portion of the ground is decidedly flat with hardly a rise of any description. Near Dhrángdra however, and running down N.N.W. and S.W. from it, are numerous sandstone ridges many of them valuable as quarries. The sandstones of Dhrángdra being famous in Guzerat, and the Dhrángdra "Chakis," or round mill-stones, common throughout the country.

Aspect of the country.

Towards the south-west of the ground surveyed, the nature of the country changes: there hills and jungle take the place of plains and cultivation. The produce of the country is much the same as detailed in former reports: wheat, bájra, cotton, jawári and til being the chief productions. Unlike the other parts of Kattywar, which have been surveyed, almost the whole of the water supply is here procured from tanks. Where there are streams, the water is generally brackish, and the inhabitants always drink in preference from the tanks of which there are generally one or more to every village. These mostly dry up in the hot weather; but in the majority of them there are paka wells, from which water is procured when the tank is itself dry. Many of the large tanks in cold weather present a very picturesque appearance with the tops of half a dozen or more wells appearing just above the surface of the water.

(3.) A peculiar feature of the country is the number of large paka wells or "báolis" generally built some hundreds of years ago in the vicinity of what were then large and populous towns. Some of them are very roomy and beautiful, the covering and the ornamentation of the approaches being very elegant and elaborate. A broad flight of steps generally richly ornamented at the sides, leads down to the water. On the first landing place you look through a long vista of 3 or 4 cupolas, on descending a few more steps to a lower landing, you again look along and through parallel rows of cupolas, and on getting to the bottom, and near the level of the water, you look through a third row forming a basement of very elegant triple-storied cupolas. These are erected over each of the 3 or 4 wells at the bottom, the whole are surrounded by a stone pathway by which you can get access to the smaller wells and to a large open circular well at the other end, from which water can be lifted to the top by the usual methods without the trouble of descending the steps. The temperature at the lower landing of these wells is cool and delightful, and would form a charming place in which to spend the heat of the day in the hot weather. It is a peculiarity of these "báolis" that there is nothing above ground to lead to the supposition that there is any thing unusual underneath, a long low stone wall, 2 feet in height, being all that is visible to the eye.

Large underground wells or "Báolis."

(4.) With the exception of a few antiquarian remains, the country is most uninteresting, no mountains or even hills worthy of the name, no fine rivers, or large forests, or picturesque views meet the eye. Towards the north a partially cultivated, treeless plain is all that the traveller sees, with an occasional tank whose low banks form the only practicable points on which to erect stations for our triangulation. This plain gradually merges into the Rann of Kutch, an extensive desert about which much has been written by various authors but of which a short description will not be out of place here.

Description of the Rann of Kutch.

It is a vast and perfectly flat tract of desert without a scrap of vegetation of any kind and so little lower in level than the country to its south that in many places it is impossible to say where the Rann begins and the mainland ceases. There is often however, an intermediate strip of land, between the cultivation and the desert, on which grows a short stunted grass, the food of the cattle and wild asses when they can get nothing better. On the other hand portions of the Rann extend inland in bays meeting the sandy beds of rivers which all sink and are lost in the sands as soon as they come in contact with the Rann.

(5.) In some few places islands rise out of the midst of it, generally shewing marks of volcanic action. Some of these islands are more or less covered with grass, to collect which carts are sent over at the proper season from the mainland. In the cold weather it is possible to traverse the Rann with impunity, as although the sun is always hot yet there is generally a cool breeze blowing up from the sea on the west; but in the hot weather I have been assured that to spend a day on the Rann would be almost certain death: I have heard of more than one authenticated case where men have got lost on the Rann and have wandered about in a circle until they have fallen exhausted. I can quite imagine this to be true; for as the hot season advances the dazzling glare is blinding and the heat overpowering. The mirage distorts and magnifies the smallest object into the most wonderful shape; a stick appears like a tree and a stone like a hill, and no distant object can be seen at all.

(6.) The composition of the surface and subsoil appears to be in tolerably regular layers of sand and clay with a large quantity of saline matter admixed. This saline deposit attracts the moisture from the atmosphere and the surface is then frequently damp. For some months in the year, the Rann is under water. When the prevalent westerly winds begin to blow in March, the water in the Gulf of Kutch is gradually heaped up, and it advances in a slow wave right up the Rann until the fall of the monsoon in June, by which time almost the whole of the western portion is covered with water, varying from a few inches to a few feet in depth. When the rain falls, fresh water is carried into the Rann by the rivers that empty themselves into it and the whole becomes a vast lake—nowhere more than a few feet in depth—and which subsides gradually at the close of the monsoon. The admixture of fresh and salt water kills large numbers of fish; and, I have, in crossing the Rann, come across the remains of myriads of prawns which appear to have met their death in this manner. I have, also in the cold weather, seen heaps of dead locusts, which fortunately for the inhabitants of Kattywar, have fallen victims to exhaustion in crossing this desert tract.

(7.) The only animals that live in this wilderness are the common antelope, which often wander out some miles and spend some hours of the day there, and return to the mainland for food and water, and the *Ghorkar* or wild ass (Khachar is the local name). The latter breed in the Rann islands during the monsoon months, finding there plenty of grass and water: after the monsoon, when the waters have retired, they sometimes cross over to the mainland, and as the Rann is then a mass of slush several inches deep, they are sometimes driven into it by men on foot who are able to pursue and drive them about until the young ones fall perfectly exhausted and are easily captured. Few however caught in this manner survive this preliminary treatment.

(8.) The Rann is crossed by several cart tracks which will be shown in the season's maps. Some of these, towards the head of the Rann, are only closed for a few weeks in the year and are even then open for horsemen and foot passengers; others nearer the head of the Gulf are closed for half the year, *viz.*, from the first rise of the water in March or April until the subsidence of the waters after the monsoons. At the head of the Rann, and included in this season's mapping, are the new and extensive Government Salt Works at Pátri, a short account of which may not be uninteresting.

Salt Manufacture.

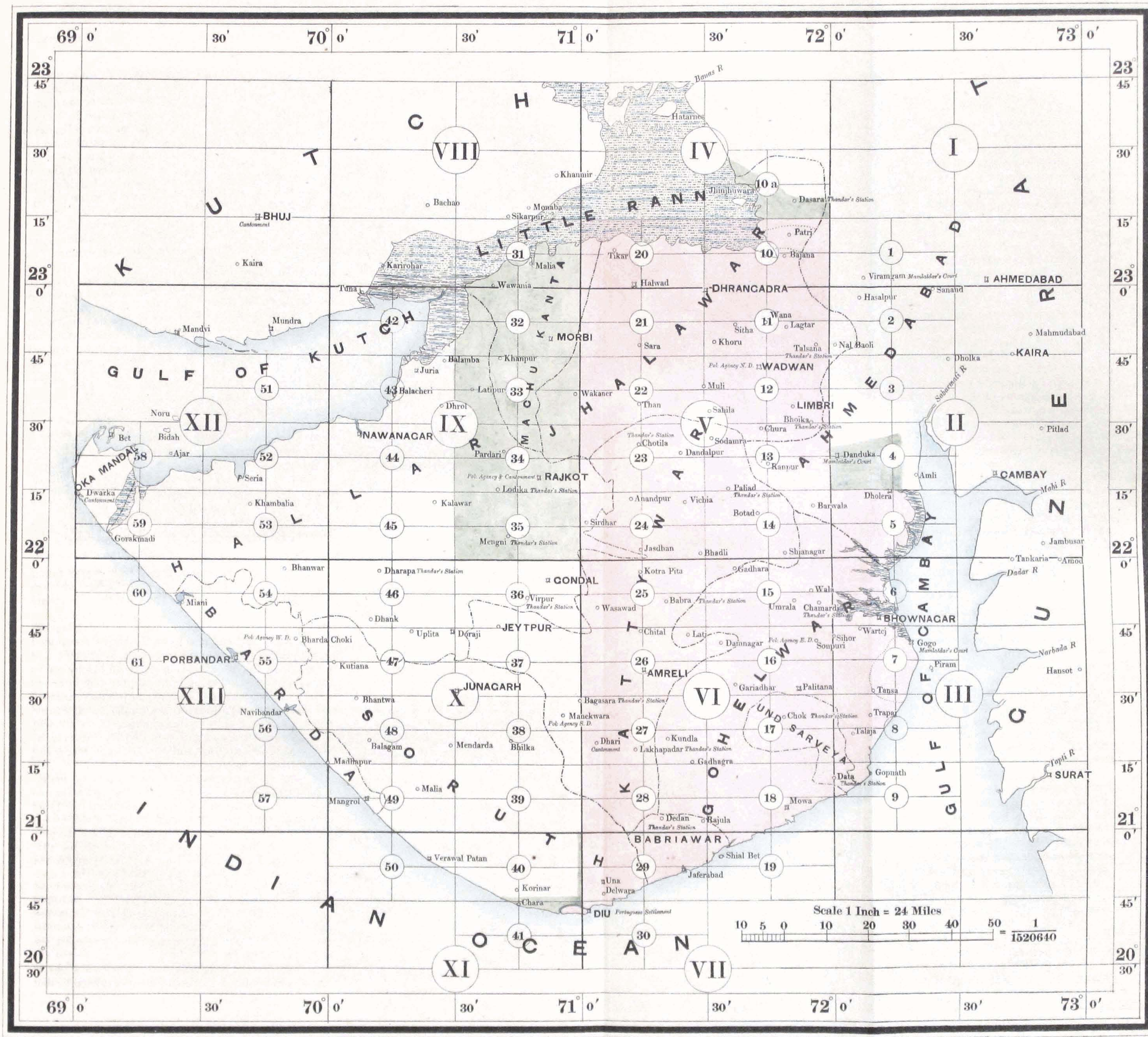
(9.) For more than a hundred years past, salt has been manufactured from water taken from wells dug in the Rann, more particularly at Kura in the Dhrángdra state and in Pátri and the neighbouring villages of Kharagora, Bajana and Uru on the eastern border of the Rann. Government has hitherto contented itself with levying a very heavy duty on all salt sold in our own districts; but on account of the large amount smuggled from Kattywar and also from the above mentioned places, Government has been compelled to undertake the manufacture itself. With this end in view, all the old Rann works have been closed (with the exception of those belonging to Dhrángdra, an independent state in Kattywar), compensation having been paid for old interests involved. All the works also on the western coast of India, between Cambay and Bombay, are tobe or have been closed, and all that part of the country will be supplied with Rann salt, manufactured at the Government Works. It is hoped by these means and by an introduction of an efficient line of patrols on the frontier, between the Kattywar states and our own districts, it may be possible both to keep the Kura salt from getting across to our own and the Gaíkwar territories and at the same time to prevent the Málwa opium from getting to Kattywar.

(10.) Prior to Government taking over charge of the new works at Pátri, the salt was manufactured by the "Agrios" (as the makers are termed) on their own account, in quantities limited by Government, to be sold to private merchants at a maximum rate of 2 annas per maund. Practically they did not get this price for it, as the merchants who purchased generally did so (on account of the abundance of the supply) at a much lower figure. Government now employ these same "Agrios," let them dig the wells and make the pans (giving them advances for that purpose) and purchase the whole of their stock of salt (if of approved quality) at 1¼ annas per maund, all round, removing the salt to warehouses on the adjacent shores that have been constructed for the purpose. The Agrios are therefore really much better off than they were before, as formerly that portion of their stock which remained unsold before the periodical setting in of the monsoon (when the whole of the works are flooded and the wells and pans filled up) was liable to be swept away. This actually occurred the year before last to the utter ruin of the salt owners, and I am informed that 42 per cent of the entire produce of the last five years has been washed away in the same manner.

(11.) It was proposed to manufacture during the past season twelve and a half lakhs of maunds of salt, which is a little above the amount estimated as required for consumption in that

GREAT TRIGONOMETRICAL SURVEY OF INDIA.

INDEX CHART OF THE KATTYWAR TOPOGRAPHICAL SURVEY.



C. Dyson Photo & 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., & S.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 1872-73.
Ditto Triangulated in advance up to 1872-73.

Photozincographed at the Office of the Superintendent Great Trigonometrical Survey, Dehra Dun, November 1873.

portion of the Presidency lying between Bombay and Ahmadabad. For this purpose 252 pans, each 250 feet long by 60 feet wide, have been constructed. The process of making the salt is very simple and is almost the same at Pátri as at Kura, but at the latter place, the pans are arranged in no sort of order, being scattered in all directions all over the place; whereas at Pátri they are arranged symmetrically in rows with spaces between for storing the salt. As soon as the monsoon has come to an end and the piled up waters of the Rann have retired, each "Agrio" sets to work to dig a well and to make his pan. The well has first to be sunk, as without the water procured from it the workmen would be unable to puddle and render watertight his pan. The sinking of the well, which he accomplishes with the aid of hired labour, occupies him some weeks. He soon reaches water, it is true, but only what is termed surface water, and which does not contain nearly so much salt in solution as another kind of water which he reaches generally at a depth of from 20 to 30 feet, on reaching which there is generally a rush of very strong brine which comes up with considerable force and rises several feet in the well: when he gets this rush of water he is satisfied and commences to prepare his pan. Sometimes however instead of tapping the brine he comes to a hard red clayey soil called "morod," and the experience of the past years has shown that when he comes to this he must abandon all hope of getting to the brine and start a fresh well elsewhere. Assuming however that he has reached good water, he prepares his pan by raising a small bank of earth all round it. He then pumps up water with the common balance pole and bucket and covers his pan with it to a depth of one or two inches. This water sinks into the ground and he then commences to puddle the pan by constantly (with the aid of his hired assistants) treading the ground, a most laborious process, for the pouring on of water and treading and consolidating has to go on until the bottom of the pan becomes quite waterproof, which from the quantity of clay in the soil it ultimately does of course in some soils quicker than in others.

(12.) This preliminary of well sinking and pan preparing generally occupies about two months, when ready the brine is pumped in to a depth of several inches and left to evaporate. As soon as the greater portion of the water has done so more water is poured on, and this is repeated perhaps once in every three or four days. Crystals of salt soon form at the bottom and the Agrios have to stir these crystals about frequently and briskly with a large rake. This goes on until a crop is ready, which generally happens about the middle of February, when all the water being allowed to evaporate, the salt, which then forms a layer several inches in depth over the whole pan, is taken out and arranged in conical heaps by the side of the pan, whence under the new arrangements, instead of being left on the ground and sold as the opportunity offered, it will be immediately carried on a tramway by trucks, to the central stores, about 2½ miles off and on high ground bordering the Rann. There it will be weighed and handed over to the Government Official deputed to receive it. This central store has been connected by a branch railway line about 22 miles in length (Pátri to Viramgám), which has been specially made for the purpose, and which was in course of construction while we were surveying the ground. The salt will be carried by the Railway Company to the depôts that are to be formed at Ahmadabad, Bhroch (Broach), Baroda, Balsar and Súrat where it will be stored away and sold to the public at a fixed rate.

(13.) Instead of taking one crop in February and another in April or May, a supply of better salt is obtained by continuing the manufacture without emptying the pan until April or May. An average crop of 18 ℔ per superficial foot of evaporating surface may be obtained from a good crop up to the middle of February, and for the second crop a somewhat larger quantity; if the crop be taken at the end of the season, only about 34 ℔ of salt of a superior quality may be obtained per foot. These quantities depend very much upon the amount of brine that may be pumped up, and if a man is lazy he will get a small return. The brine also is variable in quality, and some wells will give more salt than others. In March and April the salt is apt to receive very serious injury from the clouds of dust and sand that fly about. The Dhrángdra works at Kura appear to suffer more from this cause than the more protected works at Pátri. At the former place I was told that the manufacture was generally entirely stopped from this cause and from the supply of water in the works running short about the end of March or beginning of April.

(14.) The heat in the Rann being so excessive, it has been arranged that all the labour of carriage and storeage at the Government Works shall in the hot weather be carried on at night. At Kura the salt is generally made from surface water as they cannot obtain the brine springs which afford so rich a crop at Pátri. The reason is I believe that the whole ground at Kura is underlaid with "morod" and thus the water being deficient in quality as well as in quantity, they require two wells instead of one for each large pan: the process of manufacture is the same.

(15.) I estimated, after careful inquiries and measurements, the sale of salt at Dhrángdra to be about one lakh of maunds per annum. It has however been estimated by the Customs' Collector of Bombay at as high a figure as four lakhs, of which he assumes that 3 lakhs are smuggled across our frontier, causing a loss to our income of nearly six lakhs of rupees. Although we have been in correspondence on the subject, we cannot arrive at less discordant results. The calculations are somewhat elaborate and I need not give them here, but my own figures are confirmed by the statements of the Darbár Officials who however would naturally be disposed to estimate it at as low a figure as possible; for every thing over one lakh, which has been assumed to be the probable consumption in Kattywar itself of Kura salt, must be admitted to be smuggled.

(16.) In the Kura works, the digging of the wells and making of the pans, are undertaken by and at the expense of the "Agrios" who are assisted by their families and follow no other avocation. At our own works the salt manufacturers are also cultivators. The produce is generally sold at about 12 annas the donkey load ($2\frac{1}{2}$ maunds), but varies to from 10 to 13 annas. According to quantity of the total amount sold, one anna in the rupee is taken when the accounts are made up (annually) to defray the expense of establishment, which is very small consisting of one kárkun, one havildár and five peons: the balance is divided between the Darbár and the Agrios. Each therefore receives say $5\frac{1}{2}$ annas per donkey load or $2\frac{1}{5}$ annas per maund clear profit to the Darbár, and profit, less working expenses, to the "Agrios." Besides this there is a small duty levied of 2 pies per donkey load, or Rs. 1-8 per cart load.

(17.) The pans vary in size from 2,500 square feet to 10,000 square feet as against a uniform size of 15,000 square feet at the Pátri works. There are 80 wells at work but in most cases two wells are required for each pan. I purchased salt, retail, in the village of Kura at 112 pounds the rupee.

(18.) I have heard it suggested that the brine at the Kura wells was supplied direct from the sea by subterranean filtration. I made some experiments in the cold weather to test the same, but could detect no positive traces of tidal influence. It is true, there were periodically diurnal rises and falls in the water of the wells, but this I clearly traced to the effect of the pumping of the water up from other wells and the consequent lowering of the level of the water in the adjacent wells. I had purposed continuing the experiments in a more careful manner in the hot weather, but was unable to carry out this idea. It was said at Pátri that the water rose much higher in the wells in the hot weather than in the cold and this would certainly indicate tidal influence, as the periodical rise of water in the Rann in that season would certainly produce that effect, did subterraneous filtration exist to the extent supposed.

(19.) On the other hand at Kura very much nearer the sea, the water in the wells is said to be very much lower in the hot weather than at any other time; but it may be said that the "morod" underlying the Kura wells would prevent the influence of the tidal wave being felt there. Mr. Maury, the Customs' Officer, in charge of the Pátri works, was interesting himself in the question and has possibly carried out further experiments.

Secular depression of the Rann.

(20.) I made constant inquiries along the edge of the Rann to indeavour to get some light thrown on the subject of the supposed secular depression of the Rann; but although the oldest inhabitants recollect on about three occasions, during the past fifty years that the waters prior to the monsoon had advanced further than usual, I could not gather that there had been any permanent change of a marked nature. There is a doubt in my mind that the Rann was once the bottom of the sea or rather of a large shallow bay. At Jhinjuwára on the east edge, about 50 years ago (as far as I could learn from native reports) a large iron anchor was undoubtedly found buried in mud. It was broken up within recent years and I was never able, although I repeatedly tried, to get hold of any man who ever saw it: I have no doubt whatever that such an anchor did exist.

Extract from the Narrative Report—dated 11th September 1873—of Major C. T. Haig, R.E., Officiating Deputy Superintendent 1st Grade, in charge of the Guzrat Survey.

(2.) We were unusually late in taking the field, for the previous field season had been unusually long, which of itself called for a long recess, but apart from this, we were detained longer still by having to take up the work of utilizing the maps of the Revenue Survey, which had well nigh been abandoned as an impracticable job, but which you decided (on your inspection of this office) should again be proceeded with. Consequently it was not till the 23rd December that I left Poona myself, having sent off my Assistants a few days previously.

(3.) Owing to our taking the field so late and to the locality of our topographical work being so flat, close and wooded, we have only completed the topography of two sheets Nos. 9 and 10 and one plane table *viz.*, No. 8 of sheet 8, comprising an aggregate area of about 1,175 * square miles; but the triangulation and traversing have been pushed on, so that we have three sheets quite ready to be topographically filled in, and two others partially ready which require only some traversing for effecting the necessary connection between the Revenue Survey marks and our stations, and besides a net-work of triangles of about 3 mile sides, extended over about three-eighths of another sheet.

* Note.—Exclusive of margins.

(4.) The country topographically surveyed this year includes portions of six sub-tálukas of the Kaira Collectorate, the whole of the Pitlád Mahal (pargana) of the Gaikwar's territory, and nearly the whole of the Cambay territory, and makes complete the mapping of a continuous strip of country comprising 6 sheets lying between meridians 72° 30′ and 73° and parallels 21° 30′ and 23°, reaching from the outskirts of Ahmadabad to half way between Broach and Súrat, and containing the large towns of Kaira, Mahmudabad, Matar, Nariad, Barsad, Pitlád, Cambay, Jambusar, Amod, Wagra and Hansot, and the mouths of the rivers Narbada, Dhadar and Mahi, and about 35 miles of the Sabarmati, and the same length of its tributary the Watrak, and its confluents the Meswa and the Siri, also about 30 miles of the Khari river, the waters of which lose themselves over the rice cultivation west of Kaira, and eventually drain into the Sabarmati. The whole of this country is exceedingly flat, and with the exception of the promontories between the mouths of the rivers, is finely wooded, indeed, that of the eastern halves of sheets 8, 9, 10 and 11 is so thickly covered with trees that though exceedingly pretty to the eye of the admirer of nature, it is almost appalling to that of the topographical surveyor.

(5.) Owing to Captain Pullan being taken from this Party to take charge of the Kattywar Survey, I was unable to commence any triangulation in the Dáng district which I had intended to do.

(6.) On taking the field our strength comprised as per margin, and during the season there were the following casualties :—Captain Pullan withdrawn from 1st April 1873 to take charge of the Kattywar Survey, Mr. Hickie proceeded on 6 months' sick leave from 1st March 1873 and Mr. McA'Fee temporarily laid up by sickness for nearly a month.

Major C.T. Haig, R.E.
Captain A. Pullan, S. C.
Mr. A. D'Souza.
„ A. D. L. Christie.
„ C. H. Mc A'Fee.
„ E. J. Connor.
„ J. Hickie.
„ G. D. Cusson.
„ G. Hall.

Sub-Surveyors.

Gopal Vishnu.
Ganesh Bapuji, 1st.
Rowji Narain.
Luxumon Ghorpuray.
Mukund Dinkar.
Bhow Govind.
Balwant Govind.
Ganesh Bapuji, 2nd.
Vital Vishnu.

(7.) On a representation being made to Lieutenant Colonel Prescott, Superintendent Guzerat Revenue Survey, acquainting him with the intention of combining the results of his survey with ours, he acquiesced to a proposal to place under my orders one of his field establishments, under an Assistant Superintendent; and on my meeting him at Súrat he drew up and forwarded a letter to Government begging for sanction for this proposal which was granted.

(8.) In the Guzerat Revenue Survey the monthly cost of a native establishment is fixed at Rs. 500, the whole of which is devoted to salaries of Native Surveyors and a few peons, but not in paying measurers, whose services are provided gratis by each village surveyed; but as this service could not be rendered gratis to the establishment working under my orders, it would have been necessary, had Colonel Prescott furnished me with an establishment of full strength, for me to have provided an additional staff of measurers at a cost of Rs. 750 a month. Therefore, as my expenditure already absorbed the whole of the funds at my disposal, I was obliged to ask Colonel Prescott to give me a small establishment, the aggregate salaries of which would not exceed Rs. 200 a month, and to make over the balance Rs. 300 a month in cash to me for the provision of a staff of measurers which he did.

(9.) Accordingly on 25th February I was joined by Mr. A. Dalzell, Assistant Superintendent Revenue Survey, who was accompanied by a Vernacular Clerk and 4 Native Surveyors as per margin.

Kuber Parbhu Das, Parbhoo Kisor, Lalu Ambaram, Gopal Ganesh.

(10.) I will now describe the method in which I availed myself of the resources of the Revenue Survey maps. The western halves of the two sheets 9 and 10 had been covered with a net-work triangulation (average of two mile sides) and the eastern halves with a system of traverses, giving a larger number of fixed points than the triangulation, on account of the greater closeness of the country. The triangulation had been executed under the orders of the late Lieutenant Colonel Nasmyth who had employed some Native Surveyors of the Revenue Survey in taking measurements from the trigonometrical stations to three or more corners of the field or "number" in which they were situated, and then from these measurements inserting the positions of the trigonometrical stations on the Revenue Survey maps. The traversing was executed under my own orders, and that in sheet 9 had been laid out so as to conform as much as possible with village boundaries; that in sheet 10 was to have been run on the same principle, but my instructions were misunderstood and scarcely any points on village boundaries were fixed by it at all; so that I had to proceed by three different methods in utilizing the Revenue Survey maps in these three differently prepared areas.

(11.) With the triangulated area I proceeded thus :—The trigonometrical stations having been plotted, as stated above, on the Revenue Survey maps, I measured (with the aid of the scale at foot of each map nominally 16 in. = 1 mile) the distances from trigonometrical stations to the "tribhetas" (village boundary trijunctions), then with these distances (altered according to the 2-inch scale) as radii and the respective trigonometrical stations, plotted on the plane tables, as centres, I described arcs, the intersections of which gave the approximate positions of the tribhetas on the plane tables. I say "approximate" for no three arcs gave a single intersection but always a triangle sometimes very small but sometimes as large as the eightieth part of a square mile; the centre of gravity of which I accepted as the position of the tribheta. This thus gave me a series of points on the plane tables, corresponding to a number of points on the Revenue Survey maps, the details of which I was now able with a little tension here and pressure there to transfer with a pantagraph to the plane tables, which I did in blue ink, retaining a copy of the same on tracing linen in my office. This, though none of it was finally accepted on its own merits, proved a valuable assistance to the plane table surveyor, who filled in the details independently; the result of this portion alone is sufficient to prove that great use may be made of the Revenue Survey maps in improving the accuracy of our own, if we only take the trouble to make a more extensive and systematic connection between our fixed points and theirs; for the discrepancies between their details and ours consist only of small lateral displacements, excepting of course when roads and even rivers have altered their courses, which they have had time to do since the work of the Revenue Survey was executed; for the Sabarmati and the Watrak are in some places most capricious in this respect.

(12.) On the traversed portion of sheet 9, since, as stated in para: (10.), the traversing had been laid out to strike as many points on village boundaries as possible, the transferring of the details of the Revenue Survey maps to our plane tables was a very simple matter; for the tarverses once plotted on to the plane tables, we had the proper assigned limits—if not of each map—of groups of two or three maps, the details of which were easily plotted with a pantagraph. This was done in blue and the discrepancies between it and the subsequently and independently surveyed details, are very small indeed, and where they do occur are, as on the triangulated area, mere lateral displacements, attributable possibly to want of proper care in the drawing of the blue transfer.

(13.) Owing to my instructions being misunderstood, as stated in para: (10.), the traversing in sheet 10 struck on so few points recognizable in the Revenue Survey maps, that it was impossible to lay down their detail on the plane tables at all; I therefore had the village maps reduced by photography to the scale of 2-inches to the mile, and then traced from these reduced copies all the detail required on to separate pieces of transparent, tracing paper, which I made over to the plane table Surveyor, Mr. Cusson who found them most useful. Having fixed on his plane table the site of a village from which the roads emanate, and having gone round the boundary fixing the points where the roads intersected it; he then had on his plane table two points for each road between which he transferred the road from the Revenue Survey tracing. To check the roads thus plotted, he took one or more intermediate circuits, and then it was found that he could map the ground with but half the number of plane table stations that were necessary in ground of which we had no Revenue Survey maps. I regretted I had not adopted this simple method of utilizing the Revenue Survey maps over the whole of sheet 9 and 10, instead of mapping a great part of the country as I had done approximately in blue on the plane tables before they were taken into the field.

(14.) I distributed my party as follows:—Captain Pullan and two Native Surveyors, topography of western half of sheet 9. Mr. McA'Fee and 2 Native Surveyors, eastern half of sheet 9 and plane table 8 of sheet 9. Mr. D'Souza, Mr. Hall and one Native Surveyor, western half of sheet 10. Mr. Cusson and 1 Native Surveyor, eastern half of sheet 10.

Mr. Christie, triangulation in sheet 15. Mr. Connor triangulating and superintending 3 Native Surveyors traversing in sheets 2, 3, and 4 (Kattywar Nos.) Mr. Hickie being in very poor health I kept at Kaira plotting the trigonometrical stations and points on the sections of sheet 14 and a few traverses on some of the plane tables of sheet (9.)

(15.) Mr. D'Souza's work embraced almost no British territory and so entailed no special work in utilizing Revenue Survey maps, and I sent Mr. Hall who only joined the department on 22nd November 1872 with him to learn the ordinary method of plane table sketching.

(16.) After going round and seeing Captain Pullan, Mr. McA'Fee and Mr. Cusson and their native assistants at work, and shewing them how I wished them to take advantage of the Revenue Survey work, I proceeded to inspect Mr. Connor's work after which I was joined by the Revenue Survey Party under Mr. Dalzell near Sanand and about 18 miles from Ahmadabad, in sheet 2 (of the Kattyar Survey) on 25th February as stated in para: (9.)

(17.) I had during the previous month entertained a number of new hands for employment under Mr. Dalzell, and I had also prepared an equipment of theodolites, chains &c. for them, but I had to instruct him and his Native Surveyors in the method of traversing and of connecting traverses together, and traverses with triangulation hitherto adopted in this survey to which they had not been accustomed; and I had to give him systematic instructions to guide him in spreading his traverse meshes properly over sheets 2 and 3. This work of instruction kept me with him until 15th March when I left him to carry on his work.

(18.) To assist me in issuing instructions for systematic traverse operations, I requested Mr. Dalzell to bring with him from Colonel Prescott's office the original maps of all the villages in the Sanand and Dholka parganas. I had already obtained the fair copies of the general map of the Ahmadabad Collectorate, a rough compilation on the scale of ½ inch = 1 mile, shewing the village sites and boundaries and principal roads and tanks. This map I found most useful, though it would have been more convenient had it been on double the scale. On it I sketched out a complete project of all the traversing that I saw was requisite, having first plotted approximately on it all the trigonometrical stations falling within the two sheets, and the traverses that had already been completed by the Native Surveyors under Mr. Connor, and the village base-lines, the positions of which were derived from the original village maps.

(19.) In designing the project of the traversing, the end I kept in view was to determine the position of a point close to every village site, and the positions of all tribhetas (village boundary trijunctions) which are most valuable points, as each one is a well defined point on three different village maps; this end I believe has been fully attained.

Additional measurements were taken to the points fixed near village sites, from the nearest field trijunctions, to enable them to be plotted on the village maps. In villages which had been originally surveyed by the Revenue Survey by "means of base-lines" running close to the village site, merely the ends of the base-lines were fixed, instead of fixing a point near the village site, which answers the same purpose and involves less trouble, but the proportion of such villages in the Sanand and Dholka parganas is very small indeed. In the Ulpar táluka, Súrat District, where Mr. Dalzell and his party were employed at the latter end of the season, almost every village had been surveyed with a base-line and sometimes with two or three at right-angles to each other.

(20.) After leaving Mr. Dalzell, I again went round visiting the Assistants engaged on the topography, and this time visited Mr. D'Souza and Mr. Hall whom I had no time to visit on my pervious circuit. It was when on this circuit that Captain Pullan was withdrawn to assume charge of the Kattywar Survey, which entailed several minor changes among the plane table surveyors which will appear in the separate reports of each Asssistant, which I now proceed to give in regular order.

(21.) Captain Pullan, with Rowji Narain and Mukund Dinkar, completed the topography of the western half of sheet 9.

(22.) Mr. D'Souza had entrusted to him the western half of sheet 10, comprising plane tables 1,2,5 and 6, and under him I placed Mr. Hall and Balwant Govind. He completed No. 1 himself, instructing Mr. Hall the while, and he inspected No. 2 which he entrusted to Balwant; he then divided No. 6 into two, giving one half to Mr. Hall and the other to Balwant, while he himself took up No. 5, he completed this on the 27th March and then I sent him to take Captain Pullan's place, leaving Mr. McA'Fee the easier job of supervising the completion of plane table 6. Both Mr. Hall and Balwant Govind, after the completion of the western half of sheet 10, again joined Mr. D'Souza in the eastern half of sheet 9. Besides these he had then under him Mukund Dinkar, Bhow Govind, and Vital Vishnu to complete the eastern half of sheet 9 and plane table 8 of sheet 8. The work in this portion had progressed very slowly owing to Mr. McA'Fee's sickness, and Vital Vishnu's carelessness which necessitated the whole of his work to be done over again, and for which I dispensed with his services. Mr. D'Souza's time in this part was almost entirely taken up in examining work done by others, though he himself filled in a small portion of plane table 8 of sheet 9. He only returned to Poona on 10th June.

(23). Mr. Christie was employed all the season triangulating. He first ran a series of single triangles round the margin of sheet 15, emanating from and closing on sides of Mr. D'Souza's net-work triangulation of last year, which extends slightly into the northern portion of this sheet. This I considered sufficient triangulation in flat British territory which I intended to have traversed in the same way as sheet 14. The series comprised 40 triangles and covered an area of 161 square miles. After completing this work, Mr. Christie took up some net-work triangulation in sheet 32, three-fourths of which is foreign territory, and he covered an area of 280 square miles. As he has submitted an interesting report of his season's work I attach it as an appendix to this.

(24.) Mr. McA'Fee had under him Bhow Govind and Vital Vishnu to undertake the topography of the eastern half of sheet 9 and plane table 8 of sheet 8. He was impeded by ill health during the early part of the season, but during the latter portion he was able to work well at the supervision of Mr. Hall's and Balwant Govind's work in sheet 10. He returned to Poona on the 8th May. Bhow Govind worked well.

(25.) Mr. Connor, besides supervising three Native Surveyors Gopal Vishnu, Ganesh Bapuji 1st and Ganesh Bapuji 2nd traversing in sheets 2,3,4, (Kattywar), ran two series of triangles on meridians 72° 10′ and 72° 20′, emanating from sides of the Guzerat Longitudinal Series and closing on sides of the net-work triangulation carried into sheet 4 by Mr. D'Souza in 1868-69 and lying between the Sabarmati series and the series on meridian 72°; he also ran a chain of triangles about 23 miles long along the east flank of the series on 72°, as the greater portion of that ground is foreign territory and would therefore be outside the traversing operations. Each of the series run by Mr. Connor is about 31 miles long, they comprise 41 single triangles and 9 quadrilaterals, and cover an area of 330 square miles. These two series, with that on the flank of series on meridian 72° and the flank stations of the net-work triangulation in sheets 8,9,10 afforded points of departure and closing for the traverses which were eventually—with the assistance of Mr. Dalzell's party—so spread over sheets 2 and 3 as to determine the position of a point near every village site and of several points on the boundary of every village land. Mr. Connor also took some observations to determine the difference in level between the datums of the Railway and the Ahmadabad and Viramgám road, so as to enable me to convert the levels of the latter into absolute heights. He returned to Poona on 30th April.

(26.) Mr. Hickie was in too bad health to be employed on out door work, and therefore I kept him in the office working at the plotting of traverses and triangulation on the office charts, and in plotting some traverses on plane tables and also in pantagraphing village boundaries on to the sections of sheet 12. He proceeded on 6 months' sick leave from 1st March.

(27.) Mr. Cusson, assisted by Luxumon Ghorpuray, was entrusted with the topography of the eastern half of sheet 10. He completed this on the 15th May when he proceeded to join Mr. Christie to assist him in the triangulation of sheet 32. I had intended Mr. Cusson to undertake part of the triangulation of that sheet independently, but owing to unavoidable delay in providing him with a proper theodolite and equipment, this intention was abandoned and so he merely made himself generally useful to Mr. Christie.

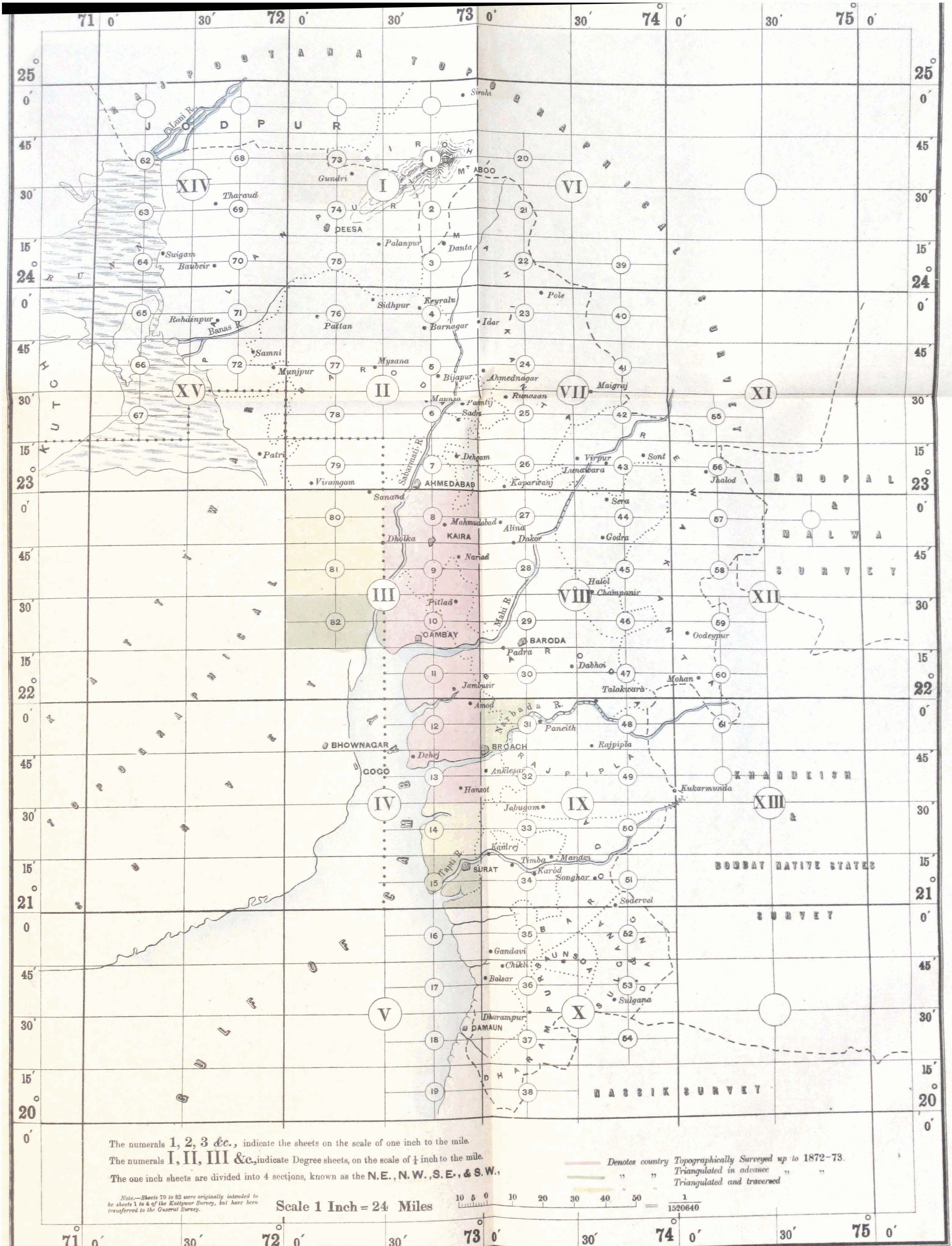
(28.) I have been well satisfied with the diligence of all my Assistants and also with that of all the Native Surveyors, excepting Vital Vishnu who has been discharged, and Balwant Govind whose salary was reduced for carelessness. I append tabular statement showing the amount and quality of the work done by each.

Extract of Report from Mr. Christie to Major Haig.

(8.) The country in sheet 15 was one uniform level throughout, perfectly open in the Olpad táluka, west of the Tapti, and also in the Gaikwadi territory, south of the Purna river up to the Railway line : eastward it became more and more woody and consequently unfavorable for triangulation. In sheet 32 the country was perfectly open and level up to the eastern boundary of the 2nd plane table ; at this point the character of the country is completely changed, high rocky hills and extensive ridges densely covered with jungle, taking the place of wide plains of open arable ground, almost entirely devoid of trees, except in and about the villages. With the change in the country, is noticeable a striking contrast in the appearance and condition of the inhabitants. Instead of the well clothed and well to do men and women living in decent weather-proof houses surrounded by many little appliances, which go towards supplying the scanty requirements of a native home, one is painfully struck with the wretchedly ragged and attenuated appearance of the hill men (mostly Bhíls) and their families. The idea of abject poverty produced by the appearance of the people, is only painfully increased by sight of the wretched hovels in which they live. Their huts are with hardly any exception, mere grass sheds affording the most meagre shelter from the inclemency of the weather, owing to the clumsy, careless manner in which they are put up. In the month of May when thunderstorms, accompanied with heavy falls of rain, were of almost nightly occurrence, their huts were in so dilapidated a state as to offer barely more protection than might be afforded by a good sized umbrella. Altogether the utter indifference for creature comforts displayed by the Bhíls, is perfectly surprizing. Although the country further on is very hilly and densely wooded, I am told carts are used throughout. A very small portion of the land is under cultivation owing to the scanty population which is almost entirely composed of Bhíls, whose chief occupation consists in felling timber, which they carry for sale to the nearest market. Good water is obtainable at almost every village though wells are few in number ; the want of them being met by pits dug in the sandy beds of the nallas with which the country is everywhere intersected.

(9.) At the village of Ratanpur I came across large pits which had been excavated to obtain the well known "Cambay Stone" which are here found in large quantities. These pits are worked by agents of the Cambay Lapidaries. After collecting sufficient quantities they burn them in kilns when only such as assume a bright translucent appearance are retained ; these are then packed up in gunny bags and carted to Cambay.

(10.) Wild animals are numerous though owing to the heavy cover very difficult to get at. From the closest inquiries I could make, I was surprised to learn that these jungles up to at least the meridian of 73° 30′ are not at all malarious even in the cold weather. This seems to be borne out by the appearance of the natives who though lean and squalid from poor living, present none of the miserable effects of systems emaciated by disease so noticeable in tracts notoriously feverish such as the forests in North Canada.

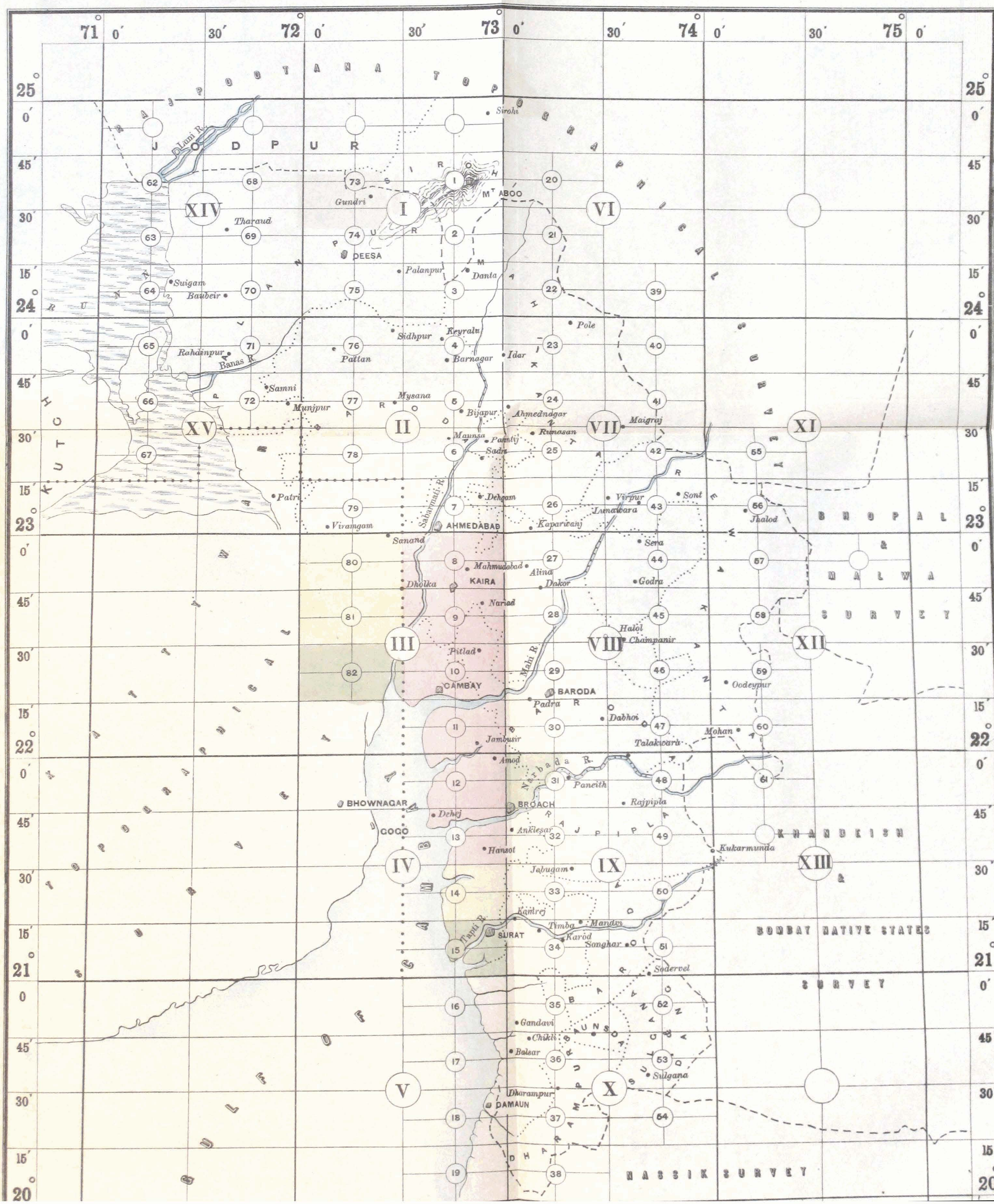


C. DYSON, Photo & Zinco.

Photozincographed at the Office of the Superintendent Great Trigonometrical Survey, Dehra Dun, November 1873.

GREAT TRIGONOMETRICAL SURVEY OF INDIA

INDEX CHART OF THE GUZERAT TOPOGRAPHICAL SURVEY



TABULAR STATEMENT OF WORK IN GUZRAT, DURING THE FIELD SEASON 1872-73.

Triangulation.

OBSERVER'S NAMES.	Instrument used.	Area triangulated.	No. of stations visited.	3 ANGLES OBSERVED.				2 ANGLES OBSERVED.			REMARKS.
				Triangles.	Triangular error.	Error per mile.	No. of Heights.	Triangles.	Error per mile.	No. of points.	
Mr. A. Christie, ...	6″ by Troughton & Simms'	441	68	90	″ 10·1	Not known	59	578	Not known	366	39 tribhetas and 14 boundary marks fixed by azimuths and distances. Total distance chained 39 miles.
,, E. J. Connor, ...	Ditto	330	60	78	16	Feet 0·5	50	234	,,	133	51 tribhetas fixed by azimuths and distances. Total distance chained 52 miles.
	Total, ...	791	128	168	......	......	109	812	......	499	

Plane Tabling.

No.	NAMES.	Plane Tabling.	Stations per square mile.	REMARKS.
1	Captain A. Pullan, S.C. ...	120·0	8·1	
2	Mr. A. D'Souza, ...	180·0	8·5	Examined 360 square miles.
3	,, C. H. McAFee, ...	35·3	12·0	Do. 132 do.
4	,, G. D. Cusson, ...	168·0	6·0	
5	,, G. Hall, ...	54·0	17·4	Do. 36 do.
	Native Surveyors.			
1	Rowji Narain, ...	120·0	10·3	
2	Luxumon Ghorpuray, ...	121·0	8·0	
3	Balwant Govind, ...	167·0	10·8	
4	Mukund Dinkar, ...	113·0	12·3	
5	Bhow Govind, ...	158·0	17·0	
	Total	1236·3	11·0	Mean.

Traversing.

No.	NAMES.	Linear miles of Traverse.	REMARKS.
	Native Surveyors.		
1	Gopal Vishnu, ...	175·0	
2	Ganesh Bapuji, 1st	130·1	
3	Ganesh Bapuji, 2nd	226·0	
	Revenue Surveyors.		
1	Kuber Parbhu Das, ...	59·8	
2	Lalu Ambaram, ...	57·5	
3	Gopal Ganesh, ...	56·7	
4	Parbhoo Kisor, ...	67·8	
	Total	772·9	

Extract from the Narrative Report—dated 25th September 1873—of Lieutenant J. HILL, R.E., Offg. Dy. Superintendent 2nd Grade, in charge Kumaon and Gurhwal Survey Party.

The Recess of 1872.

The party was employed during the recess of 1872 on computation and mapping, including the preparation of four fair sheets of the Kumaon and Gurhwal Survey which were completed and sent for publication to the head-quarters office at Dehra Dún before the party took the field.

Plan of operations for the field season.

(2.) The plan of operations for the field season was as follows:—1st, to send in September two assistants to survey topographically the whole of the Mána Valley and a portion of country in the eastern half of Sheet XII which had been left unfinished in 1868: 2nd, in November, when the weather becomes too cold to carry on a survey in such elevated regions, to move those two assistants southwards to commence the topography of Sheets XXI and XXII; and 3rd, to employ the main strength of the party (recess duties being done) on the topography of the following districts, viz:, the Bhábar tracts from Haldwáni eastwards to the Sárdah river, the lake country to the east of Naini-Tál, the country round Lohu Ghát, and those portions of the Gori and Rámganga Valleys which lie in the vicinity of Askot. In addition to providing for the above work, which all lies in Kumaon and British Gurhwal, the plan of operations had to include arrangements for commencing a triangulation to the west of the Ganges and its tributary the Mandagni river with the object of providing points for a topographical survey of Tíri Gurhwal, Dehra Dún, Jaunsár and Báwar in the first instance, and subsequently for the survey of other districts to the westward.

The field season of 1872-73.

(3.) With the above objects in view, the party took the field as follows:—Messrs. L. Pocock and H. Todd started for the Mána Valley on the 27th September. Lieutenant Harman started for Naini-Tál on the 1st November. Messrs. J. Peyton and J. Low left on the 9th November, the former for the Bhábar hills east of Haldwáni, the latter for Lohu Ghát, and Mr. E. F. Litchfield left on the same day to take up his work to the east of Naini-Tál. On the 22nd November Mr. E. C. Ryall started for the Bhábar tracts near Haldwáni, and Mr. T. Kinney, who had been detained in quarters later than the other assistants to examine maps and to accompany the civil authorities on their inspection of the boundary of Masúri and Landaur, started on the 4th December for his work near Debi Dhúra to the east of Naini-Tál.

(4.) When the assistants had left head-quarters, I commenced my march to Haldwáni, taking with me as my office assistant Mr I. Pocock, who had lately joined the Department. Our road lay through Hardwár, and on arriving there I made an inspection of the staving done by men whom I had sent out before the end of the recess to prepare for the commencement of the new triangulation of Dehra Dún, &c., and in spite of very hazy weather I succeeded in taking observations from three stations. I then continued my march to Haldwáni, which I made my head-quarters until the 19th March, when I moved them to Almora. During the greater part of the season, while my head-quarters were stationary at Haldwáni and Almora, I was travelling about with a small camp inspecting the work in Sheets XXV, XXVI, XXXI, XXXIII and XXXIV. On the 7th May I despatched the head-quarters camp in charge of Mr. I. Pocock by the plains road back to Dehra, and I myself left Almora with a very light camp to inspect the work in Sheets XXI and XXII, and in the Mána Valley: that done, I returned through the hills to Masúri, arriving there on the 7th June.

(5.) I now proceed to report separately on each officer's work, the details of which are tabulated on page 37—a.

Lieutenant H. J. Harman, R. E.

(6.) Lieutenant Harman's ground was of three distinct varieties. To the north he had to sketch the lake country which includes Naini-Tál, Bhím-Tál, Sát-Tál and Naukuchia-Tál. In this district the differences of level are very great, and the ground, which is crowded with important details, is also so complicated that in many instances the 1-inch scale was found inadequate to represent all its characteristic features. Southwards the ground changes its character; the limestone of the lake district giving place to intricate sandstone hills resembling the Sewáliks. The northern slopes of these sandstone hills are more cultivated than any other similar ground in Kumaon or Gurhwal (probably on account of the proximity of Naini-Tál and the good roads which pass through this district to the plains), their southern slopes however are uncultivated. At the foot of these southern slopes lie the flat tracts of the Bhábar. They are in general covered with *Sál* forest on the more raised plateaux, and on the lower flats with *Khair* and *Sissu* and other jungle. Of late years owing to the exertions of the present Commissioner of Kumaon considerable portions have been cleared and irrigated, and in the neighbourhood of Haldwáni in particular there is now a large extent of cultivated land.

DETAILS OF TOPOGRAPHY ON SCALE OF 1 INCH = 1 MILE. KUMAON AND GURHWAL PARTY. SEASON 1872-73.

NAMES.	Area surveyed, in square miles.	Number of Plane Table Stations.	Average number of Plane Table Stations per square mile.	Length of Traverse lines in miles.	Length of Traverse lines cleared in miles.	Number of Boundary pillars fixed.	Area under cultivation in square miles.	Range of altitude above Sea level, in feet.	Average rate of work per diem, in square miles.	Remarks.
Lieut. H. J. Harman, R.E., ...	70	230	3·1	...	...	...	8	1400 to 5000	2·1	Densely wooded and intricate sandstone hills, terminating in the Bhábar flats.
	41	134	3·3	...	...	...	7	2000 „ 8200	2·0	Lake country near Naini-Tál. Intricate, and in general covered with forest.
	157	...	...	191	157	9	33	780 „ 1400	3·6	Bhábar flats, chiefly covered with dense forest and jungle.
E. C. Ryall, Esq., ...	116	255	2·2	...	...	...	0	900 „ 5700	3·3	Densely wooded and intricate sandstone hills, terminating in the Bhábar flats.
	*184	...	...	382	324	32	4	800 „ 1200	4·4	Bhábar flats, chiefly covered with dense forest and jungle.
Mr. J. Peyton, ...	100	150	1·5	...	...	...	3	3000 „ 16000	5·0	Mixed ground in the Gori Valley, partly forest, partly open, including lower spurs of snowy ranges.
	*280	550	2·0	...	...	...	14	1300 „ 7000	4·0	Densely wooded and intricate Bhábar hills, and hills to their north of a simpler character.
„ J. Low, ...	172	416	2·4	...	...	...	64	1700 „ 7000	3·0	Mixed ground, including the cultivated gently-sloping hills of Lohu Ghát.
	258	646	2·5	...	...	...	31	2500 „ 8900	2·5	Mixed ground in the Rámganga Valley, with comparatively bold features, and much forest.
„ L. Pocock, ...	335	104	0·3	...	...	...	1	6000 „ 25000	14·0	Bold high ground in the Mána Valley, culminating in some of the loftiest Himalayan peaks.
	199	150	0·8	...	...	...	11	3500 „ 20000	5·5	Ground south of the foregoing, also with very bold and commanding features.
„ H. Todd, ...	88	26	0·3	...	...	...	1	5000 „ 21000	9·0	Ditto ditto.
	200	130	0·7	...	...	...	9	4000 „ 21000	5·2	Ditto ditto.
„ T. Kinney, ...	260	511	2·0	...	...	...	38	2700 „ 7500	3·4	Mixed ground east of Naini-Tál, in some parts covered with dense forest.
„ E. F. Litchfield, ...	174	320	1·8	...	...	...	21	2700 „ 8200	2·4	Ground east of Naini-Tál and adjoining the lake district, chiefly covered with forest.
	100	180	1·8	...	...	...	8	8000 „ 12000	3·7	Mixed ground in the Gori Valley with comparatively bold features, and much forest.
Total, ...	2734	...	...	573	481	41	253	...	...	* These areas include 55 square miles of the Nepál border sketched from Kumaon.

Details of Triangulation.

NAMES.	Area triangulated, in square miles.	Number of Stations visited.	Number of points fixed by intersection but not visited.	Number of stations whose positions and heights have been fixed.	Number of stations whose positions only have been fixed.	Number of hill tops cleared of forest.	Average area in square miles to each trigonometrical point.	Average area in square miles to each trigonometrical height.	Number of triangles of which all 3 angles have been observed.	Number of triangles of which only 2 angles have been observed.	Number of points whose elements have been computed.	Remarks.
E. C. Ryall, Esqr., ...	270	21	† 7	27	0	2	10·0	10·0	15	11	...	Bhábar district east of Huldwáni, and Naini-Tál.
Mr. L. Pocock, ...	83	9	59	55	13	41	1·2	1·5	7	87	...	Dohra Dún.
Total, ...	353	30	66	82	13	43	...	...	22	98	203	† This number includes 4 peaks in Nepál.

(9.) Lieutenant Harman's field work consisted in surveying topographically 268 square miles of most intricate country, in helping Mr. Ryall for a week at computations, and in doing the work specified in the two preceding paragraphs. This was an excellent season's work; large in amount and, as I found on inspection, of a very thorough and satisfactory character.

E. C. Ryall, Esq.

(10.) The portion of country surveyed by Mr. Ryall adjoins and lies to the east of Lieutenant Harman's Bhábar ground, which it resembles only in a general way. To the north it rises into sandstone hills of the Sewálik formation which are thickly covered with *sál, dhau* and *chír* forest. Below these hills are flats of a much wilder character than those lying to the westward. The flats are here almost free from irrigated clearings except at Barmdeo; they are very densely wooded, and are intersected by numerous tortuous streams and watercourses, intermingled with swamps, cane and bamboo jungle. This ground presents great obstacles to the Surveyor. Its climate only admits of work being carried on without great danger to health during the months of December, January and February, during which time the jungle grass is high, and the Surveyor, shut in on all sides, is obliged to have his way laboriously cut before him, and is restricted exclusively to the traverse method of surveying in order to map the hidden features of the country.

(11.) While Mr. Ryall was surveying this difficult tract of country, he carried on hand in hand with his topography a minor triangulation to determine the positions of some points which were required for traverse purposes. He computed out the elements of these points in the field with Lieutenant Harman's assistance; and I may here remark that he also employed himself on computations while marching to his ground at the commencement of the field season. He finished his topography on the 1st May and then went to Naini-Tál to determine trigonometrically the height of the Naini-Tál lake. After his arrival there he was weather-bound for some days, but on the 8th May he completed the necessary observations; and, his field work being done, he started for recess quarters.

(12.) Mr. Ryall's out-turn of work is, as usual, large. His survey embraces an area of 270 square miles, and its execution is in all respects most creditable to him.

Mr. J. Peyton.

(13.) Mr. Peyton's survey was exclusively topographical and was confined to hilly country. His first piece of work consisted in sketching the portion of the Bhábar hills which lie immediately to the north of Lieutenant Harman's and Mr. Ryall's Bhábar survey. The southern part of this hilly tract is especially troublesome to sketch, owing to the denseness of the forest with which it is covered, and to the sparseness of the population and the consequent difficulty in procuring coolies. Proceeding northwards the hills become simpler in their character, more free from forest and less thinly inhabited, and sketching becomes proportionately easier. Mr. Peyton finished the survey of this tract of country on the 12th March, and then started to take up his second piece of work, which includes Askot and part of the eastern side of the Gori Valley.

(14.) Within the northern limits of this second portion of his survey are some of the spurs of the snowy range which separates the Gori Valley from the wild district of Dharma. A very unusual fall of snow commenced about the end of April and continued, off and on, for about a fortnight, rendering the high ground inaccessible and obliging Mr. Peyton to close work on the 17th May without having quite finished the work allotted to him. Besides the obstruction caused by snow, his work was retarded by a very extraordinary fog which lasted during the greater part of April and which, while at its thickest, rendered objects invisible at a distance of a couple of hundred yards. In spite of these drawbacks Mr. Peyton succeeded during the field season in surveying 380 square miles of country, all the varied features of which he delineated with his usual artistic skill.

Mr. J. Low.

(15.) Mr. Low was employed during the field season on the topography of two separate portions of Kumaon. Towards the close of the season he commenced, and he is still engaged upon a triangulation of the Juár Valley; but as its details belong properly to the year 1873-74 they are not included in the present Report. His first duty was to finish the survey (commenced during the previous field season by Mr. L. Pocock) of the portion of country which includes Lohu Ghát and lies between Pathoragarh and Champáwat, descriptions of which places are contained in paras: (19.) and (23.) of my last year's Narrative Report. The country surveyed by Mr. Low is of a character similar to what is there described. Broad open flats, looking from a distance almost like one plain and terminating on the north-west in a very sudden fall, reach from the now deserted station of Lohu Ghát to Deo Náth, where a gently undulating country commences which extends as far westward as Debi Dhúra. Mr. Low finished his survey of this tract of country by the middle of February and then started to take up his second piece of work which consisted in sketching the portion of the Rámganga Valley which lies near Askot and is included in the westerm half of Sheet XXXI. This portion of country does not call for a fuller description than what is contained in the tabular statement on page 37—a It is situated close to the country mentioned in para: (14.) but as it does not quite attain in any part to an altitude of even 9000 feet above sea level, Mr. Low was not compelled to close work in consequence of the bad weather described in that paragraph. His work was much delayed however by the dense fog and by the rain, and his health being also very indifferent he did not succeed in finishing his topographical work until the end of June.

(16.) During the field season Mr. Low completed the sketching of 430 square miles of hill country. The improvement in his sketching this year is very remarkable. His Rámganga plane-table sketch, his most recent piece of work, is far better than anything he has hitherto turned out and is in every respect a very creditable performance.

Mr. L. Pocock.

(17.) Mr. Pocock reached his ground in the Mána Valley on the 12th October and commenced his sketching close to the famous temple of Badrínáth. I subjoin the notes he made while working in this very interesting portion of country.

"The portion of the Mána Valley surveyed by me lies in the *Pati* of Pailkhanda, *Zillah* Gurhwal. The climate is very cold in October and November. Towards the end of October the people begin to leave the valley for Chamoli and Karn Prág, and by the 25th November not a soul remains at Mána. They do not return to their villages till the months of May and June when the snow is sufficiently thawed to admit of their doing so. The ground which I have sketched is most precipitous and in many parts it is quite inaccessible.

At Mána itself and on the surrounding mountains there is no forest, but lower down—commencing from Benakuli where the Mána people collect their wood supply in April, May and June—wood of various kinds is to be found. At Mána the only grain which grows is *kotu pákpar*, the seed being put down in May and the harvest cut in September. The soil is so poor that it will not yield but every other year, and the produce is then only about 200 maunds. This *kotu* is eaten uncooked by the Mána people after simply making a mash of the flour; their breakfast consists of this as a rule. There is near Mána a fine piece of level ground on either side of the Alaknanda river which is used for cultivation. The mode of cultivation is similar to what is used all over Gurhwal. After sowing their fields, the majority of the men go off with barley, rice, flour, *kotu* and a small quantity of *gur*, laden on goats and sheep, to Tulingmat and Chaurangghar in Thibet. This barley, rice, &c. is brought up from Rámnagar and Kohdwára during the winter months in exchange for salt and borax taken down. In all, over three thousand goat-loads of salt are brought into Mána by the Mána people and by Bhoteas; the latter coming over the pass when they are hard pressed for barley and rice.

That part of the river Alaknanda (including its northern tributary the Susawati) which lies in my work has its source from several glaciers, and is not anywhere fordable, both on account of its depth and great velocity. Its bed is of boulders, and the stream even in October and November is frozen along the sides, and would be so entirely but for the friction caused by its violent motion.

There is a small three-cornered lake (each corner having a name) near Mána called Satopant or Karchákul which is considered holy. It is said that it is fathomless and that no bird can fly across it, and it is resorted to by a few of the pilgrims who go to Badrínáth. The people of the Mána Valley throw the ashes of their dead into it, and they also make several offerings at the lake to propitiate the deity who is supposed to inhabit the spot, so that the pass may not be blocked up and closed for traffic by heavy falls of snow, which they believe would be the case if these offerings were neglected.

The Badrínáth Temple is very well known all over India, and is presided over by a high priest called the Raulji or Raul Sáhib, who is a Bráhman of the Deccan of the highest caste. This temple is allowed a revenue from the Government, a number of villages in Gurhwal and Kumaon being obliged to pay to the Raulji. The deity Badrínáth is considered the most holy, because supposed to be self-created, and for this reason even more sacred than Jagarnáth. (Jagarnáth is of wood carved by a carpenter; hence the tradition among the natives of this country that carpenters never attain a ripe age.) The idol of Badrínáth is of some fine black stone which has the appearance of marble. In a good season twenty-five to thirty thousand rupees are offered up at the Badrínáth shrine, and the amount allowed by Government is seven thousand rupees; notwithstanding this the temple is involved a good deal in debt. The debt appears to have been handed down. All the dishes in the temple are of pure silver, and the top of the temple is covered with a wash of gold.

The Márchas, or Mána people, are fine strong fellows but are greatly addicted to drinking a horrible liquor which they extract from rice and other grains. The Márchas though they profess to be Rájpúts, without the sacred thread, are of a low caste, and are not allowed to enter the temple of Badrínáth. They are well to do, and besides their sheep and goats they own ponies, Thibetan dogs, yáks and jobas. The yák is very sure footed and does to ride. The joba is a cross between the yák and the cow and is even a more useful animal than the yák, as he can endure greater extremes of heat and cold.

On the road from the Badrínáth Temple to the Satopant Lake is a water-fall called Bosidhára which is believed to stop flowing on being sighted by anybody of immoral or bad character. The Márchas firmly believe this and tell a story of such a thing occurring during the time when the British were taking Kumaon and Gurhwal. The Rája of Kumaon believing that by making a pilgrimage to the Satopant lake the progress of the English would be stopped, determined on doing so; but no sooner did his eyes rest on Bosidhára than it ceased to flow, for he was a tyrant and an oppressor of his people.

The road along the river in my portion of the work is very good as far as Mána. Above that it is very bad in some parts. Just near Mána the road crosses from the left to the right bank over a natural bridge formed by an immense rock under which the river flows. Here too the river has a fall of over a hundred feet.

The *Bhojpata* or birch—met with here just below the limits of perpetual snow—is a very useful tree. The trunk is used for *ballis* or rafters and the bark (*shág*) placed over these and pressed down with earth, forms the roofing of the houses."

(18.) Some further information regarding this part of Gurhwal is contained in para. (7.) of my last year's Narrative Report.

(19.) Mr. Pocock finished his work in the Mána Valley on the 8th November and then marched southwards to take up the sketching of the western portion of Sheet XXII. This part of the country is thickly covered with forest. It contains some very high ground; but in general it is of a moderate elevation, the highest point here visited by Mr. Pocock being about 12,400 feet above sea level, and the majority of his stations being very much lower.

(21.) By reference to the table on page 37—a, it will be seen that in spite of illness Mr. Pocock turned out a large amount of work, his topography embracing an area of 534 square miles and his triangulation an area of 83 square miles. This large out-turn is of a very satisl factory character. His sketching has been carefully done, and, though he still lacks the manuaskill which has been attained to by most of the other members of the party, his style of sketching is steadily improving.

Mr. H. Todd.

(22.) Mr. Todd was directed to sketch the part of the Mána Valley which extends from the upper limit of Mr. Pocock's work as far northwards as the Mána Pass. In accordance with his instructions he made for the pass as rapidly as possible so as to commence his sketching there and to work downwards as the intensity of the cold increased. On the 26th October he reported to me that he had been obliged to abandon this piece of work owing to the utter insufficiency of the triangulation, and that he had come down from the pass and commenced sketching to the south of Mr. Pocock. During the time that Mr. Todd was up near the Mána Pass he spared neither himself nor his establishment, but did his best, I believe, to fix his position and commence his sketching, though unfortunately without success. The season was an exceptionally severe one, the thermometer at noon on the pass standing at 12° below freezing point, and by the time Mr. Todd reached his ground south of Mr. Pocock both he and his establishment were much knocked up; but in spite of this he worked hard and by the 12th November he had completed 88 square miles of survey.

(23.) On receiving Mr. Todd's report I wrote to Mr. J. Low who had triangulated the Mána Valley for his explanation of the alleged failure in his triangulation. He stated in his reply that he considered the points he laid down were sufficient for the purposes of plane-tabling, and that he would undertake to sketch the ground in question himself without any additional trigonometrical stations. Here the matter rests for the present; for although I had intended to decide the question when I made my inspection of the Mána work in May, I was unable to do so as the people had not returned to their villages and all the valley was closed beyond the village of Mána which was the extreme point I was able to reach.

(24.) On completing the work specified in para. (22), Mr. Todd marched south and commenced, on the 19th November, the sketching of the western portion of Sheet XXI. The following are his notes on this part of the country.

"This piece of work comprises portions of Painkhanda and Malla and Talla Dasoli. The country is intersected by three immense spurs jutting out from the snowy range of Trisúl and terminated by the river Alaknanda. The northern faces of these spurs are of easy slope and densely covered with chestnut, hazelnut and fir trees. The villages are few in number and the cultivation very limited. The ground under cultivation yields sufficient crops for the support of the villagers; the surplus finds a ready sale among the Márchas (the inhabitants of the Mána and Níti Valleys) whom the severity of the climate during winter compels to migrate to these parts. Another means of support is the rearing of the carrier sheep for which the nature of the country is well adapted affording, as it does, very extensive pasturage. These sheep are readily purchased by the Márchas for trading purposes. The road running along the left bank of the Alaknanda, and along which the trade is chiefly carried on, is, for the greater portion, in very fair order. The upper road *viá* Rámni to Joshimat and Níti is a very narrow one, with very steep ascents and descents."

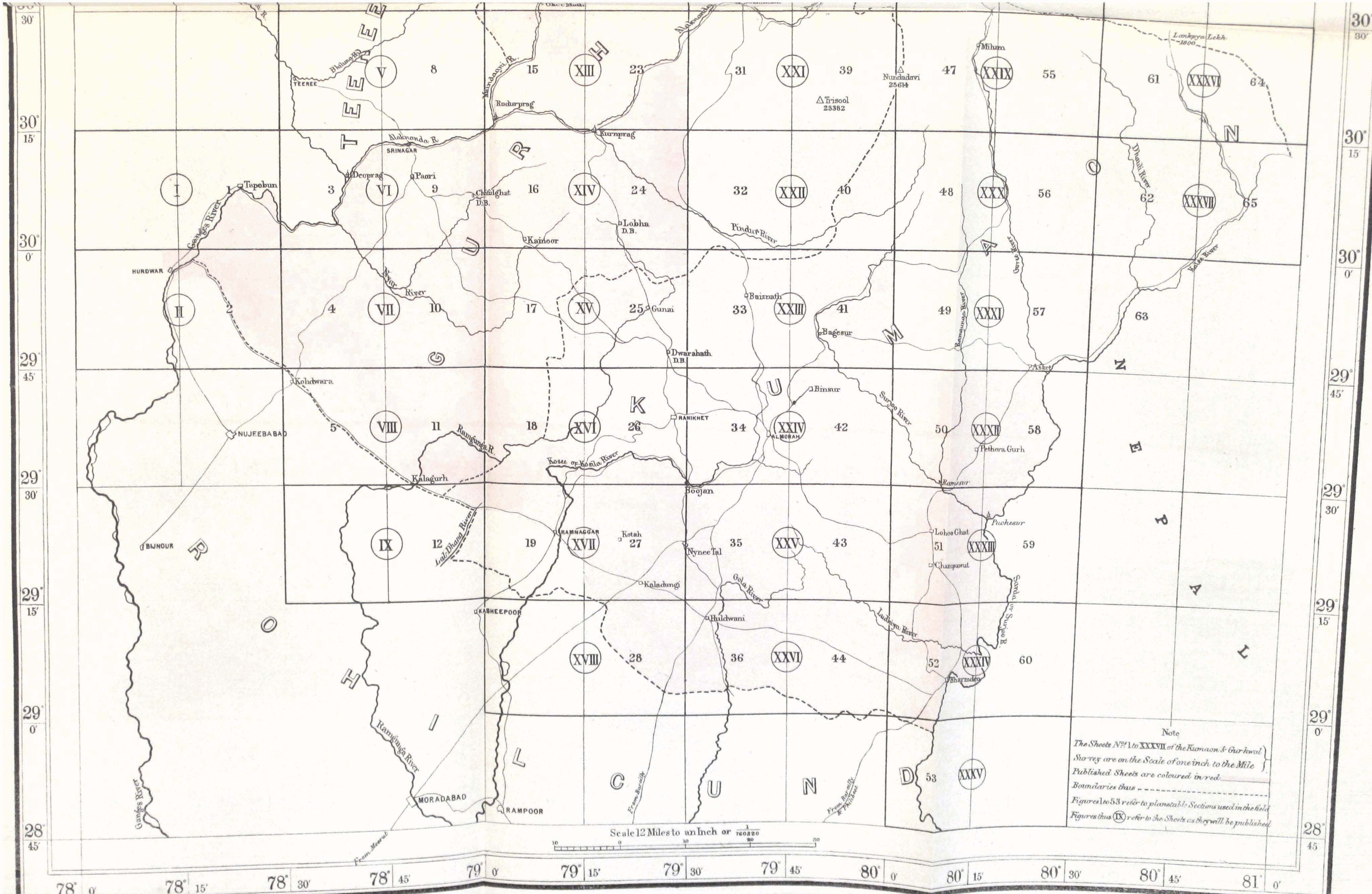
(25.) While working here Mr. Todd's health, which had suffered severely from his exposure to the great cold in the Mána Valley, completely broke down. In his anxiety to do a good season's work he was too long silent regarding his illness; but at last (and after he had succeeded in finishing more than two-thirds of his plane table) he reported that his illness had increased alarmingly and he forwarded a medical certificate recommending that he should be given work in a warmer part of the country. On receiving it I directed him to march to Debi Dhúra and there join Mr. Kinney who would give him a plane table I had sent him for the purpose. Mr. Todd accordingly marched for Debi Dhúra and arrived there on the 29th January. Mr. Kinney was then a couple of days march distant, but on hearing of Mr. Todd's arrival he went at once to Debi Dhúra and found Mr. Todd so seriously ill, both bodily and mentally, that it was necessary for Mr. Kinney to accompany him to Almora which was the nearest place where medical assistance could be obtained. The Civil Surgeon of Almora recommended that Mr. Todd should at once stop work and go on leave; I therefore sent him with that object to Dehra, where he arrived on the 18th February.

(26.) Mr. Todd was able to complete the sketching of 288 square miles before his illness compelled him to stop working. I found his work, as usual, both as regards its accuracy and its execution to be thoroughly satisfactory.

Mr. T. Kinney.

(27.) Mr. Kinney reached his ground near Debi Dhúra and commenced his sketching on the 26th December. The part of the country he surveyed lies to the east of Naini-Tál and, as regards its general character, is like ground of a similar altitude elsewhere in Kumaon. The following are some extracts from the notes made by Mr. Kinney while he was carrying on his survey.

"Debi Dhúra is rather a pretty spot with comparatively level ground broken by ravines; some of the spurs being cleared and cultivated, while some are covered with oak and rhododendron. About the temples and *dharmsálas* there are a few deodars also, some of them very fine trees and apparently of considerable age. There are two temples here, or rather shrines, for no actual temple now exists, though there are evidences of one or more having been here formerly, in the fragments of carved stones lying about and built into the *dharmsálas*, some few blocks which look like capitals of pillars being still perfect. The two shrines are sacred to two distinct deities; the minor one, which is on the top of the hill, being dedicated to a *Deota* (masculine) who is supposed to be a Rájpút; the principal one being that of the *Debi* (female) and having a resident Bráhman priest. This latter shrine is situated at the base of a cavity formed by two enormous boulders whose tops rest against each other at a height of about 40 feet from the ground. There are many such boulders scattered about the immediate neighbourhood, some even of greater size than the two forming the temple. The ground about Debi Dhúra is remarkably well watered, almost every little ravine having water in it. A number of



COMPILED UNDER THE DIRECTION OF MAJOR T. G. MONTGOMERIE, R.E., OFFG. SUPDT GREAT TRIGONOMETRICAL SURVEY OF INDIA.

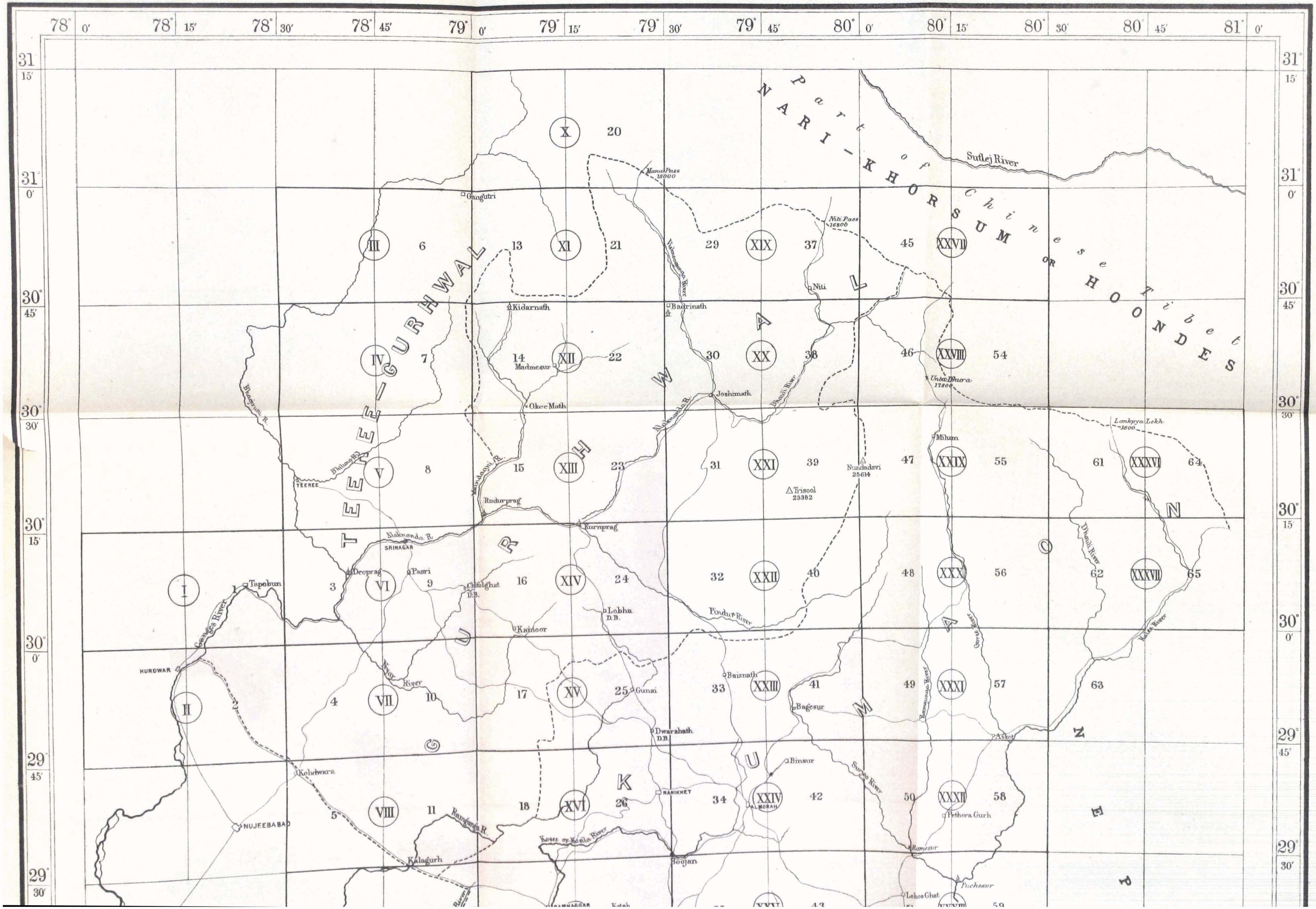
C. Dyson, Photo

C. G. Ollenbach, Zinco.

Photozincographed at the G. T. Survey Office, Dehra Dun November 1873.

GREAT TRIGONOMETRICAL SURVEY OF INDIA.

INDEX TO THE SHEETS OF THE KUMAON AND GURHWAL SURVEY



dharmsálas are built near the principal shrine for the accommodation of the people who visit it at the annual *mela*, or festival, which is held in the month of *Sáwan* (June—July). I am informed that a stone throwing fight generally winds up the *mela*—I can obtain no other reason for this annual skirmish (in which it is said men are occasionally severely wounded) but that it pleases the Debi.

The ground in the southern portion of my plane-table section is much bolder, and the ridges generally are considerably higher than in any other part. Another peculiarity of the topography of this part of the country is the occasional lowness of the watersheds: between two high points the ridge, in some instances, suddenly sinks so low that unless one were to stand on the actual pass or saddle formed by the sinking of the ridge it would be difficult to believe that one did not see two spurs running down from distinct ridges into a valley between.

On the southern ridge of the Deogúr hill the oak forest is remarkably fine, the trees growing thickly together and attaining a great size: they are very straight too, some of them as tall and straight as the largest *chír* pines, and they are also branchless to a considerable height. I should imagine that this forest, extending as it does a considerable distance along the ridge, would be of great value.

At Manglalek there are iron mines which are partly worked by Doms from various surrounding places, but chiefly by those of Manglalek itself and of Nai village in the Chaubhainsi *Pati*. The ore is smelted down in the valley of the Ladhia river at a place called Bori-ka-khera, which is also a depôt for the sale of the iron, as the *lohárs* from all parts of the surrounding district come to Bori to purchase the rough metal for their work. The mine now worked is situated below the village of Manglalek—between it and Salián—the former workings in the village of Manglalek itself have been abandoned since last year.

The portion of Chálsi *Pati* to the N. and N.E. of Debi Dhúra as far as Gágar and Múlakot is most extraordinarily well cultivated; not a trace of jungle or even of waste land can be seen, and the steepest ravines are terraced to the very bottom. There are no less than thirty villages—many of them very large ones too—within an area of some eight or nine square miles.

The road from Debi Dhúra *viá* Jenti to Charonj, the point of its junction with the main district road a few miles north of Dol, is a new road, having been made only some 16 years ago, while the other road has been in existence since the Katúr Ráj, having been merely improved and repaired by the British Government. The new road, though it lessens the distance from Almora to Debi Dhúra considerably, is a very steep one and is very little used; the district dák, however runs on this road—the dák chaukies between Almora and Debi Dhúra being at Charonj and Jenti."

(28.) Although Mr. Kinney did not reach his ground until the field season was far advanced, and though he lost some days in attending on Mr. Todd, he completed the sketching of a full plane-table section on the 16th April. His work has been carefully and well done, and, as usual, he has given me complete satisfaction.

Mr. E. F. Litchfield.

(29.) Mr. Litchfield commenced to plane-table the part of country allotted to him east of Naini-Tál on the last day of November. This piece of country, which separates the hilly country surveyed by Lieutenant Harman from Mr. Kinney's ground, is intersected by good district roads and is in general very thickly covered with forest; it contains one lake (Malwa Tál), and it is also remarkable for a very sacred peak called Kailás Parbat which is annually visited by hundreds of pilgrims. Mr. Litchfield finished his work here on the last day of February, and then marched to take up his second piece of work, which consisted in sketching that part of the Gori Valley, in Sheet XXXI, which lies between the ground assigned for survey to Messrs. Peyton and Low. This piece of country calls for little description: it is chiefly remarkable for the number of roads which have been cut through it by an enterprising Thibetan named Dhannu for the benefit of his countrymen who trade in salt and borax. While working here Mr. Litchfield was much hindered by the thick fog and bad weather already noticed in para. (14); he also unfortunately became very ill towards the end of the field season and was obliged to close work on the 22nd April without having quite finished his sketching.

(30.) Mr. Litchfield's field work consisted in sketching 274 square miles of hilly country, all of which work I found very carefully and satisfactorily done.

Mr. I. Pocock.

(31.) Mr. I. Pocock joined the Department on the 28th October and was posted to this party on the same day. I have employed him on various duties, all of which he has performed to my satisfaction. He has acted as my recorder, and has learnt to use an 8-inch theodolite. During my inspection tours he has taken charge of the head-quarters camp. As a rule he has been employed in my office on current work and on the ordinary computations which are carried on in a topographical party. He has applied himself diligently to learn his work, and has proved himself to be a valuable office assistant.

Health of the party.

(32.) The health of the party during the field season was not good. Nearly every assistant suffered more or less from ill health, and there were many bad cases of fever among the native establishment. The men working in the Bhábar suffered most, Mr. Ryall at one time having only one-fourth of his men fit for duty. A severe out-break of cholera also took place in the district about the beginning of February and the country under survey was not free from the epidemic during the whole of the remainder of the field season. Although the district suffered severely from this out-break of cholera, the survey establishment escaped with very few fatal cases.

General Review of the field operations.

(33.) In spite of many drawbacks the field season was, I think, a successful one. The weather was, in general, most unfavourable to survey operations. The winter set in in the Mána Valley unusually early and with exceptional severity. Elsewhere there was much fog and rain. The health of the assistants was not good, and three of them were compelled by illness to stop working before the end of the field season. Labour was very scarce over the greater part of the country under survey, and in the Bhábar in particular it was with the greatest difficulty that the panic-stricken inhabitants, flying from the cholera, could be prevailed upon to give any assistance to the surveyors. Whole districts were deserted, and in such places the survey could only be carried on by the expensive plan of hiring permanent coolies from elsewhere. In such a country also as Kumaon, some parts of which are deadly and others inaccessible at certain seasons of the year, and where consequently the climatic changes must influence the movements of surveyors, much precious time is unavoidably lost in marching. Yet, by the end of the field season the large area of 2734 square miles had been topographically surveyed.

(34.) On reference to page 37—a, it will be seen that there is little uniformity in the daily rates of work there tabulated. This is due to the great variety in the physical characteristics of the country surveyed, which includes ground of all kinds, from the low swampy plains of the Bhábar and Tarai to the inaccessible snowy ranges which separate British territory from Chinese Thibet. In the high ground among the snowy ranges where the surveyor can exercise little choice in the selection of his stations, but must be content to sketch the country from such points as are accessible to him, a survey partakes somewhat of the nature of a reconnaissance and can be carried on at the rapid rate of from 9 to 14 square miles a day. In the moderately high ground of the Sub-Himalayas a good surveyor works at an average rate of about 3 square miles a day; while in the flat Bhábar tracts, where the method of survey employed is that of straight parallel traverses, the daily rate of work is about 4 square miles. It will thus be seen that for a country like Kumaon no rule can be framed to fix one good uniform rate of work, or, which comes to much the same thing, one uniform number of plane-table stations per square mile.

(35.) While on the subject of the methods of surveying employed by this party I may remark that a plan for recording plane-table traverses has been in use for the last two years and has been found to answer its purpose. A circle is described round the graticule on the plane table and graduated to quarters of a degree from left to right, commencing from the south—(or an ordnance survey cardboard protracter may be used instead). In traversing, the azimuths of back and forward stations and of trigonometrical points are taken by placing the sight rule over the centre of the circle, intersecting the objects, and then reading the angles off the graduated circumference. This can be done very quickly, for between each observation it is not necessary (as it is with a prismatic compass) to wait while the needle comes to rest. The azimuths also are referrible to the true meridian and are not mere compass bearings: they are therefore all the more quickly plotted on an ordinary graticule; and having been read off a circle of large diameter, they possess considerable accuracy. The azimuths, chained distances &c. are entered in a field book, and a record is thus preserved which is capable of being utilized at any future time, and which would prove very convenient if an enlargement of the scale of the survey became necessary.

The present recess of 1873.

(37.) Since the commencement of the present recess the party has been employed on computations, and on the preparation of the fair maps of the country surveyed during the past field season, four of which maps should be ready for publication before the party again takes the field.

Extract from the Narrative Report—dated 5th August 1873—of Captain J. HERSCHEL, R.E., Deputy Superintendent 2nd Grade, in charge Astronomical Party No. 1.

Subjects of this report.

(2.) My principal subject will necessarily be that to which the field season of 1872-73 was devoted, namely the experimental determination of longitude-differences; but before entering upon that it is necessary that the subject of former reports should be brought to a conclusion. I refer to the latitude operations on the Central Indian Meridian.

Additional comparisons of Astronomic with Geodetic latitudes.

(3.) The general results arrived at were presented in a tabular statement in the postscript to my last report: there is little to add to that statement so far as astronomic co-latitudes are concerned. The geodetic elements of the SOMTANA and BADGAON groups have been sent to me, giving the following comparisons, which are not in any way specially remarkable.

No. of Station and Group	Geodetic Latitude	Geodetic Longitude	Co-latitude Geodetic	Co-latitude Astronomic	Diffce. $\lambda_o - \lambda_c$	Variation in Group
	° ′ ″	° ′ ″	° ′ ″	″	″	″
XXXII	19 1 30·43	77 39 44	70 58 29·57	38·39	− 8·82	+ 0·20
XXXIII	2 52·09	46 2	57 7·91	17·23	9·32	− ·30
XXXIV	9 33·24	43 28	50 26·76	35·65	8·89	+ ·13
XXXV	7 23·72	37 14	52 36·28	45·33	9·05	− ·03
Somtána Group	19 5 ...	77 41 ...	70 54 ...		− 9·02	...
XXXVI	20 41 32·82	77 35 13	69 18 27·18	37·76	−10·58	+ ·61
XXXVII	44 26·93	38 59	15 33·07	44·46	11·39	− ·20
XXXVIII	44 14·73	44 10	15 45·27	56·66	11·39	− ·20
XXXIX	48 18·55	38 21	11 41·45	52·83	11·38	− ·19
Badgáon Group	20 44 ...	77 39 ...	69 15 ...		−11·19	

Longitude-difference: possible misconception of the object in view.

(4.) I turn now to the other part of my subject. And here I find it advisable to guard against a not unlikely misconception of the aim and object of such operations as are now to be described.

The object *not* geographical.

(5.) With few exceptions, and those of quite modern date, determinations of longitude-difference by astronomical methods have had for their object the longitude of points either geographically undetermined or only approximately known; that is to say, the object has been *geographical*. This is the case wherever the extremities of the line of operations have been unconnected by triangulation. Where such triangulation exists the difference of meridian is known thereby with much greater accuracy than any astronomical methods not of the highest order of precision can approach. The extension of the electric telegraph has greatly simplified the problem in certain respects, and *for the purpose above-mentioned* has made the operation a really easy one. But that purpose is in no respect the one in view at present. The Trigonometrical Survey of India has long since mastered the geography of India, although it has been unable to place India correctly on the map of the world. That has been done with considerable accuracy by the Astronomers of Madras; and will no doubt be done with still greater precision by telegraphic determination of longitude-difference from Greenwich. Still that is not the present object.

General notion of the real purpose.

(6.) It is not very easy to say what *is* the object but, speaking generally, it may be said to be to *try* whether the Earth's form has been correctly surmised by those Geodesists who, having compared the curvatures of different meridians (as obtained by measurements of degrees of *latitude*) with each other, concluded that the meridional sections are not all alike and that the Earth's form is not, as had been assumed, a spheroid of revolution with a *circular* Equator, but a spheroid with perhaps an *elliptical* cross section. It is obvious that here we have need of an order of accuracy far greater than would suffice for geographical purposes.

Reasons for insisting on the distinction.

(7.) It seems necessary to insist somewhat on the distinction here drawn, as in all the accounts of the operations of this description to which I have had access—with certain exceptions in which the object is avowedly that which I have just mentioned—there is an undisguised faith in the overpowering simplicity of the method which cannot fail to raise the question where is the difficulty? It will perhaps be sufficient to reply, that in the exceptions to which I have alluded the whole tenor is one of exhaustive research into minute causes of error—that every effort is made to eliminate or hunt them down—in order that the result may bear close comparison with trigonometrical measurement.

(8.) With so much of preface I may proceed to indicate the principal features of the first attempts to put into practice the Telegraphic Method in India.

Equipment.

(9.) The Equipment consists of two superb-looking transit instruments of 5 inches aperture and 5 feet focal length, constructed under the superintendence of Col. A. Strange by Cooke and Sons of York: of two astronomical clocks by Frodsham and of two chronographs by Secretan and Hardy of Paris besides relays and batteries.

(10.) To describe all these in detail would extend this report to too great length. I will therefore only indicate the main features as they gradually presented themselves to me as requiring especial attention. For I ought not to omit to state that I came to the task profoundly ignorant of all details and more especially so in regard to the proper management of electro motive force, with which I had never had any practical acquaintance. Practice and incessant study of the subject have done much to remove the innumerable difficulties which were encountered from first to last; but I am not ashamed to own that to the very last there remained, in the management of the chronographic record especially, a considerable amount of uncertainty.

Description of instruments confined to particular features.

(11.) I have thought it best hitherto to speak in the first person, so as not to involve my colleague, Captain Campbell, in any of the statements I might make; but he will, I feel sure, bear me out in what I have just said as to the difficulty of securing satisfactory chronographic record.

(12.) The source of these difficulties is to be found in the fact that the record consists of a mark made on the revolving drum and paper by the passage of an electric spark of high tension generated in a Ruhmkorff's coil by the interruption of a strong galvanic current, which is, so to speak, the second of three links in the chain of agency between the clock or observer and the drum. We have first the line or Daniell current, broken at will by the observer; its cessation breaks the local or Bunsen circuit and current; the interruption of the latter induces in the Ruhmkorff coil the statical electricity whose discharge by spark upon the paper burns the required mark. But in order that all this may happen, not only must the whole of the apparatus be properly adjusted, but the Bunsen current must be strong enough to induce a strong spark, and the spark must find its way through paper of exactly the requisite degree of dampness. That the paper may be always properly damp it must be prepared with a deliquescent, and the degree of impregnation with the latter must depend on the hygrometric condition of the air. Here at Bangalore we are at the mercy of changes of wind which set calculation at defiance; paper that will do well enough in the early part of the evening may be almost dripping or as dry as a bone a few hours later. Accordingly I found it necessary at last to have variously prepared papers at hand to suit different weathers.

Principal source of practical difficulties to be found in the dependence on frictional electricity.

And on the proper hygrometric conditions of the record paper.

(13.) But perhaps the Bunsen battery is the most troublesome and provoking source of failure. There are about a score of tricks which it has, any one of which will impede its action or obstruct it altogether. Sometimes when it is out of temper it will play 2 or 3 of these at once, and an hour or more will be wasted in the attempt to force or coax it to behave. Lastly, there is always more or less uncertainty *which* is in fault, the relay, the battery, or the paper. As I say, to the last I never could guarantee a satisfactory record; and it is not surprising therefore that at first, with many other difficulties unexplained, the finest nights were often the ones when least seemed to be done.

The Bunsen battery a source of trouble, due to inconstancy.

Behaviour of the clocks.

(14.) Of the Clocks I have nothing but good to say.

Of the Chronographs.

15. Of the Chronographs—one is a miracle of regularity, and deserves the highest commendation. The other is very provoking.

Relays.

(16.) The Relays have done their duty creditably, but they are I think of bad pattern and ought to be changed I cannot explain their defects here.

(17.) I have here merely glanced at the different sources of trouble. As a rule they are not such as can be removed before hand; partly because their causes are but little understood, partly because they arise from and in the actual working, by expenditure of material, by the action of chemical products of that expenditure, or by change of weather. They are matters of detail individually, but each has a more or less direct and important share in the whole, and they are rarely all absent at once.

Precise causes of failure always uncertain because of their variety.

(18.) Lastly, I may add on this subject that where the united action of two otherwise independent observatories is essential to the success of a particular class of operations, the chances of miscarriage are greater than if one only is concerned.

Combined action of two independent operators also necessary for complete success.

(19.) For the determination of longitude-difference chronographically there appear to be two distinct classes of method, in which one clock, and two, respectively, are used. I am not prepared to enter fully into the subject of their respective merits here, further than is requisite to explain the demands upon the Telegraph Department for the use of the public wires. But it is necessary to take into consideration that the transmission

Chronographic determinations of longitude considered with reference to demand on public telegraph lines.

of a telegraphic signal represents a certain lapse of time, the neglect of which would involve an error—depending of course on the distance—equivalent perhaps to an error of measurement of 1 foot in 5 miles. Consequently any method which leaves this out of consideration depends in fact on others which do not; for the interval of lost time must be computed from an assumed velocity. 1°. If one chronograph only is used, the distant signals *must* be transmitted to it, and must arrive late, and the error in question occurs. 2°. If two chronographs are used—and still one clock—observer's signals are transmitted to the clock station, arriving late, and clock signals are sent to him, also arriving late, and therefore making *his* signals appear too early. This combination therefore—of one clock and two chronographs—provides for the transmission-lapse. In both the cases mentioned however, it is to be noted that the line-wire is required during the whole duration of the *transits* at one—the distant—station. 3°. If two clock's are used one at each station, their errors and rates may be ascertained independently, by any number of stars and to any degree of precision, without leading to a knowledge of longitude-difference. But no sooner is any signal *timed* by both—being transmitted for the purpose by the line-wire—than the clock—difference is known (subject as before to the delay in transmission) and hence the longitude-difference. The direction in which the signal is sent will determine whether the clock difference is too small or too great on account of the delay and by sending alternately the excess and defect (if equal) become known. With two clocks therefore, and two chronographs, all that is required of the wire is to transmit "comparison signals:" the rest is local work. It is obvious however that as the latter equipment includes the former, and with it the power of employing the methods which are suitable to it, the full equipment gives the choice of the 3 methods, two of which employ the line largely, and the 3rd only at intervals of two or three hours.

Transmission lapse equivalent to 1 foot in 5 miles.

Method where two clocks are used.

(20.) The quantity to be found being not an *absolute time*, but a *difference of times*, it is not necessary to know exactly the actual clock errors, but the difference of these. This is a very important point—which does not seem to have been taken advantage of in either of the few continental operations of this kind which I have been enabled as yet to procure. As the whole of our regular work has been based upon it to that extent over-riding such precedent as we have—I must extend this portion of my subject to explain the reasons for adopting it. The best way to do so will be to give our actual system and the process by which it is proposed to deduce the longitude-difference.

Absolute time not required; only difference of times.

(21.) Clock comparisons are exchanged at 8-30, 10-30, 12-30, P.M. Between these hours transits are taken "locally" at such times that *the same sets of stars are observed at both stations*, as far as circumstances permit. Certain intervals are arranged for taking instrumental errors of adjustment; and that is the whole of the programme.

Ordinary programme.

The reductions may be outlined thus:—comparisons give *clock differences* and *transmission lapse*: selections from the transits give rate of each clock, and therefore clock-difference at any time other than that of comparison: [or if the comparisons are sufficient, the difference at any intermediate time is known from them alone. It is an open question which method will be best, in this respect.] Transit of *any* star over both meridians gives two clock times whose difference equals the clock difference at the moment of transit over the E. meridian + longitude-difference + effect of rate of W. Clock during the interval from one meridian to the other. The only unknown quantity here is the longitude-difference, which is therefore determined from this equation. Every star observed at *both* stations gives thus a measure of the required longitude-difference, without any regard to its precise R. Ascension at the time, to find which would require a large amount of really unnecessary labour. For it is to be remarked that the only way in which *actual* (as distinct from relative) time or rate enters in the final expression of longitude-difference is in the adopted value of rate-effect during the passage of a star from one meridian to the other a minute quantity, not liable to sensible error, which *must* enter in any case, whatever the system or treatment.

Rationale of reductions.

(22.) I am at a loss to account for the non-appearance of this view of the matter in any practical shape, in the publications to which reference has been made; for the principle which underlies it is certainly sound. It is possible that, collaterally, knowledge of stars' places is advanced, and that longitude *alone* is not admitted to be the sole object in view. And no doubt it is contrary to general principles to proceed by selection from observations to obtain that which might be made to depend upon all. It is however to be remarked that the use of the chronograph makes a vast difference in the application of such principles. The reason for not discarding observations actually made has some reference to the labour of making them. The chronograph gives us the means of obtaining a large mass of *available* record with very little more trouble than is required for a small quantity and it is

Reasons for adopting a method not generally practised.

at this stage—before the real labour begins—that the selection may be made. It is in the *reading off* of the chronographic record that we must look for reasons for or against the utilization of all or only some of the available material.

Anticipation of some results.

(23.) My departure on furlough while a considerable portion of such material remains still unworked, prevents me from doing more than hazard a few numerical results; which my colleague Capt. W. M. Campbell, R.E., will no doubt be able in due time to present in a more satisfactory form. I should not however be acting fairly towards him, considering the large amount of work to be done before a full report can be looked for—either in thus deserting him or in anticipating the conclusions at which he may arrive—but for the fact that my taking furlough last year was deferred only for the sake of commencing this work, and that I am now enabled to leave the prosecution of it in worthy hands.

Flexure of one of the telescopes supposed to detract from the value of the operations.

(24.) There is one respect in which there is unhappily grave reason to suspect any appearance of accuracy which the results may hereafter present. Owing to some cause which has completely baffled detection, it is almost certain that the liability of the tube or axis of one, and perhaps of the other, of the two transit telescopes to lateral flexure is very considerable. This is a very common failing in large instruments, I believe, but at the same time one very apt to be overlooked owing to the great difficulty of proving satisfactorily its existence. Of course it is still more difficult to investigate and allow for it. If it exists to the extent to which my experiments point it will I fear be necessary to take the fact largely into consideration.

Personal equation determined conclusively.

(25.) Very careful observations have been made for the determination of our relative personal equation, with results which I have reason to believe highly satisfactory. There is nothing to be apprehended on this score.

Clock comparisions supply evidence of first rate performance

(26.) The comparison of clocks at Mangalore and Bangalore have been all read off, reduced and collated for the purpose of determining clock-difference, relative rate, and transmission-lapse. The results are both satisfactory and suggestive. The extreme *change* of relative rate shown would amount if continued to only 0″·17 per diem; but being undoubtedly only an exaggerated differential change due to a regularly repeated daily oscillation, it is probable that ± 0″·08 per diem more correctly represents the range of *accidental* variation, at the times of comparison. This gives a high character to the clocks. The transmission-lapse, or retardation of the delivery of the signal is still more remarkable, but less easy to understand.

Transmission-lapse or retardation of delivery presents extraordinary features.

Whatever be its value, it consists of two distinct elements, viz:, the delay on the line, and the delay at the magnet. From the nature of the comparison the latter is present in both circuits—the local clock circuit and the distant clock circuit—and if to a like extent, the effect is eliminated in the comparison; and the delay on the line is alone visible in these. But such a condition would be accidental: theoretically there must be a retardation peculiar to each relay, and its adjustment, and strength and direction of current passing through it; and it is the difference of these retardations—more correctly the excess of that belonging to the line-relay and current over that belonging to the local relay and current—which will tend to swell the total. Instead of an excess there may be a defect in which case the line retardation may be reduced in amount if not negatived. It is certain that the magnetic force is more effective with a current in one direction than another. We have here then all the elements of diversity necessary to produce a varying total retardation and as a matter of fact we do find the following values, the distance being 245 miles.

	Current.	
	Positive	*Negative*
Singals from E.	0″·028	0″·003
,, W.	·022	·011

These depend on a sufficient number of independent determinations to leave no doubt whatever that they must be explained in some such way as indicated. The mean of the four would I conceive be free from every kind of *error* and would presumably be slightly in excess, if any thing, of the true retardation *along the line*. Its value, ″·018, gives a velocity of 13,600 miles per second, which is double the value generally assigned.

Velocity of transmission seems to be twice as great as determined in other similar operations.

(27.) It is hardly necessary to say that the worth whatever it may be, of the primary operations is not in the least affected by a collateral issue such as this. But it shows very unmistakeably that there may lurk small constant lapses of time in apparent instantaniety, which require very close looking after.

(28.) I have thought it unnecessary to enter into many details of time place and season, in this report, because from beginning to end, though the *venue* was changed ostensibly with a view to obtain local determinations of longitude-difference, the real object was and could be nothing more than *practice*—with such ultimate fruit as successful or unsuccessful prosecution might haply produce. In this matter one is wholly dependent on coincidence of a variety of conditions, and geodesy must stand aside if these are not convenient. Thus Bangalore and Madras were in every way suitable—and Mangalore was a convenient extension of the arc although whether in part or as a whole, it is of very little consequence to geodesy whether the determination is good or bad. It is a short arc, across a peninsula, incapable of extension, and unrepresentative (owing to medial table land) as a part of the normal figure and cannot be accepted as such without large reservation. But the presence of the Telegraph, the Railway, the Triangulation, and the absence of the ordinary waste of time and trouble and money in marching and camping in strange countries, made it certainly an expedient selection for a trial campaign.

Comparative worthlessness of the present arc from a geodetical point of view counterbalanced by practical advantages as an arc of experiment.

Extract from the Narrative Report—dated 19th September 1873—of Captain W. M. CAMPBELL, R.E., Deputy Superintendent 3rd Grade, in charge Astronomical Party No. 2.

In my narrative report for season 1871-72, dated 14th August 1872, I was unable to give any of the results of my work, *viz.* the determination of Latitudes on the Mangalore Meridional Series, because the reductions at that time were not nearly completed.

(2.) I have already informed you, that as these reductions were brought near completion, a startling difference was found between the results by N. and S. Zenith stars respectively: the co-latitude given by the former, being always in excess of that derived from the latter, or in other words, the instrument measures all Zenith Distances in excess of the truth.

"N—S difference" Zenith Sector No. 1.

This fault will be spoken of as the "N—S difference." A similar difference has been found in other instruments, notably in one of the Astronomical Circles lately in use, in which case it increased to so serious a quantity that the instrument was laid aside.

The sister Zenith Sector, used by Captain Herschel during three field seasons, shows hardly any trace of "N—S difference," season 1869-70 giving, $N-S=-0''\cdot09$ and season 1871-72, $+0''\cdot29$.

The difference given by Zenith Sector No. 1 has features which, so far as I know, have not been found in other cases of the same kind. The Astronomical Circle measured Zenith Distances in defect of the truth, the amount of error being subject to no law that could be traced.

Zenith Sector No. 1 measures Zenith Distances in excess of their true value, and the most superficial examination shows that the error is a function of the Zenith Distance, being nearly exactly in direct proportion to it.

This law has been taken advantage of, and a set of corrections computed for each station, the application of which bring the results into as close accordance as could be wished for.

Attempt to correct results for "N—S difference."

The method employed was the following:—

It was assumed that the error of each Zenith Distance measured, was C. Sin Z. D., C being a constant for each station, which was computed by the simultaneous solution of a set of equations, one for each star, of the form

$$M + C.\ \mathrm{Sin}\ a - A = 0.$$

in which A is the observed co-latitude by the star whose Zenith Distance $=a$, (N.Z.D. being + and S.Z.D. —) and M is the most probable value of co-latitude by all stars.

(3.) The accompanying tables give abstracts of the results at all stations, showing the effect of the application of these computed corrections, with other particulars.

It will be observed, that no alteration in the position or use of the instrument appears to affect the "N—S difference," and all comparison of the results seems to lead to the conclusion, that this difference will not affect final results obtained from an equal number of north and south stars, of nearly equal mean Zenith Distance. Still less might it be expected to affect the result of observations of pairs of north and south stars, but unfortunately that system involves the use of stars, whose places are not known with the degree of accuracy desirable, besides other disadvantages.

Effect of "N—S difference."

(4.) In table II the effects are shown, 1st of the reversal of the instrument on its pier, and 2nd of the order of Face-observation followed, and these are separated into two sets *viz* : those belonging to the three stations at which the reversal of the Sectors with reference to the microscopes was carried out, (see para. 26 of my last year's report) and of the others, at which this change was not made.

Effect of reversing the Zenith Sector.

So far as can be judged this reversal of Sectors appears to be useful, but the number of cases is so small that the result may be merely fortuitous.

(5.) In table III, different values of the general mean co-latitudes are arrived at, by combining the means given by several pairs of sets of observations. The mean of these values is what I should adopt as the final value, (unless indeed the proposed correction of the observed results is allowed, in which case I should prefer the value so obtained to any other) and it is taken out at the foot of the table and compared with the Geodetic Latitude for each station.

Adoption of final results.

This comparison shows a relative northerly attraction, with reference to the origin of Geodetic Latitudes, *viz* : Calcutta, at every station except Mangalore, where the opposite obtains in a slight degree. About Hunawali and Koramoragúda, the topography of the country strongly points to the probability of attraction such as these results show, because these stations are near the verge of the Mysore plateau, where there is a precipitous descent of fully 2,000 feet to the low country of Kanara. The result at Mangalore, on the contrary, is the reverse of what might have been looked for.

Apparent deviation of plumb-line.

(6.) A disagreeable feature in these results is the discrepancy between the two values of the co-latitude of Kundgorl, amounting to 0"·23, but this is capable of a certain amount of explanation.

Discrepancy between two sets of observations at Kundgorl.

During the first set of observations at this station the position of the instrument was the same throughout, and is believed to have been that known as "Azimuthal Stud North," and the Sectors were not reversed. Now at four other stations where the Sectors were not reversed, the mean difference between the results obtained with Azimuthal Stud North, and South, was 0"·13, North being in excess of South, and if half of this quantity be considered as a correction to the result in either position, and applied to the first value obtained at Kundgorl, the discrepancy becomes 0"·23—0"·07 = 0"·16. Very little faith can be put in this mean difference of 0"·13 as it is derived from only four values, so discordant as to give a *p. e.* of their mean = ±0"·17, actually greater than the quantity itself, but it affords a plausible explanation of the otherwise startling discrepancy under notice. For many reasons the second value of Kundgorl is much to be preferred to the first.

(7.) The stars used throughout season 1871-72 were selected with reference to both the Greenwich seven-year Catalogues of 1860 and 1864, and their places depend on a mean number of observations of 26 and 19 in these catalogues respectively. The places adopted were the means of the two catalogue values, weighted according to the number of observations belonging to each. Of 96 stars common to both catalogues and reduced by each to January 1, 1872, the mean difference of resulting N. P. D. was 0"·16—that from the catalogue of 1860 being the greater.

Selection of stars.

TABLE I.—ABSTRACT OF RESULTING CO-LATITUDES

as observed, and as treated for " N—S difference"—Season 1871-72.

STATION.		North Stars		South Stars		Mean Co-latitude as deduced from observation					Mean Co-latitude after correction for N—S					General Mean Co-latitude		Diff. $\frac{N+S}{2}-\frac{n+s}{2}$	Diff. of Mean Z. D. $A-B$	By computation M and Log. C
		No.	Mean Z.D. A	No.	Mean Z.D. B	Mean by N. Stars		Mean by S. Stars		Diff. $N-S$	By N. Stars		By S. Stars		Diff. $n-s$	Observed $\frac{N+S}{2}$	Corrected $\frac{n+s}{2}$			
						N	p.e.	S	p.e.		n	p.e.	s	p.e.						
	° ′		° ′		° ′	″		″		″	″		″		″	″	″		° ′	″
Majala Co-lat.	73 13	22	5 29	22	5 30	5·635	±·112	3·671	±·073	+1·964	4·653	±·070	4·656	±·071	−0·003	4·653	4·655	−0·002	−0 1	4·66 1·0132
Mawinhunda Co-lat.	73 34	19	5 56	19	5 52	56·749	·148	54·326	·106	2·423	55·528	·068	55·533	·080	·005	55·537	55·531	+ ·006	+0 4	55·53 1·0737
Naolur Co-lat.	74 34	16	6 13	16	6 19	32·938	·163	30·121	·088	2·817	31·536	·076	31·548	·046	·012	31·530	31·542	− ·012	−0 6	31·54 1·1133
Kundgorl Co-lat.	74 44	23	5 54	24	6 15	46·642	·139	44·800	·108	1·842	45·744	·080	45·749	·062	·005	45·721	45·746	·025	0 21	45·75 0·9421
Kundgorl 2nd Visit		16	6 29	16	6 31	46·826	·159	44·134	·124	2·692	45·478	·079	45·489	·086	·011	45·480	45·484	·004	0 2	45·48 1·0780
Hunawali Co-lat.	75 43	15	6 2	16	5 28	30·351	·110	28·428	·097	1·923	29·337	·069	29·343	·060	·006	29·390	29·340	+ ·050	+0 34	29·34 0·9843
Koramoragúda Co-lat.	75 51	15	5 6	16	5 31	59·263	·126	57·477	·130	1·786	58·399	·116	58·407	·077	·008	58·370	58·403	− ·023	−0 25	58·40 0·9865
Mangalore Co-lat.	77 7	22	5 45	22	6 13	43·039	·112	41·278	·128	1·761	42·190	·065	42·196	·074	·006	42·159	42·193	·034	0 28	42·19 0·9291

The mean *p.e.* of $\frac{n+s}{2}$ for all stations is ±″·052, the mean number of stars per station being 37.

Using Zenith Sector No. 2 at 6 stations in Season 1869-70, Captain Herschel's resulting co-latitudes gave an average *p.e.* = ±″·049, his mean number of stars being 55. These results agree closely, as might be expected supposing the treatment of the observed quantities of Sector No. 1 to have eliminated the effects of the "*N—S* difference" of that instrument.

TABLE II.—ABSTRACT OF RESULTING CO-LATITUDES

from observations taken in different ways—Season 1871-72.

No.	Station.	By observations taken with Instrument in opposite positions.									By observations taken with different order of Faces.								
		Azimuthal Stud North.				Azimuthal Stud South.				Diff. $\frac{a+b}{2}$ minus $\frac{c+d}{2}$	Face East, face West.				Face West, face East.				Diff. $\frac{p+q}{2}$ minus $\frac{r+t}{2}$
		By N. Stars a	By S. Stars b	Diff. $a-b$	Mean $\frac{a+b}{2}$	By N. Stars c	By S. Stars d	Diff. $c-d$	Mean $\frac{c+d}{2}$		By N. Stars p	By S. Stars q	Diff. $p-q$	Mean $\frac{p+q}{2}$	By N. Stars r	By S. Stars t	Diff. $r-t$	Mean $\frac{r+t}{2}$	
				(N−S)				(N−S)					(N−S)				(N−S)		
		"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
1	Majala ...	5·66	3·86	+1·80	4·76	5·18	3·25	+1·93	4·22	+·54	5·70	3·92	+1·78	4·81	5·36	3·32	+2·04	4·34	+·47
2	Mawinhunda* ...	56·74	54·44	+2·30	55·59	56·89	54·24	+2·65	55·57	+·02	57·11	54·41	+2·70	55·76	56·63	54·27	+2·36	55·45	+·31
3	Naolur* ...	32·96	30·23	+2·73	31·60	33·15	30·06	+3·09	31·61	−·01	33·12	29·85	+3·27	31·49	32·95	30·33	+2·62	31·64	−·15
4	Kundgorl ...	Observn's. taken in one position only, believed to have been "Azimuthal Stud N."									46·85	44·92	+1·93	45·89	46·45	44·64	+1·81	45·55	+·34
5	Ditto * ...	46·85	44·11	+2·74	45·48	46·79	44·18	+2·61	45·49	−·01	46·73	44·21	+2·52	45·47	46·93	44·08	+2·85	45·51	−·04
6	Hunawali ...	30·25	28·29	+1·96	29·27	30·44	28·61	+1·83	29·53	−·26	30·90	28·84	+2·06	29·87	30·08	28·08	+2·00	29·08	+·79
7	Koramoragúda ...	59·45	57·41	+2·04	58·43	59·07	57·34	+1·73	58·21	+·22	59·18	57·62	+1·56	58·40	59·36	57·22	+2·14	58·29	+·11
8	Mangalore ...	43·11	41·20	+1·91	42·16	42·90	41·40	+1·50	42·15	+·01	42·90	41·25	+1·65	42·08	43·16	41·29	+1·87	42·23	−·15
	Mean Difference due to position of Azimuthal Stud $\left(\text{or } \frac{a+b}{2} - \frac{c+d}{2}\right)$ ...									+·007	Mean difference due to order of observation $\left(\frac{p+q}{2} - \frac{r+t}{2}\right)$ ...								+·21
	At Stations (1) (6) (7) (8) ditto ...									+·13	At Stations (1) (4) (6) (7) (8) ditto ...								+·31
	Ditto (2) (3) (5) ditto ...									·00	Ditto (2) (3) (5) ditto ...								+·04

* At Stations (2), (3) and (5) only the reversal of the Sectors with reference to the Microscopes was introduced.

TABLE III.—ABSTRACT OF RESULTING CO-LATITUDES.—*Season* 1871-72.

Method of arriving at General Mean Co-latitude.	Majala 73° 13′	Mawinhunda 73° 34′	Naolur 74° 34′	Kundgorl 74° 44′	Kundgorl 74° 44′	Hunawali 75° 43′	Koramoragúda 75° 51′	Mangalore 77° 7′
	″	″	″	″	″	″	″	″
(1) Observed Mean by North Stars $= N$; Do. South Stars $= S$; $\frac{N + S}{2} =$	4·653	55·537	31·530	45·721	45·480	29·390	58·370	42·159
(2) Corrected Mean by North Stars $= n$; Do. South Stars $= s$; $\frac{n + s}{2} =$	4·655	55·531	31·542	45·746	45·484	29·340	58·403	42·193
(3) Mean of all observations azimuthal Stud North $= A$; Do. do. Stud South $= a$; $\frac{A + a}{2} =$	4·490	55·580	31·605	...	45·485	29·400	58·320	42·155
(4) Do. Face order E.W. $= B$; Do. do. W.E. $= b$; $\frac{B + b}{2} =$	4·575	55·605	31·565	45·720	45·490	29·475	58·345	42·155
(5) Do. Zeros about 0° $= C$; Do. do. 180° $= c$; $\frac{C + c}{2} =$	...	55·506	31·464	...	45·510			
Means of all the above omitting (2)	4·573	55·557	31·541	45·721	45·491	29·422	58·345	42·156
Do. Latitudes $= A$	55·427	4·443	28·459	14·279	14·509	30·578	1·655	17·844
Geodetic Latitudes $= G$	59·271	6·666	33·673	17·793	17·793	35·009	9·116	17·248
Difference $A - G$	−3·844	−2·223	−5·214	−3·514	−3·284	−4·431	−7·461	+0·596

The Geodetic Latitudes here given for Majala, Mawinhunda, Naolur and Kundgorl, are those given in the "Preliminary chart of the Mangalore Meridional Series" corrected by + 4″·16. Those of Hunawali, Koramoragúda and Mangalore, have been supplied by Major Branfill Deputy Superintendent in charge Madras Party.

N.B. Hunawali and Koramoragúda are the same points as Major Branfill's Húnavalli H.S. and Koramúr H.S.

(8.) During the past Field Season, I have been associated with Captain Herschel in the determination of differential Astronomical Longitudes by means of the Electric telegraph. Captain Herschel, who had charge of the combined operations, has lately proceeded to Europe on furlough. Before his departure he submitted a report of our work, but at that time the reductions were not far enough advanced to enable him to give any Longitude results, and his report was less full in many respects than it probably would have been had he had more time at his disposal. In the following remarks I shall endeavour to make the general narrative of our operations more complete, and to describe the instruments used, in such detail as may appear necessary. I hope also to be able to give at least some idea of the results obtained.

Field Season 1872-73.

(9.) The instrumental equipment consists of two complete sets, each set comprising: a Transit Telescope, a Chronograph, with accompanying electrical apparatus, and an Astronomical Clock.

Description of Instruments.

(10.) The Transit Telescopes are by Cooke and Son of York, sister instruments known as No. 1 and No. 2, of nearly identical dimensions. The focal length is slightly over 5 feet, and diameter of object glass 5 inches, the whole of which is effective. There are two wire diaphragms one of which carries a single vertical and a pair of horizontal wires, the latter about 1′ apart. The other a set of 25 vertical wires arranged in groups of 5 each. The latter is worked by a micrometer screw, and the former may be called fixed although a screw is provided for adjusting its position as required. (Each instrument has two "Eye Ends" precisely alike, except that the micrometer diaphragm of one has only the usual set of 5 transit wires, being intended for "Eye and Ear" Observations.)

Transit Instruments.

The 25 vertical wires were conveniently named A, B, &c. to Y, the centre one being M. Their mean distance apart is 36″·6 = 2·44 equatorial seconds, and the groups are separated by double intervals.

The micrometers have double heads, one graduated to show revolutions and the other for divisions, the two being connected by a set of toothed wheels. The value of a revolution was found to be so nearly identical in the two instruments, that a mean value has been used for both, *viz.*: $1^{R} = 33''{\cdot}75$, which is nearly exactly equivalent to 100 revolutions per inch of screw. The micrometer head is protected by a cap, which being screwed on after setting to a particular reading, insures it against being accidentally disturbed. There is a small window of talc through which the setting can be inspected. A screw is provided for rapidly traversing the eye piece during observations, so that the star may be kept close to the centre of the field. The plate carrying the wire diaphragm is capable of adjustment for verticality of wires.

Micrometers of Transit Instruments.

The set of eye pieces comprise direct eye pieces of various powers, with prisms for oblique use, and a Bohnenberger eye piece for use with the mercury trough. The latter has been used throughout for all observations, that of No. 1 instrument is much superior to that of No. 2, both in construction and magnifying power, the former being about 160 and the latter not more than 80.

Eye pieces of Transit Instruments.

There are two setting circles attached to the tube of the telescope, each 7½ inches in diameter, graduated to 20 minutes and reading to 1 minute by verniers, and each provided with a coarse level. They are not fixed but can be turned round and clamped in any position, which admits of adjustment for setting by declinations direct, or by Z. Distances &c. There is no means of clamping the telescope when set.

Setting Circles.

(11.) Two kinds of wire illumination are provided:—1*st*. The ordinary dark wires in bright field—2*nd*. Bright wires in a dark field, the arrangement being as follows. In the cube of the axis (see para. 12) there is a light plate revolving on an axis at right angles to both telescope and transit axes, (cut out in the centre so as not to interfere with rays from the object glass) and capable of being moved through an arc of 45° by a rod with a handle projecting close to the eye piece.

Wire illumination.

A lamp is placed opposite one end of the transit axis, which is perforated. When the plate is inclined at 45° to the transit axis, the light from the lamp is reflected directly on to the wires by a small black glass reflector, placed in the centre of the opening in the plate; *i.e.*, approximately at the intersection of the transit and telescope axes. When the plate is turned so that its plane coincides with the transit axis, the light is intercepted by a set of four prisms and reflected downwards, between the telescope tube and an inner tube provided for the purpose, the four sets of rays converging slightly, so as to strike upon four prisms attached to the frame carrying the wire diaphragms, two on each side, and slightly above the plane of the wires. The latter prisms again reflect the light at right angles so that the rays are now nearly in the plane of the wires, which thus become illuminated by the rays from the prisms on each side, the field remaining dark. Both kinds of illumination are fairly satisfactory.

The object glass is fixed in its cell, so as to be pinched at three points only, and the cell, instead of being screwed into the telescope tube, has close contact with it only at three points where it is attached by three screws, and these are equidistant, so that the object glass may be put on in three different positions.

Object glass fittings.

(12.) The frame of the telescope consists of three principal pieces, *viz.* : the axis, the object-half, and eye-half, which pack for travel separately.

Frame of Transit Telescope.

The shape of the axis is a central cube of 9½ inches side, supported by conic frustra 9¼ inches in diameter at junction with cube, and 9¾ inches axial length, tapering to 3 inches diameter and terminated by enlarged cylindrical shoulders 3¾ inches diameter and 2¼ inches wide, into which lastly the steel pivots are fixed, the axis having I believe been shrunk on to them. The pivots are 1·9 inches diameter perforated by an opening 0·9 inch diameter, and they project 1·9 inches from the axis shoulder. The total length of axis is thus 37·3 inches, and 33·5 inches between shoulders. It weighs about 65 lbs. and the thickness of the metal is about 0·37 inch throughout the cube and cones, which were cast in one piece, the cube being strengthened by ribs. The conical parts were turned both inside and out to insure as perfect symmetry as possible.

Axis.

Of the four faces of the cube parallel to the axis, one pair are perforated by openings of 3½ inches diameter for collimation observations. They can be closed with caps and are crossed by spokes which support the illuminating plate. The other pair are cut out with openings of 6·8 inches diameter for the attachment of the telescope half tubes, with an annular space 0·6 inch wide outside, turned down about 0·07 inch or 0·08 inch below the surface.

(13.) The two halves of the telescope are each attached to the axis by 12 powerful steel bolts, which pass through a flange at the base of the tube, ¼ inch thick and projecting 0·7 inch, and screw into the metal of the cube which is 0·37 inch thick. The tubes are farther steadied by circular flanges projecting about 0·07 inch and fitting into the annulus outside the opening in the cube. The two half tubes are quite plain except that about 1½ inches from their bases, arms are cast upon them to support levels, to which I shall allude below. The object half is about 2 feet 8½ inches long from axis to outer surface of object glass, and weighs (with dew caps 6 inches long but without levels) 32 lbs.

Telescope tube.

Object half tube.

The eye half tube is only 1 foot 10¾ inches long from axis to where it is cut off for the attachment of the "eye end" (of which there are two, *vide* para. 9) by four brass screws. The "eye end" is composed of two concentric tubes to allow of the focussing adjustment, (which is performed by two opposing screws acting on a stud) it is 6 inches long measured to the plane of the wires, 3¾ inches diameter and weighs 6 lbs. The weight of the eye half altogether (without levels) is 40 lbs. The total weight of the telescope is thus 65 + 32 + 40 = 137 lbs.

Eye half tube.

(14.) Each telescope was intended to have a set of four hanging levels, but No. 2 was sent out before they were ready, and the level bubbles provided with No. 1 are of very inferior quality.

System of Levels of Transit Instruments.

When horizontal collimators, and the mercury trough (or vertical collimator) are used together, levels are not necessary, and thus it happens that these levels have never been used during the observations with either instrument. No detailed description therefore seems called for at present, but as the system is quite novel a few particulars will not be out of place. Close above and below the cube of the axis, brackets are cast on the telescope tube carrying four arms, to which again the levels are suspended on spindles, the arms being long enough to allow the levels to revolve freely on their spindles as the telescope is rotated, always maintaining a position, if in adjustment, at right angles to the plane of revolution of the telescope.

The system has certainly advantages over the usual hanging or striding level :—1st. There are four levels in place of one—2nd. They can be read in all positions of the telescope—3rd. They are affected in the same degree as the telescope by axial flexure and by irregularities of pivot.

Advantages.

On the other hand they have objectionable features, the principal of which are:—

Disadvantages.

1st. Irregularities of figure of the spindle bearings, on which the levels hang, will affect the levels in the same way as irregularities of pivot figure, but in a much greater degree, because these spindles are only 10½ inches long, whereas the axis is above 30 inches. 2nd. The adjustments are very numerous and troublesome, and the effect on the level readings of residual error in the adjustment of the arms, varies with the position of the instrument. These arm adjustments are of two kinds and their effects vary as the sine and cosine of the altitude respectively. Considerable experience of the system (furnished with better level bubbles than we now possess) is required, before an opinion of its value can be arrived at.

(15.) The pivots rest in nearly semi-cylindrical bearings of gun metal, of their own length and diameter, but cut away in the lower part so that there is contact only on two arcs of about 60° each.

Pivot bearings.

The under surface of these bearings is spherical, fitting exactly the upper surface of the beds on which they rest, and to which they are attached by a bolt passing through a slotted hole, so that the whole forms a universal joint, which insures the equal bearing of the pivots throughout their length. Again each of these beds rests on a lower or foundation plate of iron, which lastly are placed on the masonry piers. One pivot bed has three footscrews by which the level of the transit axis is adjusted, and the other has a provision for the adjustment of Azimuth. The pivots are protected from dust by well fitting caps. The weight of each pivot bed with foundation plate is about 40 lb.

(16.) The foregoing measurements and weights are those of No. 1 telescope and do not profess to be very exact. The other instrument only differs slightly in any of these particulars, but there is an important difference in their construction, No. 2 being made of gun metal throughout, while either the axis alone or the whole of No. 1 is of aluminium-bronze.

Difference in construction of Nos. 1 & 2 Telescopes.

(17.) I have gone into great detail in the description of these instruments, because of the peculiar differences in their behaviour. The collimator readings of No. 1 are remarkably constant, and are not affected by alteration in the manner of taking them. On the other hand the collimator readings of No. 2 alter to an extraordinary extent according to the method of observation, owing to which grave doubts are thrown on the value of any determination of collimation, and to an equal degree on all work turned out with the instrument. Captain Herschel, who used that telescope during the observations for difference of Longitude, introduced a strict system of manipulation during collimation observations, admirably calculated to insure the most reliable results at the time, which will also furnish a most valuable guide for the application of corrections to the work done, in case future investigation should provide data for that purpose.

Difference of performance.

Faults of No. 2

(19.) One is naturally led to compare the behaviour of Transit Telescope No. 2, with that of Zenith Sector No. 1, having in view the possibility of tracing their faults to similar sources, and I hope that an investigation of both carried on together, may be more likely to lead to some conclusion than would be the case with either treated alone.

Faults of Transit Telescope No. 2 and Zenith Sector No. 1 compared.

(20.) In the "Monthly Notices of the Royal Astronomical Society" (*vide* February 1873 page 219) mention is made of an instrumental error found in the new Transit Circle of Cambridge Observatory, exactly similar to one feature of our Transit Telescope No. 2. It would be very interesting to know if this resemblance between the two instruments extends beyond the particular point noticed.

Similar fault found in Transit Circle at Cambridge.

I shall here quote from a memo. of Captain Herschel's on the subject, some principal points of the conclusions to which he came after an extensive series of observations with our telescope, and compare them with the facts observed with regard to the Cambridge instrument.

Some particulars of behaviour of Telescope No. 2.

Captain Herschel says :—

"Nothing is more clearly proved by every series of experiments, incidentally, than that the same object will give a different intersection reading according as the direction of previous motion (through a quarter of a circle) is one thing or the other. The reading of a horizontal collimator is 1″ greater if the telescope is brought down (*i.e.* the object glass) from the Zenith, than if it is raised from Nadir. The same difference is found very generally at the Nadir, if the telescope is turned round in different ways, the greater reading being due to a descent through the North."

Remarks by Captain Herschel.

"Provided that the general rotation is *continuous* the readings at every point are constant, except perhaps at starting. If we call the rotation through North, Zenith, South, Nadir "direct," and the contrary "reverse" and if after one or two 'direct' rotations the readings (of the North and south collimator and the mercury trough respectively) are

N S M

"then after 2 or 3 "reverse" rotations the readings will be

N + 1″ S − 1″ M + 1″

If now the rotation, ceasing to be continuous becomes oscillatory through half a circle, the element of constancy disappears, and a *progressive* change is noticeable in readings which would otherwise be reproduced, until a limit is reached regarding which there is much conflicting evidence—as to the amount, but none as to the sign. If the oscillation is through the Zenith the readings increase, and if through the Nadir they diminish; the rate of change depending on what the last condition was, being rapid if the last reading differed much from the limit. The total change is much greater in the lower than in the upper oscillation, being 4″ or 5″ in the latter to 2″ or 3″ in the former."

To this I may add, that after one kind of motion has impressed its effect on the Telescope, that effect seems to remain permanent until motion of another kind is given. The telescope shows no sign of recovering a normal position if allowed to remain at rest. Also that, in order to give the effect of any particular movement, it must be carried to a considerable extent, a quadrant at least. Now quoting from the monthly notices—

Additional features.

Particulars as to Transit circle at Cambridge.

" When the instrument is turned through the south horizon to the Nadir, the reading of the observed Nadir point is about 1·″5 in excess of that which is obtained when the instrument is turned through the north horizon to the Nadir." It is added (page 220) that after many experiments were tried to correct this error without effect—" Professor Adams fears that there is a defect at some point of the tube itself so that it yields to a certain extent and does not recover itself until its weight is brought to act in the opposite direction. If this be the case, the only cure of the evil will be to replace the faulty tube by a new one."

Chronographs.

(21.) The chronographs are called A and B, and are exactly alike. They were made by Messrs. Eichens and Hardy of Paris, the latter taking charge of the Electric arrangements.

The instruments may be said to consist of 3 parts :—

1st. The clock work for driving and regulating.

2nd. The revolving barrel carrying the paper on which the record is impressed.

3rd. The carriage carrying the recording styles.

The regulator.

(22.) The regulator, so far as I know, is of quite a novel construction. It consists of a pair of governor balls connected, by a train of toothed wheels, with a small fan revolving on a vertical spindle, at the rate of about 30 revolutions per second, inside a fixed cylinder, in the circumference of which little windows are cut for the passage of air. An outer cylinder, with a corresponding set of windows, fits closely over the fixed one, and is connected with the governor balls in such a way that, as the latter rise owing to an increase of speed, the outer windows come into coincidence with the inner and allow the air to pass, whereby the resistance offered to the fan is increased and the rate of the machine checked.

Curious difference in behaviour.

The two instruments present a curious difference in the action of this regulator. In B it never rests for an instant, the outer fan-cylinder being in a constant state of oscillation ; but in A it preserves one position pretty steadily for a while and then shifts to another. This difference has always existed and its cause could not be traced by the maker himself. As might be expected, the rate of B is found to be more uniform than that of A.

The barrel.

(23.) The barrel is $11\frac{3}{4}$ inches wide and 3 feet 1·6 inches in circumference, and weighs about 45lbs. Each instrument has three spare barrels. The paper used is about 3 feet $2\frac{1}{4}$ inches long and is put on with common paste.

The style carriage, &c.

(24.) The style carriage rests on a table parallel to the axis of the barrel, and is made to travel along it by a screw which is geared with the barrel. There are two styles carried by arms which project over the barrel, so that the styles rest upon the paper, and trace a spiral thereon, progressing at the rate of slightly more than $\frac{1}{8}$ inch per revolution. The barrel is intended to revolve once in 2 minutes; hence the whole of it is traversed by the styles in about 3 hours, and a second of time corresponds to 0·313 inch linear space. There is a third arm which can also be furnished with a style if required, but it usually carries a small sharp-edged roller, which presses on the paper and traces a line thereon. The styles terminate in rounded platinum points which should rest as lightly as possible on the paper. The arms are insulated from the metal of the carriage by a block of ebonite. The points of the styles cannot be brought nearer to one another than about $\frac{1}{6}$ inch, they are therefore adjusted to follow one another at a convenient distance apart, tracing parallel lines just so far separated as to prevent possible coincidence of the marks made. The record is made by electricity, the paper being prepared for the purpose, as will be explained.

(25.) There are several provisions for ungearing the barrel, style carriage, &c. and for raising the styles off the paper. The details of these instruments are beautifully worked out, a degree of care and attention which is not often met with in like matters, being given to the most insignificant parts.

The behaviour of B may be considered perfect, that of A is not quite so satisfactory.

The Clocks.

(26.) The clocks are ordinary astronomical 8 day clocks by Frodsham, exactly alike, with the usual arrangement for breaking an electric circuit every second, *viz*:, by a 60 toothed wheel revolving once in a minute. One tooth is cut off so that one second signal is missed, this is made to agree with 0ˢ on the dial, and thus the commencement of each minute can be traced. Table IV will give some idea of the performance of these clocks.

The method of recording by electricity.

(29.) The method of obtaining the record by electricity is as follows :—One style is always in connection with the clock, and the other is generally at the disposal of the observer, hence they will be spoken of as the "Clock Style" and "Observatory Style." Each has an electrical apparatus composed as under.

1st. A metallic circuit passes through the clock, a voltaic battery of any sort, and the coils of a relay, the armature of which is acted opon by a spring, so that it is drawn away from the "contact stud" whenever the current is broken its range being limited by a "back stop." This circuit is called the "relay circuit."

Relay-circuit.

2nd. A Bunsen battery is placed in a metallic circuit which passes through the core of a Ruhmkorff, or induction coil, and is complete while the armature of the relay touches the 'contact stud.'

Bunsen battery.

The outer or small wire of the Ruhmkorff coil is carried to the chronograph, one end being attached to the foundation plate, and the other to a style, so that the metallic circuit is only interrupted by the paper, which intervenes between the point of the style and the metal of the barrel.

Ruhmkorff coil.

(30.) The 'relay circuit' being broken by the clock, the relay coils become demagnetized and the armature is drawn away from the 'contact stud' by the spring, thereby breaking the Bunsen circuit and causing the demagnetization of the core of the Ruhmkorff coil. The consequence of the last effect is, that the induced electricity in the outer wire of the coil, which is of considerable tension, owing to the length and fineness of the wire, is discharged through the paper, leaving thereon an indelible mark, always spoken of as a 'dot'. This process is gone through at each beat of the clock, and second 'dots' are recorded on the paper only omitting the first of each minute.

A signal by clock traced.

(31.) An exactly similar arrangement is provided for the 'observatory style,' the 'relay circuit' in this case being broken by the observer at pleasure by means of a key or tappet which he holds in his hand. It should be noted that all signals are made by break of circuit, a method undoubtedly superior as regards instantaniety to the opposite plan of signals by making circuit.

Similar arrangement for observer.

(32.) There must of course be an interval of time between the generation of the singal by the clock, or observer and the record thereof on the paper, and this 'retardation' of the signal has been the subject of considerable discussion. The demagnetization of a coil on inturruption of current may be considered instantaneous, for successive changes of magnetization and demagnetization have been obtained at the rate of 14,000 a second (see "Electric Telegraph, Lardner and Bright" page 26). The act in which appreciable 'retardation' creeps in, if at all, is in the withdrawal of the relay armature from the 'contact stud' by the spring, for until the separation is complete the signal cannot pass. The tension of this spring should therefore be as great as possible, compatible with certainty that the attraction of the coils when remagnetized will be sufficient to overcome it, failing which the armature will be held back and the circuit permanently interrupted. A spring which loses its tension very rapidly on being relaxed is the best adapted for the purpose, because the attraction on the armature varies inversely as the square of its distance from the magnet. For the same reason the 'back stop' should also be adjusted to allow as small arrange as convenient.

"Retardation."

Where it occurs.

Precautions.

(33.) The chronograph affords the means of measuring this 'retardation' as follows: If the 'relay circuit' of one style is passed through the other style, so as to be complete while it (the latter) is in contact with the metal of the barrel, then by breaking this contact, a spark is passed through the first style. The first style is placed on a strip of paper and the second on the bare barrel, close alongside, (the metal being scrupulously clean) lines are drawn with thick ink across the paper and metal parallel to the axis of the barrel, and the chronograph is set in motion. The ink lines are quite sufficient to break the metallic contact and record 'dots' on the paper, and the distances of these 'dots' from the lines causing them being compared with the actual distance of the styles apart, afford an absolute measure of the 'retardation'.

Means of measuring 'retardation.'

This experiment has been tried sufficiently to show, that with good current force allowing of strong spring tension, the 'retardation' is barely appreciable, but that it is easy to make it very sensible by decreasing the current force, and necessitating a weak spring.

Results of such measurement.

Provided that the currents used are at all fit for working with, the effect of 'retardation' need cause no anxiety whatever; because, besides the minuteness of the quantity, it must be nearly constant, and so long as it is constant its magnitude is of no importance.

(34.) The paper is prepared by dipping, first in a solution of ferro-cyanide of potassium and then in one of chloride of calcium, the latter being intended to keep the paper properly damp, but it is always sadly dependent on the state of the atmosphere. While working in this dry climate in February I was driven to despair by the difficulty of keeping my paper damp enough, and

Preparation of paper.

a week afterwards in Madras, I was forced to have a lamp always burning below the barrel, because the paper was too damp for use unless it felt quite warm to the hand.

We found chloride of calcium a very difficult article to procure, and I believe we bought up nearly every pound of it to be had in India, in December last.

Batteries 'relay circuit.'

(35.) We have always used Menotti batteries for the 'relay circuit,' as the most convenient from their simplicity and constancy, and because they are universally used by the Telegraph Department in this country. This part of the apparatus gives no trouble, as soon as one has gained very slight experience in adjusting the relays.

Objection to Bunsen batteries &c.

I wish I could say as much of the Bunsen batteries, which on the contrary are very troublesome and require constant care and attention. When all goes well, that is when the Bunsen batteries are working properly, and the paper is in exactly the right state of dampness, the record is all that can be desired, the electric spark leaving beautiful black 'dots' but the slightest fault any where mars the record terribly, and increases in proportion the labour of reading it afterwards. The Bunsen batteries are also objectionable, because of the nature of their ingredients, *viz*:, Sulphuric and Nitric acids, which are very expensive, not always easy to procure, and very troublesome to carry about. For all reasons the substitution of something else for this part of the apparatus, would be a very great advantage.

Preliminary practice.

(37.) I shall now pass on to the actual field operations. In November last we began work with the instruments close alongside of each other, and took a number of observations for practice.

On Base-line.

We then took up positions at the two ends of the Base-line, to connect which a flying telegraph line had been erected, and went through further practice, exchanging stations in the middle. These observations when reduced should afford values of the difference of longitude of the two ends of the Base, and of our relative personal equation, at that time.

Madras and Mangalore.

At the beginning of March we attacked the Madras-Mangalore Arc, Captain Herschel remaining here, while I proceeded first to Madras and afterwards to Mangalore.

Station at Madras.

(38.) The station at Madras was about 65 feet due north of the meridional circle of the Madras Observatory, which Major Branfill connected with our principal triangulation in 1865.

Station at Mangalore.

The longitude station at Mangalore was 63 feet due south of the trigonometrical point.

Telegraph connections.

At Madras advantage was taken of the permanent wire connecting the Observatory with the telegraph office, and at Mangalore a temporary line of about ¾ mile in length was errected between the telegraph office and our station.

At Bangalore, Captain Herschel's station, the S.W. End of the Base, was also connected with the telegraph office.

System of observation.

(39.) Owing to the difficulty of obtaining the use of the lines except for short periods, we were obliged to adopt the system of comparing clocks at certain intervals. Captain Herschel had obtained the concession of the line for four periods of 15 minutes each, during each night, and

Nightly programme.

he adopted the following programme. At hours 8-30 to 8-45; 10-30 to 10-45; 12-30 to 12-45; and 2-30 to 2-45, Madras M.T., the line was claimed for clock comparisons.

The intervals were appropriated to observation of transits, collimation &c., thus :

At Madras 8-50 to 9-10, Transits ; 9-10 to 9-55, Collimation and Level ; 9-55 to 10-15, Transits ; the same order being repeated between each pair of Clock Comparisons.

Exactly the same division of time was observed at Bangalore, only retarded by the difference of longitude, with a view to the same stars being observed at both stations.

Choice of stars.

Acting on this principle, any star is as good as any other for mere determination of difference of longitude, and stars were therefore selected following each other as rapidly as convenient for observation, care only being taken, to observe every Nautical Almanac Star available for the determination of Clock rates. We were thus able to get 6 to 10 stars in each interval of 20 minutes, giving in a full night's work about 45 or 50 stars observed at both stations, and therefore as many individual measures of difference of longitude.

Position of Telescopes.

The Transit telescopes were not reversed on their pivots throughout the observations at Madras, Bangalore and Mangalore, and the position of No. 1 at Madras and Mangalore were the same.

There are advantages in preserving one position, but on the whole I think reversal in the middle of observations at each station would be judicious.

Clock comparisons.

(40.) The method of comparing clocks, which we finally adopted, was as simple as possible. Observer at E (East Station) took the initiative, and at the agreed time gave the ordinary call signal to the telegraph office, continuing it until put in connection with W (West Station). E then placed his clock in circuit with line wire and battery, so as to transmit second signals to W, who received them on his chronograph paper through the 'observatory style,' alongside of those made by his own clock. E continued these until an agreed instant, or until stopped by W breaking his connection with earth, and in either case he immediately prepared to receive similar signals from W. One minute was considered the minimum for a set of signals, and the interchange of two such sets composed one "complete comparison," from which a mean difference of clocks can be deduced with the effect of the transmission delay of the signals eliminated. If no hitch occurred a 'complete comparison' only occupied from 3 to 5 minutes and left 10 minutes at our disposal, we used then to repeat the process reversing the direction of current.

Reversal of current direction.

The first set of signals were always transmitted with zinc to earth at the transmitting station, and this was called "forward current:" for the second set, copper was put to earth by the transmitter, and the current was called "backward." The idea was that a difference of transmission velocity due to current direction might possibly be found, besides which in case of the existence of earth currents (a very common case on the Bangalore-Madras line) they might interfere more with signals given with one direction of current than with the contrary, and therefore the systematic use of both gave the best chance of success. From two 'complete comparisons'

Determination of transmission delay.

the following can be deduced, *viz :*, two mean clock differences, from each of which the effect of tramission delay ($= r$) is eliminated, hence the relative clock rate during the interval becomes known, and lastly, by applying this rate four values of r can be found, *viz :*

r from E to W with 'forward current'
r_1 ,, W to E ,, do.
r_2 ,, E to W ,, 'backward current'
r_3 ,, W to E ,, do.

If r, r_1, &c. can be accurately determined any signal may be utilised for determining clock difference, if only the current direction be known, otherwise no incomplete comparison can be used without introducing an error equal to r.

System of recording simultaneously on both chronographs.

(41.) For two nights on each section we obtained the use of the line wire for two hours at a time, with a view to trying the system of simultaneous record of transits on both chronographs, a system much superior to that depending on clock comparisons only. Between Madras and Bangalore clouds prevented our taking advantage of this concession, but on the Bangalore-Mangalore section we were more furtunate, and got a good many observations, though not nearly so many as could be desired, owing chiefly to my Bunsen batteries at Mangalore breaking down at a critical time.

On this system we began by a clock comparison as usual, then both of us observed transits, each recording simultaneously on both chronographs, and again compared clocks. Both before and after we each took transits for local clock rate.

Return to Bangalore.

(44.) I returned to Bangalore from Mangalore on the 10th May and we then undertook a set of observations to determine our relative personal equation.

Observations for "Personal Equation."

The instruments were put up alongside of each other, and on four nights we observed a set of stars changing telescopes in the middle of the set each night, and alternating the order so as to eliminate the effect of change of stars' places.

These observations were recorded with a common clock on separate chronographs.

On a fifth night we took divided transits, changing places at the same telescope in the middle of each, and changing the order for alternate stars. We did this with both instruments.

"Style Equation."

(45.) Owing to the two styles following one another on the barrel, the events recorded by the leading style will appear to have taken place later, with reference to the other, than they really did. The correction required to reduce the 'observatory style' to the 'clock style' is called the "style equation" and is generally nearly exactly one second.

Original method of its determination.

Our original system of determining the 'style equation' was by putting the clock in connection with both styles, so that they recorded the same signals on the revolving barrel. If constant strenth of currents could be insured for each relay, the 'style equation' by this method would contain the effects of 'retardation' of both relays, and therefore in applying it to the observations these effects would be completely eliminated, but practically it is impossible to maintain such constancy of current, particularly when taking the 'style equation' in conjunction with clock comparisons, for then the clock not only makes the double set of marks on the local barrel, but is also in connection with line, and marking on the far barrel.

Objections.

I now think the system of applying the absolute distance, measured by passing a spark through each style on the barrel at rest, is the least likely to introduce error, the effects of 'retardation' being guarded against by the precautions noted in para. 32.

Method preferred.

(46.) With a view to maintaining constancy of current for each relay throughout the operation of comparing clocks and taking the corresponding run for 'style equation', we began working with a somewhat complicated arrangement of batteries, the rationale of which would be troublesome to explain intelligibly on paper. Its chief feature was, that the power was divided into two halves, one placed at each station—that is to say, if 10 cells were required to give a working current on the line, we divided them into 5 at each end, of course taking care that the opposite poles were put to earth. It took us a great deal of trouble to bring this system into working order when we were only separated by the short wire along the Base line, and when we tried it again between Madras and Bangalore, over 200 miles apart, it was, as might be expected, much more troublesome. I believe the difficulty was due to want of perfect insulation on the line, allowing the current to escape to earth, a condition which must obtain in all land wires to a greater or less degree.

Original arrangement of batteries.

Its difficulties.

If the insulation were perfect, the current force on the whole line from 5 cells at each end would be exactly the same as from 10 cells at one end, and if the line were cut at any point (contact with earth of course not being allowed) all current would instantly cease.

Causes of failure.

With a battery only at one end, breaking the circuit at that end must of course cut off all current. But with two batteries acting in concert, when the current of one is cut off that of the other will not cease entirely, because the faults of the whole line will remain open for its escape, and there will be residual current of greater or less force according to the position and resistance of the faults. This was what we found, and the residual current was strong enough to prevent the break circuit signals from the far station being perceived. The system worked well at times, but invariably either became very uncertain in its action or broke down altogether under the influence of dew, which was remarkably heavy at Madras. After struggling to maintain it for some days, we threw it over by mutual consent in favor of the simpler plan of a battery at the sending station only, and from that time we had no further trouble to speak of.

Abandonment.

(47.) I think I may say with confidence, that no difficulty will henceforth be experienced in carrying out such operations, between two stations connected by a fairly well insulated wire of any moderate length, say 500 or 600 miles, and I see no reason to doubt the practicability of using much greater lengths of such line in favorable weather. During experimental work between Madras and Bangalore, we obtained working currents on at least one occasion with only one Menotti cell in use.

Opinion as to future similar operation.

(48.) I shall now offer some remarks on the reduction of the observations. The first thing to be done is of course the transcription of the chronograph sheets, and this is most laborious and trying work, involving several distinct operations. *1st.* The sheet is examined, and the transits marked out so as to be easily followed. *2nd.* The 'style equation' has to be applied, which I have always done as follows:—The best mean value of the equation that can be got from the recorded values, is taken up with a pair of compasses and pricked off on the paper several times over, for reference and recovery in case of need. Then putting one point of the compasses in the centre of a transit 'dot' with the other a prick is made in the line of the clock marks, and therefore exactly in the position the 'dot' would have held had the difference of styles been non-existent. *3rd.* The position of the pricks so made, is read off by a small glass scale on which lines are drawn dividing a second space into 10 equal parts. This being applied to any second containing a prick, so that the outer lines of the scale intersect the second 'dots' the prick is read off to $\frac{1}{100}s$, and by estimation to $\frac{1}{10}s$. The lines of the scale converge, so that it can be adapted to second spaces of different lengths.

The reduction.

Transcription of chronograph sheets.

Application of 'style equation.'

Reading off.

(49.) When the chronograph rate is very bad, and irregular, it may be necessary to apply the equation in this way to avoid sensible errors ; but if the rate is fairly steady, as it is in the vast majority of cases, the application of the equation to the mean of observations is all that can be required. The process, has hitherto always been gone through as it does not take long, is more rigorous, and makes the record easier to read, but its advantage is certainly open to question, as the minute errors intended to be avoided are of such a kind as to be certain to cancel each other in the long run if allowed to enter, and moreover similar errors may be introduced in the process of applying the equation.

Remarks on the process.

The rate and ease of reading off is very dependent on the clearness of the record sheet, and the rate of the chronograph. Under favorable conditions, I have pricked off and read 33 transits, aggregating 635 wires, in 2 hours, which gives an average of 5·3 'dots' per minute.

(50.) Every wire read is reduced to the centre wire, for which purpose the wire intervals were computed for every star observed; the Equatorial intervals having been in the first place determined by numerous transits of stars of small N.P.D. The case of missed wires is so common, that this method is very much simpler than that of reducing to the mean of wires.

Reduction of transits to centre wire.

(51.) All Nautical Almanac stars observed are used to determine the clock rate and azimuthal deviation at each station, each night, and this I think has been the weakest part of our work, and the part most open to improvement in future similar operations, first by the introduction of distant referring marks or better fixed collimators, and second, by more attention to the stars used for the purpose.

Stars observed for clock rate and azimuthal deviation.

But no possible error in these determinations can appreciably affect the results of our past work, because absolute rate is only required for the reduction of one clock to the other, for the interval due to difference of longitude, or during about 11 minutes.

Absolute clock rate of little consequence on that arc.

The importance of this point increases in direct proportion to length of the arc of longitude under measurement.

(52.) Both determinations of local clock rates are combined with the relative clock rate given by the clock comparisons, to deduce an absolute rate for one clock. In doing this the relative rate by the comparisons is considered as correct, being far more trustworthy than that given by a combination of the two computed absolute rates. The two latter are then assigned weights, (somewhat arbitrarily) according to their agreement each day with the mean of all days, on the grounds that the clock comparisons, as well as the daily clock errors, show that the general clock rates were very steady.

Combination of clock rates.

The following simple combination then gives the absolute rate adopted, say for the west clock, $= \frac{n\, r_W + m\ (R - r_E)}{n + m}$, where r_E, r_W are the computed absolute rates, with weights m, n, and R is the relative rate by clock comparisons.

This is the course which has been followed in the reduction of the Bangalore-Mangalore observations, but it may require modification on other occasions.

(53.) The relative clock rate is found to vary slowly during each night's work, and its value then is different from the value during 24 hours. These differences for stations Bangalore and Mangalore are shown in table IV.

Relative clock rate varies.

It would be interesting to compare these changes of rate with readings of the Barometer and Thermometer taken during the observations, and it is a pity that it never occurred to us to use those instruments.

(54.) I shall now proceed to give as much information as possible as to the results obtained.

Results.

The results of our observations for relative personal equation are given in table V and give a mean value of 0s·036, Captain Herschel's time of observation being so much later than mine. Another value of equation will I hope be arrived at when the observations on the Base line are reduced, and it will certainly be more satisfactory to have a value both before and after the principal operations, but we had both done so much preliminary practice before commencing the final work, that we must have entered on the latter with strongly acquired habits of observation, and no after change in our equation need I think be apprehended.

Personal equation.

(55.) The resulting values of difference of Longitude between Bangalore-Mangalore are given in table VI and these may be considered as nearly final, though possibly open to slight corrections, which may be arrived at by treatment of the results themselves.

Difference of longitude Bangalore-Mangalore.

(56.) Let us examine how such a discrepancy can arise, first supposing it to be certain that there was no mistake in the identity of the star observed at each station. The clock comparisons show the relative rate to progress so steadily, that it must be considered as beyond suspicion, that is to say, these discordances cannot be reasonably referred to irregularities in either clock.

Discordance of results examined.

They cannot arise from erroneous clock rate.

The mean *p.e.* of a transit, as given by 10 cases chosen at random, is ± ^{s}·0068 and ± ^{s}·007 for Telescopes Nos. 1 and 2 respectively, therefore the combination of the two will only account for a probable difference of ^{s}·010, and an extreme difference of say ^{s}·025. There only remain the instrumental corrections to be considered, viz: the corrections for Azimuthal deviation, collimation, and dislevelment for each instrument. Of these, the first must be absolved, because any discrepancy arising from it, could not fail to be traced at once, by comparing the results of North and South zenith stars, and if such were traced it would be easy and legitimate to correct it. We must therefore turn to the collimation and level corrections and here we find ourselves face to face with the fact noted in para. 17, viz: that from the collimation and level readings of Telescope No. 2, no certainty can be placed on any value assigned to these corrections, and an equal uncertainty must attend all observations taken with that instrument.

Nor from observation errors of transits.

Or errors of Azimuth.

There remain only errors of collimation and level.

Uncertainty as to these errors of Telescope No. 2.

(57.) The errors thus caused may be of two kinds—1st. they may be very uncertain, and therefore tend to cancel each other; or 2nd. they may be regular, thus introducing a constant error in the results. If the first, their existence need cause no anxiety as regards the result of a considerable series of observations; if the second, we may hope by a course of observations adapted to the purpose to arrive at conclusions, which will enable us to correct the results now obtained.

Resulting errors may be of two kinds.

So far as can be judged by comparing the resulting differences of longitude, given by the same star on different nights, these errors appear to be of the first kind. This is corroborated by the observations for personal equation, when the results of both instruments are combined, and treated so as to give a value of personal equation, and also of the difference of longitude between the two positions.

Most probably irregular.

This is corroborated by observations for personal equation.

The value of the equation so obtained was very good (see table V), but the deduced values of difference of longitude on different nights were, $-0^{s}{\cdot}025$, $-0^{s}{\cdot}004$, $+0^{s}{\cdot}072$ $-0^{s}{\cdot}102$; mean$=-0^{s}{\cdot}015$. The actual difference of position was 50 feet $=+0^{s}{\cdot}033$, which gives an error of $-0^{s}{\cdot}048$ to the mean deduced value, but this result evidently cannot be trusted as an indication of any constant error, because the deduced value, $-0^{s}{\cdot}015$, has a probability of error $=\pm 0^{s}{\cdot}036$, actually more than double its own magnitude.

I have referred these discrepancies to Telescope No. 2 only, because the collimation readings of the other show no signs of similar faults, it would, however, be unsafe to conclude that that instrument is perfectly free from them, and indeed it is nearly certain that every instrument must be similarly affected in some degree, if the cause be as suspected irregularity of flexure.

Telescope No. 1 probably not wholly free from such defects.

(58.) From all the clock comparisons taken between Banglore and Manglore, values of the transmission time of a signal, viz: r r_1 r_2 r_3 (see para. 40) have been deduced (by Captain Herschel before leaving) and are given in his report. The results are very interesting and possess features which seem to call for remark and in some respects for explanation if possible. The only determination of this velocity by other observers to which I have access, are those given in the Monthly Notices of the Royal Astronomical Society as follows: (See February 1872 p. 179 and February 1873 p. 233).

Determination of transmission velocity of a signal.

by other observers.

1*st.* By special experiments in America between Cambridge and San Francisco—Mean transmission time through 7,200 miles of wire, including 13 relays$=0^{s}{\cdot}827$, whence velocity$=$8,706 miles per second.

American.

2*nd.* During the Electro-longitude operations in Switzerland already alluded to (para. 55) the velocities of 7,300, 7,840 and 9,000 miles per second were arrived at.

Swiss.

3rd. Your own approximate observations with Major St. John R.E. between London and Teheran gave the velocity through 3,870 miles with 5 relays at more than 7,740 miles per second.

London and Teheran.

Of these the American determination appears to be the most valuable because resulting from special experiments, and it seems reasonable to assume that it was obtained under varions conditions of current direction, in which case it should be comparable with our mean value of 15,312 miles per second, affording a difference of no less than 6,606 miles per second to be accounted for.

American value preferred.

And compared with ours.

As mentioned above, the American signals passed through 13 relays, and were necessarily retarded by each. Our results on the contrary are only affected by *difference of relay retardation*, because they are obtained from the comparison of two signals of which each passes through one relay, and one through the line wire in addition.

Attempted explanation of discrepancy.

(59.) The discrepancy between our values with opposite current direction is very great—'forward' current giving a velocity of 9,800 miles per second and 'backward' 35,000 miles. Some part of this may perhaps be due to relay action, as I shall try to explain.

Difference of our results due to direction of current.

Partly explained.

When the direction of the line current was reversed that of the local clock relay was left as before (which was rather an oversight) and consequently in taking a comparison 'forward,' both sets of signals (distant and local) passed through the relay coils in the same direction, whereas with 'backward' current the directions through the two relays were opposite, and it is posible that this difference may affect the relay retardation, and as stated above relative relay retardation enters into every comparison. If this effect does exist to an appreciable degree, it will not be difficult to detect it by experiments which I propose to try as soon as convenient.

Considerable discrepancies, however, in such results as those under investigation, will not be wondered at when the minuteness of the quantities, (owing to the short length of wire used) the comparatively large errors which may possibly be introduced in the process of dealing with them, (reading off the chronograph sheets for instance) combined with the small number of individual observations, are kept in mind.

Uncertainties of such determination.

But all these considerations combined, seem to me to be insufficient to explain away the difference of velocity, according to current direction, at which we have arrived.

(64.) The general arrangements with the Telegraph Department were of course made by Captain Herschel, but both at Madras and Mangalore, particularly the former, many details were left to my care and I beg here to record my gratitude for the attention and courtesy shown to me on all occasions by the officers of that department with whom I was brought in contact, particularly J. Burke Esq. Officiating Superintendent, Madras Division and W. P. Johnston Esq. Assistant Superintendent, in charge Head Office. My best thanks are also due to Mr. Pogson, Government Astronomer of Madras, who took a pleasure in facilitating my operations in every possible way.

Personal acknowledgements.

My Assistant, Mr. Bond, superintended all building operations, preceding me to Madras and Mangalore for that purpose, and also executed a considerable quantity of computations (for wire intervals &c.) in the field. I have every reason to be satisfied with him, and his promotion to a higher grade on 1st July last was well deserved.

Since Captain Herschel's departure his Assistant, Mr. Belcham, has been at my disposal, and I have found him an excellent computer.

Lieutenant Harman R.E., who arrived here, from Head Quarters at Dehra, on 20th August, has at your desire given me his aid in office, and I owe him thanks for the zealous manner in which he has attacked the work.

(65.) In conclusion I would express my regret, that Captain Herschel should have been obliged to leave in an unfinished state, the operations of which he has had chief charge from the beginning, and I feel bound to guard against the possibility of any of the credit, which is due to him, being transferred to me by the accident of his departure at such a time, leaving the completion of the work, and to a great extent the reporting on it, in my hands. The conduct of the operations was his throughout, and whatever credit may be considered due to the results belongs properly to him. For my own part, I am very sorry that his departure should have brought to a close our association in these operations after so short a campaign.

Conclusion.

Table IV.

Longitude operations. Arc Bangalore-Mangalore. Abstract of relative Clock rates deduced from Clock comparisons.

Date		Clock difference by comparisons	Mean hour of comparison	Deduced relative clock rate per hour	For each night: Mean clock difference	For each night: Mean hour	Deduced *daily* relative rate per hour	Remarks
		m s	h	s	m s	h	s	
April	26th	12 25·215	14·835					This Table is expressed in sidereal time, which was about 2¼ hours in advance of Mean time.
				·666	12 25·869	15·817		
		12 26·523	16·798					
„	27th	12 38·065	10·837				·643	
				·659				
		12 39·386	12·841					
				·659	12 39·388	12·844		
		12 40·712	14·854					
							·623	
„	28th	12 53·097	10·909					
				·660	12 53·786	11·953		
		12 54·475	12·997					
„	29th	13 8·068	10·973					
				·641			·622	
		13 9·352	12·977					
				·634				
		13 10·616	14·972					
				·621	13 9·980	13·984		
		13 11·885	17·015					
„	30th	13 22·967	10·985				·623	
				·669				
		13 24·308	12·988					
				·661	13 24·310	12·999		
		13 25·654	15·024					
May	1st	13 37·688	11·065				·609	
				·635				
		13 38·974	13·091					
				·630	13 38·970	13·090		
		13 40·247	15·113					
							·608	
„	2nd	13 54·469	14·663					
				·649	13 55·088	15·617		
		13 55·706	16·570					
							·623	
„	3rd	14 9·500	14·817					
				·658	14 10·068	15·679		
		14 10·635	16·541					

The published notices of the Meteorological Observatory at Bangalore gave the following means for week, from 27th April to 3rd May. Thermometer daily means. Dry 81°·2, Wet 61°·7, Max. 95°·7, Min. 70°·8 Barometer and Humidity both steady throughout.

No such data are available regarding Mangalore, but the daily range of temperature there must have been much smaller than the above, and was probably included between 87° and 78°. At Bangalore a harsh dry west wind prevailed, generally lulling during the latter part of the night. At Mangalore a fresh sea breeze blew all day, dying away at night.

The clocks at both stations were about equally protected.

Table V.

Results of observations at Bangalore May 1873, for determination of relative personal Equation of Captains Herschel and Campbell.

Method of determination	No. of observed values	Mean value $\frac{H-C}{E}$	Mean value p. e.	Combn. weight W	E × W
By sharing transits, Telescope No. 1	20	+ ·043 s	± ·0046	47100	+2025·3
do. do. do. 2	21	+ ·026	± ·0043	54300	+1411·8
By reduced transits on four nights, Telescope No. 1	48	+ ·068	± ·0063	24800	+1686·4
do. do do. 2	61	+ ·014	± ·0064	25000	+ 350·0
By reduced transits of both instruments combined with their ΔL.	113	+ ·038	± ·0066	22700	+ 862·6
Sums ...	263	...	...	173900	+6336·1

Adopted value of Equation, or (H−C) $= + \frac{6336\cdot1}{173900} = +\overset{s}{\cdot}036$ (±·0024) which means, that the time of an observed transit by Captain Campbell must be corrected by + ·036 s to make it comparable with the same observation by Captain Herschel.

Table VI.

Longitude operations. Arc Bangalore-Mangalore. Abstract of Results.

Ap. 26th	Ap. 27th	Ap. 28th	Ap. 29th	Ap. 30th	May 1st	May 2nd	May 3rd	* May 2nd	* May 3rd	
INDIVIDUAL VALUES ON EACH DAY										
10′	10′	10′	10′	10′	10′	10′	10′	10′	10′	
s	s	s	s	s	s	s	s	s	s	
56·71	56·71	56·85	56·64	56·74	56·87	56·93	56·85	56·74	56·92	* By transits observed at Bangalore, and recorded on both chronographs.
·73	·78	·81	·76	·75	·89	·72	·85	·78	·85	
·62	·76	·73	·81	·68	·79	·74	·80	·84	·70	
·74	·76	·75	·78	·66	·85	·72	·78	·75	·90	
·70	·74	·79	·70	·79	·76	·79	·82	·73	·81	
·65	·69	·71	·65	·64	·78	·71	·76	·59	·83	
	·69	·71	·61	·72	·79	·65	·63	·74	·94	
	·59	·73	·76	·67	·86	·57	·81	·63	·88	
	·60	·75	·79	·68	·91	·71	·71	·65	·88	
	·62	·66	·73	·67	·83	·61	·72	·75		
	·61	·68	·78	·62	·76	·63	·83	·67		
	·59	·68	·72	·61	·77	·73	·79			
	·73	·66	·80	·73	·79		·79	56·719	56·852	Means
	·72	·67	·62	·63	·87		·83			
	·74		·69	·67	·60		·79			
	·75		·71	·82						
	·73		·59	·80						
	·68		·75	·58						
	·66		·72	·65						
	·68		·65	·81				−·028	−·033	Correction for transmission time, W. to E. deduced from the observations themselves.
	·69		·65	·73						
	·73		·56	·78						
	·68			·70						
	·62									
	·65									
	·68							Corrected		
56·692	56·688	56·727	56·703	56·701	56·808	56·709	56·784	56·691	56·819	Means
±·0130	±·0075	±·0105	±·0105	±·0096	±·0132	±·0182	±·0104	±·0148	±·0162	p. e.
General Mean (using combination weights) = 10 m 56·723 s ± ·0036										
General Mean after correction for personal equation = 10 m 56·759 s ± ·0043										

N.B. Correction for personal equation = + 0·036 s ± ·0024 s, to observed time of observer at Mangalore, or West Station.

Extract from the Narrative Report—dated 9th October 1873—of Lieutenant A. W. BAIRD, R.E., Assistant Superintendent 1st Grade, in charge Bombay Tidal and Leveling Party.

History of the Party.

The Bombay Leveling Party was formed in October 1869, and I was appointed in charge of it D.O. No. 55 of 1869 dated 27th September 1869, to be employed in connecting together and reducing to the common datum of mean sea level, the various lines of levels which had been executed in the Presidency in the course of Irrigation, Railway, or other Public works, and it was contemplated to commence operations to determine whether any change of the relative level of land and sea in the Runn of Cutch was going on.

Certain changes rendered it necessary for you to order the services of the Party to be placed under the late Colonel Nasmyth, R.E., for employment in the Guzerat Party, *vide* D.O. dated 1st November 1869. In consequence of the reduction of expenditure in the Survey Department, ordered by the Government of India, the operations of the Bombay Leveling Party were ordered to be suspended, and the party to be broken up, by D.O. dated 31st March 1870.

By letter from the Officiating Superintendent G. T. Survey No. $\frac{1}{1016}$ dated 16th August 1872, I was ordered to consider myself in charge of the Tidal and Spirit Leveling operations, in the Bombay Presidency, and as a preliminary arrangement to obtain copies of all the correspondence, in connection with the subject, from Major Haig, R.E., and Captain Trotter, R.E.

A few Khalásis and one Native Sub-Surveyor were entertained in October 1872, for the nucleus of the Party, which was then formed as the Bombay Tidal and Leveling Party. The services of the Native Establishment of No. 4 Extra Party, were placed at my disposal for employment with the Bombay Tidal and Leveling Party on the completion of the Pendulum operations in Bombay. This took effect on the 1st April 1873. The Native Establishment of No. 3 Extra Party was also transferred to the Bombay Presidency, to be employed in the operations, by D. O. dated 4th August 1873. Mr. F. Bell, Surveyor 3rd Grade was transferred to the Party, by Departmental Order dated 11th August 1873.

Reconnoisance of the Gulf of Cutch to fix three Tidal Stations.

In November 1872 you ordered me to proceed on a reconnoisance of the Gulf of Cutch, for the selection of sites for the Tidal Observatories, and sent me certain instructions for guidance on the subject: "One being required as far into the Runn as possible, to which the tide has free access &c." "Another near Beyt Island and a third as nearly as possible equidistant from the two former." The stations were to be all on the south side of the Gulf if practicable; if not, the north side of the Gulf to be examined. Failing to find any of these sites, the south coast of Kattywar was to be examined.

In compliance with your verbal orders given prior to the letter above mentioned, I left Bombay on the 13th November 1872, to carry out the reconnoisance, and proceeded *viâ* Rajkote to Jaoria Bunder close to the head of the Gulf of Cutch; and then I received your letter with instructions above referred to. I hired a small country boat without delay, and commenced the examination of the foreshores of the Gulf. I informed you of some of the difficulties I had to contend with in procuring a boat &c. but I completed the duty sooner than I anticipated, and returned to Bombay at once, to follow up your further instructions. The report of my reconnoisance of the Gulf, brought to your notice the various places I visited, and examined, and those I finally selected.

Results of Reconnoisance.

The results may be briefly stated as follows:—Hunstul about 18 miles from Jaoria at the head of the Gulf, Nowanar on the Cutch coast about 15 miles from Moondra, and Okha point, opposite the island of Beyt, were considered the only points suitable. Hunstul point had 72 feet of water at low water, within 100 feet of the shore, Nowanar 19 feet and Okha point 23 feet. Hunstul is about 16 miles from the nearest village where drinking water can be procured, Nowanar is 9 or 10 miles from drinking water, and Okha point has Beyt within 1 mile, but a boat would be required for communication with it. With the exception of Nowanar being on the Cutch coast, the actual positions of the selected sites almost exactly coincided with those required, and you were pleased to convey your approval of the way the reconnoisance had been executed.

Return to Bombay to make preparations for the trial of Instruments &c.

Having selected the sites for the Tidal observatories I proceeded to Bombay, to carry on the alterations to the old machines, in order to utilize the scales of wheels for different ranges of the tides &c., to procure pipes, cylinders, observatories, &c. and make all the arrangements, for taking up every thing requisite for carrying on the Tidal observations on the Gulf.

I arrived in Bombay on the 9th January 1873, and after a few days I arranged with Major Merewether, R.E., to be allowed to carry out my work at the Harbour-defence workshops. This was the most convenient place for the purpose, as I was enabled to have every thing done on the spot without delay, and under my own superintendence.

General site of the observatories settled.

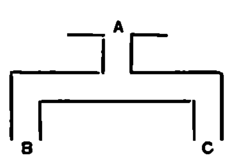
The first thing to be decided on, was to arrange how the observatories were to be fixed, whether on dry land close to high water, and having a pipe connection with the sea, or actually in the sea on Piles. I submitted various proposals after having made enquiries regarding cast and wrought iron piles &c., for your consideration ; finally you decided on adopting the positions for the Tide Guages in the vicinity of the high water line.

General details of the arrangements to be followed.

A water tight iron cylinder for the float to work up and down in, with a pipe of sufficient diameter—*viz*; 2 inches—to connect with deep sea, has to be sunk to a depth of 3 or 4 feet below the level of the sea, at Low Spring Tides ; and the only feasible way of carrying this out—considering the nature of the ground—secured to be by sinking a brick well of small diameter, to receive the cylinder; arrangements have been made accordingly. The cylinder having been placed in position, a two inch wrought iron gas pipe will be connected with the bottom of the cylinder by a small bend, this pipe will then be brought up vertically to a height corresponding with 1 or 2 feet below the lowest high water. The bank will be cut away as quickly as possible to this depth, and the pipe taken straight out, until it reaches the sloping surface of the shore, and this it is hoped, will be done by working as many men as possible, in clearing away the sand when the tide is very low. The rigid iron pipe is then to be carried down along the slope to reach low water springs. Here a brass connecting arrangement will be fitted, to which a flexible gutta percha pipe of 2 inches diameter with a rose at the end, will be attached, and carried out about 120 feet to the deep water. The extreme end of this pipe with the rose will be supported 3 feet above the ground under water, by a small buoy fixed to an anchor by a chain ; and this buoy again will have a chain attatched to it, thus connecting the whole to a mark buoy on the surface of the water, which will rise and fall, with the tide. It is hoped by this means to secure the pipe from being filled up with silt, and choking. The size of the pipe, and the number of holes of the rose, and their size, have been calculated, (and a sufficient margin left in case of small quantities of silt getting deposited) so that the rise and fall of the water in the cylinder may correspond with that of the sea. Two of " Bull's Dredgers" have been bought to use in sinking the wells, and the wooden framework and bricks have also been purchased for this purpose.

General description of the apparatus &c.

The cylinders for the project have been made up in sections of 4 feet 2 inches in length, with an interval diameter of 22 inches. A sheet of wrought iron being bent to the size required, and rivetted to form a cylinder, a cast iron flange was fitted on to each end, and the faces of these carefully turned. The size of the cylinders was decided on so as to utilize the iron sheets most economically, and when finished 4 men could carry one of these sections. The bottom section will have a flat iron plate carefully screwed to one end, to represent the bottom of the well. The holes for the bolts and nuts have been carefully fitted and when joined, the whole cylinder will form a water tight well. The two-inch gas pipe was bought in Bombay and had thimbles for connecting the lengths together, but it has since been found, that even with the greatest care, there is a chance of leakage which would be a cause of great anxiety and trouble ; so, small cast iron flanges have been made up to screw on to each end, and this will render the connection water tight, and the pipes will be more easily fixed together. A stop-cock has been carefully fitted on to the top bend for each Observatory, for exhausting the air in the first instance. The brass connecting arrangement here described, has been procured for each place, to connect the rigid and flexible pipes.

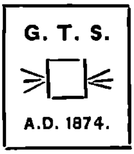


The iron pipe is fixed by a flange at **A** ; at **B** the long flexible pipe is screwed on, and at **C** a brass disc is also screwed on. When the flexible pipe has to be examined for cleaning, the disc will be unscrewed at **C**, (under water of course) a short length of spare flexible piping with a rose at its end, fitted on, and taken out to deep water temporarily. The pipe at **B** taken off, and cleaned, the disc being screwed on at **B** temporarily ; then when finished, the long pipe is replaced at **B**, and the disc at **C**. In this way it is hoped there will be no stoppage in the work. The flexible pipe is 2 inches diameter with copper inside, just the same as suction pipe. These pipes are in lengths of 50 or 60 feet, the smaller ones for temporary use only 20 feet : they have couplings and unions for connecting with each other. The rose at the end is a copper cylinder about 2½ inches diameter, with 150 holes of $\frac{3}{10}$ of an inch bored in them, and have screws for fitting on to the end of the flexible pipe.

The buoys are what is termed Nun Buoys, and have been procured on indent from the Dock-yard. The smaller ones have an arrangement attached to them for holding up the rose at the end of the pipe, and will be secured to an anchor so as to be always 3 feet from the bottom. The upper end, as I have previously mentioned, will be attached to a chain fixed to the upper buoy, which will float on the surface and mark the position, and also be the means of lifting up the pipe for cleaning. This is a rough sketch of the plan to be adopted, as far as we can, and it is believed that with very small modifications, which may be necessary, and can be determined on the spot, that the arrangement is the most effective, and simple, for the purpose. A cleaning rod, in lengths of about 12 feet, with a brush at the end has also been made up.

The observatories themselves are 12 feet by 9 feet and about 12 feet high in the centre, the roof sloping from the ridge to the sides which are about 8 feet high. They have been made as portable as possible, and are clinker-built, but it was found in Bombay that a tarpaulin was necessary to keep out the rain which is very heavy here during the monsoons. All the other material for the construction of the observatories on the sites selected has been procured, and with the exception of the sheds for the men in charge to live in, very little has to be bought on the spot.

Fifty Bench-mark stones have also been made up, and cut in this manner, ready to be laid down.



The description of the observatories in working order will more properly be reported on when they have been finished and fixed, but what I have said brings to your notice what has already been done. The size of the observatories has been found to be most convenient; when all the instruments are fitted up, perhaps an additional 6 inches in width would be an advantage.

Arrival of the machines.

The self-registering tide gauge No. 7, which had all the latest improvements—such as friction rollers, improved pencil holder, swivel for the float &c.—and one self-registering Aneroid Barometer, were received from England in November 1872, when you were in Bombay. The remaining five Aneroid Barometers, and six self-registering Anemometers together with some differential scales, and other Office requirements, were received about the end of May 1873. Tide Gauges Nos. 2 and 3 had been lying in the Superintending Engineer's stores in Bombay for some time. No. 1 was received from Major Branfill, Madras Party, and also Nos. 5 and 6 from Calcutta, so that with the exception of No. 4 all the Tide Gauges, I believe, are now in my charge.

Alterations of the Instruments &c.

While the cylinders, piping, and Observatories for the Tidal Stations were being made up, the alterations to the self-registering Tide Gauges were commenced. Friction rollers were made up here for Nos. 2 and 3, and those that came out from England were fitted on to Nos. 1, 4 and 5. The pencils for all have also been made similar to No. 7, as also swivels for the floats, and generally they have all been overhauled. I tried various plans for fixing the diagram on the barrel, and finally adopted clips secured to the barrel with screws, and having a small moveable plate to be jammed by two pinching screws, one of which is rivetted to the plate and the other free. This has been found to answer admirably, and it has been fitted to all the Tide Gauges. Zero lines for height, and 12 o'clock lines have also been carefully marked on the barrels, so that by rubbing with a hard pencil on the paper diagram, they are transferred to it. I regret to say that the barrels of all the instruments are not quite circular in cross section nor are they quite straight longitudinally. This is the fault of the maker who probably found the sheet brass too thin to turn on a lathe. Also one of the barrels which came from Calcutta has been seriously indented, and the pencil was bent and rendered useless: the latter has been repaired, but the barrel must be left as it is. Scales of wheels for working the various tides to most advantage, to suit the 5 feet barrel, as sent out by Mr. Adie, have been fitted to all the machines, and in order to do this, various parts of the instruments had to be made entirely new.

The self-registering Aneroids have also had some slight alterations made. These instruments were received from England so rusty in some parts, that it was imperative that I should hand them over to an experienced watchmaker at once. The clock hands, pointers of the aneroids, and the small hooks at the end of the gold threads, had to be cleaned and oiled, and when possible, covered with a coat of protecting lacquer. Also two of the gold threads were imperfect, one being broken altogether. The action of the escapement of the clocks in some of those last received, have given a great deal of trouble. The repairs of these instruments have been executed very well: a longer arm of iron being put on to make up the deficiency of the length of the broken gold thread. It is to be regretted however that out of the 6 instruments, 2 are by no means working properly, and may have to be sent back to England for repair. Zero lines for height have been marked on the barrels.

The Anemometers came out safely from England with the exception of one which has been repaired here, but all the clocks had the main springs in such a rusty state, that it was apparent new springs would have to be got at once, and accordingly arrangements were made for getting out good springs without delay, and they are expected by next Overland Mail, so it is to be hoped the alterations will be finished before we leave for the Gulf of Cutch. After working these instruments as will be afterwards mentioned, some alterations were necessary to keep out the rain water from the working gear; this has been done by fixing on small copper covers like candle extinguishers round the outer shafts, also by fixing a piece of tube to the bottom of the small box on the top, to prevent water getting down the velocity shaft, and an escape hole drilled in the box.

These are the main alterations to all the machines.

Arrangement followed in Bombay to test the working of the machines.

The next thing to be noted is the arrangement followed in Bombay to test the working of the machines. On account of the sea receding at low water spring tides too far from the Bunder, it was necessary to adopt some plan, for the water being prevented from leaving the connecting pipe with the cylinder. This was done by causing the 2 inch pipe to end in a small tank, as low down as possible. As the friction at the vertical bends would be the main cause of any retardation to the flow of water, the piping was given several vertical bends in order that the test should be much more severe than the actual conditions of the observations at the tidal station on the gulf of Cutch. Three cylinders were erected side by side, *i. e.* about 9 feet apart, their observatories being close together. The small 2 inch pipe in connection with each ended in a tank to represent low water mark. The basin in which the gauges were erected was unfortunately one in which a great deal of thin mud settled. The 2 inch piping entered each cylinder about 9 inches from the bottom; it was 300 feet long in 2 instances and some thing short of that in the other.

Difficulties arise from the air in the connecting pipe.

The connection having been made, it was apparent after a few days that a quantity of air must have collected at the upper vertical bends of the pipes, as the water did not rise and fall properly in the cylinder, stop-cocks were inserted at the highest vertical bend in each system, and these when opened under water allowed the air to escape, and at first it seemed as if all had been extracted and the arrrangement working properly. On the 20th May Nos. 2 and 3 cylinders were working properly, the water inside being measured from the top of the cylinder very carefully with a measuring rod, and compared with the reading of a temporary tide gauge which had a fixed relative height to the cylinder.

From 1st to the 25th June, both Nos. 2 and 3 cylinders worked well, but in placing the pipe for No. 1 down in the tank, a bad connection had been made, and there was a leak evidently in the pipe: this drew the water out of the small tank at the first low tide, and so spoiled the working of all three cylinders. The piping for No. 1 was carefully relaid, but it was some time before it was considered satisfactory. No. 2 cylinder after the 25th June did not require to have the stop-cock opened until the end of the experiments. In Nos. 1 and 3 air seemed to collect in small quantities, and it was very difficult to exhaust it, so much so, that I tried all sorts of plans before succeeding. The difficulty was that at high water the sea covered the stop-cock.

Now at the future tidal stations the sea will not have access to the stop-cock, and so if it is opened at high water the pressure of the sea water (which is higher than the stop-cock of course) will drive out the air, and there will be no superincumbent column of water to keep it in.

To get over this difficulty in Bombay I had a small tube about 3 feet long screwed into the stop-cock of No. 1, so that on opening the stop-cock when the sea was well over it the water did not act above the orifice to keep the air in, and it rushed out at once, and the water inside the cylinder quickly assumed the same level as that of the sea outside.

Anemometer set up.

Having set up the tide gauges on trestles and arranged their floats &c., I then had an anemometer put on a shelf in each observatory; taking care to place the whole of the working gear for outside, well clear of the ridge. In putting up these instruments great care has to be taken. The long pipe in which the several rods and pipes work, must be allowed to assume its own position without being forced in any way, otherwise the crown-wheels at the bottom may be thrown completely out of gear. Also, the cups must be fitted on properly not upside down otherwise the spiral will turn the wrong way and tear the paper on the barrel and perhaps seriously injure the instrument.

Flooring underneath anemometer.

After several days with various results from the 3 instruments almost side by side, it was thought advisable to put a flat flooring about five feet square outside, immediately above the ridge piece, to prevent eddies underneath the cups and fans. No doubt this had some beneficial effect, but unfortunately in the trial of the instruments, a much more serious cause of error was found out, so that it was impossible to say, how far the arrangement acted to keep away any back draught of air, which it was supposed would occur from the shape of the roofs.

A self-registering aneroid barometer was also set up in each observatory. A rain gauge was also set up outside.

Levels of bed-plates of the tide gauges connected; comparison of the height of water and 30 inch line on diagram.

The levels of the bed-plates and tops of the cylinders were approximately connected for comparisons with the temporary tide gauge, and making allowance for the swell (causing the float of the temporary tide gauge to be unsteady) the water inside and outside being found to correspond in level, a comparison of the position of the pencil on the diagram, to the depth of the water in each cylinder from bed-plate was made.

During the time the machines had been put up and were being tried, I engaged some natives for the work in the observatories, and taught them what was to be done, and by the time the instruments were put on trial they were fairly well acquainted with their duties; they were all young and inexperienced consequently they have come on small pay, but I have every hope of their doing their work satisfactorily, and meanwhile I have called them Apprentice Sub-Surveyors. I have also had daily report forms printed for transmission to me; 3 sets of these, filled up for the month the instruments were being tried, accompany this report just as they were sent me by the Sub-Surveyors.

Sub-Surveyors taught the work in the observatories.

The results of the trials of the tide gauges may be considered very satisfactory; there were some interruptions, in the continuity of the work; but these I think are most unlikely to happen at the Gulf of Cutch, and with ordinary care the Sub-Surveyors ought not to have any breaks in their work. As regards the rats eating the diagrams, I have tried poisoning them but with no great effect: it is believed that blue stone mixed with the paste will keep them off: ants also may get at the clocks and this will always be a source of anxiety, and these (or the rats climbing up the pendulum) may stop the clock; still chalk lines drawn round the feet of the trestles may prevent the ants passing up, and I have also been advised to put some wood ash all round the feet on the floor. The diagrams, of which a set are submitted, speak for themselves, and you will observe that the jagged lines only occur at the head of the curves, just when the swell has time to act, *viz.* at the turn of the tide, when there is no rise or fall to speak of, for some time, and so the pumping action has time to make itself felt.

General results.

Regarding the aneroid barometers I do not consider them satisfactory instruments. Two are useless, but of the remaining four, I am in hopes of getting three safely up to Cutch, and if so they will give good results. But I thought it advisable to recommend to you that one mercurial barometer, should be placed in each observatory, so that readings might be taken at different times during the day; these would fulfil the double purpose of being a check on the Aneroids, and also in case of the failure of the latter there would be a set of independent barometric readings; this proposition you have sanctioned.

With regard to the working of the anemometer, the results of the trial have given me a very good deal of experience, and I have been enabled to make such alterations, and additions to these instruments which I think will fulfil the purpose for which they are intended; and it is most likely now that 5 of the 6 instruments will give very correct results, and no annoyance with proper care in the future operations.

The rain gauges are simple bottles in a tin case with a tube attached to the top (which is moveable) going into the bottle: also a glass measure: they are by Casella: and there is of course no trouble with them. One thing I may mention, that the rain is very local here, often half an inch in a day more at the workshops with one of the same gauges than at the observatories was registered, the distance between those places being about ¼ of a mile.

There is still one thing to be ascertained about the self-registering tide gauges, and that is whether the stop-cock must be opened or not after the air has been thoroughly exhausted, which can be done in a couple of high tides. The results of the working of No. 2 observatory would seem to settle the point: for, the stop-cock there was not opened for nearly 3 months, and yet the action of the water in the cylinder was perfect during that time. But in Nos. 1 and 3 observatories air collected at the top bends. I feel very confident that a leak, perhaps very small, occurred in the connecting pipes there. The gas pipes were screwed together by thimbles and were very difficult to lay, and I think were the cause of the leakage. I have, since the pipes were taken up, got small cast iron flanges fixed on to these gas pipes, and I am now almost sure of an air-tight connection: and the pipes will be much more easily laid. By opening the stop-cocks for a second or two at high water, there will be no chance of air collecting and it does not interfere with the working of the instruments.

On the whole then I think the testing of the instruments show, that now we may expect very good results if they are carefully looked after, and no unforeseen accident causes any interruption.

The bench-mark outside the gate of the Harbour Defence Workshops, marked in Mahratta (270), and close to the post office pillar, was connected by leveling with the bed-plates of the tide gauges in No. 1 and No. 3 observatories, and also with another bench-mark on the 14th step at the end of the Harbour Defence Bunder.

Bench-marks in connection with Town Hall datum connected with the bed-plates by leveling.

From this it was an easy matter to lay down on the diagrams of the tide gauges the mean level of the sea to which the heights in the Bombay Tide Tables are referred.

Discrepancy of the Diagram and the Bombay Tide Tables.
* Not printed.

I attach the statement marked A* of the heights as shown by the diagram (being the actual heights of the water as they occurred) compared with those given in the Tables. The high waters have only been compared, as of course we had no low water shown on the sheets, with the exception of 2 at the greatest neaps. The tank line represented our low water line.

You will observe that the times of the high waters agree very well, but the heights are very much out in some cases.

Greatest discrepancy in time is	.. ..	42 minutes
Least „ „ „	.. ..	1 „
Average „ „ „	.. ..	14 „
Greatest „ „ height is	.. ..	0·88 foot
Least „ „ „	.. ..	0·00 „
Average „ „ „	.. ..	0·26 „

Discrepancies of the Aneroids inter se.
* Not printed.

Statement marked B* shows the discrepancies of the records of the Aneroid barometers as read from each at 10 A. M. and 4 P. M. daily. Before commencing recording the readings for the trial month, I gave the value of each index error to the Sub-Surveyor in charge, and the figures in red in the daily reports (a set of which are herewith sent) show the corrected values. The index error was obtained by comparison with the mercurial barometer sent from Calcutta which had previously been compared with the standard barometer there.

The greatest discrepancy between any two of the instruments was.	0·179 inches
The least was	0·023 „
The average	0·061 „

Discrepancies of Anemometers.
* Not printed.

Statement C* shows the discrepancies of the Anemometers. You will observe that the greatest discrepancies for each day are noted in a column for the purpose.

The greatest discrepancy of any day was	140 miles
The least	10 „
The average of the daily discrepancies was	54½ „

The directions recorded by each instrument are almost identical.

Personnel of the Party.

The party may now be said to be almost completely formed and consists of one Officer in charge, 1 Surveyor, 2 Native Sub-Surveyors and 5 Apprentice Sub-Surveyors, 1 Writer, 1 Recorder, 1 Hospital Assistant (not yet joined), 1 Mechanic and about 45 Khalásis and Peons. Mr. Bell joined the party lately from Mussoorie and during the short time he has been with me he has shown himself most useful in every way, and I have no doubt will give me valuable assistance in carrying on the operation.

Narsing Das Sub-Surveyor has also lately joined; the high character he has received from the officer under whom he has lately been serving, and the way in which he has worked since he joined me are sufficient grounds for considering him as likely to perform the duties entrusted to him in a satisfactory manner.

I have lately had some trouble with a Sub-Surveyor who resigned a few days ago. You have been pleased to accept his resignation, and I have engaged an observer from the temporary establishment of the Colaba Observatory on the same pay. He seems very intelligent and I have no doubt will soon pick up the duties in the Tidal Observatory.

The Apprentice Sub-Surveyors have given me every satisfaction and I think they have now a fair knowledge of their duties in the Tidal Observatories but notice of their services can only be taken in the next Annual Report.

Trouble of generally carrying on the work in Bombay.

It may not be out of place to state that I had considerable trouble in carrying on the work in Bombay. The machines having to be altered, air lodging in the bends of the connecting pipe, the stoppage of the clocks and the very bad state of some of the machines when received from England also the damage done by the monsoon to one of the Anemometers, breakage of the gold threads in the barometers, rats eating diagrams of the tide gauges, and ants getting into the clocks of the barometer, were all sources of considerable anxiety to me.

Inability to commence the reductions of the Tuticorin Observations.

The printed forms from England for the reductions of the Tidal Observations by harmonic analysis have only lately been received; but even had they reached me early in the recess, I should have been unable to have commenced the reduction of the observations taken at Tuticorin in 1871-72 which you sent me some time ago. I had my time fully employed in looking after the work here, and I had no assistant until quite lately, for the Apprentice Sub-Surveyors were newly taken on, and had to work in the tidal observatories.

My acknowledgements are due to Major Merewether R.E. the Executive Engineer of the Harbour Defence for the assistance he has rendered me from time to time here, and placing at my disposal the use of part of the Bunder, and generally in giving me the use of workshops in making up the equipment for the Tidal Observatories.

Assistance received from Harbour Defence Workshops.

Mr. Morris, the Mechanical assistant of the Harbour Defences, has been most obliging in every way, and has helped me in the construction of almost all the different stores for our use, in the alterations of the machines, and in fact throughout in many of the difficulties I had to contend with. During the time we had the trouble with the air getting into the connecting pipes, he took the most lively interest in helping me to overcome this obstacle and enabled me to get men to go into the water and raise the pipes at any time when required, and this had often to be done long before or after the usual working hours, to suit the tides.

Extract from the Narrative Report—dated 1st May 1873—of J. B. N. HENNESSEY, ESQ., Deputy Superintendent 1st Grade, G. T. Survey, in charge Computing Office.

Calculating Branch.

(3.) The numerous and not unimportant duties imposed by current demands are not susceptible of being presented in the form of a summary; an idea of their nature and extent can therefore be formed only from the statements which are hereafter given; but apart from these, it may be generally stated, that amongst the leading objects kept in view during the past year, the completion of Volumes III and IV of the Principal Triangulation and the reduction of the secondary operations, N. W. Quadrilateral, which are to appear in the Abstract volumes of the Great Trigonometrical Survey of India, are to be reckoned. Volumes III and IV are almost completely out of hand; so much so, that they may be said to await the services of the bookbinder, pending completion of the Reduction Chart (to illustrate these volumes) which is in course of being engraved at the Surveyor General's Office, Calcutta. And with regard to the Secondary Triangulation, it may perhaps be remembered, that in my last report, mention was made of a suitable process which I had devised for fitting in the Secondary Triangulation by a dispersion of angular errors where this procedure was considered desirable: the Secondary Series of the Great Arc and Great Indus, and a few on the Rahún and Karáchi, have been fitted in by this process.

Part of work summarized.

(4.) The details of the ordinary calculations are as follow:—

Ordinary calculations detailed.

Examination and Correction.

Angle Books	.. ..	1¼ Vols:	
Principal Triangulation.	Azimuths by Circumpolar Stars ..	40 Stations.	
Secondary Triangulation.	Log. Sines	280 Triangles.	
Do.	Log. Sides	2,553 ,,	(in duplicate)
Do.	Latitudes, Longitudes and Azimuths (single deductions)	162 Points.	

Computations in Duplicate.

Principal Triangulation.	Spherical Excess	21 Triangles.
Do.	Weights	33 Angles.
Do.	Azimuth by Circumpolar Stars ..	1 Station.
Do.	Do. Level and Collimation Corrections	12 ,,
Secondary Triangulation.	Traverse	32 Sets.
Do.	Adjusted by Angular corrections ..	1,245 Triangles.
Do.	Log. Sines	6,253 ,,
Do.	Log. Sides	4,410 ,,
Do.	Feet and miles	5,836 ,,
Do.	Latitudes, Longitudes and Azimuths (single deductions)	3,920 Points.
Explorations.	Co-ordinates of Route-Survey Khulm to Bokhara.	
Do.	Do. 141 other points.	
Do.	Latitudes by Circum-meridian observations ..	51 Points.
Do.	Longitudes deduced from traverse	20 ,,
Do.	Heights by Barometer	82 ,,
Do.	do. Thermometer..	108 ,,

Calculating Branch.—(Continued.)

(5.) The work performed in connection with the Typographic and Photozincographic presses, I notice, as in my last report, under two heads.

For the volumes on the operations of the G. T. Survey, &c.	*Compiled or otherwise prepared.*
Principal Observed Angles	10 pages.
Azimuths observed to Circumpolar Stars	25 „
Principal Triangles. Great Indus Series	10 „
Do. Karáchi „	12 „
Do. Gurhágarh „	6 „
Do. Rahún „	6 „
Principal Latitudes, Longitudes, Azimuths and Heights. Great Indus Series	28 „
Secondary Triangles. Great Indus Series	23 „
Spirit-Levelled Heights. Tuticorin to Cape Comorin base-line	5 „
Do. Section IX, Season 1871-72	19 „
Total	144 pages.

besides the above, 25 plates of figures for Volumes III and IV were roughly plotted for the guidance of the drawing branch.

Numerical Charts.	*Compilation of data for projection.*
Budhon Series	Latitudes, Longitudes, Azimuths and Heights.
Amúa „	Do.
Rangír „	Do. (in part)
N. W. Himalaya Series. Sheet No. 3	Do.
Bombay Triangulation. Sheet No. 9.	Do.
Reduction Chart of the N. W. Quadrilateral.	

Numerical Charts.	*Compilation of data for press.*
Budhon Series	Sheets Nos. 1 to 4.
Amúa do.	Do. Nos. 1 and 2.
Bombay Triangulation	Do. No. 9.
Sutlej Series	Do. Nos. 1 to 4.
Gurhágarh Series	Do. Seasons 1860-61-62.
Description of Bench-Marks, &c., for Level Chart	Do. No. 3.

the amount of compilation involved in above is estimated at 300 pages.

Numerical Charts.	*Compared.*
Amúa Series	2 sheets.
Budhon do.	4 „
Gora do.	1 „
Sutlej do.	4 „
Rahún do.	2 „
Gurhágarh do.	1 „
N. W. Himalaya Series	3 „
Bombay Triangulation	1 „
Assam Valley (1871-72)	1 „
Bider and Biláspur do.	1 „
Bangalore N. Section do.	1 „
Biláspur „ do.	1 „
Reduction Chart N. W. Quadrilateral	1 „
Total	23 sheets.

Examined.

Spirit-Levelled Heights by the Revenue Survey Department, for incorporation into Level Route Map of the Western Himalayas. [Sheets.

Index to Main Lines of Levels G. T. Survey.

Index to Preliminary Charts N. W. Quadrilateral.

Ditto N. E. do.

In addition to the foregoing, 1170 pages of proofs were read and compared twice, and 1029 pages of proofs were examined by a single reader and passed for the press.

Calculating Branch.—(Continued.)

Instrumental Work.

(6.) The 24-inch theodolite in use on the Bráhmaputra Series was cleaned and adjusted; and Captain T. T. Carter, R.E., was instructed in the departmental method of observing azimuths to Circumpolar Stars. Captain Chapman of the Yárkand Expedition was taught (by Mr. Cole) the use of the subtense theodolite, and the computation of Time, &c., from observations taken with this instrument. Captain H. Trotter, R.E., received instruction in the observation and computation of Lunar Zenith-distances for finding longitude; besides the discussion of various professional subjects, preliminary to his departure with the Yárkand Expedition. A ten-foot iron end-bar was constructed for the Executive Engineer Ránikhet division, and the length compared with the G. T. Survey Standard Bar **A**. The index errors of 18 boiling point thermometers were determined for the use of the explorers, whose surveying instruments were generally examined and put in order. Observations for Time were taken on 13 days and the results computed. Meteorological observations were made in Dehra observatory on every day of the year without exception; the daily results were reduced and communicated as usual, month by month, to the Reporter on Meteorology, N. W. Provinces, and a table of the monthly means is appended to this report.

Pendulum Observations.

(7.) Consequent on the appointment of Captain W. J. Heaviside, R. E., to the charge of the Pendulum party, he was instructed in the use of the transit instrument and the methods of making and computing observations with the pendulums of the Royal Society, processes which Captain Heaviside's skill and aptitude soon enabled him to master. He was also assisted in connection with three centigrade thermometers, and in preparing working tables of corrections for these thermometers and tables of differences of expansion between the Russian pendulums and their scale; besides such other questions as arose from time to time, on which my co-operation was desired. The services of a check computer were placed at his disposal for some 3 weeks to assist in the reduction of his observations, besides that 18 sets of the latter were reduced in the Computing Office under directions from the Superintendent.

Protection of Stations.

(8.) Replies to 280 letters, in connection with the protection of Stations, were drafted by Mr. C. Wood under the Superintendent's directions; and 32 supplementary and duplicate lists, including 118 stations were issued to district officers. These lists in the first instance are partially of a tentative nature; for, owing to modern alterations in the boundaries of districts, &c., it is only after due reference and correspondence that it can be settled in which of two contiguous districts a given station is situated. Speaking in this sense, 20 districts have been settled during the past year, making about 238 districts in all, which have been placed on this satisfactory footing; the corresponding check lists, including some 1,900 principal stations, have been disposed of to date.

(9.) Some of the miscellaneous duties discharged are as follows.

Miscellaneous.

Prepared:—three copies of Vocabulary of Indian names and words for office use; four Auxiliary tables for departmental use; Duplicate of pendulum observations at Dehra and Kaliána; Polymetrical tables for Major Montgomerie's route map; and tables of Latitude, Longitude and Height of points on the N. W. Frontier for Colonel Walker's Map of Turkestan, 2nd edition. Service books, 120 in number, were filled in at a cost of no little time and patience. The Cost book of the G. T. Survey was brought up for the year 1872-73, and it, together with the Budget comparison table, is now kept to date, monthly. The records of the Bombay Island survey were generally examined with a view to ascertaining their eligibility for incorporation with other materials. Compiled and passed through the press Introduction to Great Arc Series for Volume IV. Supplied data to 34 Executive Officers, involving a considerable amount of compilation and calculation. Accounts kept and monies disbursed to explorers, for a few weeks; translated their letters, &c., &c. To these may be added the investigation and detection of a mistake in the method of determining the percentage of error in certain traverses.

Typographic Branch.

(10) The work performed by the Printing Office since 1865-66 is concisely stated hereafter.

	1865-66	1866-67	1867-68	1868-69	1869-70	1870-71	1871-72	1872-73
Pages composed,	377	756	641	697	693	819	1,143	1,420
Do. printed,	53,329	93,411	126,696	155,025	106,231	234,828	241,348	273,157

Typographic Branch.—(Continued.)

the total pages composed last year may be subdivided under the following heads.

Observations and Calculations for the volumes of the Great Trigonometrical Survey in hand	.. 787	pages.
Spirit-Levelled Heights	.. 33	„
Data for Charts, Descriptions of Bench-marks, Routes, Professional Orders and Memoranda	.. 483	„
Report to Government 1871-72	.. 117	„
Total	.. 1,420	pages.

Drawing Branch.

(11.) The work executed in the Drawing Office is exhibited in the table which follows this report.

Photozincographic Branch.

(12.) The work performed by the Photozincographic branch is given in the following tables, under the heads Maps, Numerical Charts, Diagrams and Forms.

Maps.

Subject	When published	No. of parts	No. of copies printed
Prints of maps published in former years	..	27	1,164
Index to Kashmir Triangulation Charts	June 1872	1	111
Spirit Levelling operations, No. 11	July „	1	100
Routes in Northern India, No. 1	„ „	1	115
Do. do. No. 3	„ „	1	108
Do. do. No. 4	August „	1	112
Do. do. No. 2	„ „	1	109
Index to Northern Portions of Bombay Triangulation	„ „	1	350
Do. Main Lines of Levels, G. T. Survey	„ „	1	381
Spirit Levelling operations, No. 10, 2nd edition	September „	1	105
Index to Main Lines of Levels, G. T. S. (reduced scale)	„ „	1	432
Routes in North-Western Himalayas (reduced scale)	October „	1	77
Index to Kattywar Survey	„ „	1	741
Do. Kumaon and Gurhwal Survey	November „	1	518
Do. Guzerat Survey	„ „	1	554
Trans-Frontier Map, No. 7 skeleton	December „	1	248
Kumaon and Gurhwal, sheet No. 2 skeleton	January 1873	1	104
Do. do. No. 2 contoured	„ „	1	112
Do. do. No. 18	„ „	1	109
Do. do. No. 23 contoured	„ „	1	105
Do. do. No. 32 do.	February „	1	105
Dingri Maidan	„ „	1	570
Trans-Frontier Map, No. 4	„ „	1	60
Kumaon and Gurhwal, sheet No. 17 skeleton	March „	1	100
Spirit Levelling operations, No. 8	„ „	1	105
Kattywar, sheet No. 25	April „	1	105
Turkestan Map, sheet No. 1 (2nd edition)	„ „	1	210
	Total ..	53	6,910

Numerical Charts.

Subject	When published	No. of parts	No. of copies printed
Kashmir Triangulation, No. 5	June 1872	1	70
Do. do. No. 7	„ „	1	75
Bangalore Meridional Series, S. section, Season 1870-71	„ „	1	65
Rahún Series, Season 1856-57	July „	1	25
Do. do. 1852-53	„ „	1	66
Bider Longitudinal Series, Season 1870-71	„ „	1	70
Kashmir Triangulation, No. 1	August „	1	70
Do. do. No. 8	„ „	1	66
Do. do. No. 6	„ „	1	68

Photozincographic Branch.—(Continued.)

Numerical Charts.—(Continued.)

Subject	When published	No. of parts	No. of copies printed
Kashmir Triangulation, No. 10	Septer. 1872	1	62
Do. do. No. 9	,, ,,	1	65
Sutlej Series, No. 1	October ,,	1	65
Kashmir Triangulation, No. 2	,, ,,	1	65
Assam Valley Triangulation, Season 1871-72	,, ,,	1	65
Sutlej Series, No. 2	November ,,	1	65
Kashmir Triangulation, No. 4..	,, ,,	2	67
Do. do. No. 3	,, ,,	2	65
Rahún Series, Season 1856-57 (2nd edition)	December ,,	1	65
Sutlej Series, No. 3	,, ,,	1	66
Rahún Series, Season 1855-56	,, ,,	1	65
Sutlej Series, No. 4	January 1873	1	67
Biláspur Series, N. section, Season 1871-72	,, ,,	1	65
Northern Portions of Bombay Triangulation, No. 9	,, ,,	1	66
N. W. Himalaya Series, No. 3	,, ,,	1	67
Bider Longl. and Bilúspur Meridl. Series, Season 1871-72 ..	February ,,	1	65
Gurhágarh Series, Season 1860-61	,, ,,	1	66
Budhon Series, No. 2	,, ,,	1	65
Do. do. No. 4	,, ,,	1	65
N. W. Himalaya Series, No. 1	,, ,,	1	66
Do. do. No. 2	,, ,,	1	63
Budhon Series, No. 1	March ,,	1	65
Do. do. No. 3	,, ,,	1	64
Gora Series, No. 2	April ,,	1	65
Bangalore Meridional Series, N. Section, Season 1871-72 ..	,, ,,	2	67
	Total ..	37	2,206

Diagrams.

Subject	When published	No. of copies printed
Diagrams of Bench-Marks and Plates of Figures to illustrate Vols. III and IV,	May 1872	931
	June ,,	1,317
	July ,,	640
	August ,,	190
	September ,,	515
	October ,,	478
	November ,,	448
	December ,,	529
	January 1873	1,247
	February ,,	2,862
	March ,,	1,752
	April ,,	1,146
	Total, ..	12,055
Professional and Office Forms, ...	1872-73	12,549

Photozincographic Branch.—(Continued.)

5,634 Maps and 3,254 Charts were issued during the year. The forms were expended, as usual, as fast as they could be printed. Contrasting the work performed since 1870-71, we have

Year	Maps	Charts	Diagrams	Forms
1870-71	6,465	839	13,205	10,482
1871-72	10,131	1,375	4,937	13,655
1872-73	6,910	2,206	12,055	12,549

An Abstract of the work executed since 1866-67 stands as follows.

Subject	Number of Prints						
	1866-67	1867-68	1868-69	1869-70	1870-71	1871-72	1872-73
Maps, Charts and Diagrams,	7,118	7,376	5,538	12,315	20,509	16,443	21,171
Forms, ...	5,152	10,531	10,800	13,571	10,482	13,655	12,549

thus in 1866-67 the total of the prints was 12,270; in 1872-73 this total was 33,720; in other words the work has nearly trebled in 6 years; in fact, the value of the process cannot be ranked too high.

(13.) I conclude my report for the year 1872-73 by noticing the conduct of the assistants placed under my care.

Mr. W. H. Cole, M.A., continues to be the excellent assistant I have always found him; his natural abilities are now all the more valuable that his experience is growing matured, and these combined with his patience and good temper enable me to leave many a subject to his entire control.

Calculating branch.

In all the details of my duties, I could wish for no more efficient assistant than Mr. Charles Wood: he continues active, willing and quick in detecting mistakes. Mr. H. W. Peychers is fast becoming a very useful hand, and I have good reasons to be satisfied with his conduct. Baboo Gunga Pershad maintains the excellent opinion I have frequently expressed of him; in addition, his patience and care in going through the tedious process of training new computers are commendable. Baboo Cally Mohun Ghose has, I am glad to say, paid more attention to practical matters, by which his general attainments, which are good, promise to be enhanced. Baboo Kally Coomar Chatterjee continues to be accurate, painstaking and trustworthy. Nothing could exceed Baboo Gopal Chunder's care, and were it only possible to induce him to "put on a little more steam," his value would be increased; he takes care of the records to my satisfaction, besides discharging the duties of a computer. Baboo Tarapodo continues steady and useful. Of the new hands, Mizaji Lal makes himself generally useful, a most desirable trait, which Shoshee Bhooshun Shome seems inclined to follow. The other new hands are sufficiently promising to admit of the hope that I may be able to notice them by name next year.

Photozincographic branch.

Mr. Ollenbach continues hardworking, painstaking and neat fingered: he works with undiminished interest, and I hope to be able to add, that his methodical procedure is equal to his zeal. Mr. Dyson is the same cheerful, ready hand as ever.

Printing branch.

Mr. O'Connor is zealous and generally efficient as I have always been able to report of him: he would add to my peace of mind could he but induce his compositors and pressmen not to transplant blunders into proofs, where accuracy prevailed before.

Drawing branch.

Mr. Atkinson has now discharged his new duties as Chief Draftsman for more than a year, and promises to prove equal in accuracy, method and management to the requirements of his place. I trust in due course to be able to report, that by dint of careful study and reflection, Mr. Atkinson maintains his knowledge of geographical subjects up to date, as well as manages and improves the promising assistants under his charge. Shaikh Saidoodeen Hoosain continues to be one of the neatest of draftsmen, besides that his knowledge of events and records in the drawing office makes him generally useful: the other draftsmen have given me satisfaction, and of the assistant draftsmen Shamlal and Poorno Chunder promise to become excellent hands.

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

YEAR & MONTH.	BAROMETER.						HYGROMETER (monthly mean)				THERMOMETER.								WIND.		CLOUD.		RAIN.	
	At 9 h. 30 m. A. M.			At 3 h. 30 m. P. M.			At 9 h. 30 m. A. M.		At 3 h. 30 m. P. M.		Dry Bulb.					Wet Bulb.								
	Highest.	Lowest.	Monthly Mean.	Highest.	Lowest.	Monthly Mean.	Temperature of Dew point.	Humidity.	Temperature of Dew point.	Humidity.	Max: reading in Sun's rays.	Min: reading on grass.	Max: reading in air.	Min: reading in air.	Monthly Mean in air	Max: reading Wet.	Min: reading Wet.	Monthly Mean: Wet.	Average direction.	Monthly Mean force in lbs. per square foot.	Monthly Mean At 9 30 A. M.	Monthly Mean At 3 30 P. M.	Number of days it fell.	Fall in inches.
1872	in.	in.	in.	in.	in.	in.	°		°		°	°	°	°	°	°	°	°						
January	27·902	27·681	27·804	27·809	27·602	27·716	47·0	·782	47·7	·599	79·0	31·1	70·6	36·3	55·2	64·7	33·1	48·0	N.	·00	6	5	9	6·58
February	·812	·630	·744	·799	·576	·659	44·7	·668	42·4	·455	91·7	33·7	78·4	36·0	57·0	63·8	32·1	47·8	W.	·00	4	5	6	2·25
March	·868	·518	·694	·758	·468	·611	53·4	·551	50·2	·355	100·6	45·3	90·4	50·3	69·9	67·4	43·2	56·1	W.	·00	2	3	3	·55
April	·815	·474	·613	·677	·404	·534	54·8	·470	53·0	·355	106·5	49·1	92·8	54·0	74·0	76·0	47·6	56·2	W.	·01	3	4	4	1·28
May	·614	·380	·499	·551	·303	·424	59·7	·437	57·4	·326	110·9	57·0	99·7	61·8	81·7	77·0	48·5	64·1	N.	·00	2	2	4	1·36
June	·528	·232	·409	·444	·180	·329	70·2	·619	69·5	·548	114·4	68·3	102·8	70·9	84·3	80·2	55·4	71·4	W.	·00	4	4	13	12·03
July	·541	·293	·406	·486	·244	·341	74·8	·837	75·2	·831	103·3	65·9	88·7	69·8	79·4	84·7	62·2	73·0	N.	·00	7	8	25	31·80
August	·615	·326	·424	·523	·259	·347	75·3	·877	76·7	·828	101·5	69·6	89·4	71·0	79·3	81·8	61·7	73·4	W.	·00	8	8	28	22·74
September	·639	·450	·562	·598	·381	·476	71·9	·826	73·5	·785	103·8	60·8	88·8	62·9	76·7	80·2	56·4	70·3	N.	·00	4	6	18	14·79
October	·807	·531	·691	·725	·461	·600	59·3	·625	60·3	·517	99·9	50·8	86·0	53·1	70·8	75·5	43·9	60·2	N.	·00	0	1	0	·00
November	·833	·682	·787	·766	·617	·699	50·4	·584	50·5	·435	92·4	42·0	81·8	44·8	64·2	65·5	38·2	53·0	N & W.	·00	1	1	1	·12
December	·983	·664	·785	·903	·585	·695	48·7	·715	49·1	·496	86·9	40·0	71·6	42·8	58·7	62·6	37·5	50·0	N.	·00	1	2	1	·20

ABSTRACT OF RAIN-FALL AT DEHRA DOON G. T. SURVEY OFFICE FROM 1861 TO 1872.

MONTH.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
January, ...	——	——	3·31	·36	1·93	——	1·25	2·69	1·67	·04	·46	6·58
February, ...	——	——	·00	2·18	6·48	——	1·46	7·28	1·43	1·39	2·54	2·25
March, ...	——	——	1·69	·52	4·67	——	1·43	1·74	7·25	4·13	·00	·55
April, ...	——	——	·33	·21	1·35	2·50	·74	·84	·11	1·84	·43	1·28
May, ...	——	——	·34	2·53	6·45	——	3·21	·82	·00	·31	3·44	1·36
June, ...	12·19	——	12·10	·29	2·10	8·21	9·94	6·83	2·96	7·04	24·34	12·03
July, ...	24·53	28·66	36·96	37·60	19·12	34·75	28·69	21·26	20·66	33·05	36·32	31·80
August, ...	54·75	45·22	24·78	22·59	29·40	23·70	23·63	12·85	16·79	28·45	38·39	22·74
September, ...	9·31	20·20	2·19	7·21	10·06	5·60	3·81	3·02	22·56	13·78	11·03	14·79
October, ...	·02	5·52	·60	1·68	·00	·20	·93	·05	2·39	1·39	·00	·00
November, ...	·01	·00	·92	·17	·00	——	·00	·00	·00	·00	·00	·12
December, ...	·00	·00	·60	·03	4·02	——	·00	·18	1·22	·01	1·32	·20
Total, ...	100·81	99·60	83·91	75·37	85·58	74·96	75·09	57·56	77·04	91·43	118·27	93·70

NOTE.—Where blanks occur no record is forthcoming. Height of Barometer Cistern above Mean Sea Level, 2232·41 feet.

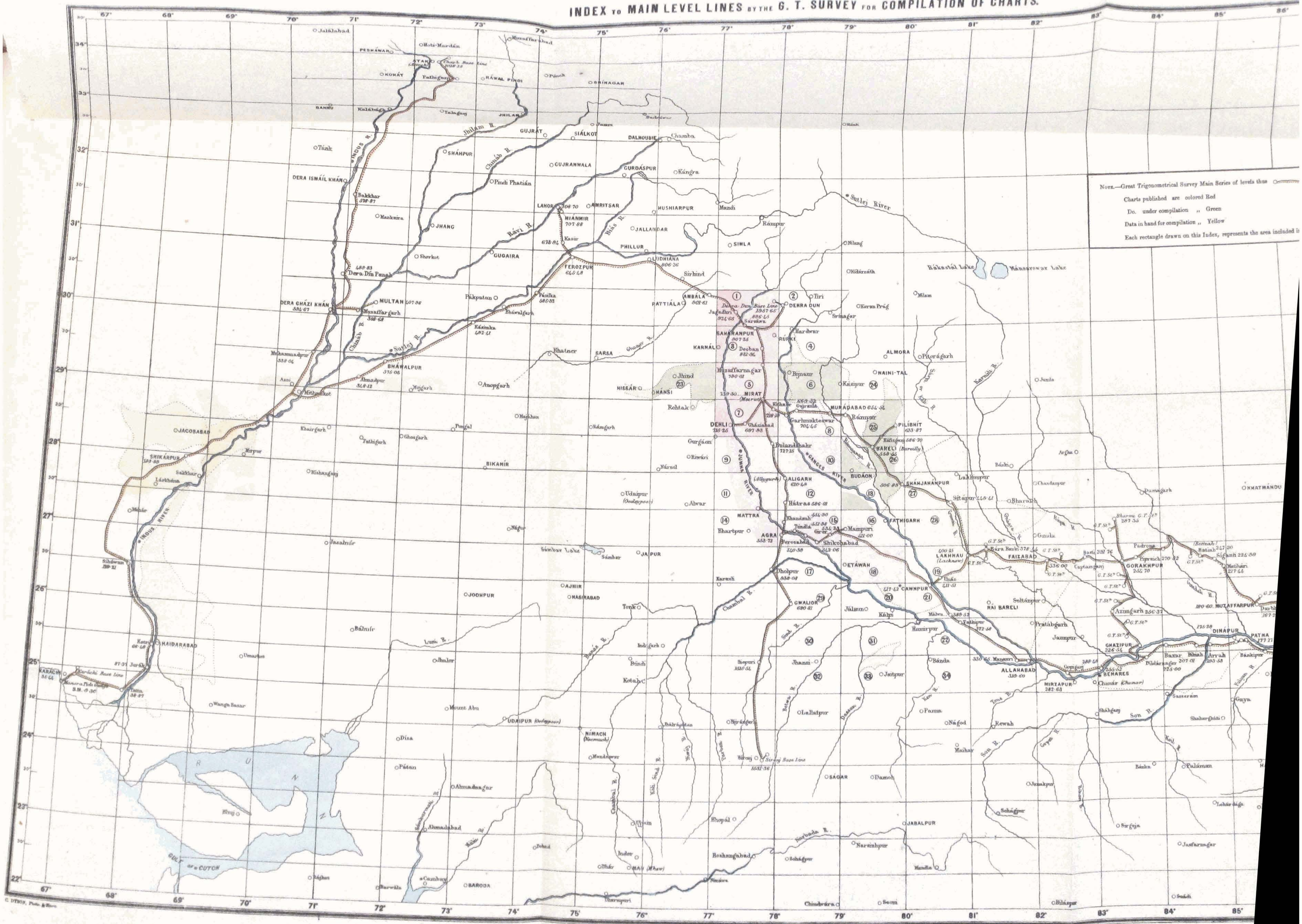
Annual Return of amount of Work executed in the Drawing Branch of the Office of Superintendent G. T. Survey, from 1st May 1872 to 30th April 1873.

Description of Work.	Number of sheets or diagrams. Finished	Number of sheets or diagrams. In hand	Scale 1 inch =	Remarks.
Compilation			Miles.	
Map of Turkestan in 4 sheets. 2nd edition	4		32	For Photo-zincography.
Sheet No. 4 Northern Trans-British Frontier	1		16	ditto.
Do. No. 7 ditto ditto ditto	1		16	ditto.
Do. No. 4 Map of Routes in Northern India	1		16	ditto.
Map of the Dingri Maidan and Upper Arun River	1		8	ditto. Reduction to ½ scale
Sheet No. 6 of Spirit-Levelled Heights		1	2	ditto.
Do. No. 8 ditto ditto	1		2	ditto.
Do. No. 10 ditto ditto (2nd edition)	1		2	ditto.
Do. No. 23 ditto ditto	1		2	ditto.
Do. No. 26 ditto ditto		1	2	ditto.
Section IX of Spirit Levelling Operations 1871-72, to illustrate Book of Heights	1		20	ditto.
Index Map to Main Level Lines of the G. T. Survey ...	1		40	ditto. ditto.
Index Charts				
Kashmir Triangulation	1		32	ditto.
Northern Bombay Triangulation	1		16	ditto. ditto.
Preliminary Numerical Charts of the N. W. Quadrilateral ...	1		32	ditto.
Final Numerical Charts of the N. W. Quadrilateral	1		32	ditto.
Preliminary Numerical Charts of the N. E. Quadrilateral ...	1		32	ditto.
Final Numerical Charts of the N. E. Quadrilateral	1		32	ditto.
Preliminary Numerical Charts				
Kashmir Triangulation, Sheet No. 7 (projected by Mr. W. G. Beverley)	1		4	ditto.
N. W. Himalaya Series, Season 1851-52, (in 2 sheets)	2		4	ditto.
Budhon Meridional Series, Nos. 1 to 4	4		4	ditto.
Rahún ditto ditto, Season 1855-56, and 1856-57 (redrawn)	2		4	ditto.
Gurhágarh ditto ditto ditto 1860-61 (redrawn), and 1861-62	2		4	ditto.
Biláspur ditto ditto ditto 1871-72 Northern Section	1		4	ditto.
Assam Valley Triangulation, Season 1871-72	1		4	ditto.
Rangír Meridional Series, Nos. 1 to 3		3	4	ditto.
Bider Longitudinal and Biláspur Meridional Series, Season 1871-72	1		4	ditto.
Bangalore Meridional Series, Season 1871-72, Northern Section	1		4	ditto.
Amúa ditto ditto, Nos. 1 and 2	2		4	ditto.
Northern Bombay Triangulation, Sheet No. 9	1		4	ditto.
Gora Meridional Series, Nos. 1 and 2	2		4	ditto.
Final Numerical Charts				
Great Arc Series (Principal Triangulation), Nos. 1 to 6		6	4	ditto.
Karáchi Longitudinal Series (ditto) Nos. 1 to 5		5	4	ditto.
Plates.				
Of Figures to illustrate Volumes III and IV of the operations of the Great Trigonometrical Survey of India	25			ditto. ditto.
Miscellaneous.				
Colored 8,443 copies of maps, and performed numerous other miscellaneous duties.				

Northern Section.

GREAT TRIGONOMETRICAL SURVEY OF INDIA

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



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

Rules for pronouncing Indian proper names; *a* has a variable sound as in woman, rural, paltry; *á* as in tartan; *i* as in clique; *í* as in ravine; *u* as in bull; *ú* as in rural; *o* as in note; *e* as *a* in say; *au* as *ow* in cloud; *ai* as *i* in ride; *g* as in *gong*; abad as ábád; bazar as bázár. Exceptions to spelling by rule are indicated thus *C

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

10 5 0 10 20 30 40 50 100 150 200 Miles

Photozincographed at the G. T. Survey Office, Dehra Dun; November 1873

GREAT TRIGONOMETRICAL SURVEY OF INDIA

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

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

Rules for pronouncing Indian proper names; *a* has a variable sound as in woman, rural, paltry; *á* as in tartan; *i* as in clique; *í* as in ravine; *u* as in bull; *ú* as in rural; *o* as in note; *e* as *a* in say; *au* as *ou* in cloud; *ai* as *i* in ride; *g* as in *gong*; abad as ábád; basar as bázár. Exceptions to spelling by rule are indicated thus *Calcutta, *Calicut, &c.

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

Photozincographed at the G. T. Survey Office, Dehra Dun, November 1873

Notes on the Maps of Central Asia and Turkestan which have been compiled and published in the Office of the Great Trigonometrical Survey of India, under the superintendence of Colonel J. T. Walker, R.E.

In the year 1862 I was called on to compile a map of "Asia between the parallels of 20° and 60°" to accompany the Report on the Trade and Resources of the Countries on the North Western Boundary of British India, which was published by the Punjab Government. While thus occupied I realized how very slight and inaccurate was the knowledge then possessed in India of the regions lying between the Russian and the British Frontiers. I went to England in 1864 and found that neither in the India Office nor in the archives of the Royal Geographical Society was any better information forthcoming. It appeared that our knowledge of the Geography of these regions was almost solely derived from the maps which had been compiled in 1711 by the French Jesuits in the service of the Emperor of China, and for which the only data had been "divers very exact journals," "itinerary distances," and the "latitudes and longitudes given in the tables of Nassir Addin, Olug Beig, and other Eastern Astronomers, quoted by Abû'l Feda."* These maps had no pretensions to accuracy and they contained very little detail; and the Messrs. Schlagintweit had recently come to the conclusion, from their own observations, that the positions of Kashgar and Yarkand on the Jesuit's maps were erroneous by 2° in longitude.

(2.) This state of things being most unsatisfactory, I obtained the permission of the Secretary of State for India to proceed to St. Petersburg, to ascertain whether any more accurate and valuable information might be obtained from Russian sources. The Russian Government was known to have recently obtained, by the treaty of Pekin, a grant of land in Kashgar, in Eastern Turkestan, for the errection of a factory; the Russian frontier had been recently carried south-wards into Western Turkestan, and thus embraced a portion of what to Englishmen was still a *terra incognita;* and there was much reason to believe that Russian Officers had already acquired a large amount of information regarding the regions to the south of their frontier line, and that they would not be unwilling to impart this information to a British Officer.

(3.) At St. Petersburg, I received every assistance from Lord Napier, the British Ambassador, by whom I was introduced to General Miliutine the Minister of War, M. Golovinne the Minister of Public Instruction, and Admiral Lütke the President of the the Russian Geographical Society. I readily obtained access to the Archives of the Geographical Society, which were replete with valuable publications and maps, many of which had not yet found their way to England. To obtain free access to the Topographical Department of the War

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* See Pere du Halde's China, and more particularly the Geographical observations on the Map of Tibet, by Pere Regis.

Office was anticipated to be a more difficult matter, for in all parts of the world the time honored custom still prevailed of treating the documents in such offices as secret and confidential, and not to be shown to foreigners; but General Miliutine at once authorized my admission to the Topographical Office, and I have every reason to believe that I was shown all the maps it contained of the regions in which I was interested. In one respect I was disappointed; I found that the Russians had not carried their explorations to any thing like the distance beyond their frontier, that the British had done in India; though they were then holding the north-west portion of Kokan, around Tashkend, they had very little knowledge of the central and eastern portions of that important Khanat; the treaty by which they had obtained a grant of land for a factory in Kashgar was still a dead letter, only one Russian Officer having visited Kashgar, and he went there in disguise and was unable to take any observations for fixing it's position; and it appeared that such knowledge of Turkestan as was possessed by the Russians was derived, for the most part, from the same sources as our's,—namely from the maps of the French Jesuits, which were a century and a half old. But there were expectations that this state of ignorance would not last long; the Russian Government had appointed as Political Agent to the Native States in Turkestan an accomplished astronomer, M. Charles Struve, who was expected to determine the correct positions of all places of importance near the boundary line, and thus it was hoped that very valuable data for the rectification of the existing maps would be soon forthcoming.

(4.) I obtained the following maps;

1. Southern and Eastern Siberia including parts of Mongolia and Chinese Tartary, recently published by the Russian Geographical Society.

2. Central Asia between the parallels of 20° and 50° and meridians 40° to 90° East of Greenwhich, by the Topographical Department of the War office; 1863.

3. Western Siberia, and the countries between the parallels 42° to 62°, and meridians 62° to 85°, by the Topographical Department of the War Office; 1848.

4. A manuscript map of the Khanat of Kokan, based on information recently supplied by the Russian Consul at Guldja.

5. A catalogue of the latitudes, longitudes and heights of all positions of importance in Asiatic, Russia, Persia, Chinese, Tibet and Tartary which had been determined up to 1863 by triangulation or Astronomical observations.

6. Various publications of the Russian Geographical Society.

(5.) Returning to England I secured the assistance of Mr. Robert Michell in making translations of the various Russian documents I had received and in transliterating the names on the maps; and for some years afterwards, up to the time when Mr. Michell obtained an appointment in the India office, I was regularly supplied by him with translations of Russian publications furnishing new information on the Geography of Central Asia.

(6.) In 1866 my map of Central Asia was published; in it's compilation the whole of the regions to the north of 40° were taken from the Russian sources indicated in the preceeding paragraph; all to the south of 38° from British sources; for some portions of the intermediate belt of two degrees in latitude it was still necessary to depend on the maps of the French Jesuits which have already been mentioned, though additional details were furnished by recent itineraries. The position of Ilchi, in Khoten, having been lately determined by Mr. Johnson, in connection with the operations of the Trigonometrical Survey of India, furnished a point to which the details in the Jesuit's maps could be referred with accuracy, so that there was reason to hope that the correct positions of the chief towns in Eastern Turkestan had been fairly approximated to.

(7.) Very shortly after the publication of this map, I received from M. Otto Struve, Director of the Poulkova Observatory, a list of nearly fifty positions near the southern borders of the Russian territories, which had been recently determined by his brother Charles, whom I have already mentioned as having been deputed for this purpose by the Russian Government.* The results shewed that the existing maps required a considerable amount of rectification, and strange to say to a much greater extent in latitude than in longitude. Thus the town of Chemkend, which had been hitherto supposed to be in latitude 42°43′ and longitude 69°40′ from Greenwich, was found to be in lat. 42°18′ and long. 69°36′; Tashkend required to be placed upwards of thirty miles further south and about twenty to the east, and generally a very considerable amount of southing was required for all the chief towns between Aulicata and Bokhara.

(8.) I then commenced the compilation of the map of "Turkestan, with the adjoining portions of the Russian and the British territories." It was constructed in four sheets which were published consecutively during the years 1867 and 1868. For the southern portions of this map, which indicate the regions immediately adjacent to the British Frontier, there were then no other materials available than those which had been used in the map of Central Asia, but I had obtained several Russian maps, in addition to the astronomical points, for the correction and amplification of the geography of the regions contiguous to the Russian Frontier. Of these the most accurate and valuable was Admiral Butakoff's map of the Sir-Daria (Jaxartes), and Severtsoff's Geological map of the country lying between the Sir-Daria and the River Chui. I also obtained copies of the sketch map of Northern Bokhara with the conterminous portion of Turkestan, which was prepared for Saturinoff's Journal of Struve's mission to Bokhara in 1865, the Chart of Routes in Kokan from Tashkend to Namangan and Margilan published by the Russian Geographical Society in 1867, and a map of Turkestan published at St. Petersburg by A. Ilyin.

(9.) Geographical science, when it is not advanced by sound and systematic surveys but is dependent on information acquired from the itineraries of travellers and from cross questioning the inhabitants of a *terra incognita*, has to make it's way by zig-zags of approach, often over-shooting the mark to which it is directed, sometimes perhaps going wrong altogether, but yet always endeavoring to reach it's goal by successive approximations. This is pre-eminently the case as regards the geography of the portions of Central Asia which respectively lie beyond the boundaries of the Russian and the British territories, and more so as regards the former than the latter, for accurate and continuous surveys on a trigonometrical basis have now been carried up to the British frontier, throughout it's entire length, whereas on their side the Russians have not yet had time to execute such surveys, and their maps are mostly compiled from reconnoisances and itineraries, of varying orders of merit, which are put together on the basis of a few points whose positions have been determined astronomically. It is evident therefore that until all such data have been superceded by the results of a rigorous and systematic survey, Central Asian geography can only be considered as a preliminary approximation, which is liable to be largely corrected in future.

* While engaged in these operations M. Struve was taken prisoner, and held in captivity in Bokhara for several months, which probably was one of the causes of the subsequent extension of the Russian boundary in that direction.

(10.) Sir Roderick Murchison, in his address to the Royal Geographical Society at the anniversary meeting in May 1869, said of the map of Turkestan that "this work of Colonel Walker's does not enter into great topographical detail, but it is invaluable as a combined view of the sound results obtained up to the latest date, and marks a step in our chartography of that region such as has not been made for nearly thirty years." But such has been the progress of geographical exploration, on the part of the British as well as the Russians, since the publication of that map that it is now found to need numerous corrections and additions, and to be altogether insufficient for present requirements. It moreover contains a grave error in an attempted rectification of the course of the Zarafshan river; in the preceding map of Central Asia that river was shown as rising in the hills south of the Khanat of Kokan at a distance of about 4½° to the east of Samarcand, and trending westwards, between two parallel ranges of mountains, until it reached the vicinity of Samarcand; but in Saturinoff's map (see para. 8) the source of the river is placed in the Lake Iskunder at a distance of barely a degree to the east of Samarcand, and the two ranges to the south of Kokan give place to a single range; the propriety of this rendering was supported by a recent determination of the position of the town of Kokan, placing it more than a degree to the south of the position which had been previously accepted. These supposed rectifications were introduced into the Turkestan map, but they have now been found to be erroneous; the river Zarafshan was afterwards explored to it's source by M. Fedchenko, and the original rendering of the river is now known to be much more accurate than that by which it was for a time supplanted.

(11.) To correct this error, and to utilize the results of recent surveys and explorations, a new edition of the map of Turkestan has been prepared. It has been extended west-wards to embrace the Caspian sea, which was not shown in the first edition. In it's compilation the following recent maps and documents have been used in order to correct and add to the details in the first edition.

From British and Asiatic Sources.

1. Trans Himalayan Explorations under the superintendence of Major Montgomerie; *viz.*, the Pundit's Explorations of the Upper Basins of the Indus, Sutlej and Brahmaputra rivers, 1865-67; the Mirza's Route from Badakshan across the Pamir steppe to Kashgar, 1868-69; and the Havildar's route from the Panjab to Badakshan, through Swat, Dir, and Chitral, 1870.

2. Two skeleton maps (without hills) by Major Montgomerie, called "Trans Frontier Maps, compiled from Route Surveys and Astronomical Observations made by British and Asiatic explorers from the side of India"; 1872-73.

3. Captain Carter's chart of trigonometrically fixed points west of the Indus, between the British Frontier and the water-shed of the Hindu Kush; 1869-70.

4. Map of the Sistan boundary by Major Lovett; 1872.

5. Report of General Sir Frederic Goldsmid on the Sistan boundary; 1872.

6. Route from Bam to Sistan and thence to Meshed by General Sir F. Goldsmid, 1872.

7. Route from Shiraz to Bam, Major Lovett; 1872.

8. Route from Teheran to Bushire, by Major St. John; 1871.

9. Map of Affghanistan compiled in the Quarter Master General's Office, Simla, 1871.

10. Colonel Johnstone's Sketch Map of the North Western Frontier, from Fort Abazai to Fort Mackeson, 1869-70.

11. The communications of Messrs. Hayward and Shaw to the Royal Geographical Society, published in the Society's volumes for 1870 and 1871.

12. Map of Central Asia, by John Arrowsmith, 1872.

13. Map of Eastern Turkestan, to illustrate Mr. Forsyth's Journeys, 1871.

14. Travels in Central Asia by Mir Izzat-Ullah, in the years 1812-13, published 1872.

15. Journey from Peshawar to Kashgar &c. by Faiz Buksh, 1870.

16. Route from Kokan to Peshawur, *viâ* Karategin, by Shazada Sultan Muhamad of Kokan.

17. Map of Independent Territory west of Indus and south of Oxus, compiled by a Moulvie in the service of Captain Ommaney, Deputy Commissioner of Hazara.

18. Reports of the meetings of the Royal Geographical Society, published in "Ocean Highways, the Geographical Record" by Clements Markham, C.B., 1872-73.

19. Colonel Yule's Introduction to the second edition of Wood's Oxus, 1872.

20. Map of Central Asia, compiled at Topographical Department of War office, and corrected to March 1873.

From Russian Sources.

21. Additional astronomical determinations of position, by M. C. Struve.

22. Map of the Khanat of Kokan, by M. C. Struve, scale 20 versts=1 inch; 1871.

23. Map of Turkestan by Captain Liusilin and Colonel Narbut, of the Russian Topographical Department; 1871.

24. Map to illustrate Baron Osten Sacken's Route from Vernoe to neighbourhood of Kashgar; 1868.

25. Topographical sketch of the Zarafshan valley by M. Fedchenko; in the Journal of the Royal Geographical society for 1870.

26. The principality of Karategin, by General Abramof, Chief of the Zarafshan district; in the Journal of the Royal Geographical Society for 1871.

27. M. Fedchenko's accounts of his expedition up the Zarafshan valley in 1870, and his travels through the Khanat of Kokan in 1871, as translated in "Ocean Highways" from the proceedings of the Imperial Russian Geographical Society for October 1872, and published in the proceedings of the Berlin Geographical Society.

28. Chart of Central Asia, by the Russian Topographical Department; 1863; new edition corrected up to end of 1872.

(12.) I very much regret that I am unable to add to the above list M. Fedchenko's new map of Kokan, which I have made several efforts to obtain but hitherto without success. It should be very valuable, for M. Fedchenko has succeeded in penetrating into Karategin, and reaching the neighborhood of the celebrated Tirak pass between Kokan and Kashgar, and he has thus had great opportunities of correcting erroneous geography; he is stated to believe that he has cleared up "many points which are yet problematical," and also to be of opinion that "there remains now but very little to determine on one of the great geographical mysteries of the world." I am informed that he is preparing an elaborate account of his explorations and solutions of geographical mysteries, and that the publication of his map will be postponed until his book is ready.

(13.) It is desirable that I should here point out the geographical alterations and additions which have been made in the construction of the second edition of the map of Turkestan now in publication, giving my reasons for them wherever necessary.

1. The map has been enlarged so as to embrace the region between the meridians of 46° and 58° East of Greenwich, to which much interest attaches at the present time.

2. The error in the course of the Zarafshan River, noticed in para. 10, has been rectified.

3. The route from Badakshan to Kokan, *viâ* Kolab and Karategin, is stated by M. Fedchenko to have been originally traced inaccurately, because of the errors in the position in Kokan. It is now made to cross the great range of mountains to the south of Kokan nearly a degree to the east of the position formerly accepted, at the Karategin pass of M. Struve's map. Much additional information regarding this route and the valley of the Surkhab river has been obtained from the Itinerary of Shazada Sultan Muhamad of Kokan, whose route from Kokan to Lungur Eshan goes through several places on Abdul Majid's route; from Lungur Eshan to Abigurm the Shazada's route keeps near the river Surkhab, passing through several places noticed in General Abramof's account of Karategin, while Abdul Majid appears to have taken a more direct route to Kolab, keeping away from the river and crossing several spurs of the Darwaz hills. From Abigurm the Shazada proceeded *viâ* Baljawan, which is believed to be near the Surkhab River, to Kolab, where his route joins that of Abdul Mejid.

4. In the delineation of the Khanat of Kokan M. Struve's map has been exactly followed up to the meridian of the Karategin pass, 72° 20′; but from that point eastwards, I have thought it desirable to make some considerable deviations. M. Struve places the Tirak pass* very much closer to Kashgar, than is reconcileable with the information given in the itineraries of Muhamad Amin, and Mir Izzat-ullah; he makes the distance from Kashgar equal to 2·7 tenths of the distance between Kashgar and Kokan, while they agree very closely in making it 4·4 tenths of that distance, the difference being equivalent to about 1⅓ of a degree in longitude. M. Struve's geography of this region is probably based on native information which is no better than that furnished by the itineraries of Muhamad Amin and Izzat-ullah; I have adopted a mean between his value and their's, and assumed the Tirak pass to be at 3·6 tenths of the distance from Kashgar that Kashgar is from Kokan. I thus place the pass in long. 74° 15′, instead of 74° 55′ as by M. Struve, but our latitudes are the same, *viz.*, 39° 42′. The position adopted for the first edition of my map of Turkestan was 39° 18′ by 72° 48′, nearly half a degree to the south and a degree and a half to the west of the position now adopted. I trust that the uncertainty about the position of this pass—which is an obligatory point of the highest importance—has been cleared up by the labors of M. Fedchenko. He is reported to have said, in a preliminary account of his travels, that the pass should be shifted 80 versts (53 miles) to the west and 30 versts (20 miles) to the north "of the position hitherto given on the maps"; but as it is not stated on *what* maps, the information is indefinite; it tends however to confirm the propriety of my deviation from M. Struve. In the new edition of the Russian Chart of Central

* Otherwise spelt Terek, Turak, Tareck by various authorities, and Teezuk by the translator of Mir Izzat-Ullah's travels.

Asia (28 of para. 12) the pass is placed in lat. 40° 8′ by long. 73° 30′. The geographical zigzags of approach to this pass would seem to have gone very wide of the mark hitherto.

5. I have placed the town of Kashgar in lat. 39° 29′, long. 76° 12′, and that of Yarkand in lat. 38° 20′, long. 77° 30, the positions determined by Major Montgomerie from the route surveys of his native explorers, and upheld by him in his recent Trans Frontier skeleton maps.

6. The original delineation of the district of Tashkurgan has of course been superceded by the Mirza's survey of the route from Badakshan across the Pamir Steppe to Kashgar. A comparison of the Mirza's route with those of Muhamad Amin and the map constructed by Captain Lumsden from Muhamad Amin's itineraries, shows that there is much probability that the Sussogh Kul of Abdul Majid's itinerary is in reality Wood's Sirikul or Lake Victoria, though it has hitherto been placed about 45 miles to the north-west of that lake;* Muhamad Amin gives a lake—merely called Ab-i-Pamir Kalán—in a similar position relatively to another lake which he calls Sirikul and which was therefore supposed to be Wood's lake. But it is now quite clear that this Sirikul is identical with the Mirza's Barkut Yassin Lake, which lies about 40 miles to the south-east of Wood's Sirikul; as the word Sirikul literally means a lake on a summit, and there are many lakes so situated in this region, the name is not sufficient to ensure identification. The merging of the Sussogh Kul into Wood's lake has a very important bearing on the geography of the Pamir Steppe; it throws the starting point of our best itineraries across this region to the Tirak pass considerably to the east, and as the position of the pass has been carried still further to the east, I have found it necessary to move Lake Karakul about 1½° in the same direction.

7. The region lying between the eastern edge of the Pamir Steppe, the valley of the Surkhab River and the River Panja of Wakhan—the southern branch of the Oxus—covers an area of about 40,000 square miles which is still a *Terra Incognita* to Englishmen. It is probably a highly elevated plateau, which culminates in the Bam-i-Dúniah, the highland of the Pamir on which Wood's lake is situated. To the south-west it is bounded by a prolongation of the spur from the Hindu Kush range northwards passing between Ishkashm and the upper sources of the Kokcha river, which must take the form of a highly elevated scarp on it's western face, which towers over the valley of the Kokcha, while it's eastern face has a comparatively slight command over the elevated plateaux of Wakhan and Shagnan. It is not improbable that this scarp is prolonged northwards and then north-eastwards into Karategin, and that it's crest is the watershed between the *Terra Incognita* and the valley of the Surkhab River. The whole of the drainage of this region appears to join the Panja River on the east side of this range, the united streams forming the Oxus, which, after bursting through it's mountain barriers, and descending from a probable elevation of 7,000 feet to one of 700, enters an alluvial plain as a noble stream having a breadth, opposite Sarchasmah, of upwards of a mile in winter and some six miles in summer during the melting of the snows. The Shazada Sultan Muhamad is my authority for the breadth of the Oxus at this point, and though he may have exaggerated it, yet the fact that neither his itinerary nor that of Abdul Majid mentions the passage of any river on the routes between Lungur Eshan and the Oxus, shows that the existence of large rivers flowing westwards through the *Terra Incognita* into the Surkhab is highly improbable, and strengthens the pro-

* Major Montgomerie I find has adopted this view, and is supported in it—though with some hesitation—by Colonel Yule.

bability of these rivers joining the Oxus above the point of it's entry into the lowlands.

8. A recent writer in the Times—see the Mail of 9th April, 1873—in reviewing Colonel Yule's edition of Wood's Oxus, draws attention to "the curious forgeries produced by dearth of information concerning Central Asia." He says of these forgeries that "they have been adopted in Colonel Walker's map, and transferred from it to others, even that of the Topographical Department; thus the course of the Oxus in it's northern bend, and the districts of Shagnan, Roshan, and even Wakhan, are tortured out of shape and place." This would be very sad and pitiful if it were only true. But as a matter of fact Shagnan and Roshan do not appear in either of the maps which I have published hitherto, though they will be found in the new edition of Turkestan. On the other hand Wakhan has always been shown without having undergone a process of torturing, for it was placed exactly as Wood—the only Englishman who has ever been there—placed it, and Wood's rendering is accepted and followed by Colonel Yule. Shagnan and Roshan fall within the *Terra Incognata*, as will be at once evident from an examination of the attempts to give them shapes and places which have been made by the geographers who are believed to have known or to know most about them. For example, Shagnan—which in deference to Colonel Yule will hereafter be spelt Shighnan—is shown in Wood's map as the portion of the valley of the Panja river *below* Wakhan, having the direction S. S. E., to N. N. W., with a length of about 60 miles. In Colonel Yule's it lies in great part in a lateral valley, called the Shak-dara, about 30 miles to the north of and nearly parallel to, the course of the Panja River through Wakhan; it has the direction N. E. to S. W., with a length of 110 miles and an average breadth of 30 miles; beyond it (northwards) a third parallel valley is shown, which Colonel Yule thinks may be the *Vallis Commendarum*. Colonel Yule and Lieutenant Wood agree in locating Shighnan wholly between the 37th and 38th parallels of latitude; but according to M. Fedchenko *(see Ocean Highways for December* 1872, *page* 289*)* the Shighnan territories must reach to a distance of at least a degree further north, for he says that the valley of the Muk-su separates them from the Alai plateau; he believes that they "lie to the east of Darwaz, extending probably two degrees along the meridian", or in other words that they embrace an area which is far greater than has hitherto been imagined by the best English authorities on the subject. The matter is one of no small importance, if Colonel Yule is correct in his statement that Shighnan acknowledges the supremacy of Badakshan.

9. In the first edition of the map of Turkestan the District of Darwaz is placed wholly to the north or on the right bank of the Oxus, and it is retained there in the second edition, because I have failed to discover any satisfactory authority for extending it to embrace a portion of the region on the left bank of the Oxus; the fact however that this has been done in Colonel Yule's map and Lieutenant Wood's also is, I must admit, a strong argument against the validity of my own conclusions, and the accuracy of my information.

10. Colonel Yule observes in his Essay that I have "more than once expressed an opinion that there is no well-defined range where the Hindu Kush is represented on our maps", and he adds that he thinks these words are far too strong. They appear to be quoted from the printed report of a discussion at the meeting of the Royal Geographical Society on the 24th April 1871; I cannot find them anywhere else. The words taken by themselves may well

be considered to be too strong, but Colonel Yule has overlooked the circumstance that they were spoken with reference to Mr. Shaw's discovery of places in the Karakoram range where there is a break of continuity in the range, and the line of watershed is almost lost, and can only be traced with difficulty, on the high table lands into which the range disappears for a while to reappear further on beyond them. Speaking of the Hindu Kush range I expressed my belief that a counterpart to the break of continuity in the Karakoram would be met with there, and I think there can be very little doubt of this. At a subsequent meeting of the Royal Geographical Society, on the 13th May 1872, I said of the portion of the Hindu Kush range which lies to the north of the valley of Chitral that, as our geographical knowledge improved, "we should probably find that the system of mountain chains, as represented in our maps, would require great alteration, that the dark range now representing the watershed would be found much lower than is now supposed, and that the higher ranges were to the south of it." Colonel Yule must I think agree with me, for in his recently published map the watershed has, for the first time, been greatly subordinated, and nearly disappears altogether, in the vicinity of the passes leading out of the upper Chitral valley into the Sarhad Wakhán and Pamir, where hitherto it has invariably been shown as a great range towering over all others. The depression of the main line of watershed as compared with the great mountain ranges is a well known feature in Himalayan geography, the counterpart of which doubtless obtains in the Hindu Kush range also. And I find that Major Montgomerie has recently arrived at the conclusion that the watershed line between the Hindu Kush and the Karakoram ranges lies considerably behind (to the north of) the line of high peaks which he fixed trigonometrically several years ago, and which have ever since been accepted as the actual line of watershed, whereas they are now ascertained to belong to off-shooting higher ranges.

11. Numerous additions and rectifications of the geography of the countries between the watershed of the Hindu Kush and the British Frontier line have been made on the basis of Captain Carter's triangulation, by which upwards of a hundred hill peaks have been newly fixed in this interesting region. The Havildar's expedition through Swat, Dir and Chitral to Badakshan has not only furnished very valuable details in itself, but has been otherwise serviceable in enabling Major Montgomerie to utilise the results of an exploration through the Swat valley to the sources of the Swat river and thence westwards into the Panjkora valley, which was made some years ago by one of his explorers, who was unfortunately murdered in Swat; his papers were recovered, but they were wanting in some particulars which were necessary for their verification, and this missing link has been furnished by the Havildar's survey, which fixed the closing point of the previous survey.

12. The geography of Kaffiristan is still dependent on the valuable rough sketch which was compiled by Lieutenant (now Major General) Peter Lumsden in 1858, from information supplied to him by Kaffirs; this sketch was published in Major H. B. Lumsden's account of the Mission to Kandahar, and it's general accuracy has been corroborated by Captain Carter's recent operations, which have fixed a large number of hill peaks in Kaffiristan and proved that the disposition of the mountain ranges is very closely in accordance with what is shown in Lieutenant Lumsden's sketch.

13. Colonel Johnstone has ascertained that there is a very remarkable bend in the course of the Kabul river through the range of hills which separates the

valleys of Jellalabad and Peshawur, and his delineation thereof, in his map of the North Western Frontier from Fort Abazai to Fort Mackeson, is corroborated by Captain Carter's operations. On the authority of the map of Afghanistan which was constructed by Colonel Garden, late Quarter-Master-General of the Army, from the route surveys of the officers of his Department, the river is shown on all modern maps as having a nearly straight course through those hills; Colonel Garden's surveyors however worked through the Khyber pass, from Jamrud to the vicinity of Lalpura, and did not traverse the course of the river, so they could only shew it approximately, whereas Colonel Johnstone has succeeded in surveying it's course westwards beyond the Peshawur valley up to the bend in question. On the other hand beyond the bend his map is based on native information, and it brings Lalpura several miles to the east of the position which is given by Colonel Garden, most probably from actual survey. Colonel Johnstone's rendering of Lalpura is followed in the map of Afghanistan compiled in the Quarter-Master-General's office at Simla in 1871, but I think on insufficient grounds; I have therefore retained Lalpura in the position assigned to it by Colonel Garden. As regards the great bend in the Kabul river, I may observe that it is not a new discovery but the re-discovery of a fact which was well known to Lieut. Wood, who states at the end of his book that, on leaving Afghanistan, he and Dr. Lord embarked on the Kabul river at Jellalabad "on rafts of inflated skins, and dropped down with the stream to Peshawur;" so remarkable a feature could not have escaped the attention of so accurate a geographer, and accordingly it will be found duly portrayed in the map accompanying his book.*

14. A route survey, the details of which have not yet been published, has been carried by Major Montgomerie's Havildar from Kabul to Bokhara; it slightly alters the positions of Balkh and Karshi, which may now be considered to be known very approximately, and it adds new details which, though somewhat meagre, are not without interest. Unfortunately the Havildar did not pass sufficiently near Shahr-i-Sabz to be able to determine whether M. Khanikoff is correct in placing Yakobak some 30 miles to the east of that town, or M. Fedchenko in removing it to about half that distance to the south. M. Fedchenko's rendering, being the latest, has been adopted.

15. The valuable surveys of Major's Lovett and St. John in Persia, and along a considerable portion of the line of boundary between Persia and Afghanistan, have been carefully incorporated into the new map, and the details of the countries on either side of the lines of survey have been re-adjusted so as to harmonize as closely as possible with the rectifications now furnished.

16. The surveys of the Pundits near the sources of the Indus and the Sutlej Rivers have been incorporated into the new map, and also a route from Rudok to Keria and Khotan, passing to the east of the Kuen-lun range, over the Aksai Chin or White Desert; and a few corrections and additions have been made—on the authority of Messrs. Forsyth, Shaw and Hayward,—to Mr. Johnson's delineation of the regions to the north of the Karakoram Range and the Changchenmo valley, which had been previously adopted.

* It is much to be regretted that this map was constructed on so small a scale; this was evidently done to enable it to embrace the course of the Indus from Attock to Karachi; but at the present time the chief interest of the book and map centers in the regions north of the parallel of 34°, and if the original surveys are still forthcoming their publication on a large scale would be a great boon to geographers; had this been done originally, the mistake in the delineation of the Kabul River would probably not have been made. As regards the position of Lalpura, I have heard from Colonel Johnstone, since the above was in type, that he has discovered an error in the construction of his map which accounts for his disagreement with Colonel Garden.

(14.) As regards boundaries, they are the *bête noire* of a geographer, more particularly when they are shifting and uncertain; but they increase the interest with which a map is regarded, and as approximations are better than nothing at all, some of the principal boundary lines are shown approximately in the new map.

1. For the Russian Boundary I have adopted the line given in the latest of the Russian maps already cited, on which it is shown; the last map of all however does not indicate any portion of it to the west of a meridian line passing nearly midway between Bokhara and Samarcand.

2. The northern boundary of Persia has been carried along the entire course of the Atrek river from the point where the river enters the Caspian Sea to the point where it's principal source is supposed to originate; thence it is drawn eastwards for about one hundred miles and then diverted to the south-east, in a nearly straight line, to the point where the Heri-rud crosses the parallel of 36°; here it is made to meet the northern boundary of Afghanistan. The boundary between Persia and Afghanistan is thence drawn as following the course of the Heri-rud river south-wards to a little above Shahesk (lat. 34° 40′) where it leaves the river and is carried due south to the parallel of 33°, and then is bent slightly west-wards to cross the road between Lash-Jowain and Birjand at the wells of Chah-i-Sagak; thence it is carried south-east and south-wards to the Sistan District, through which it follows the line demarcated by General Sir F. Goldsmid, which is generally south-east down to the fort of Nadali—lat. 31°, long. 62°—and south-west onwards to a point, in lat. 30° long. 61¼°, where it is supposed to meet the boundary of Beluchistan. Thence the boundary line between Persia and Beluchistan is carried in a south-easterly direction towards a hypothetical point in the valley of the Mashkid river, in lat 27¾° long 63¼°, which is beyond the limits of the map.

3. The northern boundary of Afghanistan is drawn as trending E.N.E. in a nearly straight line, from the point where the Heri-rud River crosses the parallel of 36°, to Khoja Saleh on the River Oxus. It is carried thence up the course of the Oxus and it's principal source—the Panja River—to Wood's Lake Victoria, in conformity with the line of boundary which has been approved of by the British and the Russian Governments.

4. A very considerable portion of Eastern Turkestan, which in the first edition of the map was shown as Chinese Territory, is now subject to the Atalik Ghazi, whose territorial acquisitions appear to be daily increasing; this is more particularly the case eastwards towards China, where they have extended beyond the limits of the map; even westwards there has been some extension, according to M. Fedchenko, who says that "a large portion of the Kokan Khanats must be cut off and made over to the territories of Yakúb Beg". I have not attempted to assign any boundaries to the countries under the sway of this acquisitive potentate.

5. The northern boundary of the territories of the Maharajah of Kashmir has—on the authority of Mr. Forsyth—been brought back a considerable distance from the line indicated in the first edition of the map. It is now carried along the northern edge of the Chang-chenmo valley and over the ridges of the Karakoram and Mustagh ranges, up to a point on the meridian of 75°, whence it is turned south-west to meet the meridian of 74°, and is then carried—as formerly—along the ridge of the range on the southern side of the Gilgit Valley down to the River Indus. The highly elevated but uninhabited region of table lands between the Karakoram and the Kuen-lun ranges, was believed—on information derived from Mr. Johnson—to appertain to the Maharajah of Kashmir, at the time when

the first edition of the map was published; it would however appear to be a sort of no-man's-land at the present time. Yassin and the valleys of the upper sources of the river of Gilgit are at present subject, if at all, to Chitral rather than to Kashmir.

(15.) I cannot close these remarks without expressing my obligations to M. Otto Struve, the Director of the Imperial Observatory at Poulkova, for favoring me with the results of his brother's astronomical determinations from time to time, immediately after they were deduced; to the Baron Osten Sacken—late Secretary to the Imperial Geographical Society of Russia—to whom I am indebted for many valuable communications; and to Captain Lütke, the present Secretary, who promptly responded to my application for geographical information, by sending me one of the few photographed copies which had been made of M. C. Struve's valuable map of Kokan. To Mr. Clements Markham, C.B., of the India Office, and to Colonel Thuillier C.S.I. Surveyor General of India, I am indebted for early copies of all maps giving new information of the geography of Central Asia, which have been published in England or communicated to the India office. In the compilation of my first maps I was largely indebted to the late Mr. William Scott, who for many years was Chief Draftsman in the office of the Trigonometrical Survey at Dehra Dún; the compilation of the present map has been, in a great measure, my own work, but in executing it I have been much assisted by my present Chief Draftsman, Mr. George Atkinson.

J. T. WALKER, Colonel, R.E.,
Supdt. Great Trigonometrical Survey of India.

Dehra Dun,
4th June 1873.

Postscript, December 11*th*, 1873.—Since the preceding notes were published, I have received a letter from Mr. Forsyth in which he demurs to being named as my authority for the alteration in the northern boundary of the territories of the Maharajah of Kashmir which brings it a considerable distance within the line indicated on the first edition of my map of Turkestan. Further correspondence has elicited the fact that Mr. Forsyth was not aware that I had simply followed the delineation adopted in his own map of Eastern Turkestan (*see clause* 13 *of art.* 11) which was compiled in 1871 under his superintendence—in the Surveyor General's Office at Calcutta—to illustrate the report of his first journey to Yarkand; there the new boundary line is shown, but on the authority—as it now appears—of a map constructed by the late Mr. Hayward, which Mr. Forsyth had furnished to be used in the compilation of his own map, unfortunately without stating that he objected to the alteration. Under the circumstances it is to be regretted that any alteration was made, and that Mr. Forsyth should have been brought forward as the authority for a line of boundary to which he objects most strenuously, in opposition to the views held by Mr. Hayward and other persons.

J. T. W.

Note on the alterations and additions in the Re-prints of Sheets No. 1 *and* 3 *of the 2nd edition of the Map of Turkestan, which were published in the Office of the Great Trigonometrical Survey of India in November* 1873.

It has been thought desirable to incorporate into Sheets No. 1 and 3 of the Turkestan map (2nd edition) the information which was appended to them in a separate "Addendum" when they were published—in April last—and which was not received in this office until after they had been passed through the press.

(2.) The opportunity has been taken to make some alterations in the delineation of the boundaries of Persia in accordance with information received since the issue of the map. It must be understood however that any delineation of this and of other boundary lines which have not been determined and surveyed can only be considered as an approximation, to serve as a *pis aller* until conclusive results are obtained from actual survey.

(3.) The hills in the basin of the Atrek River and its affluents have been taken from the latest edition of the London War Office map of Khiva; further details of the Sir-daria District have also been added from recent maps of the Russian Topographical Department.

(4.) Major Lovet, R.E., who was employed on the Sistan Boundary Commission, has furnished a list of a few errata in the routes from Shiraz to Bam and from Nasirabad to Birjand. In making the requiste corrections a serious error was discovered in the positions of Birjand and Káin and all places on the road between them; the data by which they had been laid down—on sheet No. 3—were the latitudes and longitudes which are given in Major Evan Smith's Tabular Itinerary of the march of the Sistan mission from Bunjar to Mashad; but the longitudes there given of Birjand, Káin and all intermediate places are found to be half a degree too great or too much to the east, by comparison with the details of the distances and bearings which are given in the itinerary, and with Major Lovett's map of the route. These errors have been corrected in the Re-print.

J. T. WALKER, COLONEL, R.E.,
Supdt. Great Trigonometrical Survey of India.

DEHRA DOON,
5th January 1874.

GENERAL REPORT

ON THE OPERATIONS

OF THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA,

DURING

1872-73,

Prepared for submission to the Government of India.

BY

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SUPERINTENDENT OF THE SURVEY.

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